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Sensitive Periods for the Effect of Child Maltreatment on Psychopathology Symptoms in Adolescence

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Keywords
Maltreatment · Neglect · Sensitive periods · Accumulation of risk · Psychopathology

Abstract

Introduction: Child maltreatment is among the strongest risk factors for mental disorders. However, little is known about whether there are ages when children may be especially vulnerable to its effects. We sought to identify potential sensitive periods when exposure to the 2 most common types of maltreatment (neglect and harsh physical discipline) had a particularly detrimental effect on youth mental health. ***Methods:*** Data came from the Future of Families and Child Wellbeing Study (FFCWS), a birth cohort oversampled from "fragile families" (n = 3,474). Maltreatment was assessed at 3, 5, and 9 years of age using an adapted version of the Parent-Child Conflict Tactics Scales (CTS-PC). Using least angle regression, we examined the relationship between repeated measures of exposure to maltreatment on psychopathology symptoms at age 15 years (Child Behavior Checklist; CBCL/6–18). For comparison, we evaluated the strength of evidence to support the existence of sensitive periods in relation to an accumulation of risk model. ***Results:*** We identified sensitive periods for harsh physical discipline, whereby psychopathology symptom scores were highest among girls exposed at age 9 years (r^2 = 0.67 internalizing symptoms; r^2 = 1% externalizing symptoms) and among boys exposed at age 5 years (r^2 = 0.41%). However, for neglect, the accumulation of risk model explained more variability in psychopathology symptoms for both boys and girls. ***Conclusion:*** Child maltreatment may have differential effects based on the child's sex, type of exposure, and the age at which it occurs. These findings provide additional evidence for clinicians assessing the benefits and drawbacks of screening efforts and point toward possible mechanisms driving increased vulnerability to psychopathology.

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Introduction

Childhood maltreatment is one of the most potent though preventable risk factors for psychopathology throughout the lifespan [1]. One of the dominant approaches to operationalizing the relationship between maltreatment and psychopathology is the cumulative risk model, which states that the number of exposures to any risk factor will determine its impact above and beyond the intensity or type of risk factor [2]. However, there are mixed findings in support of this additive assumption of risk because current research has not fully explored if the cumulative effect of multiple instances of maltreatment, for example, could be explained by a single, more intense experience out of many or the context of when and how the maltreatment occurred in the child's life [2, 3]. Emerging research, particularly from animal studies, suggests maltreatment may not have consistent effects throughout childhood, but rather there may be sensitive periods when the developing brain is particularly vulnerable to adversity [4]. The sensitive period model presumes the developmental timing of exposure is most important for determining the effect the exposure will have on later outcomes such as psychopathology symptoms, positing that the occurrence of exposure coincides with peak periods of brain plasticity, making exposure to maltreatment in one time period more likely to produce a greater effect than exposure to that same exposure occurring earlier or later in development [5–8]. Yet, in humans, such sensitive periods have been largely unidentified due to a scarcity of research and mixed results (for a comprehensive review of this literature, refer to Schaefer et al. [9]). Some prospective studies have found early maltreatment (before age of 5 years) is more strongly associated with psychopathology risk [10–12]. Prospective studies have found later maltreatment (after age of 10 years [13] or during adolescence [14]) is most harmful. Some find no developmental timing differences [15–17]. Well-powered prospective research in large and diverse samples is needed to determine if and when sensitive periods occur. Such research can increase understanding of the processes linking maltreatment to mental health problems and suggest optimal time points for screening and prevention efforts to reduce the negative consequences of adversity exposure [4].

The current study addresses this need by analyzing data on child maltreatment from a population-based cohort of high-risk children followed from birth through adolescence. Children from "fragile families," defined as unmarried parents, were oversampled. This dataset contained repeated measures of children's exposure to neglect and harsh physical discipline, the 2 most common types of child maltreatment [18, 19], and measures of child's internalizing and externalizing symptoms. Although the effects of more extreme forms of physical abuse on psychopathology risk are well established, numerous studies suggest physical discipline practices, such as spanking, slapping, and hitting [20], are associated with various negative developmental outcomes, including increased child aggression [21], slower cognitive development [22], and poor mental health in childhood [23] and adolescence [20]. Indeed, informed by this considerable body of research, the American Academy of Pediatrics released a policy statement urging parents to desist from physical and harsh verbal discipline [24, 25].

