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Trajectories of Depression and Anxiety Symptoms in Adolescent Girls: A Comparison of Parallel Trajectory Approaches

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Abstract

Longitudinal mixture models have become popular in the literature. However, modest attention has been paid to whether these models provide a better fit to the data than growth models. Here, we compared longitudinal mixture models to growth models in the context of changes in depression and anxiety symptoms in a community sample of girls from age 10 to 17. Model comparisons found that the preferred solution was a 5-class parallel process growth mixture model that differed in the course of depression and anxiety symptoms reflecting both ordering of symptoms and qualitative group differences. Comparisons between classes revealed substantive differences on a number of outcomes using this solution. Findings are discussed in the context of clinical assessment and implementation of growth mixture models.

Course of depressive and anxiety symptoms among youth could be important for identifying youth at risk for persistent problems. A number of studies have characterized symptom courses as individual differences in initial levels and longitudinal changes in severity (e.g., Garber, Keiley, & Martin, 2002; Van Oort, Greaves-Lord, Verhulst, Ormel, & Huizink, 2009). Thus, a single population can be described by a single pattern that varies in a matter of degree. More recently, other studies have characterized course variability in depression and anxiety in terms of individual differences in initial levels and longitudinal changes in severity that vary across unobserved (i.e., latent) subpopulations using longitudinal mixture models (e.g., Feng, Shaw, & Silk, 2008; Rhebergen et al., 2012). However, no studies have examined whether longitudinal mixture models provide a statistically better fit to their data than growth models. Further, if mixtures are necessary, few studies have investigated how different modeling decisions address theoretically motivated questions.

Examinations of the longitudinal course of psychopathology have often relied on growth models to estimate a single trajectory with individual variability in starting point and rates of

change. A number of studies have modeled changes in depressive symptoms across adolescence (Garber et al., 2002; Keenan, Feng, Hipwell, & Klostermann, 2009; Measelle, Stice, & Hogansen, 2006) and from adolescence through early young adulthood (Galambos, Barker, & Krahn, 2006; Galambos, Leadbeater, & Barker, 2004; Ge, Lorenz, Conger, Elder, & Simons, 1994; Kim, Capaldi, & Stoolmiller, 2003). These studies consistently found linear increases in depressive symptoms with individual differences in rates of increases. In addition, there appeared to be gender differences, such that samples of females demonstrated greater increases in symptoms than mixed-sex or all-male samples.

Fewer studies have investigated the course of anxiety symptoms across adolescence and young adulthood (Hale, Raaijmakers, Muris, Van Hoof, & Meeus, 2008; Keenan et al., 2009; Van Oort et al., 2009). Hale et al. (2008) found that levels of panic, school anxiety, and separation anxiety decreased, whereas levels of social phobia did not significantly change from age 12 to 16. However, gender differences were found for symptoms of generalized anxiety disorder (GAD) with increases observed for girls, but decreases for boys. Van Oort and colleagues (2009) found that decreases in symptoms of GAD, panic, social phobia, separation anxiety, and obsessive-compulsive scores from ages 10 to 18 were reducing but decelerating over adolescence. Using data from the Pittsburgh Girls Study, Keenan et al. (2009) found that parent reports of their daughters' general and social anxiety showed an increase from ages 6 to 8 with a plateau between ages 8 and 10 and a linear decrease from age 10 through age 12. However, separation anxiety demonstrated a linear decrease from age 8 through 12. Thus, these studies provide overall patterns of symptom changes in depression and anxiety across much of adolescence. It is noteworthy that although all published models ultimately demonstrated excellent fit, the initial a priori models did not consistently provide good fit. The required post-hoc modifications could suggest that alternative models provide better fit.

Studies have also examined whether there are subgroups that differ in trajectories of depression (Brendgen, Wanner, Morin, & Vitaro, 2005; Dekker et al., 2007; Rhebergen et al., 2012; Stoolmiller, Kim, & Capaldi, 2005) and anxiety (Broeren, Muris, Diamantopoulou, & Baker, 2013; Duchesne, Vitaro, Larose, & Tremblay, 2008; Feng et al., 2008; Morin et al., 2011) using longitudinal mixture models (B. O. Muthén & Muthén, 2000; Nagin, 1999). These data-driven approaches seek to identify similar individuals based on their longitudinal trajectories of an outcome, here symptoms of depression, anxiety, or both.

Examinations of longitudinal mixture trajectories of depression and anxiety have varied across the range of ages sampled, the number assessments, the length of follow-up, the specific outcome measure, the treatment of gender in the analysis, the specific analysis employed, and the number of classes in the preferred solution. Despite these marked methodological differences, four distinct classes of depression course have been consistently identified: very mild or absent symptoms, consistently moderate symptoms, increasing levels of symptoms, and high but decreasing levels of symptoms (Brendgen et al., 2005; Dekker et al., 2007; Rhebergen et al., 2012; Stoolmiller et al., 2005; Yaroslavsky, Pettit, Lewinsohn, Seeley, & Roberts, 2013). Similarly, three classes of anxiety course have been consistently identified: very mild or absent symptoms, moderate symptoms, and generally a

course of increasing symptoms (Broeren et al., 2013; Crocetti, Klimstra, Keijsers, Hale, & Meeus, 2009; Duchesne et al., 2008; Feng et al., 2008; Legerstee et al., 2013; Morin et al., 2011). When examined individually, the trajectories of depression and anxiety generally reflect ordered (e.g., high, moderate, and low) symptom levels across time. However, it remains to be tested whether these models provide a better account to the data than a growth model; that is, a one-class solution describing the population as it varies in initial levels of depression and anxiety and rate of change over time.

