



# Daily Mood Reactivity to Stress during Childhood Predicts Internalizing Problems Three Years Later

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## Abstract

The mental health toll of common school problems that many children encounter every day is not well understood. This study examined individual differences in mood reactivity to naturally occurring school problems using daily diaries, and assessed their prospective associations with youth mental health, three years later. At baseline, 47 children ages 8 to 13 years described common problems at school and mood on a daily basis, for 8 weeks. Thirty-three youth returned for follow-up three years later at ages 11 to 17 years. Children and parents also completed one-time questionnaires about youth mental health at baseline and follow-up. There were individual differences in the within-person associations between school problems and same-day and next-day mood. A greater tendency to react to school problems with more negative mood or less positive mood on the same day predicted more parent-rated internalizing and externalizing problems and child ratings of depression symptoms three years later, relative to baseline levels of symptoms. Daily diaries can help to identify specific targets of psychosocial interventions in real world settings.

**Keywords** Mood reactivity · Internalizing problems · Daily diary · School problems · Adolescence

The years that span childhood and adolescence are characterized by important developmental changes that shape health and well-being. Due to biological maturation and social transitions from elementary to high school, peer relationships become more salient and school work becomes more challenging (Steinburg 2020). Psychiatric disorders, including

depression and problematic use of substances often emerge during this period, with the median age of onset for mood disorders being 13 years (Merikangas et al. 2010). Although the mental health consequences of exposure to severe school-related events such as peer victimization are well-established (Schwartz et al. 2015), we know little about the mental health toll of daily stressors, defined as any event that could be perceived by the youth as stressful, unpleasant or distressing, including problems with school work or peers. A closer examination of children's affective responses to such problems that arise in daily life (i.e., stressors) and their longer-term implications for mental health may uncover more practical targets of intervention.

From late childhood to adolescence, youth become increasingly sensitive to school stressors, such as difficulties with peers and disappointing grades. These stressors can evoke negative emotion and dampen positive emotion (Bai and Repetti 2018; Flook 2011; Kiang and Buchanan 2014), and short-term responses to such events may impact longer-term health outcomes (Obradović 2012; Repetti et al. 2011; Suor et al. 2015). The current paper uses electronic daily diary methodology to assess negative and positive mood reactivity to stressful experiences that arise in daily life in late childhood. We define mood as a prolonged internal affective state that lasts for several hours to days, in contrast to emotions, which

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last for briefer time intervals. We examined how mood reactivity contribute to between-person differences in mental health three years later.

## Stress, Mood and Mental Health

School is an important developmental context, where children may encounter diverse interpersonal and non-interpersonal stressors that have detrimental effects on their mental health. An investigation of 7th graders found that school work and relationship with friends were the first and third most common sources of worry. In turn, these worries were associated with higher odds of being diagnosed with depression and conduct disorder (Low et al. 2012). Children's responses to challenges at school may moderate the effects of such experiences on their mental health (Aldao et al. 2016). For example, 5th to 7th graders who reported that they would react to threats of peer rejection with withdrawal and anxiety endorsed more depression symptoms one year later. Those who reported an anger reaction were more likely to show aggressive behaviors (Zimmer-Gembeck et al. 2016).

Developmentally, some youth show increased levels of affect dysregulation and stress sensitivity from late childhood to adolescence (Gunnar et al. 2009). Those who are more sensitive to threats or have more difficulty managing their responses may be especially at risk for developing emotional or behavioral difficulties (Compas et al. 2017; Eisenberg et al. 2010). Because these processes are implicated in nearly all aspects of mental health, youth with more internalizing or externalizing problems also exhibit greater affect dysregulation and stress sensitivity (Compas et al. 2017; Lopez-Duran et al. 2009). This paper focuses on individual-level variability in negative and positive mood responses to school problems in the daily lives of healthy children. Daily mood reactivity may represent a manifestation of between-person differences in neurobiological stress response and emotion regulation processes, and indicate risk for later problems (Repetti et al. 2011).

## Naturalistic Assessment of Mood Reactivity

Intensive repeated methodology such as electronic daily diaries offer a unique approach to the assessment of mood reactivity. Electronic diary methods complement other assessment strategies such as one-time questionnaires and laboratory studies by capturing daily variability in subjective experiences while minimizing recall bias and decreasing participant burden (Bolger et al. 2003; Houben et al. 2015). The current study used data from eight consecutive weeks of daily surveys to measure each child's mood reactivity, represented by same-day associations between experiences with school problems (i.e., academic and peer problems) and negative and positive

mood. Some children's daily mood may be closely tied to stressors at school, while others' mood may be more weakly linked to such experiences.

The within-person association between school problems and mood in daily life has been established through a number of studies. School-age children and adolescents tend to report more negative mood and less positive mood on days when they experience more problems at school (Flook 2011; Kiang and Buchanan 2014; Morrow et al. 2014; Nishina and Juvonen 2005; Schneiders et al. 2006; Timmons and Margolin 2015). These stressors may also contribute to mood on the next day. However, few investigators have considered this possibility in youth, and existing studies provide inconsistent results, with some showing evidence for continued distress on the next day (Timmons and Margolin 2015), and others, none (Chung et al. 2011; Kiang and Buchanan 2014). It is also possible that a subset of children continue to experience high levels of negative mood and low levels of positive mood the day after experiencing a stressor. Individual variability in the extent to which a stressful day at school continues to impact mood on the following day may be an indicator of mood regulation with consequences for mental health.

Few daily diary studies have examined the between-person variability in the strength of the same-day link between stressors and mood. This exploration has mostly been limited to the study of individual-level moderators of the within-person associations (Schneiders et al. 2006; Timmons and Margolin 2015). For instance, a five-day study of young European adolescents showed that the same-day link between academic problems and anxious mood is stronger among those with more internalizing and externalizing problems (Schneider et al., 2006). Another study found that 5th graders who reported more negative emotion in response to stressors at school over five consecutive days also had more internalizing problems (Bai and Repetti 2018). However, the mental health outcomes in that study were assessed in the same year as the diaries; the developmental implications of children's short-term responses to daily stressors remain unclear. The current study extends past work by examining the developmental sequelae of daily mood reactivity to school stressors in an intensive longitudinal study that conducted a follow-up with youth three years after their participation in a 56-day long daily diary period.