We brought three key innovations to these analyses. First, we examined psychopathology outcomes during adolescence, which allowed us to evaluate the longer term impacts of maltreatment on psychopathology in youth. If there was a latency or time lag between the onset of maltreatment to presentation of behavioral symptoms, studies like ours, which follow children for longer, are likely to detect sensitive periods, as compared to studies of shorter duration. Second, among prospective studies examining the role of child maltreatment timing on psychopathology risk [10–17], the size of this study (n = 3,474) was considerably larger (average for prior studies was n = 826). Thus, we had greater statistical power to detect potential sensitive period effects, if they existed. Third, we evaluated the strength of evidence to support the existence of sensitive periods compared to an accumulation of risk model [2], in which the effect of maltreatment on psychopathology symptoms is presumed to increase with the number of occasions exposed, regardless of timing. Few prior studies [26] have compared the sensitive period model to alternative life-course models to determine which model better explains risk for psychopathology. This dearth of comparison is a major limitation as it could explain mixed results among prior studies.

Methods

Participants and Procedures

Data came from the Future of Families and Child Wellbeing Study (FFCWS), formerly known as the Fragile Families and Child Wellbeing Study, a birth cohort study following a random sample of nearly 5,000 families in 20 large cities (populations over 200,000) [27] in the USA. FFCWS oversampled families with unmarried parents in an attempt to capture a nationally representative sample of fragile families who may be vulnerable to risk factors associated with nonmarital childbearing, such as poverty. Between 1998 and 2000, mothers and fathers in 75 hospitals were interviewed after their child's birth, referencing approximately 4,898 births to 3,711 unmarried and 1,187 married parents; nonmarital births and families who were socioeconomically disadvantaged were oversampled. A description of

sociodemographic characteristics of the sample and key study variables is presented in Table S1 (for all online suppl. material, see www.karger.com/doi/10.1159/000530120), available online. Families were interviewed again when the child was 1, 3, 5, 9, and 15 years of age. Follow-up interview completion rates were excellent (89% of mothers at age of 1 year, 86% at age of 3 years, 85% at age of 5 years, 76% at age of 9 years, and 73% at age of 15 years).

Ethical Considerations

Informed consent was obtained for each family at each interview. The Institutional Review Boards at Columbia University and Princeton University approved the FFCWS. Additional details on participation, including attrition at each wave of assessment, are publicly available online [28].

Measures

Predictors: Exposure to Childhood Maltreatment

Assessments of neglect and harsh physical discipline were derived from the Parent-Child Conflict Tactics Scales (CTS-PC), a frequently used measure to assess child maltreatment in population-based samples [19, 29, 30]. The CTS-PC was reported by primary caregivers (most often mothers) at child ages of 3 years, 5 years, and 9 years and collected mostly via computer-based in-home assessments with an interviewer and sometimes by a telephone.

The FFCWS CTS-PC measure included a subset of items from the CTS-PC and its supplemental scale on neglect, designed to capture mild and moderate maltreatment (5 neglect items and 5 harsh physical discipline items; see Supplement 1, available online). Items asking about severe physical maltreatment (e.g., "burned or scalded him/her on purpose," "grabbed him/her around the neck and choked him/her") were omitted by FFCWS to avoid potentially implicating parents and necessitate involvement of child protective services. Items capturing more mild forms of corporal punishment [31] (e.g., "spanked him/her on the bottom with a hand") were not included in our measure of harsh physical discipline. Consistent with prior studies using the CTS-PC in FFCWS [32], harsh physical discipline was coded as a dichotomous variable indicating presence versus absence of the following: (1) the parent had shaken the child at any point in the past year and/or (2) the parent had hit the child with an object on 3 or more occasions in the past year. See Supplemental Materials for details on the specific items included.

Children were coded as having been exposed to neglect if their primary caregiver reported at least 1 of these events in the past year at any frequency: (1) parent had to leave child home alone even when an adult was needed; (2) parent was so caught up in own problems that they were not able to express love to child; (3) parent was not able to make sure child got food when needed; (4) parent was not able to make sure child got to the doctor or hospital when needed; and (5) parent was so drunk or high that they had problem taking care of child. These items were also chosen to be consistent with prior studies in the FFCWS [33–35].

Outcome: Child Behavior Problems

At age of 15 years, child behavior problems were assessed using items from the Child Behavior Checklist (CBCL/6–18), one of the most commonly used measures of psychopathology symptoms in children [36]. Primary caregivers rated their child's behavior on 34 items using a 3-point scale (0 = not true; 1 = sometimes true; 2 = very true or often true). We analyzed raw total scores from the internalizing (analytic sample $\alpha = 0.88$; 8 items) and externalizing subscales (analytic sample $\alpha = 0.91$; 20 items), which were square root transformed prior to analyses to improve univariate normality and then converted to z-scores to aid interpretability. Parent report of psychopathology was analyzed, as it was far more comprehensive than child self-reports (which only focused on measuring depressive symptoms). As we have described elsewhere [37, 38], the occurrence, predictors of, and consequences for discrepancies between parental and child reports are important to study in their own right and could be important in a future investigation.