Although studies of changes in depression and anxiety have examined these outcomes separately, depression and anxiety typically co-occur extensively in youth (Angold, Costello, & Erkanli, 1999). Indeed, latent variable modeling studies of depressive and anxiety disorders (e.g., Krueger, 1999; Krueger & Markon, 2006) and symptom scales (Markon, 2010) suggest that a higher order domain of internalizing disorders can explain the cross-sectional associations between depression and anxiety. However, unique aspects of these disorders are included in these cross-sectional models (i.e., residual terms that are not associated with the broader internalizing dimension) and these are manifest from childhood through adulthood (Chorpita, Albano, & Barlow, 1998; Joiner, 1996; Prenoveau et al., 2010). Thus, although correlated, changes in one form of psychopathology might be distinct from changes in the other. It is possible that distinctions between depression and anxiety might be revealed in longitudinal course.

One approach to modeling latent trajectories of multiple outcomes comes from Nagin's dual trajectory model (Jones & Nagin, 2007) that estimates relatedness between each outcome using a latent transition model. Individuals are partitioned into classes for each growth process and the association between depression and anxiety classes is defined by conditional probabilities of joint class membership, rather than on associations between depression and anxiety within a specific class. Findings could suggest the presence of classes that do not exist.

An alternative model can identify classes of individuals based on the growth of depression and anxiety symptoms simultaneously. Thus, class membership would explain parameters relevant to the course of depression and anxiety. Olin, Klein, Lewinsohn, Rohde, and Seeley (2010) estimated parallel process latent class growth models (LCGMs) of depressive and anxiety disorders from adolescence through age 30. In these models, latent class variables were defined by growth parameters for both depressive and anxiety disorders (growth parameter variance estimates were fixed at zero). Using this method, the authors identified a total of six classes: persistent depression with low anxiety, persistent anxiety with moderate depression, increasing depression with low anxiety, high initial but decreasing anxiety with modest depression with a more gradual decrease, consistently low probabilities of both depression and anxiety, and a class with a marked increase in anxiety from ages 21 to 26 with a low but gradual increase in depression. The authors found relative specificity for risk factors, such that parental history of depression predicted offspring courses more characterized by depression, whereas parental history of anxiety predicted offspring courses more characterized by anxiety. However, only a single model type was estimated in this study. Thus, it remains unclear whether the parallel process LCGMs are preferred over different model types.

In addition to comparisons between growth models and longitudinal mixture models, there are also important differences between longitudinal mixture models. The most restrictive mixture model is a LCGM (Nagin, 1999) that specifies that all individuals within the same class follow the same latent trajectory. This involves restricting within-class variability on growth parameters to zero (e.g., parameters labeled a–d in Figure 1) and the association between the intercept and slope parameters within class to be zero (e.g., parameters labeled e–h in Figure 1). Both of these constraints (and theoretical assumptions) could be overly restrictive. Increased modeling and conceptual flexibility comes with growth mixture models (GMMs) that permit estimating variance estimates of growth parameters (i.e., being estimated as a nonzero value). Classes are characterized by mean-level differences in growth parameters, but all classes would have the same degree of variability in growth parameters (e.g., parameters labeled a–d in Figure 1 can vary across different classes). However, the assumption that all classes will have the same degree of variability is testable. For example, one could test whether the variability in the starting point of individuals following a trajectory of very low symptoms is equal to the variability in the starting point of individuals following a trajectory of very high symptoms. Classes with smaller variance estimates would indicate that class members are more similar in their courses, on average, than in classes with larger variance estimates. In addition to the variance estimates, covariance parameters between growth parameters can also be estimated (e.g., parameters labeled e–h in Figure 1 can vary across classes). Similarly, questions of whether the associations among the growth factors is the same or different across classes could be tested. Specifically, some classes might reflect patterns that higher (or lower) starting levels are accompanied by faster reductions over time, whereas others might reflect no associations between starting levels and change over time. It is important to explicitly examine how growth parameter variability and associations between growth parameters differs across sub-groups of individuals (see Table 1 for a summary of these model types).

This study examined parallel symptom trajectories of depression and anxiety in a large sample of girls from the Pittsburgh Girls Study (PGS). Previously, Keenan et al. (2009) reported on parent reports of depression and anxiety from age 6 through 12, with a focus on the developmental interface of anxiety and depression. In those analyses, homotypic continuity of depression and anxiety symptoms from early childhood to early adolescence was more common in girls than heterotypic continuity; little variance in year-to-year changes in depression symptoms and later depressive disorders was accounted for by anxiety symptoms. This study differs from previous work in a number of ways. First, we focus on girls' self-reports of depression and anxiety from age 10 to 17, a developmental window marked by substantial increases in internalizing pathology, particularly for girls (Costello, Copeland, & Angold, 2011; Hankin et al., 1998; Lewinsohn, Hops, Roberts, Seeley, & Andrews, 1993). Second, in keeping with the goal of this special section, we compared parallel process latent growth curve (LGC) models to parallel process LCGMs (Nagin, 1999) and variations of GMMs (B. O. Muthén & Muthén, 2000). We sequentially tested GMMs that permitted variability between classes on the mean levels of growth parameters; variance estimates for growth parameters; covariation between growth parameters; and, finally, variance estimates for and covariation between growth parameters. Class differences in growth parameter variance estimates indicate whether some classes

include individuals who have more similar trajectories (i.e., lower variance estimates) than individuals in other trajectories. Class differences in covariance estimates between growth parameters indicate whether the relationship between two outcomes, here, depression and anxiety, differs across subgroups. Ultimately, this work can build a more nuanced model to represent the longitudinal courses of anxiety and depression in adolescent girls. Third, in addition to comparing models based on statistical fit, we also examined how caretaker (e.g., psychopathology, parenting) and youth characteristics (e.g., additional psychopathology, peer relationships) were meaningfully related to trajectory features (e.g., growth parameters, if LGC, or class membership, if LCGM or GMM).

