



Heterogeneity in Developmental Trajectories of Internalizing and Externalizing Symptomatology: Associations with Risk and Protective Factors

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Abstract

Among a large sample of youth (9–10 years old at baseline) from the Adolescent Brain Cognitive Development (ABCD) Study® ($n = 11,661$) we modeled trajectories of psychopathology over three years and associated risk and protective factors. Growth mixture modeling characterized latent classes with distinct psychopathology trajectories. Results indicated four different internalizing trajectories: a high-decreasing class, a moderate-decreasing class, a moderate-increasing class, and a low-stable class. There were also four externalizing trajectories: a moderate-decreasing class, a high-decreasing class, a moderate-increasing class, and a low-decreasing class. We used parallel process growth analysis to examine the co-development of internalizing and externalizing symptoms and characterized five trajectory classes with distinct patterns of co-development. These classes were differentially associated with negative life events, neighborhood safety, and parental acceptance. Together, the findings characterize general developmental patterns of psychopathology, quantify the proportion of youth that follow each pattern, and identify key predictors that discriminate these patterns.

Keywords Psychopathology · Development · Risk and resilience · Latent growth modeling

Introduction

The transition from childhood to adolescence marks a period of important social, physical, and neurobiological changes that correspond to increased risk for psychopathology [37] including internalizing symptomatology (e.g., anxiety, depression) and externalizing symptomatology (e.g., aggression, rule-breaking behaviors). Many studies have examined trajectories of these symptom domains over time to better understand fluctuations across developmental stages. These prior studies often span very broad age ranges, from early to middle childhood through adolescence or adulthood (e.g., [7], [49]). There is relatively limited research examining

developmental trajectories of psychopathology specifically during the transition from childhood to adolescence, despite evidence that many common mental health disorders, such as anxiety, ADHD, and conduct disorder, peak around age 11 [33, 37]. Indeed, this transition is associated with significant changes in brain development and in the environment that may confer concurrent changes in mental health [23, 37, 60]. Thus, additional research focusing on this specific developmental window may be helpful in capturing more granular developmental trajectories and nuanced changes specific to this transitional period. The few studies that have focused on this key period have yielded mixed findings, with increases, decreases, or stability across internalizing and externalizing symptom domains [28, 36, 70]. Studies that quantify repeated measures of psychopathology specifically during the transition from childhood to adolescence are needed to clarify expected patterns of change in mental health symptoms and facilitate early identification of youth who are at heightened risk for persistent mental health problems.

Person-centered approaches, such as growth mixture modeling (GMM), offer one method for characterizing heterogeneity in symptomatology by categorizing individuals into subpopulations based on shared attributes [45]. Delineating

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these latent classes can characterize unique developmental trajectories (with the assumption of multiple populations) and quantify the proportion of youth that follow each trajectory pattern. Prior studies applying person-centered approaches have suggested the presence of multiple distinct trajectories of psychopathology. Most of this work has been conducted during early and middle childhood and has described two to four different classes of internalizing and externalizing symptoms [31, 50, 56]. Relatively few studies have focused on these patterns specifically during the transition to adolescence, however, there is initial evidence of multiple and varied trajectories during adolescence, evidenced by five different internalizing trajectories and six different externalizing trajectories from age 12 through 16 in a sample of high-risk youth [35]. While most youth demonstrated low initial symptom levels that stayed relatively stable over time, others exhibited moderate symptoms, sharply increasing symptoms, and decreasing symptoms. However, these findings were derived from a sample of youth with history of maltreatment or high risk for maltreatment. Thus, trajectories of psychopathology may be qualitatively different (e.g., more severe or increasing patterns) than those observed in the general population. Additional research is necessary to evaluate patterns of psychopathology in a “typical” sample, which may be more generalizable. The Adolescent Brain Cognitive Development (ABCD) Study is a large, population-based, longitudinal study of youth that has the potential to address these gaps in the literature. Initial findings from the ABCD Study suggest four distinct trajectories of depressive symptoms across the first three time points of the study (ages 9–12), including a persistent low pattern, a decreasing pattern, an increasing pattern, and a persistent high pattern [69]. These findings provide evidence of the rich variability in symptomatology over time in this cohort. However, they are limited specifically to depressive symptoms and do not clarify trajectories of broader symptom domains or account for co-occurrence across domains.

Changes in internalizing and externalizing symptoms are likely not independent developmental phenomena. Indeed, the co-occurrence of internalizing and externalizing symptoms in youth is relatively high [20], which may be attributable to shared transdiagnostic features, such as negative emotionality or irritability [19, 54]. This fact may explain why during childhood, high co-occurrence of aggression, hyperactivity, and anxiety can exacerbate subsequent risk for internalizing problems [68]. Similarly, in middle-childhood and adolescence, changes in one domain of symptoms may coincide with or predict changes in another domain [11, 32]. Despite these findings, changes in internalizing and externalizing symptoms are often examined separately, precluding our understanding of joint developmental trajectories. Recent research targeting this gap in the literature has demonstrated that across development most children demonstrate

various levels of co-occurring symptoms, as opposed to “pure” internalizing or externalizing symptoms [31, 58]. In a clinical sample of adolescents, internalizing and externalizing trajectories were found to be co-dependent, such that patterns of change in one domain were associated with a similar pattern of change in the other domain [47]. There is evidence of significant variability in these patterns of co-occurring symptoms in youth. In a large sample of Chinese adolescents, Wang et al. [66] described four latent classes of joint developmental trajectories: a low-risk class, a moderate co-occurring class, a chronic co-occurring class, and a pure-internalizing class. Given this evidence, it is important to consider *concurrent* developmental trajectories, in addition to separately modeling internalizing and externalizing problems.

