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SHORT REPORT

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Sensitivity to psychosocial influences at age 3 predicts mental health in middle childhood

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Abstract

Children vary in how sensitive they are to experiences, with consequences for their developmental outcomes. In the current study, we investigated how behavioral sensitivity at age 3 years predicts mental health in middle childhood. Using a novel repeated measures design, we calculated child sensitivity to multiple psychological and social influences: parent praise, parent stress, child mood, and child sleep. We conceptualized sensitivity as the strength and direction of the relationship between psychosocial influences and child behavior, operationalized as toothbrushing time, at age 3 years. When children were 5–7 years old ($n = 60$), parents reported on children's internalizing and externalizing problems. Children who were more sensitive to their parents' praise at age 3 had fewer internalizing ($r = -0.37$, $p = 0.016$, $p_{FDR} = 0.042$) and externalizing ($r = -0.35$, $p = 0.021$, $p_{FDR} = 0.042$) problems in middle childhood. Higher average parent praise also marginally predicted fewer externalizing problems ($r = -0.33$, $p = 0.006$, $p_{FDR} = 0.057$). Child sensitivity to mood predicted fewer internalizing ($r = -0.32$, $p = 0.013$, $p_{FDR} = 0.042$) and externalizing ($r = -0.38$, $p = 0.003$, $p_{FDR} = 0.026$) problems. By capturing variability in how children respond to daily fluctuations in their environment, we can contribute to the early prediction of mental health problems and improve access to early intervention services for children and families who need them most.

KEYWORDS

early childhood, ecological momentary assessment, externalizing problems, internalizing problems, susceptibility

Research Highlights

- Children differ in how strongly their behavior depends on psychosocial factors including parent praise, child mood, child sleep, and parent stress.
- Children who are more sensitive to their parents' praise at age 3 have fewer internalizing and externalizing problems at age 5–7 years.
- Child sensitivity to mood also predicts fewer internalizing and externalizing problems.

1 | INTRODUCTION

Internalizing and externalizing symptoms in early childhood predict risk of psychiatric disorders later in life (Briggs-Gowan & Carter, 2008). Increasing our understanding of predictors of mental health risk in childhood may serve to both inform intervention programs and improve access to these services. One possible source of risk for, or protection from, mental illness is sensitivity to experience. The "dandelion-orchid" metaphor posits two types of children: "orchid" children, who are highly sensitive to both positive and negative contextual factors, and "dandelion" children, who are less sensitive to environmental influences (Belsky, 2016; Boyce & Ellis, 2005; Obradović et al., 2010). However, individual sensitivity to context may be a continuous trait, rather than a bimodal one, and sensitivity to environmental influences may be domain specific (Belsky et al., 2022; Lionetti et al., 2018; Zhang et al., 2023). Children can differ specifically in their sensitivity to positive or rewarding experiences (Kujawa et al., 2020). Altered sensitivity to reward in the positive valence system (RDoC Matrix) has been suggested as both a mechanism and a moderator in the development of psychiatric disorders including anxiety (Sequeira et al., 2022) and depression (Dennison et al., 2016; Keren et al., 2018; Kujawa et al., 2019). Importantly, exploring whether children differ in their behavioral sensitivity to psychosocial influences, and whether sensitivity predicts mental health outcomes, requires repeated measurement of experiences and child behavior over time.

In our previous research, we developed an ecologically-valid task to measure day-to-day fluctuations in 3-year-old's behavior: toothbrushing (Leonard et al., 2022). Toothbrushing is a compelling task to measure children's behavior at this age because it is necessary but not especially fun or intrinsically rewarding. In the initial study, parents submitted nightly videos of toothbrushing over 2 weeks, allowing us to capture children's brushing behavior and parent talk. Parents also completed daily surveys about their stress, and their child's mood and sleep. This allowed us to examine how day-to-day fluctuations in parent talk and stress, and child mood and sleep impacted fluctuations in children's persistence during toothbrushing. We found that overall, children brushed longer on days when their parents used more praise and less direct instruction, and on days when they were in a better mood (Leonard et al., 2022). An important contribution of this repeated-measures paradigm was the ability to examine individual differences in children's sensitivity to predictor variables: children varied in whether and how strongly their persistence depended on their mood, sleep, parent praise, and parent stress. Sensitivity to mood and sensitivity to parent stress were correlated; children who persisted more when they were in a better mood, persisted less when their parents were stressed, perhaps suggesting domain-general differences in affective sensitivity.

In the present study, we followed up with children who participated in the initial study at age 3, who are now between ages 5 and 7, in order to examine whether repeated measurement of children's environment and behavior can provide insight into developmental outcomes. We explore whether children's sensitivity to social influences (i.e., parent praise and parent stress) or psychological influences (i.e., child mood and child sleep) at age 3 predict internalizing and externalizing symptoms 2–3 years later. Furthermore, repeated measurement also allowed us to investigate variability in praise, mood, stress, sleep and persistence (Ram & Gerstorf, 2009), as well as the averages across all nights of the study, in relation to internalizing and externalizing problems. If differential sensitivity to psychosocial influences predicts children's mental health outcomes in middle childhood, this may have implications for personalized interventions.