METHODS

Sample Description

The PGS ($N = 2,451$) involves an urban community sample of four cohorts of girls, ages 5 to 8 at the first assessment, and their primary caretaker, followed annually according to an accelerated longitudinal design. Low-income neighborhoods were oversampled by design, such that neighborhoods in which at least 25% of families were living at or below the poverty level were fully enumerated and a random selection of 50% of house-holds in all other neighborhoods were enumerated (see Hipwell et al., 2002, for details on study design and recruitment). The analyses presented here use eight consecutive waves of data collected (Waves 3–10), covering ages 10 to 17 years. These waves spanned the earliest assessment of girls' self-reports of depression and anxiety (as opposed to parent reports) and concluded with the last complete wave of data collection. Participants who contributed to at least one assessment during this time period were retained for analyses ($n = 2,338$; 95.4% of original sample). Girls who began the study at age 5 provided data spanning ages 10 to 14; those who started at age 6 provided data spanning ages 10 to 15; those beginning at age 7 provided data spanning ages 10 to 16; and those who started at age 8 provided data spanning ages 10 to 17. Across all cohorts, data were available on 2,289 girls at age 10, 2,259 at age 11, 2,334 at age 12, 2,199 at age 13, 2,149 at age 14, 1,611 at age 15, 1,054 at age 16, and 517 at age 17. Retention was quite high across all cohorts and assessments (mean participation = 89.6%, range = 83.1%–95.2%). Slightly more than half of the sample is African American (53.3%), 40.6% are White, and most of the remaining 5.0% of the girls are multiracial. All study procedures were approved by the University of Pittsburgh Institutional Review Board. All primary caretakers provided written consent and assent was obtained from the girls beginning at age 6.

Data Collection

Separate in-home interviews were conducted with the girl and her parent annually by trained interviewers using a laptop computer. In Wave 3, families were compensated \$70, and this amount increased slightly with each assessment wave, resulting in \$95.25 in Wave 10.

Measures

Depression was assessed using girls' reports on the Child Symptom Inventory–4th edition (CSI–4; Gadow & Sprafkin, 1994) when girls were 10 to 13 years old and the Adolescent Symptom Inventory–4th edition (ASI–4; Gadow & Sprafkin, 1997) when girls were 14 to 17

years old. The CSI-4 and ASI-4 include Diagnostic and Statistical Manual of Mental Disorders (4th ed. [*DSM-IV*]; American Psychiatric Association, 1994) depression symptoms scored on 4-point scales ranging from 0 (*never*) to 3 (*very often*) for all symptoms except changes in appetite, sleep, and school functioning (scored .5 for no and 1.5 for yes). We used total symptom severity scores. Adequate concurrent validity, and sensitivity and specificity of depression severity scores to clinicians' diagnoses have been reported for the CSI-4 and ASI-4 (Gadow & Sprafkin, 1994, 1997). The mean score for depression severity in this sample ranged from 6.63 ($SD = 4.82$) at age 17 to 7.93 ($SD = 4.47$) at age 10. The average internal consistency coefficient across data from age 10 to 17 years was $\alpha = .78$, with values ranging from $\alpha = .72$ (age 10) to $\alpha = .83$ (age 17). Despite changes in the instrument, the depression module remained intact, with similar wording and scoring of items.

Girls' reports on the Screen for Child Anxiety and Related Emotional Disorders (SCARED; Birmaher et al., 1999) were used to measure anxiety. The SCARED can discriminate between healthy and anxious youth across late childhood and adolescence (Birmaher et al., 1999; Birmaher et al., 1997). Items from the generalized anxiety, social phobia, and panic/somatic scales were used to compute a total anxiety score. The school phobia and separation anxiety scales were not administered after age 12 and were not included. Items are scored using a 3-point scale ranging from 0 (*not true or hardly ever true*) to 2 (*true or often true*). The mean anxiety severity score ranged from 12.77 ($SD = 8.43$) at age 12 to 15.41 ($SD = 10.17$) at age 10. The average internal consistency coefficient across data from age 10 to 17 years was $\alpha = .91$ with values ranging from $\alpha = .90$ (age 11) to $\alpha = .92$ (age 17). Despite clinically relevant subscales being identified in the instrument, a one-factor model for total anxiety has been shown to fit the data well (Hale, Raaijmakers, Muris, & Meeus, 2005). In addition, we estimated omega-hierarchical as an additional index of reliability and found that values ranged from .67 (age 17) to .76 (age 10) with a mean of .71 ($SD = .03$).

Criterion variables—Criterion variables were measured at age 10 and assessed domains of functioning that have established associations with internalizing psychopathology, including interpersonal functioning (e.g., Leadbeater, Kuperminc, Blatt, & Hertzog, 1999), comorbid externalizing problems (e.g., Gilliom & Shaw, 2004), caretaker psychopathology (e.g., Klein, Lewinsohn, Rohde, Seeley, & Olin, 2005), and caregiving environment (e.g., Leve, Kim, & Pears, 2005). These constructs reflect both correlates and risk factors for internalizing problems.

Child interpersonal functioning—Girls provided self-report assessments of three separate measures. The Perception of Peers and Self Questionnaire (POPS; Rudolph, Hammen, & Burge, 1995) includes 30 items scored on a 5-point scale ranging from 1 (*not at all true*) to 5 (*very true*). Three subscales, low Social Self-Worth, low Self-Competence, and Peer Victimization, had internal consistencies of α s = .73, .52, and .77, respectively. To measure relational aggression, the PGS administered five items with a 5-point answer format ranging from 0 (*never*) to 4 (*almost always*) from the Children's Peer Relationship Scale (CPR; Crick & Grotpeter, 1995). The internal consistency coefficient was $\alpha = .74$.

Child externalizing problems—Parent report of oppositional defiant disorder (ODD) and attention deficit hyperactivity disorder (ADHD) symptom scores from the CSI-4 were used. The internal consistency coefficient was $\alpha = .87$ for ODD severity and $\alpha = .91$ for ADHD severity.