Various individual and environmental level factors may explain differentiation in developmental trajectories of psychopathology [53]. Exposure to stressful and adverse experiences is one of the most robust predictors of youth mental health and well-being [26, 42]. Experiences such as maltreatment, family substance use, or exposure to violence leave youth more susceptible to both internalizing and externalizing problems. For example, in the ABCD Study, parent psychopathology and family financial adversity were among the variables with the highest predictive value of trajectories of depressive symptoms, identified based on gradient boosting machine modeling [69]. Among Chinese adolescents, higher family conflict was associated with greater likelihood of risky trajectories of co-occurring internalizing and externalizing symptoms [66]. At the same time, positive influences in the child’s environment can be protective and confer lower symptoms over time. These protective factors operate across multiple levels of a child’s environment, such as at the family level (e.g., parental acceptance) or at the community level (e.g., neighborhood safety). For example, higher parental warmth and acceptance is consistently associated with lower internalizing and externalizing symptoms during early adolescence [9], and can prevent emergence of symptoms across adolescence [52]. Similarly, youth living in neighborhoods with lower crime and higher sense of safety tend to have lower internalizing and externalizing symptoms [4, 21], [39]). Taken together, both risk and protective factors jointly contribute to different trajectories of psychopathology across development.

Despite the potential value of person-centered approaches, findings can be sample-specific and may not generalize to the broader population. Thus, there is a critical need for investigation and replication in large, diverse samples of youth in order to clarify expected developmental changes and individual differences in psychopathology. Large-scale, longitudinal studies with repeated measures of youth mental health are necessary to achieve this. The ABCD Study is an ongoing longitudinal study of nearly

12,000 families across the United States [10] and offers an unprecedented opportunity to clarify trajectories of youth psychopathology and key predictors of these trajectories. We leveraged this rich dataset, which includes repeated measures of youth mental health symptoms from ages 9 to 12 years, to parse heterogeneity in developmental trajectories and identify key environmental predictors.

The aims of the present study were to (1) characterize latent classes with distinct internalizing and externalizing symptomatology trajectories, (2) clarify the co-development of internalizing and externalizing symptomatology, and (3) examine risk and protective factors associated with trajectory class membership. Though we have noted that the extant literature is quite mixed, we hypothesized that most participants would demonstrate longitudinal increases in internalizing symptoms and decreases in externalizing symptoms based on prior studies in similar age ranges and preliminary results from the ABCD Study [3]. At the same time, we expected that there would be significant variability in the rate of change of symptoms [69] and assumed the presence of multiple subpopulations that are meaningfully distinct, demonstrated by unique associations with risk and protective factors. Specifically, we expected that latent trajectory classes characterized by higher and more persistent internalizing and externalizing symptoms would have higher risk and lower protective factors relative to other classes.

Method

Participants

Data were drawn from the ABCD Study, an ongoing longitudinal study of 11,878 children across 21 study sites in the United States [10]. Youth aged 9 or 10 at the time of the baseline visit and their parents were recruited from elementary schools within the catchment areas of the 21 research sites. Detailed information regarding recruitment strategies can be found in Garavan et al. [22]. We used data from the National Institute of Mental Health National Data Archive (NDA) 5.1 release (DOI: 10.15154/z563-zd24), which includes complete data from baseline, year 1, and year 2 follow-ups. Participants were excluded if they had a history of autism spectrum disorder, resulting in an analytic sample of $N = 11,667$. Participants in the final sample (48% female) were 9–10 years old at baseline, 10–11 years old at year 1 follow-up, and 11–12 years old at year 2 follow-up. The caregivers that participated with their child were 85% biological mothers, 10% biological fathers, 2% adoptive parents, and 3% custodial parents or other. Median household income fell between \$75,000—\$99,000. Participants identified as White (52%), Black (15%), Hispanic (20%), Asian (2%), or another race (10%).

All participants provided informed consent or assent (see [12] for ethics and oversight in the ABCD Study).

Measures

Demographic Information. The caregiver provided demographic information including the child's sex assigned at birth (male coded as 0, female coded as 1) and age.

Psychopathology. The caregiver who participated in the study with their child reported on their child's psychopathology symptoms using the Child Behavior Checklist (CBCL; 6–18 year old parent-report form) [1]. Symptoms and behaviors were rated on a 3-point Likert-type scale: "0 = Not True," "1 = Somewhat or Sometimes True," and "2 = Very True or Often True." There are eight subscales; for the present study, we used raw sum scores from the internalizing and externalizing symptom subscales to evaluate child psychopathology at each time point. The CBCL has demonstrated strong internal consistency and validity in prior research [1] as well as in the ABCD Study sample [43, 61].