2 | METHOD

2.1 | Open science practices

The preregistration for this study is available at osf.io/znyem. The code and data are publicly available at osf.io/9z43b/.

2.2 | Participants

This study was approved by the Institutional Review Board at the University of Pennsylvania. All parents provided informed consent. Families were recruited for the initial study in 2019–2020 through partnerships with local preschools and through social media. The final sample for the initial study consisted of 81 children. In June through October 2022, these families were contacted and invited to participate in a follow-up study. The final sample at follow-up consisted of 60 children (mean age at follow-up = 5.93 years, range = 5.06–7.35 years). Child gender, race and ethnicity, and socioeconomic status are reported in Table 1. Children who were included in the follow-up sample did not differ from children who did not return for the follow-up assessment on: gender ($\chi^2(1,81) = 0.67$, $p = 0.414$), race and ethnicity ($\chi^2(5,99) = 2.1$, $p = 0.718$), parent education ($t(79) = -0.94$, $p = 0.352$), or family income ($t(75) = -0.41$, $p = 0.680$).

2.3 | Procedure

For a detailed description of the initial study, see Leonard et al. (2022) and osf.io/vr2du/. In the initial study, parents were sent surveys twice a day for 16 days. Parents who expressed interest in participating in the follow-up study completed questionnaires online via REDCap (Harris et al., 2009).

2.4 | Repeated measures at age 3

2.4.1 | Toothbrushing

Parents sent in a video of their child brushing their teeth each night as part of the evening survey. Two coders used Vcode to code videos for the amount of time that the child spent brushing their teeth independently, and a third coder resolved discrepancies over 10 s. Brushing time from the two coders was averaged for analyses. Toothbrushing

TABLE 1 Descriptive statistics.

	N	Mean (SD)	Range
Age at Time 1 (years)	60	3.44 (0.27)	3.01–3.99
Age at Time 2 (years)	60	5.93 (0.60)	5.06–7.35
Family Income at Time 2 (thousands of dollars)	59	141 (48)	62.5–200
Parent Education at Time 2 (years)	59	17 (1.6)	12–20
CBCL Internalizing Problems at Time 1 (T-Score)	58	48 (9)	29–70
CBCL Externalizing Problems at Time 1 (T-Score)	58	48 (9)	37–77
CBCL Internalizing Problems at Time 2 (T-Score)	60	44 (9)	29–63
CBCL Externalizing Problems at Time 2 (T-Score)	60	43 (9)	28–71
	N	**Percent**	
Gender			
Girl	31	52%	
Boy	29	48%	
Race and Ethnicity			
White	54	90%	
Black	4	7%	
Asian	6	10%	
Hispanic or Latinx	6	10%	
Other	1	2%	

Abbreviation: CBCL, child behavior checklist.

time served as a novel, naturalistic measure of child persistence, and behavioral compliance.

2.4.2 | Parent praise

Nightly toothbrushing videos were transcribed. Two coders coded parent speech and a third coder arbitrated discrepancies. Praise was initially coded into three categories ("process praise," "person praise," and "other praise"). However, the majority of praise instances were "other praise" and "process praise," and we did not have the power to analyze the effects of specific types of praise. Thus, analyses are focused on total praise (combined across all three categories of praise). The remaining parent talk was coded into categories of distraction, instruction, and other speech. In the current study, we did not have specific hypotheses about distraction or instruction. Total parent talk was coded as the count of total parent utterances per night. In our previous study (Leonard et al., 2022), we analyzed a measure of percent praise (instances of praise divided by total parent talk per night). In the current study, we focused our analyses on total parent praise, not as a percent of total talk, because each instance of praise may be meaningful, regardless of how much additional talk it is surrounded by.

2.4.3 | Parent stress, child mood, and sleep duration

Parents reported on their stress level, their child's mood, and their child's sleep duration during the daily surveys. Parent stress was assessed in the evening on a 0 (not stressed at all) to 10 (extremely stressed) scale. Child mood was assessed in the evening on a 0 (extremely bad) to 10 (extremely good) scale. To measure child sleep, parents reported the time their child went to bed in the evening survey, and the time their child woke up in the morning survey, and the frequency and duration of any night wakings and naps. Child sleep was calculated based on their bedtime and waketime, subtracting the length of time awake during the night, and adding in the nap of the current day.