Affiliation with deviant peers was measured by asking girls a series of questions regarding whether or not any of their friends engaged in 11 delinquent activities (e.g., lying, stealing). The sum of delinquent activities is used to measure the number of delinquent activities in which girls' friends engage. The internal consistency coefficient was $\alpha = .81$.

Caretaker psychopathology—Parent self-report on the Beck Depression Inventory (BDI-II; Beck, Steer, & Brown, 1996) was used to assess depression severity over the past 2 weeks. The BDI-II consists of 21 items scored on a 4-point scale ranging from 0 (*absent*) to 3 (*severe*). The internal consistency was $\alpha = .92$. Self-report on the Alcohol Use Disorder Identification Test (AUDIT; Babor, Higgins-Biddle, Dauser, Higgins, & Bureson, 2005) was used to assess problems associated with alcohol use. The AUDIT contains 10 items scored on a 5-point scale ranging from 0 (*never*) to 4 (*four or more times per week*). The internal consistency was $\alpha = .74$.

Caregiving environment—Finally, parenting characteristics of harsh punishment, low warmth, and poor supervision were also examined. Harsh punishment was assessed by both parent and child reports on the Conflict Tactics Scale: Parent–Child version (CTSPC; Straus, Hamby, Finkelhor, Moore, & Runyan, 1998). Items referring to the primary caregiver were used and scored on a 3-point scale ranging from 1 (*never*) to 3 (*often*). Five items from the psychological aggression subscale and one item on spanking were combined to produce the harsh punishment construct. The internal consistency was $\alpha = .75$ for child report and $\alpha = .73$ for parent report. Low parental warmth was measured by parent report using six items of the Parent–Child Rating Scale (PCRS; Loeber, Farrington, Stouthamer-Loeber, & Van Kammen, 1998). Items were scored on a 3-point scale ranging from 1 (*almost never*) to 2 (*sometimes*) to 3 (*often*). The internal consistency was $\alpha = .74$. Poor supervision was assessed using five child-rated items from the Supervision Involvement Scale (Loeber et al., 1998). The internal consistency was $\alpha = .77$.

Data analysis—Initial models examined group-level linear trajectories of depression and anxiety symptoms using parallel process growth modeling. First, we tested a model specifying that relationships between depression and anxiety indicators were solely due to the relationships among the latent growth factors. Second, we tested a model that also included occasion-specific residual correlations between depression and anxiety symptom scores. We included these paths to reflect within-time associations that were not due to the growth trajectories.

After fitting these models, we fit five sets of parallel process GMMs to the data that varied from many to few constraints on growth parameters. Our models are described in Table 1 and schematically depicted in Figure 1. All sets of models were estimated for two- through nine-class solutions. We modeled LCGMs that specified that the variance estimates for the intercept and slope parameters were zero within each class (i.e., all individuals within a class

followed the same latent trajectory) and the associations between growth parameters are also zero within class. Next, we fit GMMs (GMM-1) that freely estimated variance estimates for and covariance parameters between the latent factors (i.e., not constrained to zero).

However, these were constrained to be equal across classes. Subsequently, we fit GMMs (GMM-2) that freely estimated variance estimates and covariance estimates between the latent factors, but only the variance estimates for the latent variances were permitted to vary across classes. Next, we fit GMMs (GMM-3) that freely estimated variance estimates and covariance estimates between the latent factors, but only the covariance estimates between the latent factors were permitted to vary across classes. Finally, we fit GMMs (GMM-4) that freely estimated variance estimates and covariance estimates between the latent factors and both of these sets of parameters were permitted to vary between all classes.

Models were estimated using *Mplus* 6.12 (L. K. Muthén & Muthén, 1998–2010). Data were both missing by design (i.e., across cohorts) and missing at random within cohorts or individuals. Both types of missing data are appropriately handled using full information maximum likelihood (FIML) estimation methods. Empirical comparisons of models were based on the Akaike Information Criteria (AIC), corrected AIC (AICC), Bayesian Information Criteria (BIC), sample-size adjusted BIC (aBIC), and the Lo–Mendell–Rubin Likelihood Ratio Test (LMR–LRT). Lower information criteria values indicate better fit. The LMR–LRT is a comparison of fit between the k and $k - 1$ class solutions. A significant difference indicates that the k class solution provides a significantly better fit than the $k - 1$ class solution. Simulation work (Nylund, Asparouhov, & Muthén, 2007) found that the BIC performed best of the information criteria. Thus, this criterion is weighted most strongly in empirical comparisons within model sets. We also examined the bootstrap likelihood ratio test (BLRT) as an additional index of fit. All models were estimated with a sufficient number of random starts to yield a replicated log-likelihood value. All comparisons estimated with the BLRT were significant, indicating that all differences between k and $k - 1$ classes were significant. As this was not informative, we do not present these results.

When comparing across models, we considered the most conceptually parsimonious model, the LGCM, as the baseline model. Thus, we do not consider retaining mixture model solutions with BIC values greater than the BIC for the LGCM. In addition, we did not consider models with inadmissible solutions due to negative variance estimates or negative latent variable residual error terms or correlation estimates between latent variables that exceeded 1. We compare within a set of mixture models using the BIC (Markon & Krueger, 2006) and likelihood ratio tests (Nylund et al., 2007) and between sets of mixture models using the BIC (Markon & Krueger, 2006). In addition, model selection includes some subjectivity, with attention to model estimation problems and consistency with theory.