## Current Study

Using data from eight consecutive weeks of daily diaries completed by 47 children between the ages of 8 and 13, we assessed the associations between school stressors and both same-day and next-day mood. Daily reports of negative and positive mood were examined on each day, resulting in four individual-level indices of mood reactivity: same-day negative mood, same-day positive mood, next-day negative mood

and next-day positive mood reactivity. Internalizing and externalizing problems were measured at baseline when the diaries were completed, and three years later. Given the link between affect regulation and later outcomes (Zimmer-Gembeck et al. 2016), we hypothesized that children who show greater elevations in negative mood or decreases in positive mood on days when they experience more school stressors would have more internalizing and externalizing problems at the three-year follow-up. As with same-day associations, we also predicted that children who continue to report elevated negative mood or decreased positive mood the next day would exhibit more internalizing and externalizing problems at follow-up.

## Methods

### Participants

Two-parent families with at least one child between the ages of 8 and 13 were recruited from an urban city in western United States through newspaper advertisements, direct mailings to homes within 5 miles of campus and flyers that described a study of family life, daily activities and health. Recruitment efforts were directed at eight schools, two libraries, seven community or recreation centers, and six different medical clinics serving families near the university. Flyers distributed in medical clinics specifically recruited families whose children get a lot of colds and flus. Because the larger study focused on daily family life and susceptibility to upper respiratory infections, at least one parent and the target child were screened for mental and physical health problems, yielding a generally healthy sample free of major chronic illness. The target child had to be biologically related to at least one of the participating parents. Baseline data were collected in three yearly cohorts between the months of September and May from 2009 to 2012. At baseline, 47 target children (19 boys, 28 girls;  $M$  age = 11.28 years,  $SD$  = 1.50;  $Range$  = 8–13) participated, along with all 47 mothers ( $M$  age = 43.29,  $SD$  = 6.31) and 39 fathers ( $M$  age = 43.67,  $SD$  = 8.10). The sample was ethnically diverse; parents self-identified as 45% non-Hispanic white, 22% Latino/Hispanic, 17.5% African-American, 12.5% Asian, 1.5% Native American and 1.5% “Other”. They reported a median personal income within a \$31,850 - \$82,400 bracket at baseline<sup>1</sup> and over half of all

<sup>1</sup> Response options for personal parental income were slightly modified between year 2 and 3 of study enrollment for consistency with 2010 changes in federal tax brackets. Of those enrolled during the first two years, 19.6% reported income  $\leq$  \$8350; 7.8% between \$7826–\$31,850, 35.3% between \$31,851–\$64,250, 17.6% between \$64,251–\$97,925 and 19.6%  $\geq$  \$97,926. For parents in year 3, 13.2% reported income  $\leq$  \$8375; 23.7% between \$8376–\$34,000, 44.7% between \$34,001–\$82,400, 15.8% between \$82,401–\$171,850 and 2.6%  $\geq$  \$171,851.

mothers and fathers had a bachelor’s degree or higher. Among mothers, the highest level of education achieved was a high school diploma for 4.3%, some college for 38.3%, a bachelor’s degree for 34.0%, and a graduate or professional degree for 23.4%. Among fathers, 4.9% had a high school diploma or less, 36.6% attended some college, 31.7% had a bachelor’s degree and 26.8% had a graduate or professional degree.

Three years later, 33 of the 47 youth (70.2%; 15 boys, 18 girls) returned to complete the follow-up assessment when they were between 11 to 17 years old ( $M$  age = 14.88,  $SD$  = 1.61). Mothers and fathers had the option of completing a one-time questionnaire about the youth. All 33 youth had at least one parent complete the questionnaire; the data were provided by mothers only in 23 cases, by fathers only in 7 cases, and by both mothers and fathers in 3 cases. Youth who completed the follow-up assessment ( $N$  = 33) did not differ from those lost to follow up ( $N$  = 14), with respect to age, sex, maternal race-ethnicity, mother-rated youth internalizing and externalizing problems, child-rated depression symptoms and mood reactivity at baseline.

### Procedures

**Baseline.** During an initial visit that typically occurred in the family’s home, researchers discussed study procedures with the family and obtained informed parent consent and youth assent. A second visit when participants were trained on diary procedures typically took place within a week of the first. The eight-week daily diary began on the Saturday following the second visit. Children completed daily diaries every weekday and weekend day, as close to bedtime as possible by using unique usernames and passwords to log into our study web portal. Personalized “home” pages provided a link to the current-day online diary (blocks of items were randomly ordered across days of the week). Paper diaries were available in case of technical difficulties. Child and parent participants also used the study web portal to complete one-time questionnaires about youth mental health at their convenience during the diary phase. Each child earned up to \$300, and each parent, \$350 for their participation.

**Follow-up.** Approximately three years after the baseline assessment, families who had completed the baseline procedures were contacted via mail and phone calls, to participate in a follow-up assessment. Follow-up procedures were similar to those at baseline, but involved a shorter diary phase and very limited parent participation. During an initial home visit, researchers obtained parent consent and youth assent, and trained the participants on study procedures. Youth completed one-time online questionnaires about mental health, within 4 weeks of the home visit. Each youth earned up to \$210 for participation in the follow-up assessment, and each parent could earn up to \$20 for completing an optional survey. The

university Institutional Review Board (IRB) approved all study procedures at both assessments.

## Measures

The current study uses youth daily reports of school problems and mood completed during the baseline assessment. In addition, youth and parents completed questionnaires about youth mental health at baseline and follow-up. Table 1 presents summary statistics.

**Youth Daily Diary.** The 47 children in the study completed a total of 2449 diaries (Reynolds et al. 2016). The average child completed 94% of the 56 diaries ( $M = 52.77$ ,  $SD = 6.64$ ), and of these, 96% were done on time, meaning before 9 AM the next morning. On-time and late diaries were both included in the data analyses.

**School Problems.** Daily school problems were assessed using a 10-item checklist, adapted from the Youth Everyday Social Interaction and Mood scales (YES-I-AM; Repetti 1996). The YES I AM scales were originally derived from a principal component factor analyses of ratings completed by 10 to 13 year old youth, the daily school events scales have demonstrated construct validity and internal reliability in a number of other studies (Repetti 1996; Lehman and Repetti

2007; Bai and Repetti 2018). On days when they reported having gone to school, children responded to a ten-item checklist about problems at school: five items asked about academic problems (e.g., “I made a mistake in class today”, “I had trouble finishing my schoolwork today”) and five asked about social difficulties with peers that might have occurred that day (e.g., “Another kid teased me today”, “I felt that my friends didn’t want to be around me today”). Because the primary aim of this study is to assess individual differences in mood reactivity, responses (1 = yes, 0 = no) were summed across all 10 items to create a daily school problems score. The school problems score was coded as missing if there were missing responses on one or more of the school problem items that day. Out of 1449 surveys completed on weekdays when youth attended school, 1418 (97.9%) had complete data on the school problems checklist. On average, children completed the school problems checklist on 30.7 days ( $SD = 5.72$ ,  $Range = 14–39$ ) and reported at least one school problem on 26.7% of those days ( $SD = 24.8$ ,  $Range = 0–100$ ). The intraclass coefficient (ICC), which indicates the proportion of variance attributable to between-individual differences was .59. Between-person reliability was high ( $R_{KF} = 0.99$ ) and within-person reliability was acceptable ( $R_c = 0.65$ ). High internal consistency is not expected in a daily events checklist that assesses whether events occurred, as events are not necessarily dependent or related to one another.