Risk and Protective Factors. Measures of negative life events, neighborhood safety, and parental acceptance were collected from children and their caregiver. Retrospective report of negative life events was measured at the year one follow-up with the Life Events Scale [25, 30], which indexes the sum total number of negative events that a child reported they have experienced during their life. Example items include, "Someone in family died", "Was a victim of crime/violence/assault", and "Family member had a mental or emotional problem." At baseline, neighborhood safety was measured with items from the PhenX Neighborhood Crime and Safety scale [17, 44], which asked participants to rate the degree to which their neighborhoods were safe from crime and violence (parent scores were averaged across 3 items, youth report included only 1 item. Parent and child reports were averaged together and higher scores indicated higher perceptions of safety. Parent acceptance was measured at baseline with the Children's Report of Parental Behavior Inventory (CRPBI [55]). The parental acceptance subscale includes 5 items that are rated on a 3-point Likert-type scale ranging from "0 = Not like him/her" to "3 = A lot like him/her." Example items include, "My parent is able to make me feel better when I am upset" and "My parent believes in showing his/her love for me." A minimum of four items were required to be answered to calculate a score, and item ratings were averaged together. Scores were averaged between the child's reports regarding their primary and secondary (if applicable) caregivers in order to create an overall parental acceptance variable, with higher scores reflecting greater parental acceptance.

Analytic Plan

All models were tested in *Mplus* version 8.6 [46]. To account for the complex sampling structure in the ABCD Study, we specified stratification by study site and clustering of siblings within families in all models (TYPE = COMPLEX). We used maximum likelihood estimation with robust standard errors (MLR) which are robust to non-normality, and automatic starting values with 2,000 random starts. Full information maximum likelihood estimation was used to handle missing data.

Aim 1: Characterize Latent Classes with Distinct Internalizing and Externalizing Symptomatology Trajectories

We progressively fit linear models with an increasing number of classes (with slope variance fixed to zero and residual variances fixed to be equal over time), estimating intercepts and slopes of internalizing and externalizing symptomatology across baseline (ages 9–10), year 1 (ages 10–11), and year 2 (ages 11–12). We estimated models up to six classes. While there is no clear consensus on model selection procedures for growth mixture modeling [27], simulation studies have provided support for the use of fit statistics including AIC, BIC, SABIC, and VLMR [48] and we followed model selection procedures as described by Ram and Grimm [51]. The best fitting model was defined as the model with the lowest information criteria and significant VLMR that also had acceptable entropy and at least 2% of the sample in the smallest class. Classes that included less than 2% of the sample were not considered practically meaningful.

Aim 2: Characterize Co-developing Trajectories of Internalizing and Externalizing Symptomatology

Next, we conducted a parallel-process latent class growth analysis to characterize individuals' symptom trajectories based on simultaneous consideration of internalizing and

externalizing growth factors. This method has advantages over conducting separate latent class models of internalizing and externalizing symptoms given that the two domains are highly correlated ($r = 0.55 - 0.57$ across time points). As described above, a comprehensive review of multiple criteria and fit indices were used to identify the best class solution.

Aim 3: Examine Predictors of Trajectory Class Membership

Multinomial logistic regressions were used to examine how specific risk and protective factors may be differentially associated with the different latent trajectory classes. We also accounted for the effects of age and sex given prior evidence for sex and age differences in developmental patterns of internalizing and externalizing symptomatology [3, 14]. We used the three-step procedure (R3STEP) in *Mplus* for fitting multinomial logistic regression models to account for the uncertainty of the probability of class membership [2, 64].

Results

Preliminary Analysis

Correlations and descriptive statistics for internalizing and externalizing symptoms across all time points are included in Table 1. The majority of participants (89.5%) had complete data for all model variables. We used binomial logistic regression to test if having complete data vs any missing data was predicted by demographic factors or the study variables at baseline. Having missing data on any of the variables was more likely for participants with higher baseline externalizing, lower income, or who were female or non-white. Six participants could not be included in the growth models (4 were missing information on the stratification or clustering variables and 2 were missing all symptom data), resulting in an analytic N of 11,661.

Table 1 Means, standard deviations, and correlations of internalizing and externalizing symptoms

Variable	1	2	3	4	5	<i>M</i>	<i>SD</i>	Skew	Kurtosis
1. Internalizing symptoms — Baseline						4.98	5.47	1.96	5.29
2. Internalizing symptoms — Year 1	0.69**					5.04	5.51	1.95	5.27
3. Internalizing symptoms — Year 2	0.62**	0.67**				4.87	5.59	2.08	5.94
4. Externalizing symptoms — Baseline	0.57**	0.42**	0.37**			4.39	5.78	2.32	7.22
5. Externalizing symptoms — Year 1	0.43**	0.56**	0.40**	0.74**		4.11	5.59	2.44	7.96
6. Externalizing symptoms — Year 2	0.39**	0.41**	0.55**	0.67**	0.72**	3.87	5.51	2.55	8.76

M and *SD* are used to represent mean and standard deviation

* indicates $p < .05$

** indicates $p < .01$

Aim 1: Characterize Latent Classes with Distinct Internalizing and Externalizing Symptomatology Trajectories

Internalizing symptomatology. The four-class solution demonstrated the best fit to the data for internalizing symptoms (Table S1). Class 1 was characterized by moderate initial levels of symptoms that significantly increased over time and was labeled as the *moderate-increasing* class (comprising 6% of the sample). Class 2 (2%) demonstrated a *high-decreasing* trajectory, Class 3 (84%) demonstrated a *low-stable* trajectory, and Class 4 (8%) was *moderate-decreasing* (Fig. 1). See Table 2 for the estimated slopes and intercepts for each class. We note that these class labels are subjective and were determined relative to the participants in our sample.