Covariates

We adjusted for the following covariates, measured at the time of the child's birth, to rule out the effects of baseline sociodemographic factors: maternal age; maternal race/ethnicity; maternal marital status; mother-reported receipt of public assistance, welfare, or food stamps; and maternal education. We also adjusted for maternal depression or substance use when her child was 3 years of age because parent psychopathology symptoms were associated with both child psychopathology and maltreatment in our sample and could lead to maternal bias in both the reporting of child abuse exposure and psychopathology symptoms [39, 40] (see Covariate section in Supplement 1, available online). For comparison, we also conducted analyses without adjustment for maternal psychopathology (see online suppl. Table S4, S5, available online).

All analyses were stratified by sex because stress exposure [30] and psychopathology [41–43] vary between boys and girls and may lead to differences in the effects of these life-course theoretical models [2]. We used sex stratification rather than tests of statistical interaction because interaction terms can only capture differences in magnitude of the exposure effect in the same life-course model, while stratification can capture differences in the structure of the life-course model as well as the magnitude of exposure effects.

Analyses

To minimize loss of power and reduce potential bias due to attrition, we performed multiple imputation among children with complete outcome data on psychopathology symptoms measured at year 15 (n = 3,474; see Data Analysis section in Supplement 1, available online). We used an innovative two-stage structured life-course modeling approach (SLCMA) [44, 45] to test the strength of evidence for sensitive periods. The SLCMA was originally developed by Mishra [46] and later extended by Smith [44] to analyze repeated binary exposure data across the life course. The SLCMA allows researchers to compare competing life-course theoretical models simultaneously and identify the most parsimonious explanation for variation in the outcome of interest. Details about the SLCMA are available in Supplement 1.

We considered the sensitive period theoretical model (assessed at ages of 3, 5, and 9 years) and compared it with a second model – the accumulation of risk model – in which the outcome varies with the number of occasions exposed regardless of timing (i.e., under the accumulation model there are no

Table 1. Exposure to childhood maltreatment in the total analytic sample and by age at exposure (N = 3,474)

	Childhood maltreatment							
	harsh physical discipline				neglect			
	female		male		female		male	
	N	(%)	*N*	(%)	*N*	(%)	*N*	(%)
Unexposed	1,143	68.4	1,117	62.0	1,209	72.4	1,277	70.8
Exposed	528	31.6	686	38.0	462	27.7	526	29.2
Timing of exposure								
Year 3	233	13.9	319	17.7	135	8.1	160	8.9
Year 5	287	17.8	364	20.2	139	8.3	140	7.8
Year 9	260	15.6	346	19.2	305	18.3	345	19.1

Percentages for each age indicate the proportion of children exposed among children with complete outcome data separately for males (N = 1,803) and females (N = 1,671).

sensitive periods). The SLCMA uses least angle regression (LARS) to identify which theoretical model (or set of theoretical models working in combination) is most supported by the data. When LARS identifies the accumulation model alone, it indicates no sensitive periods are supported by the data; when LARS identifies a sensitive period model, it indicates the specific period when exposure to maltreatment has the greatest effect on the outcome.

A total of 8 LARS models were conducted, corresponding to each type of maltreatment (neglect and harsh physical discipline) and outcome (internalizing and externalizing psychopathology), separately for boys and girls. We regressed the exposures on the covariates and then implemented LARS on the regression residuals to adjust for possible confounding [45]. We used the covariance test [47] to determine whether a set of theoretical models working in combination explained sufficiently more of the outcome variation than a single theoretical model, applying a Bonferroni significance threshold of 0.05/8 = 0.00625. No combination of models met this threshold; hence, all results are reported as the single best fitting theoretical model. Compared with other variable selection procedures, such as stepwise regression, the LARS has multiple benefits including greater statistical power [44], not overinflating effect size estimates [48], and not introducing bias in hypothesis tests [47].

Having selected a theoretical model using LARS, we then estimated the coefficients of the selected model for each type of maltreatment, outcome, and sex, enabling us to determine the magnitude of effect for a selected theoretical model while continuing to adjust for covariates. We calculated confidence intervals (CIs) for the effect estimates that have 95% coverage while adjusting for the selection made by LARS [44]. Although researchers have grouped adversity exposures into clusters – such as deprivation and threat, as a means to characterize the distinct neural pathways they might influence – we analyzed these exposures separately because we wanted to determine if there were unique timing-outcome effects for each form of maltreatment and preserve statistical power (a multiple prediction model with multiple exposures and life course hypotheses would both reduce power and complicate interpretation of results).

Results

Sample Characteristics

The analytic sample was nearly sex-balanced (48% female) and diverse by race/ethnicity (21.9% white; 50.3% black; 24.4% Hispanic; 3.5% other) and socioeconomic background, though skewed toward more disadvantaged families, as indicated by levels of maternal education (11.2% of mothers were college educated or higher) and receipt of public assistance/welfare (36.2%) (see online suppl. Table S1, available online). Exposure to childhood maltreatment was common, with 988 children exposed to neglect at any time point (28.4%), 1,214 exposed to harsh physical discipline (34.9%), and 334 children (9.6%) exposed to both types of maltreatment at any time point. Reports of child exposure to neglect increased with age, more than doubling between ages of 5 and 9 years, whereas reports of harsh physical discipline were stable across time (Table 1).