**Negative and Positive Mood.** Positive and negative mood scales were adapted from a prior daily diary study on emotion and illness (Cohen, Alper, Doyle, Treanor, & Turner, 2006), with the addition of two developmentally sensitive positive mood items (i.e., proud and loved) from YES-I-AM (Repetti 1996). The positive and negative mood scales originally developed by Cohen et al. (2006) has high internal reliability, ranging from 0.82 to 0.90. In the current study, daily negative mood was assessed with six items (sad, mean, unhappy, tense, angry, worried) and positive mood was assessed with eight items (lively, happy, relaxed, full of energy, cheerful, calm, proud, loved). For each item, children were instructed to “tell us how [they] felt today” on a four-point response scale, ranging from 1 (*not at all*) to 4 (*all day*). Item responses were averaged each day to create two scale scores reflecting daily negative mood and daily positive mood ( $n_{obs} = 2449$ ). In the current study, between-person ( $R_{KF}$ ) and within-person reliability ( $R_c$ ) for negative mood were 1.00 and 0.72, respectively. Between-person and within-person reliability for positive mood were  $R_{KF} = 1.00$  and  $R_c = 0.82$ . ICC estimates for negative and positive mood were .56 and .82, respectively, suggesting that there was little within-person variation in positive mood.

**Questionnaires.** The *Child Behavior Checklist (CBCL;* Achenbach 2009) is a widely used 113-item parent questionnaire that assesses parents’ report of child emotional and behavioral functioning. It shows good psychometric properties,

**Table 1.** Descriptive statistics for same-day and next-day mood reactivity at baseline and youth mental health at baseline and follow-up.

|   | N  | Mean | SD   | Min   | Max  |
|---|----|------|------|-------|------|
| AGGREGATED DAILY VARIABLES <sup>a</sup> |    |      |      |       |      |
| School problems                         | 47 | 0.62 | 1.14 | 0     | 7.37 |
| Negative mood                           | 47 | 1.27 | 0.29 | 1.01  | 2.28 |
| Positive mood                           | 47 | 2.97 | 0.70 | 1.64  | 3.99 |
| SAME DAY MOOD REACTIVITY                |    |      |      |       |      |
| Negative mood                           | 47 | 0.06 | 0.02 | 0.01  | 0.12 |
| Positive mood <sup>b</sup>              | 47 | 0.07 | 0.04 | −0.01 | 0.20 |
| NEXT DAY MOOD REACTIVITY                |    |      |      |       |      |
| Negative mood                           | 47 | 0.01 | 0.02 | −0.11 | 0.05 |
| Positive mood <sup>b</sup>              | 47 | 0.00 | 0.04 | −0.11 | 0.12 |
| BASELINE MENTAL HEALTH SCORES           |    |      |      |       |      |
| Parent – Internalizing                  | 47 | 0.11 | 0.12 | 0     | 0.56 |
| Parent – Externalizing                  | 47 | 0.13 | 0.13 | 0     | 0.47 |
| Child – Depression symptoms             | 47 | 0.20 | 0.26 | 0     | 1.20 |
| FOLLOW-UP MENTAL HEALTH SCORES          |    |      |      |       |      |
| Parent – Internalizing                  | 33 | 0.13 | 0.16 | 0     | 0.58 |
| Parent – Externalizing                  | 33 | 0.13 | 0.16 | 0     | 0.58 |
| Child – Depression symptoms             | 33 | 0.37 | 0.39 | 0     | 1.40 |

<sup>a</sup> Daily variables were aggregated by taking the mean of all available data for each child

<sup>b</sup> Values were reverse coded (multiplied by −1) for ease of interpretation; Higher scores indicate children showed greater decrease in positive mood in association with school problems

including high test-retest reliability and high external validity. The current study uses the Internalizing Problems (31 items; withdrawn, somatic complaints and anxious/depressed subscales) and Externalizing Problems (33 items; aggressive and delinquent behaviors subscales) broad-band scales. Items were rated on a 0 (*not true*) to 2 (*very true or often true*) scale and averaged such that higher scores indicated more internalizing or externalizing problems. Internal consistency of the broad-band scales at baseline and follow-up for mothers and fathers ranged from .81 to .93. At baseline, both parents independently completed the CBCL for 39 youth, and only mothers for 8. At follow-up, both parents independently completed the form for 3 youth, mothers only for 23, and fathers only for 7. Due to the high correlation and comparability between mother and father CBCL scores at baseline ( $r(37) = .67$ ,  $t(38) = 0.91$  for internalizing problems;  $r(37) = .68$ ,  $t(38) = 0.87$  for externalizing problems), we averaged mother and father reports whenever both reports were available at the same data collection point. Although the average child was described as displaying only 3–4 symptoms on each scale, this non-clinical sample includes children whose parents endorsed more than half of the internalizing and externalizing behaviors.

*Child Depression Inventory – Short Form* (CDI; Kovacs 1985, 1992) is a 10-item questionnaire that assesses children’s self-reports of affective, behavioral, somatic and cognitive symptoms of depression. At baseline and follow-up, children responded to each item by indicating which of three sentences best described how they have felt during the last two weeks (e.g., “I am sad once in a while, I am sad many times, I am sad all the time”). Item scores ranged from 0 to 2, and scores were averaged across the 10 items. The CDI shows strong psychometric properties, including high test-retest reliability, concurrent validity and predictive validity for depression (Carey et al. 1987). Cronbach’s alphas were .81 at baseline and .88 at follow-up. Although, on average, children self-reported only 2 symptoms at baseline and 3–4 symptoms at follow-up, some children reported 12 or more symptoms.