Externalizing symptomatology. The four-class solution demonstrated the best fit to the data for externalizing symptoms (Table S1). Class 1 was characterized by moderate initial levels of symptoms that decreased over time and was

labeled as the *moderate-decreasing* class (comprising 9% of the sample). Class 2 (2%) demonstrated a *high-decreasing* pattern, Class 3 (85%) demonstrated a *low-decreasing* pattern, and Class 4 (5%) was *moderate-increasing* (Fig. 1). See Table 2 for the estimated slopes and intercepts for each class.

Descriptive statistics for each class at each time point, including means, standard deviations, skewness, and kurtosis are presented in Table S2 (externalizing symptoms) and Table S3 (internalizing symptoms). The outcomes within each class were all normally distributed.

Aim 2: Characterize Co-developing Trajectories of Internalizing and Externalizing Symptomatology

A five-class model (random intercept and fixed slope) had the overall best fit to the data (Table S5). Table 3 and Fig. 2 present the estimated intercepts and slopes of the classes. Class 1 (5% of the sample) had high initial levels of internalizing symptoms and moderate initial levels of externalizing symptoms that both decreased over time and

Fig. 1 Growth mixture modeling trajectories for internalizing and externalizing symptoms (separately) from ages 9 to 12

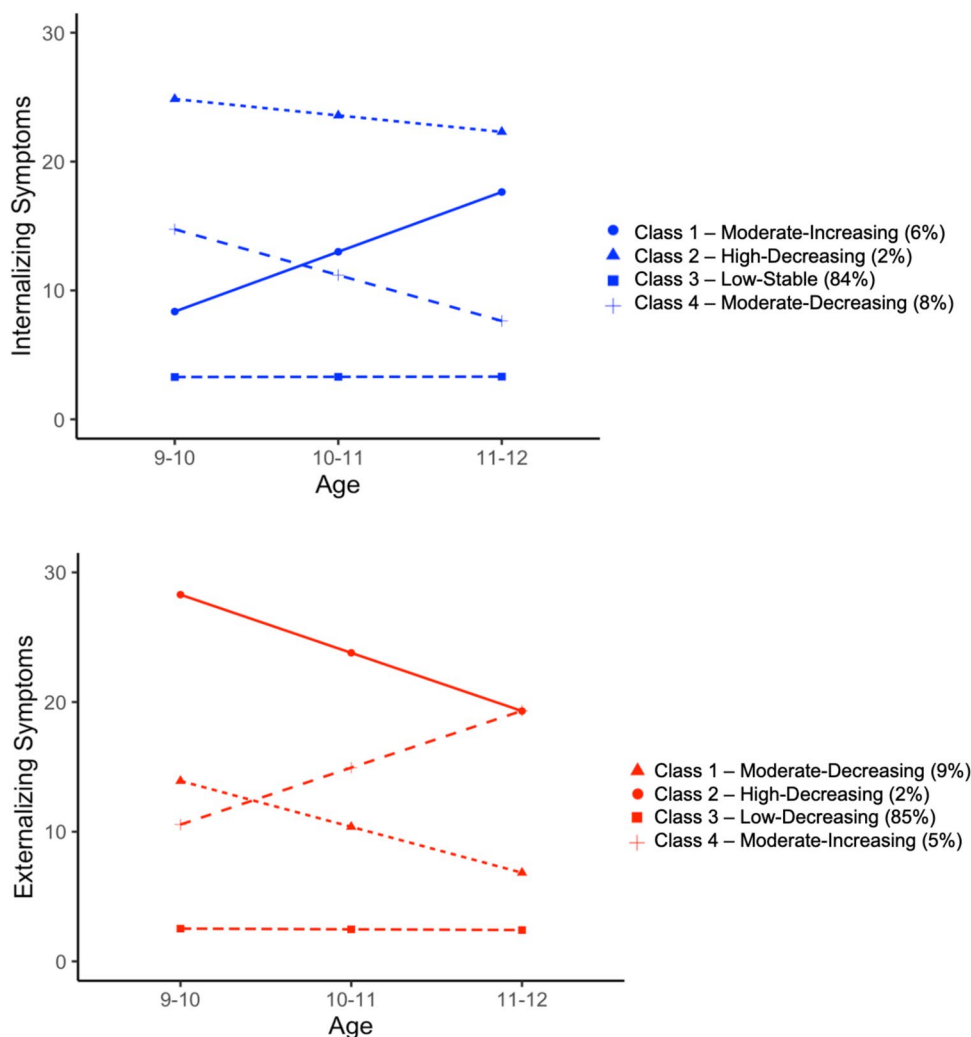


Table 2 Parameter estimates for each symptomatology class

	Intercept mean [CI]		Slope mean [CI]	
Internalizing Class 1 (6%) moderate-increasing	8.36***	[7.62, 9.10]	4.64***	[4.07, 5.21]
Internalizing Class 2 (2%) high-decreasing	24.85***	[23.13, 26.57]	- 1.27*	[- 2.54, - 0.01]
Internalizing Class 3 (84%) low-stable	3.28***	[3.16, 3.41]	- 0.02	[- 0.04, 0.07]
Internalizing Class 4 (8%) moderate-decreasing	14.74***	[13.94, 15.55]	- 3.55***	[- 4.01, - 3.10]
Externalizing Class 1 (9%) moderate-decreasing	13.92***	[13.08, 14.76]	- 3.54***	[- 4.05, - 3.03]
Externalizing Class 2 (2%) high-decreasing	28.28***	[26.62, 29.95]	- 4.49***	[- 5.93, - 3.04]
Externalizing Class 3 (85%) low-decreasing	2.53***	[2.41, 2.64]	- 0.06*	[- 0.10, - 0.01]
Externalizing Class 4 (5%) moderate-increasing	10.55***	[9.69, 11.41]	4.39***	[3.73, 5.05]