2.5 | Questionnaires at ages 3 and 5–7

At both timepoints, parents completed the preschool version of the Child Behavior Checklist (CBCL) to identify behavioral and emotional problems (Achenbach & Rescorla, 2000). We used the preschool CBCL for all children in the follow-up study in order to align with the CBCL version collected at the initial timepoint, as well as to keep scoring consistent across children. As pre-registered, we analyzed T-scores for the internalizing and externalizing composite scales. Average CBCL T-scores at both timepoints are reported in Table 1.

2.6 | Analysis plan

2.6.1 | Repeated measures variables

For each of the repeated-measures variables at the 3-year-old assessment, average and variability were calculated for participants ($n = 60$) with at least five nights of data, following guidelines from Bolger and Laurenceau (2013). Variability was calculated as the coefficient of variation (standard deviation divided by mean). Variability cannot be

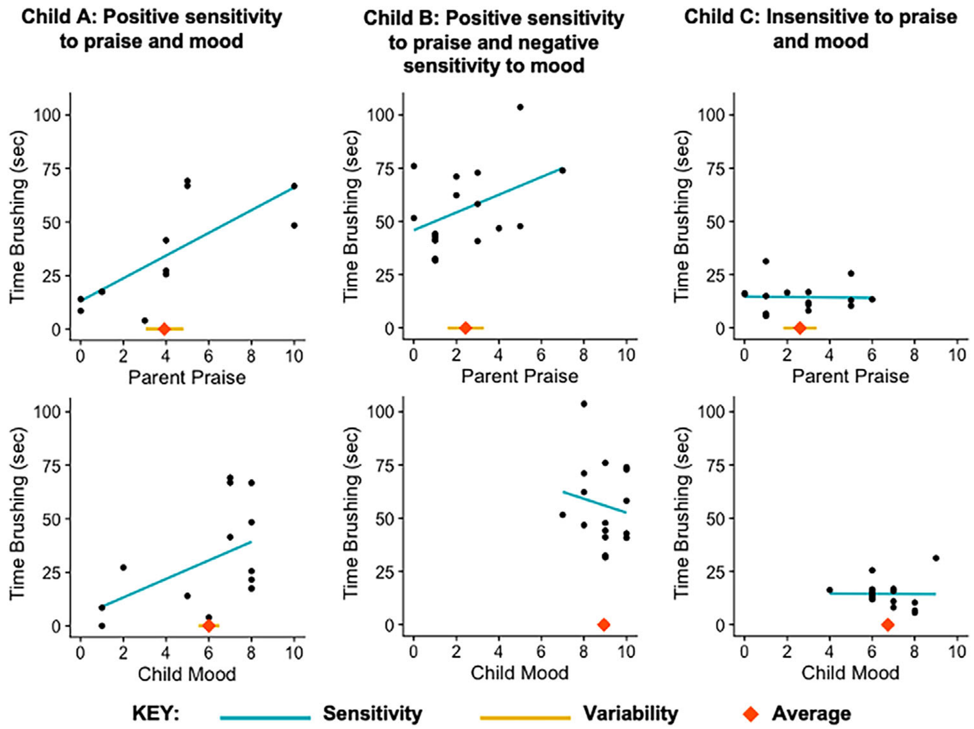

FIGURE 1 Example data for three participants. Top row shows brushing data correlated with praise data, and bottom row shows brushing data correlated with mood data. Sensitivity is conceptualized as the strength of the relationship between behavior, as measured by toothbrushing time, and predictor variables. Child A is positively sensitive to both praise and mood, child B is positively sensitive to praise and negatively sensitive to mood, and child C is insensitive to both praise and mood. Red diamonds indicate the average value of praise and mood, and yellow lines indicate the variability. Variability is measured as the coefficient of variation.

calculated when the average measure is equal to zero (e.g., for children who received zero instances of praise across all nights of the study, $n = 15$). We estimated each individual's sensitivity to four predictor variables (parent praise, parent stress, child mood, and child sleep duration) for participants with at least eight nights of data (Leonard et al., 2022). Sensitivity was calculated by extracting standardized betas from person-specific linear models predicting toothbrushing time with each of the predictor variables separately, controlling for the day of the study. Sensitivity can only be calculated for individuals with variability in the predictor (e.g., sensitivity to praise cannot be calculated for children who received zero praise across all days of the study). For example sensitivity data, see Figure 1. For histograms of average, variability, and sensitivity of each predictor variable, as well as *n*s for each variable, see Figure S1. For correlations among predictor variables, see Tables S1–S4.

2.6.2 | Statistical models

Analyses are outlined in the pre-registration (osf.io/znyem), and the deviations are described below. We tested how average and variability in parent praise, child mood, child sleep, parent stress, and toothbrushing time relate to CBCL scores at age 5–7 years using correlation and linear regression in R. We tested either 1-tailed or 2-tailed correlations depending on pre-registered hypotheses. As a pre-registered exploratory analysis, we then tested how each child's sensitivity to praise, mood, sleep, and parent stress relate to CBCL scores, using 2-tailed correlation. To correct for multiple comparisons, we used the Benjamini-Hochberg false discovery rate (FDR) (Benjamini & Hochberg, 1995). We applied FDR correction separately across the 10 tests of average measures, 10 tests of variability, and 8 tests of sensitivity.