## Data Analysis

First, we conducted multilevel linear regression analyses (PROC MIXED in SAS 9.4 software) to derive individual-level empirical Bayes (EB) estimates of same-day and next-day associations between school problems and negative and positive mood. Mood ratings on days when youth completed the school problems checklist and the next day were used in the computation of same-day and next-day mood reactivity, respectively. Second, we examined the bivariate correlations between same-day and next-day mood reactivity and youth internalizing and externalizing problems at baseline and follow-up. Third, multiple linear regression analyses tested whether mood reactivity separately predict youth mental

health three years later, over and above age, sex and baseline symptoms levels. Assuming that data is missing completely at random (Little’s test of MCAR  $X^2(7) = 3.50$ ,  $p = .836$ ), we used listwise deletion in each regression model. Analysis of power conducted on G\*Power 3.1 indicated that, the achieved follow-up sample size of 33 allows detection of a moderate to high effect size of  $f^2 = 0.26$  in multiple regressions of four total predictor variables assuming 80% power and a two-sided significance level of  $\alpha = 0.05$ . We conducted sensitivity analyses of the multiple linear regressions, by bootstrapping the standard error estimates with 1000 replications, to account for sampling error in our EB estimates of mood reactivity and non-normality in our dependent variables. All analyses were conducted on SAS 9.4 or Stata 13.1.

## Results

### Deriving Indices of Mood Reactivity

First, we tested four multilevel models (MLM) examining the within-person associations between child-mean centered school problems and four mood outcomes: negative and positive mood on the same day and next day. We included child-mean level of school problems as a covariate and specified a first order autoregressive structure for residuals to correct for time dependencies between reports on adjacent days. In each MLM, the intercept and slope of school problems were allowed to randomly vary between individuals, making it possible to extract individual-level EB estimates of the intercept and slope. Each EB slope represented the unique association between school problems and mood for that child. In order to extract EB slopes as predictors, there had to be a statistically significant random effect of school problems on mood. Table 1 presents descriptive statistics for the four indices of mood reactivity. We use the term “same-day mood reactivity” to refer to the daily association between school problems and mood observed in a child’s data. The term “next-day mood reactivity” refers to the association between a child’s report of school problems and his or her mood on the following day.

Same-day negative mood and positive mood were separately examined as the dependent variable in two MLMs. For the average child, more school problems was associated with higher levels of negative mood that day ( $B = 0.06$ ,  $SE = .01$ ,  $p < .001$ , 95% CI [0.04, 0.08]). Moreover, there was significant individual variability in the association between school problems and negative mood, as indicated by a significant likelihood ratio test of the random slope and covariance between random slope and intercept,  $\chi^2(2) = 11.0$ ,  $p = .004$ . We extracted EB slopes, which represented the unique association between school problems and mood for each child. Mean same-day negative mood reactivity across the 47 children was equivalent to the fixed effect ( $M = 0.06$ ),

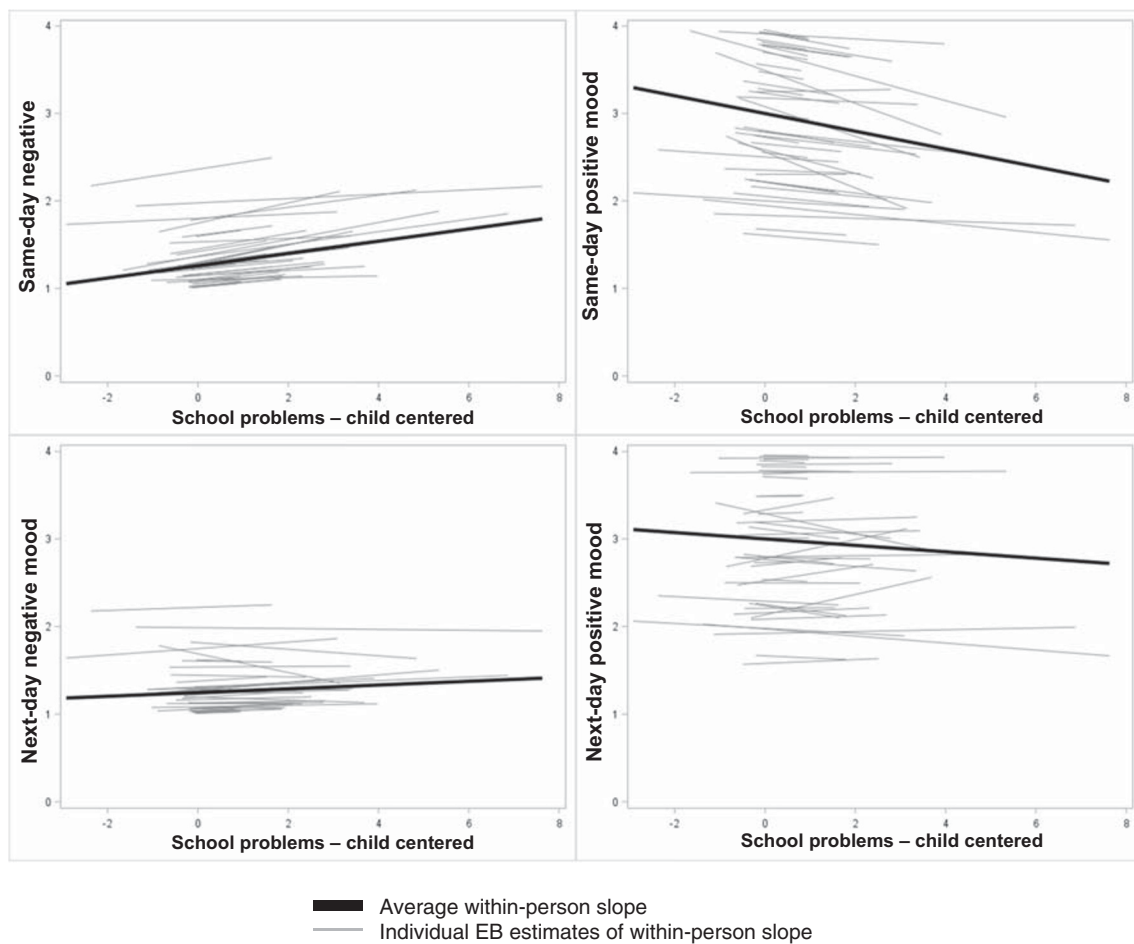
and children's slopes ranged from 0.01 to 0.12. Some children showed a negligible association between reports of school problems and negative mood that day, while at least one child showed an average increase of 0.12 points on the negative mood scale when they experienced one more problem than usual. See Fig. 1.