RESULTS

Parallel Process Latent Growth Curve Model

The initial parallel process growth model included intercept and slope parameters for both depression and anxiety and freely estimated all associations between the latent growth factors. This model provided a marginal fit to the data, $\chi^2(122) = 1354.53, p < .001$, comparative fit index (CFI) = .87, Tucker–Lewis Index (TLI) = .87, and root mean square

error of approximation (RMSEA) = .066, 90% confidence interval [.063, .069]. When the model included cross-sectional associations between the residual error terms of depression and anxiety manifest indicators (and freely estimated for all ages), model fit was good, $\chi^2(114) = 647.88$, $p < .001$, CFI = .94, TLI = .94, and RMSEA = .045, 90% confidence interval [.041, .048]. This model fit significantly better than the original model, Satorra–Bentler $\chi^2_{diff}(8) = 614.32$, $p < .001$. Thus, we retained this measurement model as the basis for the five mixture models. Additional model fit information is presented in Table 2.

LCGM

LCGMs fixed within-class variances for growth parameters to be zero, which precluded any covariance among the growth parameters (i.e., per Figure 1, parameters a–h were all fixed at zero). This also indicates that all members of particular classes follow the same latent trajectory. Admissible solutions were found in all models. A minimum value for the AIC, AICC, BIC, and aBIC was not reached through the nine-class model. The LMR–LRT found that the five-class solution fit better than the four-class solution, but the six-class solution did not fit better than the five-class solution. Based on the LMR–LRT, the five-class model is preferred.

GMM-1

In the first set of GMMs, variance estimates and covariance estimates for within-class growth parameters were freely estimated, but constrained to be equal across classes, and covariance paths among all latent factors were freely estimated, but constrained to be equal across classes (i.e., in Figure 1, parameters a–h were all estimated and constrained to be equal across classes). Admissible solutions were found in the two- through seven-class models. A minimum value for the AIC, AICC, BIC, and aBIC was not reached. The LMR–LRT found that the five-class solution fit significantly better than the four-class solution, but the six-class solution did not fit significantly better than the five-class solution. Thus, based on the LMR–LRT, the five-class solution is the preferred model.

GMM-2

In the second set of GMMs, variance estimates for within-class growth parameters were freely estimated and permitted to vary across classes, whereas the covariance estimates were freely estimated, but constrained to be equal across classes (i.e., in Figure 1, parameters a–d were estimated and permitted to vary across classes, but parameters e–h were estimated and constrained to be equal across classes). An admissible solution was only found in the two-class model and, as indicated by the LMR–LRT, fit better than the one-class solution.

GMM-3

In the third set of GMMs, the covariance estimates between growth factors were freely estimated and permitted to vary across classes, whereas variance estimates for within-class growth parameters were freely estimated, but constrained to be equal across classes (i.e., in Figure 1, parameters a–d were estimated and constrained to be equal across classes, but parameters e–h were estimated and permitted to vary across classes). An admissible solution

was found in the two- and three-class models. The LMR–LRT found that the three-class solution fit better than the two-class solution.

GMM-4

In the fourth set of GMMs, variance estimates for within-class growth parameters and covariance estimates between latent factors were freely estimated for each class (i.e., in Figure 1, parameters a–h were estimated and permitted to vary across classes). However, no admissible solutions were found due to negative variance estimates for growth parameters.

Model Selection Across Model Types

From the models tested, five candidate models emerged: the LGCM, the five-class LCGM, the five-class GMM with variance and covariance equality constraints across latent classes (GMM-1), the two-class GMM with variance equality constraints across latent classes (GMM-2), and the three-class GMM with covariance equality constraints across latent classes (GMM-3). Based on the BIC, the preferred model would be the two-class GMM with variance equality constraints across latent classes (GMM-2). This model solution was characterized by severity classes: high levels of both depression and anxiety and low levels of depression and anxiety across time. Thus, this model does not satisfy theoretical predictions or reconcile conflicting results concerning longitudinal associations between depression and anxiety in the literature. The three-class GMM with covariance equality constraints across latent classes (GMM-3) found a class characterized by high, but decreasing levels of depression and anxiety, a class of low, but increasing levels of depression and anxiety, and consistently low levels of depression. This model is more consistent with theory in that there are some longitudinal changes in levels of depression and anxiety across adolescence. However, these largely reflect differences in severity.

Based on a combination of empirical comparisons and consideration of past results, the five-class GMM with variance and covariance equality constraints across latent classes (GMM-1) is preferred. However, as a number of models failed to provide admissible solutions, our decision making is based on limited information. Our preferred solution included differences in severity, as well as in longitudinal changes (Figure 2). This model included classes with low and stable depression and anxiety (Class 1; 70.2%); high levels of depression, but moderate and stable levels of anxiety (Class 2; 11.2%); low, but increasing depression and moderate and stable anxiety (Class 3; 9.7%); moderate-high and increasing anxiety and moderate and stable depression (Class 4; 4.7%); and high, but decreasing anxiety with moderate, but decreasing depression (Class 5; 4.1%). Class sizes are reported based on the estimated posterior probabilities. Significant variability was found for all growth parameters, reflecting individual differences within class. Residual correlations between observed indicators of depression and anxiety were significant (r s ranged from .26–.36, p s < .001). Lastly, growth parameters were all significantly associated (Table 3), demonstrating that initial levels of depression and anxiety were strongly associated. The associations between initial levels of depression and anxiety and the rates of change of depression and anxiety were of similar magnitude, both within and across disorder classes. These patterns indicated that higher initial scores were associated with less steep increases (if the respective slope

parameter mean was positive) or more rapid decreases (if the respective slope parameter mean was negative) in symptom levels.

Class Comparisons on Criterion Variables

To better understand the classes, we compared the classes from the five-class GMM on youth (e.g., social functioning, ADHD, ODD) and parent characteristics (e.g., psychopathology, parenting behaviors) assessed at age 10. Tests of mean level differences were conducted using the AUXILIARY option in *Mplus*.