We conducted additional analyses to characterize the robustness of significant correlations. We pre-registered controlling for age 3 CBCL scores, in order to examine whether any of the repeated measures predict age 5–7 mental health above the predictive value of age 3 mental health. We also pre-registered controlling for the initial data collection wave. Data for the age 3 assessment was collected in two waves: January–June 2019 and March–May 2020. Thus, we proposed controlling for wave in order to test whether any findings are impacted by the pandemic. After pre-registering our analyses, we also identified child age at follow-up as an important covariate, as child age ranged from 5 to 7 years at follow-up. We report results of models controlling for these three covariates together. We report standardized effect sizes for all linear models, obtained by running the linear models after centering and scaling all variables.

2.6.3 | Deviations from pre-registration

We pre-registered applying FDR correction across the 20 primary correlations of average and variability. Because we labeled the sensitivity analyses as exploratory in our pre-registration, we separately applied FDR correction across the eight correlations between sensitivity variables and internalizing and externalizing scores. However, in order to maintain consistency in the number of tests that are corrected together, we decided to apply FDR correction separately across tests of average, variability, and sensitivity. We report results of the more stringent FDR correction across both average and variability in the Supplement (see Table S5).

We pre-registered running separate analyses for each covariate of interest (age 3 CBCL scores, and initial data collection wave). We also identified child age at follow-up as an important covariate, as described above. In order to streamline analyses, instead of running separate models controlling for each of these three covariates, we decided to control for all three covariates in the same linear model.

We pre-registered testing linear relationships between all variables. To account for the possibility of non-linear relationships between psychosocial variables at age 3 and CBCL scores at age 5–7 years, we additionally tested quadratic relationships and compared the goodness of fit between linear and quadratic models using likelihood ratio tests. Results of the likelihood ratio tests are reported in the Supplement (see Table S6). Finally, we also ran linear models including all three variables from each domain (average, variability, and sensitivity) in the same model, and report the results of these models in Table S7.

3 | RESULTS

Internalizing and externalizing problems decreased between the first assessment at age 3 years and the second assessment at age 5–7 years (Table 1, Figure S2). Internalizing problems decreased by an average of 3.1 points (6.5% decrease; $t(57) = -2.42$, $p = .019$), and externalizing problems decreased by an average of 5.7 points (11.9% decrease; $t(57) = -5.03$, $p < .001$). Correlations among predictor variables are reported in Tables S1–S4. Child mood sensitivity and parent stress sensitivity were positively correlated. Average child mood and average toothbrushing time were also positively correlated.

3.1 | Parent praise

Higher average praise at age 3 predicted fewer externalizing problems at follow-up, but not after controlling for multiple comparisons ($r(57) = -0.33$, $p = 0.006$, $p_{FDR} = 0.057$; Figure 2, Table 2). Parent praise was not associated with internalizing problems (Figure 2, Table 2). The association between parent praise and externalizing problems held controlling for covariates (Table 2). Lower variability in praise also predicted fewer externalizing problems ($r(42) = 0.52$, $p < 0.001$, $p_{FDR} = 0.003$), but not internalizing problems, and this association held controlling for covariates (Figure 2, Table 2).

Child sensitivity to parent praise at age 3 predicted internalizing and externalizing problems at age 5–7 (internalizing: $r(41) = -0.37$, $p = 0.016$, $p_{FDR} = 0.042$; externalizing: $r(41) = -0.35$, $p = 0.021$, $p_{FDR} = 0.042$; Figure 2, Table 2). Children with higher positive praise sensitivity had fewer problem behaviors. The association between praise sensitivity and internalizing problems held controlling for covariates, while the association with externalizing problems was marginal (Table 2).

3.2 | Parent stress

Greater average parent stress at age 3 predicted higher internalizing problems at age 5–7, but not after controlling for multiple comparisons ($r(58) = 0.29$, $p = 0.013$, $p_{FDR} = 0.063$; Table 2). Parent stress did not predict externalizing problems (Table 2). The association between parent stress and internalizing problems was no longer significant after controlling for covariates (Table 2). Variability in parent stress was not related to behavior problems (Table 2). Child sensitivity to parent stress at age 3 was also unrelated to either internalizing or externalizing problems (Table 2).

3.3 | Child mood

Higher average mood at age 3 predicted fewer internalizing problems at age 5–7, though this result did not survive FDR correction ($r(58) = -0.22$, $p = 0.048$, $p_{FDR} = 0.063$; Figure 2, Table 2), and was no longer significant after including covariates (Table 2). Average mood did not predict externalizing problems (Figure 2, Table 2). Variability in mood was not significantly related to internalizing or externalizing problems (Figure 2, Table 2).