Likewise, for the average child, more school problems was associated with lower levels of positive mood on the same day ( $B = -0.07$ ,  $SE = 0.02$ ,  $p < .001$ ,  $95\% CI [-0.11, -0.04]$ ). As shown in Fig. 1, the association between school problems and same day positive mood varied between individuals,  $\chi^2(2) = 23.6$ ,  $p < .001$ . When deriving individual-level measures of same-day positive mood reactivity, EB estimates were reverse coded (multiplied by  $-1$ ) for ease of interpretation. Higher values indicated a greater decrease in positive mood in association with more school problems. Thus, mean same-day positive mood reactivity was equal in magnitude but reversed in direction, relative to the average fixed effect of school problems on positive mood ( $M = 0.07$ ). Same day positive mood reactivity ranged from  $-0.01$  to  $0.20$  across 47 children. As was the case for negative mood, there was no association between daily school problems and positive mood

that day for some children. However, for other children, school problems were linked to less positive mood on the same day.

Next, two MLMs separately tested the within-person association between school problems and negative and positive mood on the next day. For the average child, more school problems did not significantly predict next-day negative mood ( $B = 0.01$ ,  $SE = 0.01$ ,  $p = .395$ ,  $95\% CI [-0.01, 0.03]$ ). Although the average child did not show an association between school problems and next-day negative mood, there was significant between-person variability in the association,  $\chi^2(2) = 7.7$ ,  $p = .021$  (see Fig. 1). Mean next-day negative mood reactivity was equivalent to the unstandardized B coefficient ( $M = 0.01$ ) and ranged from  $-0.11$  to  $0.05$ . Thus, for some children in this study, there was an inverse association between reports of school problems and negative mood ratings the following day. A higher next-day negative mood reactivity score indicated that the child's daily data showed a positive link between school problems and negative mood the following day.

Likewise, the within-person association between school problems and next-day positive mood was not significant



**Fig. 1** Within-person associations between school problems and negative and positive mood on the same day and next day.

( $B = -0.002$ ,  $SE = 0.02$ ,  $p = .906$ ,  $95\% CI [-0.04, 0.03]$ ). However, the slope significantly varied between individuals,  $\chi^2(2) = 12.6$ ,  $p = .002$  (see Fig. 1). EB estimates of the within-person association between school problems and next-day positive mood were reverse coded (multiplied by  $-1$ ) for ease of interpretation. Higher values indicated a greater decline in positive mood in association with more school problems the previous day. The average next-day positive mood reactivity score was  $-0.003$ , and the range across all children in the study was  $-0.11$  to  $0.12$ .

### Correlations between Mood Reactivity and Youth Symptoms

Next, we examined Pearson correlations between the four indices of mood reactivity, three measures of youth mental health at baseline, and three measures of youth mental health at follow-up (see Table 2). Prior to conducting correlations, we winsorized all outliers for the four reactivity and six outcomes variables that exceeded  $\pm 3$  SD from the variable's mean. Same-day positive mood reactivity, baseline internalizing problems, and baseline depression symptoms each had one outlier that was winsorized to  $+3$  SD from the mean, and the minimum next-day negative mood reactivity score was winsorized to  $-3$  SD from the mean.

Cross-sectional analysis at baseline indicated that greater same-day negative and positive mood reactivity were

correlated with more externalizing problems. Less same-day, but greater next-day positive mood reactivity were correlated with more child depression symptoms. Prospectively, greater same-day negative mood reactivity was correlated with more internalizing and externalizing problems three years later, and greater same-day positive mood reactivity was correlated with more future externalizing problems. None of the prospective links between next-day reactivity at baseline and youth mental health at follow-up was significant.

### Mood Reactivity Predicting Youth Symptoms Three Years Later

Given the lack of significant bivariate correlations between next-day reactivity and youth mental health at follow-up, a final set of six multiple linear regression analyses tested only the hypothesis that same-day reactivity scores would predict youth mental health (internalizing problems, externalizing problems and self-reported depression symptoms) three years later. All of the mood reactivity predictor variables were grand mean centered, and we used winsorized values for reactivity and mental health. With respect to covariates, models controlled for child sex (male = 0, female = 1), grand mean centered age in years at baseline, and the baseline symptom score that corresponded to the outcome of interest at follow-up (e.g., baseline depression symptoms controlled in the prediction of depression symptoms at follow-up).

**Table 2.** Bivariate correlations between same-day and next-day mood reactivity scores and youth mental health at baseline and follow-up.

|                                | 1 | 2       | 3       | 4       | 5       | 6       | 7      | 8     | 9       | 10      | 11    | 12      |      |
|--------------------------------|---|---------|---------|---------|---------|---------|--------|-------|---------|---------|-------|---------|------|
| AGGREGATE DAILY VARIABLES      |   |         |         |         |         |         |        |       |         |         |       |         |      |
| 1 School problems              |   |         |         |         |         |         |        |       |         |         |       |         |      |
| 2 Negative mood                |   | 0.65*** |         |         |         |         |        |       |         |         |       |         |      |
| 3 Positive mood                |   | -0.23   | -0.37*  |         |         |         |        |       |         |         |       |         |      |
| SAME DAY MOOD REACTIVITY       |   |         |         |         |         |         |        |       |         |         |       |         |      |
| 4 Negative mood                |   | 0.09    | 0.23    | -0.02   |         |         |        |       |         |         |       |         |      |
| 5 Positive mood <sup>a</sup>   |   | -0.11   | 0.01    | 0.36*   | 0.52*** |         |        |       |         |         |       |         |      |
| NEXT DAY MOOD REACTIVITY       |   |         |         |         |         |         |        |       |         |         |       |         |      |
| 6 Negative mood                |   | 0.11    | -0.37*  | 0.06    | -0.03   | -0.21   |        |       |         |         |       |         |      |
| 7 Positive mood <sup>a</sup>   |   | 0.10    | 0.01    | 0.07    | -0.20   | -0.20   | 0.41** |       |         |         |       |         |      |
| BASELINE MENTAL HEALTH         |   |         |         |         |         |         |        |       |         |         |       |         |      |
| 8 Parent – Internalizing       |   | 0.12    | 0.08    | -0.11   | 0.06    | 0.08    | 0.11   | 0.08  |         |         |       |         |      |
| 9 Parent – Externalizing       |   | -0.05   | -0.04   | 0.03    | 0.29*   | 0.29*   | 0.10   | 0.12  | 0.69*** |         |       |         |      |
| 10 Child – Depression symptoms |   | 0.52*** | 0.52*** | -0.45** | -0.22   | -0.44** | 0.09   | 0.31* | 0.12    | -0.17   |       |         |      |
| FOLLOW-UP MENTAL HEALTH        |   |         |         |         |         |         |        |       |         |         |       |         |      |
| 11 Parent – Internalizing      |   | 0.05    | 0.24    | -0.11   | 0.46**  | 0.29    | -0.19  | -0.10 | 0.65*** | 0.59*** | -0.06 |         |      |
| 12 Parent – Externalizing      |   | 0.08    | 0.24    | -0.07   | 0.55**  | 0.53**  | -0.34  | -0.27 | 0.41*   | 0.61*** | -0.24 | 0.68*** |      |
| 13 Child – Depression symptoms |   | 0.31    | 0.35*   | -0.13   | 0.19    | 0.23    | 0.24   | 0.33  | 0.29    | 0.41*   | 0.30  | 0.32    | 0.25 |