Exposures were somewhat correlated across time (average correlation across time points for neglect: r = 0.33; harsh physical discipline: r = 0.51; see online suppl. Table S2, available online). Children exposed to harsh physical discipline at any time point were also slightly more likely to be exposed to neglect at any time point (r = 0.28). These correlation values are well below the correlation of 0.80 observed to limit the ability of the SLCMA to identify the correct life-course model [44].

Internalizing and externalizing symptoms were moderately correlated (Pearson r = 0.51). Boys had, on average, greater levels of externalizing psychopathology at age of 15 years than girls ($p < 0.001$) (see online suppl. Table S3, available online). Girls, in comparison, had greater levels of internalizing problems at age of 15 years ($p = 0.006$). Children of mothers with less than a high school education, who received public assistance, used substances, or had periods of depression were also more likely to show higher levels of internalizing and externalizing problems at age of 15 years (all $p < 0.05$). Children born to younger and unmarried mothers showed higher levels of externalizing problems in particular ($p < 0.001$) compared to their peers.

Model Selection and Effect Estimates

Tables 2 and 3 display the life-course theoretical models selected by the LARS procedure separately for each type of childhood maltreatment exposure, psychopathology outcome, and sex. These tables also show the effect estimates and 95% CIs for these selected models, adjusted for covariates.

Table 2. Life-course theoretical models identified by the LARS as explaining the most variation in child internalizing symptoms (N = 3,474)

Maltreatment	Model(s) selected	R^2 (%)	Regression coefficient	SE	LCI	UCI
Girls (n = 1,671)						
Harsh physical discipline	Sensitive period year 9	0.67	0.13	0.04	0.05	0.21
Neglect	Accumulation	0.57	0.09	0.03	0.05	0.14
Boys (n = 1,803)						
Harsh physical discipline	Sensitive period year 5	0.41	0.10	0.04	0.03	0.17
Neglect	Accumulation	0.85	0.08	0.02	0.04	0.12

Models adjust for the presence versus absence of maternal depression and substance reported at the child age 3 assessment. For sensitive period models, the regression coefficient is the difference in the z-score for internalizing symptoms for exposed versus unexposed groups during the sensitive period; for the accumulation model, the regression coefficient is the difference in the z-score for each additional occasion exposed. Confidence intervals are adjusted for model selection; this can cause the intervals to become asymmetrical while maintaining 95% coverage. LCI, lower confidence interval; UCI, upper confidence interval; LARS, least angle regression.

Table 3. Life-course theoretical models identified by the LARS as explaining the most variation in child externalizing symptoms (N = 3,474)

Maltreatment	Model(s) selected	R^2 (%)	Regression coefficient	SE	LCI	UCI
Girls (n = 1,671)						
Harsh physical discipline	Sensitive period year 9	1.0	0.21	0.03	0.13	0.28
Neglect	Accumulation	0.06	0.07	0.02	−0.43	0.10
Boys (n = 1,803)						
Harsh physical discipline	Accumulation	1.37	0.08	0.01	0.05	0.11
Neglect	Accumulation	0.70	0.07	0.02	0.03	0.11

Models adjusted for the presence versus absence of maternal depression and substance reported at the child age 3 assessment. For sensitive period models, the regression coefficient is the difference in the z-score for externalizing symptoms for exposed versus unexposed groups during the sensitive period; for the accumulation model, the regression coefficient is the difference in the z-score for each additional occasion exposed. Confidence intervals are adjusted for model selection; this can cause the intervals to become asymmetrical while maintaining 95% coverage. LCI, lower confidence interval; UCI, upper confidence interval; LARS, least angle regression.

Internalizing Symptom Results

As shown in Table 2 and Figure 1, an accumulation model best explained the relationship between neglect and internalizing symptoms in both girls (r^2 = 0.6%) and boys (r^2 = 0.9%). For exposure to harsh physical discipline, a sensitive period at age of 9 years best explained the association with internalizing symptoms in girls (r^2 = 0.7%; see Fig. 2). A sensitive period at age of 5 years best explained the association in boys (r^2 = 0.4%; see Fig. 2). The same life-course theoretical models were chosen in the analyses, omitting the maternal psychopathology variables (see online suppl. Table S4, S5, available online).