Children with greater positive sensitivity to their own mood at age 3 had fewer internalizing and externalizing problems at age 5–7 (internalizing: $r(56) = -0.32$, $p = 0.013$, $p_{FDR} = 0.042$; externalizing: $r(56) = -0.38$, $p = 0.003$, $p_{FDR} = 0.026$; Figure 2, Table 2). These associations held controlling for covariates (Table 2). Visual inspection of the data suggested a non-linear relationship between mood sensitivity and behavior problems. Thus, we also tested a quadratic relationship between mood sensitivity and internalizing or externalizing problems. Mood sensitivity squared significantly predicted internalizing problems ($\beta(55) = 0.32$, $p = 0.008$; Figure 2) and the quadratic model was a significantly better fit to the data than a linear model ($\chi^2(1) = 7.52$, $p = 0.006$; Table S6). Mood sensitivity squared did not predict externalizing problems ($\beta(55) = 0.15$, $p = 0.217$).

3.4 | Child sleep

None of the measurements of child sleep significantly predicted behavior problems. Average sleep quantity was unrelated to internalizing or externalizing problems, as were variability in sleep and sensitivity to sleep (Table 2).

3.5 | Toothbrushing time

Neither average nor variability in toothbrushing time significantly predicted mental health outcomes (Table 2).