* $p < .05$, ** $p < .01$, *** $p < .001$

All values are based on unstandardized beta estimates

CI=95% Confidence Interval

Table 3 Parameter estimates for parallel process model of the co-development of internalizing and externalizing trajectories

	Internalizing intercept mean [CI]		Internalizing slope mean [CI]		Externalizing intercept mean [CI]		Externalizing slope mean [CI]	
Class 1 (5%) high-decreasing INT/ moderate-decreasing EXT	19.01***	[17.74, 20.28]	- 4.52***	[- 5.09, - 3.95]	10.20***	[9.10, 11.30]	- 2.52***	[- 3.03, - 2.01]
Class 2 (4%) moderate-increasing INT and EXT	7.19***	[6.18, 8.21]	2.25***	[1.65, 2.86]	12.22 ***	[10.31, 14.14]	4.66***	[3.69, 5.64]
Class 3 (4%) moderate- decreasing INT/ high- decreasing EXT	10.69***	[9.65, 11.74]	- 2.56 ***	[- 3.21, - 1.91]	21.08***	[19.49, 22.66]	- 5.59***	[- 6.46, - 4.72]
Class 4 (83%) low-decreas- ing INT and EXT	3.63***	[3.52, 3.74]	- 0.03	[- .08, 0.01]	2.86***	[2.76, 2.96]	- 0.16***	[- .20, - 0.12]
Class 5 (4%) moderate- increasing INT/ low- increasing EXT	9.60***	[8.48, 10.73]	5.19***	[4.59, 5.78]	5.19***	[4.53, 5.86]	1.57***	[1.21, 1.94]

CI 95% confidence intervals, INT internalizing symptoms, EXT externalizing symptoms

* $p < .05$, ** $p < .01$, *** $p < .001$

All values are based on unstandardized beta estimates

was labeled as a *high-decreasing internalizing/moderate-decreasing externalizing* class. Class 2 (4% of the sample) had initial moderate but increasing levels of internalizing and externalizing symptoms over time and was labeled as a *moderate-increasing internalizing and externalizing* class. Class 3 (4% of the sample) had moderate initial levels of internalizing and high initial levels of externalizing symptoms that both decreased over time and was labeled as a *moderate-decreasing internalizing/high-decreasing*

externalizing class. Class 4 (83% of the sample) was characterized by initial low and decreasing levels of both internalizing and externalizing symptoms over time and was labeled as a *low-decreasing internalizing and externalizing* class. Class 5 (4% of the sample) had moderate initial levels of internalizing symptoms and low initial levels of externalizing symptoms which both increased over time and was labeled as a *moderate-increasing internalizing/low-increasing externalizing* class.

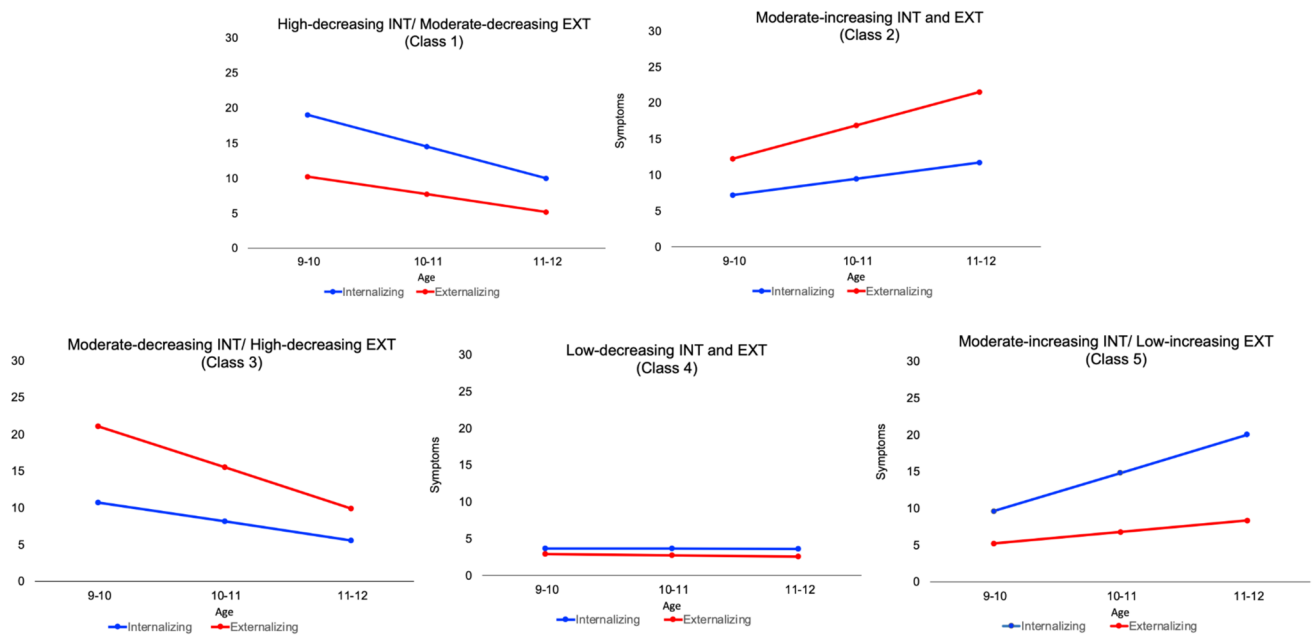


Fig. 2 Trajectories of co-occurring internalizing (INT) and externalizing (EXT) symptoms from ages 9 to 12