Externalizing Symptom Results

As shown in Table 3, the accumulation model best explained the relationship between neglect and externalizing symptoms in girls, although this was the only model in which the CI for the regression coefficient included zero. Similar to the internalizing symptom findings, a sensitive period at age of 9 years was again selected as the best fitting model for explaining the relationship between harsh physical discipline and externalizing symptoms in girls (r^2 = 1.0%; see Fig. 2). In boys, however, an accumulation model explained the most variation in externalizing symptoms following both neglect exposure (r^2 = 0.7%) and harsh physical discipline

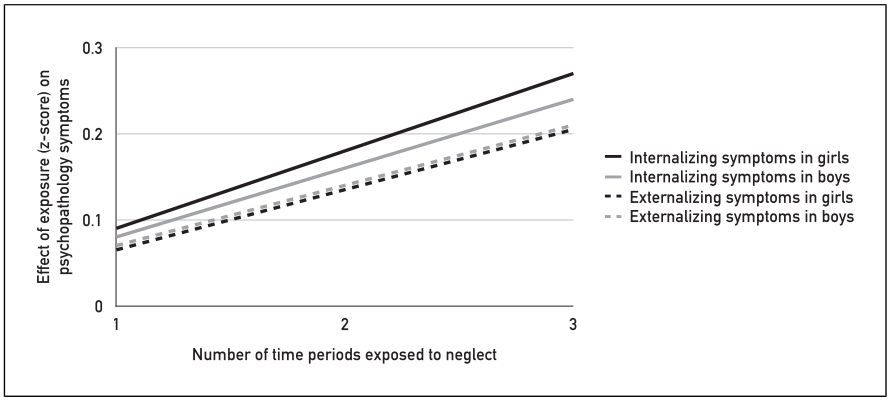

Fig. 1. Effect of accumulation of exposure to neglect on child psychopathology symptoms (N = 3,474). The accumulation model identified for externalizing symptoms in girls was nonsignificant.

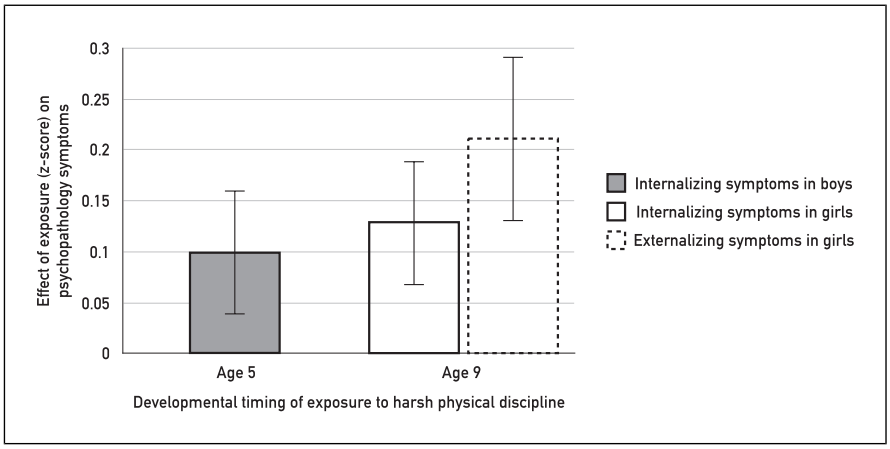

Fig. 2. Effect of developmental timing of exposure to harsh physical discipline on child psychopathology symptoms (N = 3,474). No sensitive period was identified for externalizing symptoms in boys; the accumulation model was identified instead. Standard errors are indicated with standard error bars.

(r^2 = 1.4%; see Fig. 1). These findings were also consistent when maternal psychopathology variables were removed (see Supplement 1, online suppl. Table S4, S5, available online).

Discussion

Two primary findings emerged from this study. First, we identified sensitive periods for harsh physical discipline: both internalizing and externalizing symptoms were elevated in girls exposed to harsh physical discipline at age of 9 years; internalizing symptom scores were elevated among boys exposed at age of 5 years. These findings are consistent with work by Teicher and colleagues [49, 50] in showing that physical abuse and neglect may not only have different sensitive periods for psychopathology symptoms but also the timing of these sensitive periods may be sex dependent. Our ability to detect these sensitive period effects was notable because reports of harsh physical discipline were moderately correlated over time in this sample, making sensitive periods harder to discern. The large sample size of FFCWS and the statistical power it therefore afforded enabled us to differentiate sensitive period from accumulation effects.

Second, with neglect, we saw stronger and consistent evidence for the accumulation of risk model for both boys and girls. For each additional time period of exposure to neglect, the z-score for psychopathology increased by one-tenth, on average. Though not a fully direct comparison, these findings align with the Bucharest Early Intervention Project, which found that children randomly assigned to remain in institutional care had greater psychopathology symptoms in adolescence than children who were never institutionalized or randomized to high-quality foster care [51]. However, in the Bucharest Early Intervention Project, sex differences in this accumulation effect have been observed, with girls being somewhat protected from the effects of

severe early deprivation [51]. Reports of neglect were weakly correlated across time in our FFCWS analytic sample, suggesting parental reporting was either inconsistent or experiences of neglect were intermittent, perhaps due to changes in work, childcare, and neighborhood conditions [52]. To our knowledge, this is the largest study to test the sensitive period hypothesis for neglect in children or adolescents.