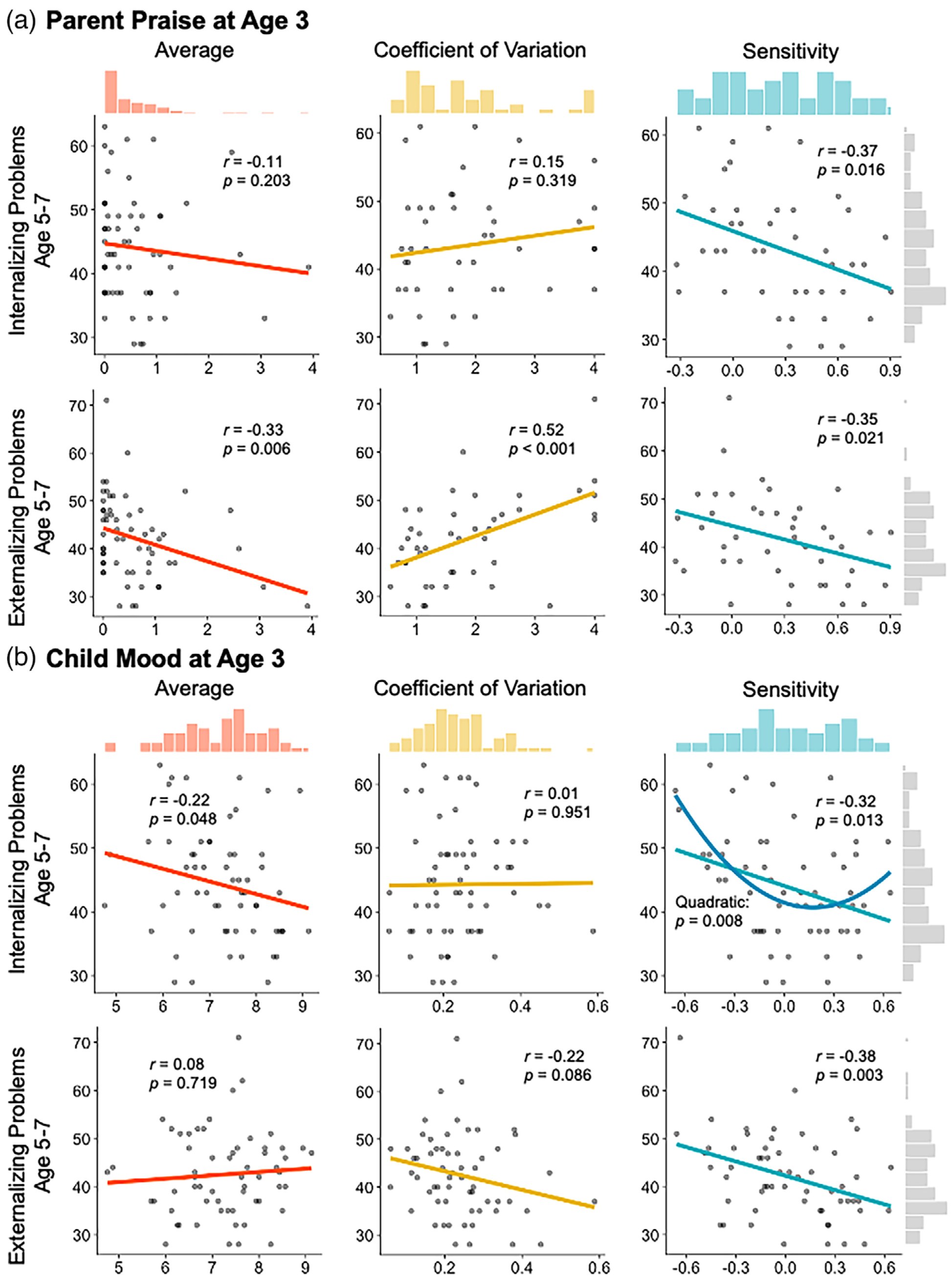

FIGURE 2 Relationships between measurements of (a) parent praise and (b) child mood at age 3, and internalizing and externalizing behavior at age 5–7. Statistics are the correlation coefficient and uncorrected *p*-value for each correlation. For mood sensitivity, we show results of the linear and quadratic relationships between mood sensitivity and internalizing problems.

4 | DISCUSSION

We conceptualized children's sensitivity to psychosocial influences as the strength and direction of the relationship between their behavior, as measured by toothbrushing time, and those influences, with a focus on parent praise, parent stress, child mood, and child sleep. Children who were more sensitive to their parents' praise when they were 3 years old had fewer internalizing and externalizing problems when they were 5–7 years old. Greater average and lower variability of parent praise predicted fewer externalizing problems. Mood sensitivity at age three also predicted fewer internalizing and externalizing problems at follow-up. Higher average child mood and lower average parent stress predicted fewer internalizing problems, though these relationships did not survive correction for multiple comparisons.

Children who were more positively sensitive to praise had fewer internalizing and externalizing problems two to three years later. Sensitivity to praise may be a child-specific factor, whereby some children find praise to be more reinforcing than other children do. This explanation would align with evidence that reduced activation of positive valence systems, including lower neurobiological sensitivity to reward,

TABLE 2 Correlations between variables measured repeatedly at age 3, and CBCL composite scales at age 5–7.

	Sensitivity		Average		Variability	
	Internalizing problems	Externalizing problems	Internalizing problems	Externalizing problems	Internalizing problems	Externalizing problems
Instances of parent praise	2-sided $N = 43$ $r = -0.37$ **$p = 0.016$** **$p_{FDR} = 0.042$**	2-sided $N = 43$ $r = -0.35$ **$p = 0.021$** **$p_{FDR} = 0.042$**	1-sided $N = 59$ $r = -0.11$ $p = 0.203$ $p_{FDR} = 0.265$	1-sided $N = 59$ $r = -0.33$ **$p = 0.006$** **$p_{FDR} = 0.057$**	2-sided $N = 44$ $r = 0.15$ $p = 0.319$ $p_{FDR} = 0.597$	2-sided $N = 44$ $r = 0.52$ **$p < 0.001$** **$p_{FDR} = 0.003$**
+Covariates (age, wave, age 3 CBCL)	$N = 42$ $\beta = -0.29$ **$p = 0.036$**	$N = 42$ $\beta = -0.27$ **$p = 0.064$**		$N = 57$ $\beta = -0.32$ **$p = 0.002$**		$N = 43$ $\beta = 0.46$ **$p < 0.001$**
Parent stress	2-sided $N = 58$ $r = -0.07$ $p = 0.616$ $p_{FDR} = 0.821$	2-sided $N = 58$ $r = 0.04$ $p = 0.778$ $p_{FDR} = 0.890$	1-sided $N = 60$ $r = 0.29$ **$p = 0.013$** **$p_{FDR} = 0.063$**	1-sided $N = 60$ $r = 0.13$ $p = 0.162$ $p_{FDR} = 0.265$	2-sided $N = 60$ $r = -0.21$ $p = 0.105$ $p_{FDR} = 0.351$	2-sided $N = 60$ $r = -0.08$ $p = 0.526$ $p_{FDR} = 0.656$
+Covariates (age, wave, age 3 CBCL)			$N = 58$ $\beta = 0.18$ **$p = 0.072$**			
Child mood	2-sided $N = 58$ $r = -0.32$ **$p = 0.013$** **$p_{FDR} = 0.042$**	2-sided $N = 58$ $r = -0.38$ **$p = 0.003$** **$p_{FDR} = 0.026$**	1-sided $N = 60$ $r = -0.22$ **$p = 0.048$** **$p_{FDR} = 0.161$**	1-sided $N = 60$ $r = 0.08$ $p = 0.719$ $p_{FDR} = 0.756$	2-sided $N = 60$ $r = 0.01$ $p = 0.951$ $p_{FDR} = 0.951$	2-sided $N = 60$ $r = -0.22$ $p = 0.086$ $p_{FDR} = 0.351$
+Covariates (age, wave, age 3 CBCL)	$N = 56$ $\beta = -0.26$ **$p = 0.041$**	$N = 56$ $\beta = -0.30$ **$p = 0.010$**	$N = 58$ $\beta = -0.12$ $p = 0.168$			
Child sleep	2-sided $N = 58$ $r = -0.003$ $p = 0.980$ $p_{FDR} = 0.980$	2-sided $N = 58$ $r = -0.19$ $p = 0.145$ $p_{FDR} = 0.232$	1-sided $N = 60$ $r = -0.13$ $p = 0.162$ $p_{FDR} = 0.265$	1-sided $N = 60$ $r = -0.11$ $p = 0.212$ $p_{FDR} = 0.265$	1-sided $N = 60$ $r = 0.11$ $p = 0.393$ $p_{FDR} = 0.597$	1-sided $N = 60$ $r = 0.11$ $p = 0.418$ $p_{FDR} = 0.597$
Toothbrushing time	N/A	N/A	1-sided $N = 60$ $r = -0.14$ $p = 0.152$ $p_{FDR} = 0.265$	1-sided $N = 60$ $r = -0.09$ $p = 0.756$ $p_{FDR} = 0.756$	2-sided $N = 60$ $r = 0.10$ $p = 0.773$ $p_{FDR} = 0.859$	2-sided $N = 60$ $r = -0.05$ $p = 0.342$ $p_{FDR} = 0.597$