Aim 3: Identify Predictors of Symptom Trajectories

Internalizing symptoms. We interpreted the results of the multinomial logistic regressions using the *low-stable* class as the reference class. As shown in Table 4, relative to the *low-stable* class, a 1-unit decrease in caregiver acceptance was associated with increased odds of being in

the *moderate-increasing* ($OR = 0.71:1$), *high-decreasing* ($OR = 0.39:1$), or *moderate-decreasing* ($OR = 0.58:1$) class. A 1-unit decrease in neighborhood safety was associated with increased odds of being in the *moderate-increasing* ($OR = 0.82:1$), *high-decreasing* ($OR = 0.62:1$), or *moderate-decreasing* ($OR = 0.72:1$) class (Table 4). Being female was associated with increased odds ($OR = 1.26$) of being in the

Table 4 Regression coefficients, confidence intervals, and odds ratios for predictors of internalizing and externalizing symptom trajectories

Internalizing trajectories	Class 1 (moderate-increasing)			Class 2 (high-decreasing)			Class 4 (moderate-decreasing)		
	B	OR	CI	B	OR	CI	B	OR	CI
Sex	0.23	1.26	[1.04, 1.52]	0.13	0.14	[0.85, 1.54]	-0.07	0.93	[0.80, 1.10]
Age	0.01	1.01	[0.99, 1.02]	0.02	1.02	[1.00, 1.04]	0.004	1.004	[0.99, 1.02]
Negative life events	-0.05	0.96	[0.89, 1.02]	0.03	1.03	[0.93, 1.13]	-0.02	0.98	[0.93, 1.04]
Parent acceptance	-0.34	0.71	[0.53, 0.96]	-0.95	0.39	[0.26, 0.59]	-0.55	-0.58	[0.45, 0.74]
Neighborhood safety	-0.19	0.82	[0.75, 0.91]	-0.48	0.62	[0.53, 0.73]	-0.34	0.72	[0.66, 0.79]
Externalizing trajectories	Class 1 (moderate-increasing)			Class 2 (high-decreasing)			Class 4 (moderate-decreasing)		
	B	OR	CI	B	OR	CI	B	OR	CI
Sex	-0.49	0.61	[0.52, 0.72]	1.06	0.35	[0.25, 0.49]	-0.42	0.66	[0.53, 0.81]
Age	-0.02	0.98	[0.97, 0.99]	-0.002	1.00	[0.98, 1.02]	0.01	1.01	[0.99, 1.02]
Negative life events	0.001	1.00	[0.95, 1.06]	0.09	1.09	[1.00, 1.19]	0.05	1.05	[1.00, 1.11]
Parent acceptance	-0.64	0.53	[0.41, 0.68]	-0.84	0.43	[0.28, 0.67]	-0.59	0.56	[0.41, 0.76]
Neighborhood safety	-0.49	0.65	[0.60, 0.71]	-0.69	0.50	[0.43, 0.59]	-0.29	0.75	[0.67, 0.83]

The low-decreasing was used as the reference class

Non-symmetric confidence intervals (CIs) are reported here, which are preferred for odds ratios; thus, the neutral point is 1, not 0. Significant effects are indicated in bold

Sex was coded as male=0, female=1

moderate-increasing class relative to the *low-stable* class. There were no significant adversity differences.

Externalizing symptoms. Similar to the internalizing trajectories, we interpreted the results with the *low-decreasing* class as the reference class. As shown in Table 4, relative to the *low-decreasing* class, a 1-unit decrease in caregiver acceptance was associated with increased odds of being in the *moderate-decreasing* ($OR=0.53:1$), *high-decreasing* ($OR=0.43:1$), or *moderate-increasing* ($OR=0.56:1$) class. Similarly, a 1-unit decrease in neighborhood safety was associated with increased odds of being in the *moderate-decreasing* ($OR=0.65:1$), *high-decreasing* ($OR=0.50:1$), or *moderate-increasing* ($OR=0.75:1$) class (Table 4). Being male was associated with increased odds of being in the *moderate-decreasing* ($OR=0.61:1$), *high-decreasing* ($OR=0.35:1$), or *moderate-increasing* ($OR=0.66:1$) class relative to the *low-decreasing* class. There were no significant adversity differences.

Co-developing symptoms. Similar to the prior models, we interpreted the results with the *low-decreasing internalizing and externalizing* class as the reference class. As shown in Table 5, a 1-unit increase in adversity was associated with 1.06:1 odds of being in the *moderate-increasing internalizing and externalizing* class relative to the *low-decreasing internalizing and externalizing* class (controlling for sex and age). A 1-unit decrease in caregiver support or neighborhood safety was associated with increased odds of being in a class other than the *low-decreasing internalizing and externalizing* class (Table 5). Being female was associated with increased odds of being in the *high-decreasing INT/moderate-decreasing EXT* ($OR=1.25$) or *moderate-increasing INT/low-increasing EXT* ($OR=1.57$) class relative to the *low-decreasing internalizing and externalizing* class. Being male was associated with increased odds of being in the *moderate-increasing internalizing and externalizing*

class ($OR=0.60$) and the *moderate-decreasing internalizing/high-decreasing externalizing* class ($OR=0.46$).