These findings provide important clues for researchers to consider in narrowing the search space to identify mechanisms underlying psychopathology risk. If sensitive periods begin after children reach specific maturational goals, as has been found [53], then our findings hint at what domains to study and when. Our results can also guide clinicians in the assessment of adversity exposure, particularly in pediatric care settings [54]. Experts have discussed *which* screening measures to use [55], *how* to address patient- and provider-level barriers to implementation [56], and general challenges of screening [57]. This study sheds light on *when* these tools should be deployed if universal screening (the ideal scenario) is not an option.

This study had four major limitations. First, there were limitations in the measurement of child maltreatment. We were unable to triangulate data from multiple sources (e.g., child self-report; administrative records) as such data were not available in this study. Further, FFCWS investigators did not ask caregivers about their children's exposure to maltreatment before age of 3 years. Children younger than 3 years of age have the highest rates of reported maltreatment, comprising one-quarter of all documented cases of child maltreatment [58]. Thus, we are likely underestimating the amount of maltreatment and also including children who were maltreated in the unexposed group. Assuming that people are unlikely to self-report abuse if there is none, our estimates are likely underestimates of the effects due to this misclassification of maltreated children. Consistent with our findings, however, a 2018 paper using data from the ALSPAC study found evidence for sensitive periods during middle childhood (defined in ALSPAC as age of 6.75 years) associated with sexual and physical abuse. This finding is striking because the ALSPAC study used the same analytic approach as ours but had maltreatment measures available as early as age of 1.5 years [26]. Nevertheless, analyses of secondary data are always limited by the measures originally collected by the primary study investigators, and for us, the timing of those measurements might not be fully optimized to detect sensitive periods. Second, as with most longitudinal studies, there was nonresponse and attrition over waves, which could bias the results (i.e., 89%, 86%, 85%, 76%, and 73% of baseline families participated at ages of 1, 3, 5, 9, and 15 years, respectively). However, it is notable that a small percentage of the sample appears to permanently attrite, or leave, the study; most families missing a wave return in the following wave [59–61]. More importantly, there is little evidence that nonresponse in FFCWS for any given wave is predicted by social-demographic factors, including marital status, education, race, health status, and poverty (see attrition tables here https://ffcws.princeton.edu/sites/g/files/toruqf4356/files/documents/attrition_table_1.pdf). These findings imply that the missing may be mostly at random and therefore not significantly biasing the results [62]. Nevertheless, we addressed this attrition through multiple imputation, though some bias from unobserved variables is still likely. Third, the SLCMA does not accommodate time-varying covariates. Thus, we were unable to account for macro-level shocks associated with the Great Recession or other factors. Future studies should investigate these additional risk factors – as well as promotive (and protective) factors – in the etiology of psychopathology. Fourth, as with the measure of maltreatment, psychopathology relied on caregiver reports, which may cause lower reported severity of symptoms. In summary, these findings suggest more nuanced work is needed to assess early exposure to maltreatment, which could lay the groundwork for research, policy, and intervention.

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Statement of Ethics

Informed consent was obtained for each family at each interview. The Institutional Review Boards at Columbia University and Princeton University approved the FFCWS (Approval #5767).

Conflict of Interest Statement

Colter Mitchell received grants R01MD011716 and R01HD076592 to support research on FFCWS. Erin Dunn, Daniel Busso, Kathryn Davis, Andrew Smith, Henning Tiemeier, and Ezra Susser report no conflicts of interest.

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Author Contributions

All authors made substantive contributions to the work presented in this paper. Erin C. Dunn led the concept and design for this paper and provided supervision. Erin C. Dunn, Daniel S. Busso, Kathryn A. Davis, Andrew D.A.C. Smith, Colter Mitchell, Henning Tiemeier, and Ezra S. Susser were involved in the acquisition, analysis, and/or interpretation of data; performed critical revision of the manuscript for important intellectual content; and had full ability to access to all the data in the study and accepted responsibility to submit for publication. Daniel S. Busso and Kathryn A. Davis conducted statistical analysis. Erin C. Dunn drafted the manuscript along with Daniel S. Busso and Kathryn A. Davis. Daniel S. Busso provided administrative, technical, and/or material support.

Data Availability Statement

The data that support the findings of this study are not publicly available due to the inclusion of confidential information that could compromise the privacy of the research participants. Access can be granted via a contract data use license to faculty and research personnel at institutions with an institutional review board (IRB) or human subjects review committee registered with the US Office for Human Research Protections (OHRP) or the National Institutes of Health (NIH), once they obtain IRB approval for their research purposes. To submit an application, you can contact ffdata@princeton.edu with the required documents listed at https://ffcws.princeton.edu/restricted. Further inquiries can be directed to ffdata@princeton.edu.