Notes: Correlations are 1-sided or 2-sided, depending on pre-registered hypotheses. Sensitivity variables are the standardized betas extracted from person-specific linear models predicting toothbrushing time with each of the predictor variables separately, controlling for the day of the study. Sensitivity is calculated for children with at least eight nights of data available. Variability is calculated as the coefficient of variation (standard deviation divided by the mean). Variability cannot be calculated for individuals without any instances of praise (i.e., mean instances of parent praise = 0). FDR correction is applied separately across the 10 tests of average variables, 10 tests of variability, and 8 tests of sensitivity. For correlations that were significant, we also report standardized betas from linear models controlling for three covariates (age at follow-up, initial data collection wave, and age 3 CBCL score).
Abbreviation: CBCL, child behavior checklist.

predicts mental health problems (Kujawa & Burkhouse, 2017; Kujawa et al., 2020; Olino, 2016; Sequeira et al., 2022). Sensitivity to praise may also depend on who is providing the praise, whereby some adults deliver praise in a manner that is more rewarding, or more contingent upon the child's behavior (Brophy, 1981; Brophy, 1981; Henderlong & Lepper, 2002). Understanding the factors that influence a child's sensitivity to praise, and other rewards, is key for reducing the emergence of behavior problems.

We found that children who received more praise on average had fewer externalizing problems at follow-up, but this relationship was marginal after correcting for multiple comparisons. It is important to note that praise was low in the context of toothbrushing; parents averaged less than one instance of praise each night. Nonetheless, we find that parents' use of praise predicts children's later behavior problems. We do not establish causality or directionality in this study. Parent praise was the only predictor variable that was measured directly; thus, one reason that praise was most predictive may be that it was not subjected to bias in parent-report.

Greater variability in parent praise was associated with more externalizing problems, which may suggest that consistent use of praise is important. This finding aligns with previous work showing that greater day-to-day consistency in positive parent-child interactions is associated with better adolescent well-being, (Lippold et al., 2016) as well as with work demonstrating that greater unpredictability in parent behavior is associated with risk for childhood psychopathology (Aran et al., 2023; Glynn & Baram, 2019; Young et al., 2020). However, there are many ways to capture variability. The measure we used, the coefficient of variation, divides the standard deviation by the mean to provide a relative index of the extent to which variables are dispersed around the mean and is a commonly used alternative to the standard deviation. However, with data that is skewed towards low mean values, as praise is here, the coefficient of variation can be inflated. The intraindividual standard deviation is another statistical measure of variability, though in practice, the standard deviation is often confounded with the mean. Different study designs, perhaps over a longer timeframe, may further elucidate the ideal quantity, timing, and delivery of praise.

Our findings contribute to multiple literatures on the relationship between praise and child behavior. In the clinical literature, effective use of positive reinforcement, including verbal praise, is a key skill taught in parenting interventions for children with behavioral disorders (Leijten et al., 2019; Leijten et al., 2018; Thomas et al., 2017). Parenting programs that include instruction in the use of positive reinforcement, and praise in particular, show larger reductions in child disruptive behavior than interventions that do not include praise (Leijten et al., 2019), though praise is not always associated with increased child compliance (Owen et al., 2012). Identifying children who are less sensitive to parent praise may help predict outcomes following parent training interventions, and suggest when parents should place increased effort towards other types of positive reinforcement to shape child behavior. In the developmental psychology literature, in both laboratory and naturalistic settings, children persist longer when they are praised for their effort, rather than ability (Cimpian et al., 2007; Lucca et al., 2019; Mueller & Dweck, 1998). Praise for effort and hard work also predicts children's belief that traits and abilities are malleable (Gunderson et al., 2013;, 2018), and children who believe that personal traits are malleable tend to have lower rates of psychopathology (Schleider et al., 2015). Thus, it is plausible that parent praise may also impact children's mental health by shaping their motivational frameworks and persistence.