For all indexes of social functioning, significant differences were observed across latent classes. The class characterized by consistently low levels of anxiety and depression (Class 1) and all other classes differed on social self-worth, peer victimization, and affiliation with delinquent peers (Table 4). The class characterized by consistently low levels of anxiety and depression (Class 1) and all other classes differed on social competence and relational aggression. However, the moderate-high and increasing anxiety and moderate depression class (Class 4) did not significantly differ from any classes. The high, but decreasing anxiety with moderate, but decreasing depression class (Class 5) displayed higher levels of self-worth relative to low, but increasing depression and moderate and increasing anxiety (Class 3) and high levels of depression but moderate levels of anxiety (Class 2) classes. However, self-worth in the moderate-high and increasing anxiety and moderate depression (Class 4) did not differ between any of the classes with elevated depression or anxiety.

Classes were compared on ADHD and ODD. For ODD, no significant differences were observed across classes. The class characterized by consistently low levels of anxiety and depression (Class 1) and all other classes differed on ADHD; however, no differences were found between classes with depression, anxiety, or both on ADHD.

Finally, we compared classes on parent depression and parenting dimensions. Parent depression differentiated between the class characterized by consistently low levels of anxiety and depression (Class 1) and all other classes, except for the class with the moderate-high and increasing anxiety and moderate depression (Class 4). Caretaker-reported harsh punishment and low warmth generally discriminated between the class characterized by consistently low levels of anxiety and depression (Class 1) and all other classes. However, no differences were found between classes with elevated symptoms of depression or anxiety (Class 2–5) on these parenting dimensions. No significant differences were observed across classes for alcohol use problems.

DISCUSSION

Depression and anxiety have heterogeneous courses. Growth models can describe course as individual differences in initial levels and rate of change. More recently developed statistical models (B. O. Muthén & Muthén, 2000; Nagin, 1999) examine whether variability could be explained by unobserved (i.e., latent) subgroups who differ on initial levels and rate of change. We examined changes in depression and anxiety simultaneously from age 10 through 17 when increases in internalizing problems are often found. In this example, we compared growth models and multiple types of longitudinal mixture models that differed in

assumptions about the number of groups and similarity and differences in classes in terms of the means and variance estimates for and covariance estimates between growth factors.

We tested a series of models that simultaneously included depression and anxiety and became increasingly complex. We estimated a parallel process latent growth model permitting variability in growth parameters; an LCGM specifying differences in mean growth parameters across classes, but no variability in those parameters within class; and four GMMs. The GMMs varied on whether classes could differ on growth parameter variances or covariance parameters. Comparing across these models presented two primary difficulties. First, comparisons between solutions within the same model type provided similar likelihood ratios and the BLRT was always significant. Thus, we relied mainly on the BIC as the primary indicator of fit. Arguments supporting the BIC as an indicator of model selection are present in the literature (Markon & Krueger, 2006) with a rule of thumb that differences in BIC greater than 10 provide support for model selection (Burnham & Anderson, 2002), and differences of this magnitude were found in our work. Second, although we tested a number of different types of models, a number of models had inadmissible solutions. Thus, we have incomplete evidence to fully support our conclusions. We had fewer difficulties estimating less complex models (e.g., parallel process latent growth models, LCGMs, and GMMs with variance and covariance parameters constrained to be equal across classes). However, estimation of more complex GMMs (i.e., permitting classes to differ on variance and covariance parameters) yielded many inadmissible solutions. The inadmissible solutions also made it impossible to empirically directly compare a number of specific critical tests to support our conclusions.

With these important caveats noted, we concluded that the analyses revealed that the course of depression and anxiety differs across subgroups of girls. We concluded that the best fitting model identified five classes reflecting heterogeneity in the courses of depression and anxiety across adolescence. When inspecting depression and anxiety individually, our results are consistent with previous work finding classes characterized by an ordering of severity of depression (Brendgen et al., 2005; Dekker et al., 2007; Rhebergen et al., 2012; Stoolmiller et al., 2005; Wickrama, Wickrama, & Lott, 2009) and anxiety (Broeren et al., 2013; Duchesne et al., 2008; Feng et al., 2008; Morin et al., 2011). However, we examined the courses of depression and anxiety simultaneously. This approach revealed that classes have similar courses on one outcome, but differed on the course of the other outcome. Two classes had similar courses of moderate and stable levels of anxiety (i.e., Classes 2 and 3); however, Class 2 had high levels of depression and Class 3 had low but increasing depression. Similarly, two classes had similar courses of moderate depression (Classes 4 and 5); however, Class 4 had moderate-high and increasing anxiety and Class 5 had high but decreasing anxiety. These reflect qualitative differences in the characterization of the classes that would not have been observed when relying on univariate growth mixture or dual trajectory models. Thus, our modeling approach was essential for identifying qualitatively different groups.

We also compared classes on dimensions of youth and care-giver behaviors. Here, we examined differences between class trajectories on youth social functioning and externalizing problems and caretaker parenting behaviors and psychopathology. These

analyses sought to provide information about how age 10 factors forecasted trajectories of depression and anxiety.

Nearly all variables that we examined demonstrated differences between the class with low, consistent levels of depression and anxiety and other classes with at least modest elevations of either depression or anxiety. This simple discrimination was found for multiple indexes of youth social functioning, including social self-worth and peer victimization, ADHD symptoms, and maternal caretaker depression. However, relatively few indexes differentiated between youth exhibiting some symptom elevations. Thus, it is crucial that future work in this area relies on key correlates of depression and anxiety and correlates that are specifically associated with either depression or anxiety. Some of these critical tests of differences between depression and anxiety could examine neural processes reflecting reward and threat processing, stress reactivity, reports of physiological arousal, onset of youth psychopathology, and parental history of psychopathology (rather than self-reports of current symptoms).