\* $p < .05$ , \*\*  $p < .01$ , \*\*\*  $p < .001$ ; <sup>a</sup> Positive mood reactivity values were reverse coded (multiplied by  $-1$ ), such that higher scores indicate greater decreases in positive mood. Outliers were winsorized to  $\pm 3$ SD from the mean

As displayed in Table 3, four of the six models testing same-day mood reactivity were statistically significant. Greater same-day negative mood reactivity predicted increases in internalizing problems ( $\Delta R^2 = 0.13$ ; Fig. 2) and externalizing problems ( $\Delta R^2 = 0.13$ ; Fig. 2) three years later, but did not predict depression symptoms. Same-day positive mood reactivity predicted increases in externalizing problems ( $\Delta R^2 = 0.08$ ) and depression symptoms ( $\Delta R^2 = 0.16$ ; Fig. 3), over and above baseline symptom levels. Findings were consistent when using unwinsorized scores. We conducted sensitivity analyses of our hypotheses by bootstrapping the standard error estimates in our regressions. When using this approach, one of the four prospective associations, positive mood reactivity predicting externalizing problems, did not reach statistical significance.

We conducted additional sensitivity analysis on a subsample of 26 youth who had complete mother reports of youth internalizing and externalizing problems at baseline and follow-up, using winsorized scores. The prospective association between same-day negative mood reactivity and internalizing symptoms at follow-up over and above baseline symptoms was replicated in this subsample ( $B = 2.05$ ,  $SE = 0.79$ ,  $p = .017$ , 95% CI [0.41, 3.70]). However, its association with externalizing symptoms escaped statistical significance ( $B = 2.16$ ,  $SE = 1.15$ ,  $p = .076$ , 95% CI [-0.24, 4.55]). The links between same-day positive mood reactivity and internalizing and externalizing problems at follow-up were not significant in this subsample.

## Discussion

The current study used a daily diary approach to assess mood reactivity to school problems in 8 to 13-year-old children, and examined its prospective links to mental health three years later. There was considerable individual variability in the same-day and next-day links between school problems and mood, and we derived four between-person measures of children's mood reactivity. Children who reported greater negative mood on days when they experienced more school problems had higher levels of parent-reported internalizing and externalizing problems three years later, over and above baseline symptom levels. The children who described less positive mood on days when they reported more problems at school experienced increases in depression symptoms. Next-day mood reactivity was not linked to mental health in adolescence. Children who are more reactive to daily school problems, reporting more negative mood or less positive mood that day, may be at greater risk for mental health problems in adolescence.

## Naturalistic Assessment of Mood Reactivity

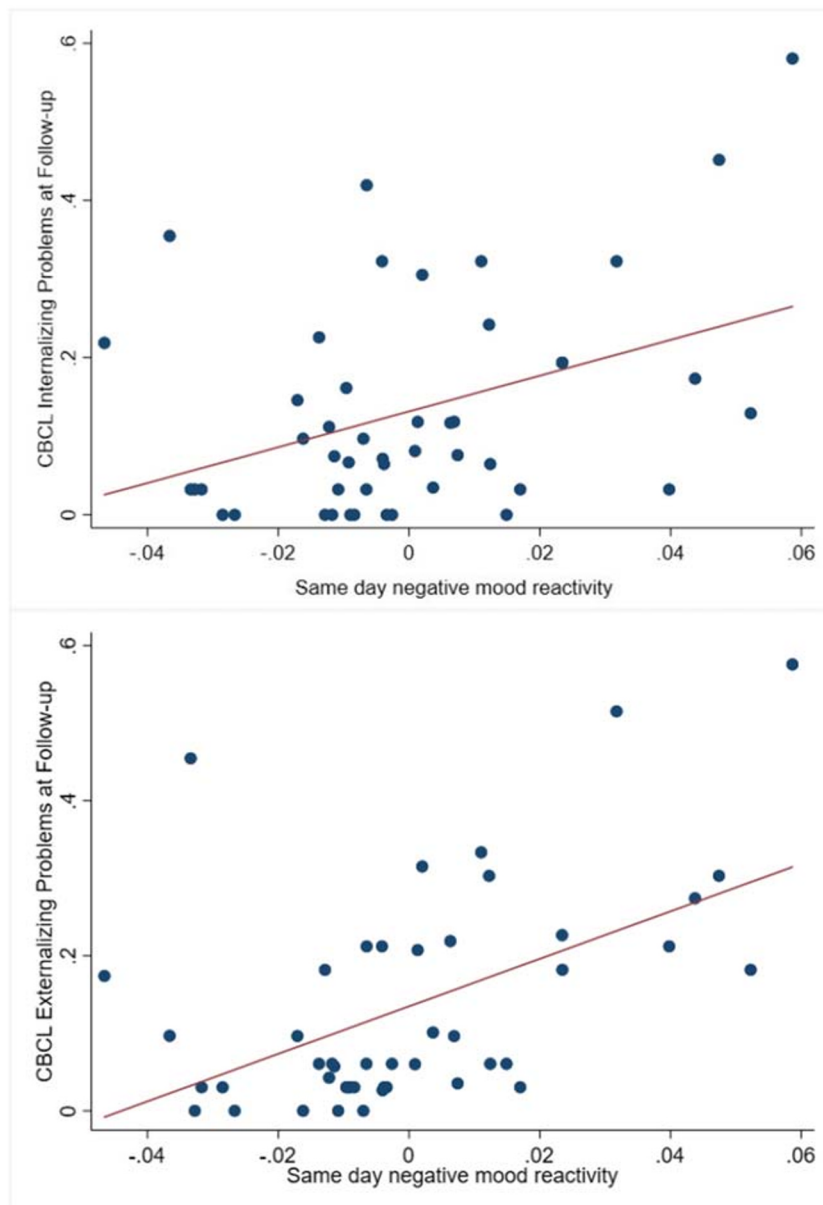
Consistent with prior findings, children reported higher negative mood and lower positive mood on days when they experienced more problems at school. In contrast, for the average child, school problems on a given day did not continue to show an effect on mood the next day. However, for both same-day and next-day associations, there were significant