Discussion

We leveraged a large and diverse sample of youth followed over three years in the ABCD Study to parse heterogeneity in trajectories of psychopathology during the transition from childhood to adolescence. We characterized four latent trajectory classes of internalizing symptoms (*moderate-increasing*, *high-decreasing*, *low-stable*, and *moderate-decreasing*) and externalizing symptoms (*moderate-decreasing*, *low-decreasing*, *moderate-increasing*, *high-decreasing*). We also examined the co-development of internalizing and externalizing symptoms and characterized five classes of youth with distinct patterns of concurrent change. Finally, we found that specific risk and protective factors predicted different symptom trajectories.

Consistent with prior work, the majority of participants belonged to a “low risk” class in which symptoms begin low and remain stable or decrease over time [38, 63]. Thus, it seems that pre-adolescents generally experience relatively low levels of psychopathology, though it will be critical to conduct follow-up analyses at later time points to evaluate whether these patterns persist over time. Despite the majority of participants being characterized as “low risk”, many youth in our sample demonstrated elevated or persistent symptomatology. Notably, many prior studies (e.g., [31, 35, 63]) have found similar proportions of youth characterized by trajectories of persistent, elevated symptomatology (around 2%). In smaller samples, this results in very small Ns in these classes. For example, Leban et al. (2021) also described a high/stable internalizing class comprising a similar proportion (2.3%) of their sample; however, this

Table 5 Regression coefficients, confidence intervals, and odds ratios for predictors of co-developing symptom trajectories

Predictor	Class 1 (high-decreasing INT/ moderate-decreasing EXT)			Class 2 (moderate-increasing INT and EXT)			Class 3 (moderate-decreasing INT/high-decreasing EXT)			Class 5 (moderate-increasing INT/low-increasing EXT)		
	B	OR	CI	B	OR	CI	B	OR	CI	B	OR	CI
Sex	0.22	1.25	[1.02, 1.53]	-0.51	0.60	[0.48, 0.76]	-0.84	0.43	[0.34, 0.55]	0.45	1.57	[1.26, 1.96]
Age	0.01	1.01	[1.00, 1.03]	0.001	1.00	[0.99, 1.02]	-0.02	0.98	[0.97, 0.99]	0.02	1.02	[1.00, 1.03]
Negative Life events	0.02	1.02	[0.96, 1.09]	0.06	1.06	[1.00, 1.13]	0.03	1.03	[0.97, 1.11]	-0.03	0.97	[0.90, 1.05]
Parent acceptance	-0.52	0.592	[0.43, 0.82]	-0.50	0.61	[0.43, 0.86]	-0.64	0.53	[0.38, 0.74]	-0.55	0.58	[0.42, 0.80]
Neighborhood safety	-0.34	0.71	[0.63, 0.80]	-0.31	0.74	[0.66, 0.83]	-0.54	0.58	[0.52, 0.65]	-0.20	0.82	[0.72, 0.93]

INT Internalizing symptomatology, EXT Externalizing symptomatology

Class 4 (low-decreasing internalizing and externalizing) was used as the reference class

Non-symmetric confidence intervals (CIs) are reported here, which are preferred for odds ratios; thus, the neutral point is 1, not 0. Significant effects are indicated in bold

Sex was coded as male=0, female=1

equated to less than 20 individuals. Large population-based samples such as the ABCD Study can complement findings from smaller samples, demonstrating points of convergence or divergence that may inform the robustness or reliability of less prevalent mental health patterns characterized in smaller studies. At the same time, we acknowledge that there is evidence to suggest that internalizing and externalizing symptoms are dimensional rather than categorical (e.g., [13, 41, 65]), and subgrouping methods such as GMM may not best represent the nature of youth psychopathology. Thus, while our approach was helpful in providing an estimate of the proportion of youth who follow particular symptom trajectories, it may oversimplify complex individual differences which are represented with dimensional approaches.

To address the fact that internalizing and externalizing symptoms often co-occur, we also characterized co-developing trajectories of internalizing and externalizing symptomatology using parallel process modeling [67]. The best-fitting model suggested 5 classes: Class 1 (high-decreasing internalizing/moderate-decreasing externalizing), Class 2 (moderate-increasing internalizing and externalizing), Class 3 (moderate-decreasing internalizing/high-decreasing externalizing), Class 4 (low-decreasing internalizing and externalizing), and Class 5 (moderate-increasing internalizing/low-increasing externalizing). Using a similar approach in a sample of Chinese adolescents, Wang et al. [66] characterized four latent trajectory classes: a low-risk class, a moderate co-occurring class, a chronic co-occurring class, and a pure-internalizing class. While there are some differences in the specific classes that were described (e.g., we did not observe a pure-internalizing class), there is also some convergence with our findings. For example, in both studies, the “low risk” class was the largest class, and this class was associated with lower risk factors and higher protective factors relative to the other classes. Beyond this low risk class, we also found small but significant classes of youth with moderate but increasing internalizing symptoms (Class 2) or increasing externalizing symptoms (Class 5). These individuals may be most at risk for developing mental health disorders in the long term.