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SUPPLEMENTAL MATERIALS

Measures

Child maltreatment

As noted in the manuscript, the Conflict Tactics Scale (CTS) was modified for use in FFCWS by removing seven items corresponding to severe physical maltreatment. These modifications excluded items on severe and very severe physical assault as defined in the original CTS-PC scale (1). The CTS-PC subscale on Physical Assault is organized by level of severity, though the items are in random order when presented to respondents. "Slapped him/her on the face or head or ears" is categorized as severe assault while "Slapped him/her on the hand, arm, or leg" is included under minor assault. "Spanked him/her on the bottom with your bare hand" is at the lowest severity measured in the scale and may not be deemed abuse if supported by reasonable disciplinary motive and force based on parental autonomy norms and scientific evidence for physical and socioemotional harm (2). For these reasons, we excluded these items to focus on more moderate physical discipline.

Furthermore, we prioritized the inclusion of items that would allow us to align our work with prior studies and thus facilitate replication of findings across studies. Previous studies' analyses of physical abuse in the FFCWS cohort used two of the 5 items in the modified CTS-PC to measure physical abuse ("Shook him/her", "Hit him/her on the bottom with something like a belt, hairbrush, a stick, or some other hard object") (3).

The complete list of items included in the FFCWS is presented below, alongside the original CTS for comparison. All of the original five neglect items were used in this study. Additional details available through the FFCWS website: https://ffcws.princeton.edu/data-and-documentation/scales-and-concepts-documentation.

Original CTS-PC	CTS-PC modified for FFCWS
Shook him/her	Shook him/her
Hit him/her on the bottom with something like a belt, hairbrush, a stick or some other hard object	Hit him/her on the bottom with something like a belt, hairbrush, a stick or some other hard object
Hit him/her with a fist or kicked him/her hard	
Spanked him/her on the bottom with your bare hand	Spanked him/her on the bottom with your bare hand
Grabbed him/her around the neck and choked him/her	
Beat him/her up, that is you hit him/her over and over as hard as you could	
Burned or scalded him/her on purpose	
Hit him/her on some other part of the body besides the bottom with something like a belt, hairbrush, a stick or some other hard object	
Slapped him/her on the hand, arm or leg	Slapped him/her on the hand, arm or leg
Pinched him/her	Pinched him/her
Threatened him/her with a knife or gun	
Threw or knocked him/her down	
Slapped him/her on the face or head or ears	

Covariates

We adjusted for the following covariates, measured at the time of the child's birth, to rule-out the effects of baseline socio-demographic factors: maternal age; maternal race/ethnicity (White, African American, Hispanic, Other); maternal marital status (married/cohabiting; unmarried); mother-reported receipt of public assistance, welfare, or food stamps (yes/no); and maternal education (college or graduate degree; some college; high school graduate; less than high school). We also adjusted for the presence vs. absence of maternal depression or substance use when the child was 3 years of age, as described below.

Maternal Depression and Substance Use

Maternal depression was assessed using the Composite International Diagnostic Interview - Short Form (CIDI-SF)[1]. The CIDI-SF is an abbreviated version of the CIDI 1, which is a standardized instrument used worldwide to estimate the prevalence of mental disorders based on Diagnostic and Statistical Manual of Mental Disorders – Fourth Edition diagnostic criteria[2]. In the current analyses, we used a more stringent diagnosis of depression based on adjustments proposed by Walters and colleagues[3], which requires depressive symptoms to be present "most of the day". Maternal substance use was determined through interviews that asked mothers about their alcohol and drug use. Mothers were coded as having used substances if they indicated that either: (1) drinking or drug-use had interfered with daily life or personal relationships over the past 12 months, or (2) they had smoked marijuana, or used cocaine, heroin, and other hard drugs in the past 12 months.

Data Analysis

Least Angle Regression (LARS)

To implement the structured life course modeling approach (SLCMA), we began by created a set of variables to encode the specific tests for sensitive periods and accumulation, as shown below.