**Table 3.** Results of six multiple regression models, each separately testing the prospective association between same-day mood reactivity to school problems and youth mental health at follow-up, controlling for baseline symptoms.

| Outcome Variables at Follow Up | Same Day Negative Mood Reactivity             |      |             |                 |             | Same Day Positive Mood Reactivity <sup>a</sup> |      |             |                 |             |
|--------------------------------|---|------|-------------|-----------------|-------------|--|------|-------------|-----------------|-------------|
|                                | B   | SE   | 95% CI      | Bootstrapped SE |             | B  | SE   | 95% CI      | Bootstrapped SE |             |
| <b>Internalizing problems</b>  |   |      |             |                 |             |  |      |             |                 |             |
| Mood reactivity                | 2.39**  | 0.82 | 0.71, 4.08  | 1.09            | 0.25, 4.53  | 0.70   | 0.46 | -0.23, 1.63 | 0.70            | -0.67, 2.07 |
| Baseline symptoms              | 0.77***                                       | 0.16 | 0.44, 1.10  | 0.17            | 0.43, 1.11  | 0.81***  | 0.17 | 0.45, 1.17  | 0.19            | 0.44, 1.17  |
|                                | $R^2 = 0.58$ ; $F(4, 28) = 9.54$ , $p < .001$ |      |             |                 |             | $R^2 = 0.49$ ; $F(4, 28) = 6.78$ , $p < .001$  |      |             |                 |             |
| <b>Externalizing problems</b>  |   |      |             |                 |             |  |      |             |                 |             |
| Mood reactivity                | 2.59**  | 0.92 | 0.71, 4.47  | 1.31            | 0.03, 5.15  | 1.08*  | 0.50 | 0.04, 2.11  | 0.73            | -0.35, 2.51 |
| Baseline symptoms              | 0.55**  | 0.17 | 0.20, 0.89  | 0.18            | 0.19, 0.90  | 0.56**   | 0.18 | 0.18, 0.93  | 0.19            | 0.18, 0.93  |
|                                | $R^2 = 0.53$ ; $F(4, 28) = 7.85$ , $p < .001$ |      |             |                 |             | $R^2 = 0.48$ ; $F(4, 28) = 6.46$ , $p < .001$  |      |             |                 |             |
| <b>Depression symptoms</b>     |   |      |             |                 |             |  |      |             |                 |             |
| Mood reactivity                | 3.04  | 2.64 | -2.37, 8.45 | 2.26            | -1.40, 7.47 | 3.63**   | 1.30 | 0.97, 6.28  | 1.53            | 0.62, 6.63  |
| Baseline symptoms              | 0.49  | 0.24 | 0.00, 0.98  | 0.27            | -0.05, 1.02 | 0.70**   | 0.23 | 0.22, 1.18  | 0.29            | 0.13, 1.27  |
|                                | $R^2 = 0.28$ ; $F(4, 28) = 2.79$ , $p = .046$ |      |             |                 |             | $R^2 = 0.41$ ; $F(4, 28) = 4.95$ , $p < .004$  |      |             |                 |             |

<sup>†</sup> $p < .10$ , \* $p < .05$ , \*\*  $p < .01$ , \*\*\*  $p < .001$ ; <sup>a</sup>Positive mood EB estimates were reverse coded (multiplied by -1), such that higher reactivity scores indicate greater decreases in positive mood; B = unstandardized coefficient; SE = standard error; 95% CI = 95% confidence interval. Models control for child sex (male = 0, female = 1), baseline age (centered), and baseline levels of outcome variable; Outliers were winsorized to  $\pm 3SD$  from the mean





**Fig. 2** Prospective associations between same-day negative mood reactivity and parent report of internalizing and externalizing problems at follow-up. Model controls for child sex (male = 0, female = 1), baseline age (centered), and baseline levels of outcome variable.

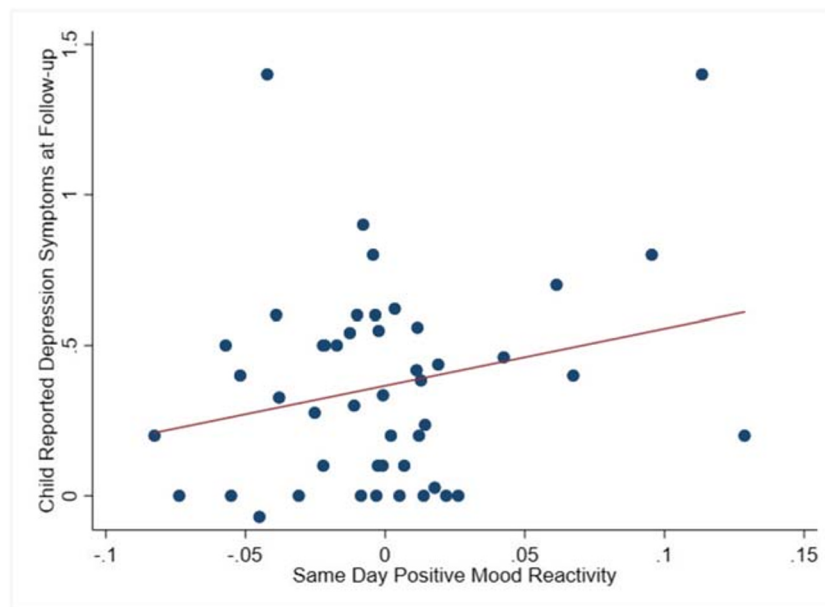
variability between individuals. For some children, these types of stressors appear to have a continuing impact on elevated negative mood or dampened positive mood the next day. This phenotype may represent a child who is more reactive to peer- or achievement-related experiences and has difficulty curtailing the duration of less desirable affective states (Compas et al. 2017; Eisenberg, Spinrad & Eggum, 2010).

The current study highlights the utility of an intensive repeated measures approach in the assessment of mood regulation. In addition to its methodological advantages over traditional questionnaires or laboratory studies (Smyth et al. 2018), intensive repeated measures capture the everyday manifestations of individual traits. These measures are particularly

informative when used to study change over longer spans of time. Intensive longitudinal studies that examine short-term and long-term developmental processes across different time scales can increase our understanding of how everyday experiences may both contribute to and reflect underlying individual differences in affect regulation, and predict future mental health.