This substantive examination of the relationships between trajectories of depression and anxiety was conducted using sophisticated data analytic methods and comparisons across related methods. We compared an array of alternative models. However, many additional models could be estimated using nonlinear (e.g., quadratic growth; Morin et al., 2011) or piece-wise growth across segments of age (Keenan et al., 2009) or across phases of physical development. These alternative specifications of time might be tied more closely to the developmental course of internalizing problems than simply age.

A number of cross-sectional studies of internalizing problems (e.g., Markon, 2010) have found that models with a single continuous latent variable provided a better fit to the data than models that include multiple classes (with or without latent variable variances). However, we found that a number of longitudinal mixture models provided a statistically better fit to the data than the parallel process LGC model. Of note, all longitudinal mixture models that provided a better fit to the data estimated the growth parameter variance estimates. Thus, the inclusion of within-class variability appears to be a key feature of fitting models to the data. Conversely, no estimated parallel latent class growth solutions provided a better fit than the latent growth models. This is consistent with the observation that LCGMs tend to overextract classes to capture variability in the data (Bauer & Curran, 2003).

In total, this work benefits from a large, prospectively assessed sample of girls from age 10 to 17. The analyses compared multiple conceptualizations of changes in both depression and anxiety simultaneously, which was operationalized as different types of growth and GMMs. Further, we attempted to identify aspects of social functioning and experience of parenting and caretaker psychopathology that differentiated between girls with problematic levels of anxiety or depression.

Despite these strengths, this work should be considered in light of a number of limitations. First, we failed to find admissible solutions for all models. This could be due to the accelerated cohort design, as there were missing data toward the later assessment ages or just that the models were poor fits to the data. Second, the assessment of anxiety severity

relied on three (as opposed to the full five potential) scales from the SCARED and trajectories of anxiety might differ when including additional types of anxiety. However, administration of the separation and school anxiety scales ceased when these concerns are reduced in adolescence. Third, our symptom measures represent clinical severity, but no structured assessments to yield diagnoses are available for the sample. Hence, direct clinical translations are somewhat limited. Fourth, we focused on a sample of all girls and we cannot speak to how these classes might differ for boys. However, as results appeared to replicate those of previous work in mixed-gender samples (Olinio et al., 2010), this concern is modest. Fifth, as models were estimated using total scores for depression and anxiety, as opposed to all individual items, it is not possible to determine whether observed changes come from developmental changes or changes in the construct. Future work estimating models using second-order growth models would help delineate these sources of variation. Sixth, there were an extraordinary number of tests conducted, both in fitting the longitudinal models as well as the group comparisons. Future work, guided strongly by theory, should be followed to reduce chance findings in growth trajectories. Constructs used for class validation should also be carefully selected to conduct critical tests.

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Figure 1.

Schematic display of models tested. For ease of presentation, only the latent growth parameters are displayed. Labels a through d indicate growth parameter variance estimates and e through h indicate covariance estimates between growth parameters. The latent class growth models constrained parameters a–h to zero across all classes. Four different growth mixture models (GMM) were estimated that differed in the patterns of constraints on these parameters. GMM-1 freely estimated parameters a through h, however, these parameters were constrained to be equal across all classes. GMM-2 freely estimated parameters a through h, however, parameters a through d were permitted to differ across classes, whereas parameters e through h were constrained to be equal across all classes. GMM-3 freely estimated parameters a through h, however, parameters e through h were permitted to differ across classes, whereas parameters a through d were constrained to be equal across all classes. GMM-4 freely estimated parameters a through h and all parameters were permitted to differ across classes.

Figure 2. Course trajectories of depression (top) and anxiety (bottom) by class according to the GMM-1 model. Lines with the same markers across the individual plots reflect the same latent class.

TABLE 1

Synopsis of constraints for each model type.

Model	Model Type	Latent Class Variable	Growth Parameter Variance Estimates	Growth Parameter Constraint	Correlation Between Growth Parameters	Correlation Parameter Constraints
LGCM	Traditional growth model	No	Yes		Yes	
LCGM	Latent class growth model	Yes	No	Fixed at zero	No	Fixed at zero
	Growth mixture models					
GMM-1		Yes	Yes	Equal across classes	Yes	Equal across classes
GMM-2		Yes	Yes	Varies across classes	Yes	Equal across classes
GMM-3		Yes	Yes	Equal across classes	Yes	Varies across classes
GMM-4		Yes	Yes	Varies across classes	Yes	Varies across classes

Note. LGCM = latent growth curve model; LCGM = latent class growth model; GMM = growth mixture model.

TABLE 2

Model fit statistics for tested models with admissible solutions (shown in bold).

Model Set	Classes	LL	Parameters	AIC	AICC	BIC	aBIC	LMR–LRT
LGCM	1	–87893.86	38	175863.72	175865.01	176082.49	175961.76	—
LCGM	2	–90142.38	33	180350.76	180351.73	180540.74	180435.89	4177.81**
	3	–89357.07	38	178790.14	178791.43	179008.91	178888.18	1531.14**
	4	–88857.99	43	177801.97	177803.62	178049.52	177912.90	973.09**
	5	–88603.99	48	177303.98	177306.04	177580.32	177427.81	495.22*
	6	–88408.66	53	176923.32	176925.83	177228.44	177060.05	380.84
	7	–88270.16	58	176656.31	176659.32	176990.22	176805.94	270.05
	8	–88147.31	63	176420.61	176424.16	176783.31	176583.14	239.52
	9	–87862.31	76	175876.62	175881.79	176314.15	176072.69	242.23
GMM-1	2	–87742.56	43	175571.12	175572.77	175818.67	175682.05	295.00**
	3	–87669.21	48	175434.42	175436.47	175710.75	175558.25	143.01**
	4	–87614.94	53	175335.88	175338.39	175641.01	175472.61	105.81**
	5	–87566.78	58	175249.56	175252.57	175583.47	175399.20	93.90*
	6	–87538.08	63	175202.15	175205.70	175564.85	175364.68	55.97
	7	–87514.97	68	175165.93	175170.07	175557.42	175341.36	45.05
GMM-2	2	–87568.30	47	175230.60	175232.57	175501.18	175351.85	641.93**
GMM-3	2	–87638.46	49	175374.92	175377.06	175657.02	175501.33	504.89**
	3	–87552.81	60	175225.63	175228.84	175571.05	175380.42	169.31**