We examined the effects of negative life events, neighborhood safety, and parental acceptance on different trajectories of internalizing, externalizing, and co-developing symptoms. Results indicated that, in general, youth with lower levels of neighborhood safety and parental acceptance were more likely to be in classes characterized by elevated and fluctuating symptoms, relative to the low-decreasing/stable classes. This is consistent with an extensive body of literature demonstrating that early family and community contexts are associated with the emergence and progression of psychopathology across development [42, 53]. While prior work has demonstrated the role of neighborhood safety on levels of psychopathology [4, 21], we expand upon these

findings to demonstrate that safety (or lack thereof) may be a precursor to long-term changes in mental health during the transition to adolescence. In particular, higher perceptions of neighborhood safety were associated with greater likelihood of low and decreasing patterns of both internalizing and externalizing symptoms. This is consistent with prior work among younger children demonstrating that higher neighborhood quality was associated with longitudinal decreases in externalizing symptoms [39]. Adversity exposure only distinguished between two of the co-development trajectory classes, distinguishing the “highest risk” class (moderate and increasing symptoms across both domains) from the lowest risk class. The relatively low degree of adversity exposure in this sample may explain the weak or non-significant associations with symptom trajectories, and precludes more nuanced distinctions between classes. Taken together, leveraging community strengths and improving neighborhood safety may be one important avenue for preventing the onset and progression of psychopathology in youth.

Boys tend to show higher levels of externalizing symptoms whereas girls tend to develop more internalizing symptoms in adolescence ([15]; [71]). We similarly found that being female increased the likelihood for a moderate-increasing internalizing trajectory (with low-increasing externalizing symptoms) relative to the “low risk” profile, whereas being male increased the likelihood for a high or moderate-increasing externalizing trajectory (with moderate internalizing symptoms). This is consistent with findings that have shown different patterns of internalizing and externalizing co-development between boys and girls, with a greater prevalence of girls in the moderate-increasing internalizing/low-increasing externalizing class relative to boys [24]. Higher risk for externalizing symptoms in boys may be attributable to factors such as lower levels of inhibitory control and slower language development [34] relative to girls during childhood [18]. For girls, earlier timing of puberty with increases in adrenal and gonadal hormones may be associated with heightened internalizing symptoms [40]. Future studies are needed to identify mechanisms that may explain these sex differences.

Results should be interpreted in light of limitations. First, GMM is an exploratory method that attempts to account for non-normality in the data; while this may be driven by the presence of multiple subpopulations, mixture models can extract artifactual subgroups and other interpretations are plausible [5, 6]. While we took steps to ensure the robustness of our models and minimize the risk of overextraction of classes (e.g., consideration of multiple fit indices, using a large number of random starts, ensuring the grouping variable is associated with other variables in predictable ways), we cannot entirely rule out other possibilities. Indeed, here we identified a “cat’s cradle” pattern for internalizing and externalizing symptoms, a pattern that frequently emerges

across diverse studies and constructs [57]. This result may reflect characteristics of the modeling approach rather than underlying developmental phenomena, and so we recommend caution in overinterpreting these trajectories as discrete subgroups. Improvement in GMM estimation and model selection is an active area of inquiry [29] and additional methodological and simulation studies will be helpful in advancing this work. Second, the first three waves of the ABCD Study only include parent reports of their child's symptoms; parents' reports may be subject to bias or differ from children's reports of their own symptoms [16]. However, prior work has found consistent trajectories of internalizing and externalizing symptoms as assessed via adolescent and parent report [8]. Finally, we note that the ABCD Study recruited a community-based sample; thus, levels of symptomatology are relatively low compared to samples ascertained based on the presence of psychopathology. Indeed, the majority of participants were characterized by low-decreasing symptom trajectories. For internalizing symptoms, the selected risk and protective factors only broadly differentiated these youth with low symptoms from the three other classes with more elevated symptoms. Samples with greater prevalence of psychopathology or inclusion of additional types of risk and protective factors may further differentiate these classes.

Despite these limitations, the present study benefits from several unique strengths. The size of this sample and its representation of youth from across the United States are particular strengths, as person-centered approaches such as growth mixture modeling often yield sample-specific findings and may have limited generalizability [5]. Thus, large samples with broad racial and economic representation, such as the ABCD Study, are essential for better delineating heuristics of change in psychopathology. Furthermore, few studies have specifically examined change during the transition to adolescence, an important period for the onset and emergence of psychopathology [33]. Finally, this study benefits from multiple informants, mitigating potential issues of shared method variance between the independent and dependent variables.

Summary

Our results highlight that there is important heterogeneity in the development of internalizing and externalizing problems in youth during the transition into adolescence. Person-centered, longitudinal approaches offer one method to parse this heterogeneity and elucidate the proportion of youth who are likely to follow different trajectory patterns. Importantly, the classes differed meaningfully on key environmental factors including parental acceptance and neighborhood safety. Multi-pronged intervention and prevention efforts that

transcend these different aspects of children's experiences may be particularly effective in mitigating the development of psychopathology across adolescence [59, 62].

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Author Contributions A.B. and K.I. conceptualized the analysis, conducted analyses, and wrote the main manuscript text. T.C. conducted analyses and assisted with major revisions. BHG wrote and edited manuscript and contributed to data visualization. DGG contributed to conceptualization and editing. All authors reviewed the manuscript.

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Data Availability Data are available from the National Institute of Mental Health National Data Archive (NDA) (DOI:10.15154/1519007).

Declarations

Conflict of interest The authors declare no competing interests.

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