### Prospective Links to Psychological Functioning in Adolescence

Individual measures of mood reactivity to school problems prospectively predicted parent-reported internalizing and



**Fig. 3** Prospective association between same-day positive mood reactivity and child report of depression symptoms at follow-up. Model controls for child sex (male = 0, female = 1), baseline age (centered), and baseline levels of outcome variable.

externalizing problems and self-reported depression symptoms three years later, over and above baseline symptoms, age, and child sex. Higher same-day negative mood reactivity scores predicted an increase in parent reports of internalizing and externalizing problems and higher same-day positive mood reactivity (less positive mood on more stressful days) predicted an increase in self-reported depression symptoms. These findings complement laboratory-based research suggesting that neurobiological reactivity to interpersonal and non-interpersonal challenges may indicate risk for mental health problems (Benito-Gomez et al. 2019; Wadsworth et al. 2019). However, given our small sample size at follow-up, the prospective findings need additional replication.

Current findings are consistent with existing daily diary and EMA research that indicates greater levels of mood reactivity in children and adults with emotional and behavioral problems (Lamers et al. 2018; Tan et al. 2012). For example, in a clinical sample of adults, those with a mood disorder reported greater negative and positive mood reactivity to daily stressors and positive events (Lamers et al. 2018). Although findings are more consistent for internalizing problems, higher levels of mood reactivity have also been observed among youth with more combined internalizing and externalizing problems (Schneiders et al. 2006). The current study extends these findings by testing mood reactivity to daily experiences as a precursor to exacerbations in symptomatology from late childhood to adolescence. In addition to being a symptom of emotional and behavioral problems, daily mood reactivity may be an early indicator of risk for worsening symptoms across adolescence.

Our naturalistic measure of mood reactivity likely represents a manifestation of individual differences in neurobiological processes underlying affect regulation (Romeo 2013). Individual differences in emotion regulation and biological stress response are driven by heterogeneity in genetic predispositions, early temperament, pubertal timing and tempo, and the early life environment. For example, negative mood reactivity may reflect behavioral inhibition, which is associated with risk for internalizing problems, especially among children who are sensitive to threat (Pérez-Edgar et al. 2011; Williams et al. 2009). Risk and protective factors early in life may also contribute to individual differences in mood reactivity during late childhood. Youth who have warm and supportive relationships at home may be less sensitive to stressors at school, whereas youth whose parents are harsh and demanding may be more sensitive (Morris et al. 2017). Studying mood reactivity in the context of everyday life can help to elucidate the pathways by which experiences in childhood accumulate to influence mental health. Moreover, this approach can help to identify specific, malleable and actionable targets of prevention interventions.

### Clinical Implications

Intensive longitudinal studies help to characterize risk and protective processes that unfold across different spans of time, in the context of daily life. Past longitudinal research has indicated that peer victimization, measured at a single point in time may be a risk factor for internalizing problems in subsequent years (Schwartz et al. 2015). However, in the day-to-

day, affective responses to within-person increases in school problems may be a more precise indicator of risk. More empirical data from intensive longitudinal studies that examine the interactions between multiple risk and protective processes unfolding over different time scales can help to inform interventions. By incorporating intensive repeated measures at various assessment points in randomized controlled trials, psychologists can better identify mechanisms of change and assess the generalization of treatment gains to real world settings.

Current findings are particularly relevant for ecological momentary interventions or “Just in Time Adaptive Interventions (JITAI),” that aim to deliver skills and alternative strategies to participants in real time (Nahum-Shani et al. 2017). Developing decision trees for when a momentary intervention should be delivered can be challenging when risk and protective factors for emotional and behavioral problems multiplicatively interact across different time scales. Although replication is required, the present findings begin to inform these decisions. For example, a child may benefit from in vivo support when reacting to a new stressor with elevations in negative mood. Ecological momentary interventions may incorporate repeated assessments of stress and mood to help guide the delivery of active treatment components.

### Limitations and Future Directions

There are several characteristics of this study that limit generalizability of findings. First, our small sample of convenience was composed of relatively healthy children from two-parent homes in a large urban city. Our sampling approach, intensity of our study procedures and study compensation may have influenced the characteristics of our small sample in ways that cannot be accounted for in our statistical models. The small sample size limited our ability to detect low to moderate effects in the planned regressions. Our failure to reject the null hypothesis in some tests of prospective associations may reflect Type II error. A larger sample would allow us to differentiate a true null from small effects, and test important moderators such as gender and the quality of the parent-child relationship. Moreover, for many youth, different parents completed the CBCL at baseline and follow-up. The inconsistency in raters likely reduced the temporal stability of CBCL scores across the two assessments, and only some of our findings could be replicated in sensitivity analysis conducted on a smaller subsample of youth who had complete mother-rated CBCL scores at baseline and follow-up. Second, although the long diary duration helped to increase variability within and between individuals, school problems were endorsed fairly infrequently. Therefore, our study findings only generalize to youth who experience relatively infrequent problems at school. Youth who are chronically stressed at school may show different patterns of mood reactivity to deviations from

their own norms. Replication in more diverse samples that include participants with higher or more variable stress exposure is needed. Third, children only completed one diary each day, which reduced the burden of participation across the 56-day study period. In comparison to ecological momentary assessments conducted throughout the day, end of day surveys are more susceptible to influences from recall bias. Participants may have under-reported stressors. In addition, adolescents experience an improvement in mood across the day, resulting in the best mood at night time (Díaz-Morales et al. 2015). Relatedly, the daily association between school problems and mood may be inflated by state-dependent recall, and youth may report more school problems on nights when they are feeling more distressed. However, the consistency between current and past findings lend further credence to the interpretation that school problems influence mood (Bai and Repetti 2018; Leger et al. 2018). Choosing a sampling strategy that captures enough variability across days while minimizing the burden of participation remains a conundrum for psychologists who want to study affect regulation in daily life.

Despite these limitations, this study is one of the first to use intensive longitudinal methods to examine the developmental sequelae of daily mood reactivity. We found that youth who reported more negative mood on days when they experienced problems at school show increases in internalizing and externalizing problems. Likewise, children who described declines in positive mood on high-stress school days reported increases in symptoms of depression. Researchers should continue to explore the use of intensive repeated measures to naturalistically assess mood reactivity and examine the stability of reactivity over time. Mood reactivity to negative events – however minor – may be an important predictor of mental health in adolescence and a useful indicator of a need for intervention.

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### Compliance with Ethical Standards

**Conflict of Interest** The authors declare that they have no conflicts of interest.

**Ethical Approval** All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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