Note. LGCM = latent growth curve model. LCGM = latent class growth model: Growth parameter means are freely estimated and differ across classes; however, variance estimates for growth parameters are constrained to zero. GMM-1 = growth mixture model Set 1: Growth parameter means are freely estimated and differ across classes; variance estimates for growth parameters and covariance parameters between growth parameters are estimated; however, they do not differ across classes. GMM-2 = growth mixture model Set 2: Growth parameter means are freely estimated and differ across classes; covariance parameters between growth parameters are estimated; however, they do not differ across classes; variance estimates for growth parameters are estimated and permitted to and differ across classes. GMM-3 = growth mixture model Set 3: Growth parameter means are freely estimated and differ across classes; variance estimates for growth parameters are estimated; however, they do not differ across classes; covariance parameters between growth parameters are estimated and permitted to differ across classes.

*
 $p < .05$.

**
 $p < .01$.

TABLE 3

Descriptive statistics for GMM-1 growth parameters and within-class associations between growth factors.

		Depression				Anxiety			
		Intercept		Slope		Intercept		Slope	
		<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>
<i>M</i>	Class 1	8.71	.95***	-.02	.16	19.68	1.98***	2.27	.42***
	Class 2	6.48	.15***	-.26	.03***	11.58	.28***	.02	.06
	Class 3	9.86	.71***	-.46	.23*	31.98	1.77***	-3.39	.58***
	Class 4	12.81	.62***	-.36	.21	17.31	1.35***	-.16	.32
	Class 5	7.96	.67***	1.28	.18***	17.17	1.40***	.72	.40
Variance		6.16	.71***	.17	.03***	30.55	2.94***	1.24	.15***
Correlations Among Parameters									
Depression	Intercept	—							
	Slope	-.71***		—					
Anxiety	Intercept	.74***		-.53***		—			
	Slope	-.45***		.65***		-.48***		—	

Note. Top portion of the table displays the mean and standard errors for the growth parameters for the five-class growth mixture model with equality constraints on variance and covariance parameters across classes (i.e., GMM-1). The bottom portion of the table displays the correlations between the growth parameters within classes.

* $p < .05$.

*** $p < .001$.

TABLE 4

Comparison of GMM-1 model classes on maternal and youth characteristics.

	Class 1a		Class 2b		Class 3c		Class 4d		Class 5e		χ^2
	<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>	
Low Social Self-Worth (C)	12.68	0.09 ^c	13.82	0.29 ^b	13.62	0.29 ^b	13.75	0.44 ^{ab}	15.01	0.51 ^a	35.04 ^{***}
Low Self-Competence (C)	12.37	0.08 ^a	13.27	0.25 ^b	13.09	0.24 ^b	13.09	0.36 ^{ab}	13.92	0.43 ^b	23.78 ^{***}
Peer Victimization (C)	27.00	0.16 ^c	30.29	0.51 ^b	29.43	0.52 ^b	29.40	0.78 ^b	32.51	0.85 ^a	71.55 ^{***}
Relational Aggression (C)	5.97	0.04 ^a	6.62	0.14 ^b	6.34	0.13 ^b	6.33	0.20 ^{ab}	6.85	0.24 ^b	29.40 ^{***}
Deviant Peer (C)	2.58	0.06 ^{ab}	3.79	0.21 ^a	3.45	0.21 ^a	3.38	0.32 ^a	4.03	0.36 ^a	36.99 ^{***}
ODD Severity Score (P)	4.88	0.09	5.80	0.30	5.42	0.291	5.33	0.44	5.38	0.48	7.35
ADHD Severity Score (P)	11.35	0.19 ^a	13.53	0.58 ^b	13.12	0.57 ^b	13.43	0.97 ^b	14.33	0.95 ^b	21.41 ^{***}
Parent Alcohol Use Problems (P)	2.17	0.07	2.60	0.27	2.56	0.27	2.12	0.31	2.34	0.33	0.91
Parent Depression (P)	6.75	0.21 ^a	8.88	0.68 ^b	8.49	0.67 ^b	8.82	1.04 ^{ab}	9.05	1.06 ^b	14.59 ^{**}
Harsh Punishment (C)	8.21	0.05 ^{cd}	9.63	0.19 ^a	8.79	0.18 ^{bd}	8.78	0.30 ^d	9.55	0.32 ^{ad}	53.92 ^{***}
Harsh Punishment (P)	8.92	0.05 ^b	9.62	0.16 ^a	9.24	0.16 ^{ab}	9.34	0.23 ^{ab}	9.42	0.23 ^a	20.81 ^{***}
Low Warmth (P)	8.62	0.06 ^b	9.19	0.16 ^a	8.99	0.17 ^a	9.31	0.28 ^a	9.11	0.26 ^{ab}	18.01 ^{**}
Poor Supervision (C)	4.69	0.03 ^b	4.88	0.09 ^{ab}	4.77	0.09 ^{ab}	5.13	0.18 ^a	5.09	0.19 ^a	15.93 ^{**}

Note. Subscripts that differ reflect significant differences at $p < .05$. P = parent report; C = child report; ODD = oppositional defiant disorder; ADHD = attention deficit hyperactivity disorder. *ns* reflect rounded counts based on estimated posterior probabilities.

^a $n = 1,642$.

^b $n = 262$.

^c $n = 228$.

^d $n = 109$.

^e $n = 97$.

^{**} $p < .01$.

^{***} $p < .001$.