Children's sensitivity to their own mood was negatively associated with their internalizing and externalizing problems. In other words, the children who developed the most behavior problems were those who tended to persist less on days when they were in a positive mood. An exploratory follow-up analysis suggested that this relationship may be non-linear; children with the lowest internalizing scores were those whose persistence did not vary significantly with their mood. This finding presents the intriguing possibility that children whose behavior does not depend on their mood are more likely to be resilient. This hypothesis broadly aligns with clinical practice: in cognitive behavioral therapy, the goal of treatment is not to eliminate negative emotions entirely, but rather to help patients learn to tolerate their emotions and reduce the impact on their functioning.

In contrast to measures of parent praise and child mood, we found little evidence that parent stress predicted later internalizing or externalizing problems. Higher average parent stress predicted higher child internalizing problems, though not after correction for multiple comparisons; this effect may be driven by shared environmental or heritable vulnerability, or bias in parent-report. It is worth noting that this sample was socioeconomically advantaged, and majority White. Further, given that many of the families participated in the study early in the COVID-19 pandemic, parent experiences of stress may have been unusual and difficult to report. There is also some evidence that retrospective reports of stress are more predictive of subjective life outcomes than prospective measures (Reuben et al., 2016). Thus, it is possible that a different measurement of parent stress in a broader sample may provide insight into children's sensitivity to stress and subsequent mental health.

We did not identify any associations between mental health symptoms and measures of sleep quantity. One possibility is that most children in the sample were getting enough sleep to support their behavioral outcomes (Teti et al., 2022). All but one child met the American Academy of Sleep Medicine's recommendation of 10–13 h of sleep per day (Paruthi et al., 2016). Sleep schedules may have been unusual for the families at the 3 year-old timepoint because of pandemic changes in family schedules. Furthermore, we relied on parent-report of children's sleep, and did not collect data on sleep quality. More intensive measures like actigraphy could provide more precision in assessing child sleep, particularly for nighttime wakings (Lam et al., 2011). Given the strong associations between sleep and health (Matricciani et al., 2019), exploring children's individual sensitivity to sleep within more varied contexts and samples is an important future direction.

Toothbrushing time was not significantly related to mental health. We might have expected to find a relationship given previous research linking greater persistence (as measured with a challenging puzzle task) with lower levels of externalizing problems (Zhou et al., 2007). It is possible that toothbrushing, because it is not a cognitively challenging task, measures children's ability to tolerate boredom, whereas puzzle tasks measure children's ability to tolerate frustration. Boredom tolerance and frustration tolerance may be differentially related to mental health. The toothbrushing task may be more predictive of other outcomes such as children's learning.

This study has a number of limitations. First, the sample size is relatively small, as we recruited families that had participated in the initial study 2 or more years ago. Second, our sample is skewed towards higher-income and highly-educated families in a Western, Educated, Industrialized, Rich, and Democratic (WEIRD) cultural context, so we cannot draw conclusions about how these findings may differ in other contexts. Parenting practices, including the use of praise, vary cross-culturally (BigFoot & Funderburk, 2011; Leung et al., 2009), and thus it will be important to explore questions around children's sensitivity to their environment and physiological states in other contexts. Third, with the exception of praise, our measurements rely on parent-report. Some studies suggest that parent-report of child behavioral symptoms may be biased by factors such as parent personality traits and psychopathology (Durbin & Wilson, 2012), though results are mixed (Olino et al., 2021). Fourth, it is unknown whether praise during toothbrushing captures parents' use of praise in other contexts. Children are also sensitive to many other aspects of parenting, such as harsh punishment (Ferguson, 2013), which are unlikely to be captured in the toothbrushing paradigm. The toothbrushing paradigm might also not capture potential downsides of praise. Some research suggests that inflated praise can have an adverse effect, particularly for children with low self-esteem (Brummelman et al., 2014). Fifth, due to limited variability in the types of praise that parents use, we analyze only total instances of praise. The language and affect that parents use to deliver praise may influence how the praise is perceived, so total quantity of praise is unlikely to fully capture variation in praise delivery.

In sum, we found that daily fluctuations in parent praise and child mood at age 3 predicted children's mental health outcomes in middle childhood. These results have important implications for parenting interventions for children with behavior problems. Our work suggests that not all children are equally sensitive to psychosocial influences such as parent praise, and their own mood. An important future direction is to explore whether sensitivity to praise and mood are malleable, by intervening with children or with parents. By capturing variability in how children respond to daily fluctuations in their environment, we can contribute to the early prediction of child mental health problems and improve access to early intervention services for children and families who need them most.

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CONFLICT OF INTEREST STATEMENT

The authors declare that they have no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are openly available at osf.io/9z43b/.

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