Description of the coding scheme used to create variables for the SLCMA that tested the accumulation of risk model and sensitive period model, with exposure to neglect as the example

Life course model tested	Definition	Number of Variables	Specific variables entered into the LARS model
Accumulation of risk (by duration)	Sum of the total number of time periods of exposure to a specific adversity. To test whether the total number of time periods of exposure to a given adversity explains the most variance in psychopathology outcomes.	1	neglect_accumulation=count of the number of time periods exposed to neglect (range 0-6)
Sensitive period	A single developmental time period at which there can be exposure to adversity. To test if presence vs. absence of a given adversity at a specific time period explains the most variance in psychopathology outcomes.	6	neglect_period1= exposed (1) vs. unexposed (0) at time period 1 (18 months) ; neglect_period2= exposed (1) vs. unexposed (0) at time period 2 (30 months); neglect_period3= exposed (1) vs. unexposed (0) at time period 3 (42 months); neglect_period4= exposed (1) vs. unexposed (0) at time period

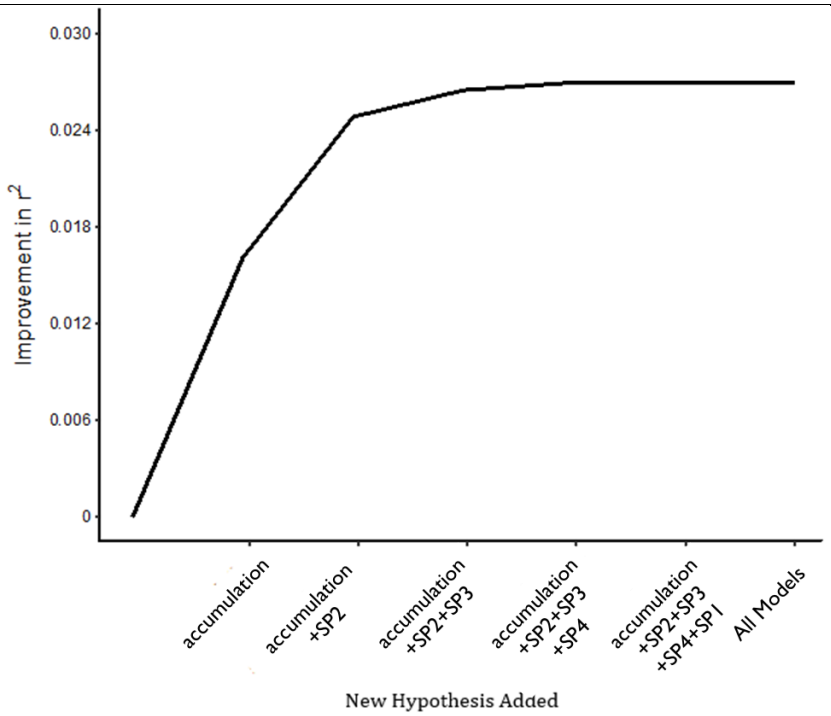
	4 (57 months); neglect_period5= exposed (1) vs. unexposed (0) at time period 5 (69 months); neglect_period6= exposed (1) vs. unexposed (0) at time period 6 (81 months)

This table was adapted from: Dunn, E. C., Soare, T. W., Raffeld, M. R., Busso, D. S., Crawford, K. M., Davis, K. A., . . . Susser, E. S. (2018). What life course theoretical models best explain the relationship between exposure to childhood adv and psychopathology symptoms: recency, accumulation, or sensitive periods? *Psychological Medicine, 48*(15), 2562-257.

These "encoded" variables were each entered into a Least Angle Regression (LARS) procedure [4], which is the first stage of the SLCMA. LARS first identifies the single encoded variable with the strongest association with the outcome. It then identifies the combination of two variables with the strongest association, followed by three variables, and so on; this process continues until all variables are included. Thus, this procedure enables us to identify the most parsimonious explanation for the variation in the outcome of interest—that is, it identifies the smallest combination of encoded variables that explain the most outcome variation, as determined by the percent of variance explained (r^2). The results of the LARS procedure are presented in two ways: in the form of a covariance test and an "elbow plot" (see figure below for example). The covariance test evaluates the null hypothesis at each step in the LARS procedure that adding the next encoded variable does not improve r^2. The elbow plot, in turn, shows the increase in overall model r^2 as additional predictors are added to the model. Where the elbow plot plateaus indicates the point at which the addition of more predictors to the model offers diminishing improvement in fit. This point then represents an optimal balance of parsimony and thoroughness.

In the second stage, the theoretical models determined in the first stage were carried forward to a single multiple regression framework, where measures of effect were estimated for all selected hypotheses. The goal of this second stage can be to determine the contribution of a selected theoretical model after adjustment other selected theoretical models, in instances where more than one theoretical model was chosen in the first stage. Of note, only the first selected variable was chosen here.

Elbow plot illustrating the LARS variable selection procedure testing life course models



SP = sensitive period

Missingness

Of the 4898 families enrolled in the FFCWS at birth, 1424 children were missing outcome data at Year 15 and were therefore excluded from the analysis. Of the remaining 3474 families, 1702 children were missing data on at least one covariate or exposure variable. Children excluded from our analytic sample due to missing outcome data (n=1424) did not significantly differ from children who were included with respect to gender (p=0.25), nor maternal marital status (p=0.09). Missingness differed by maternal education (λ^2=49.09, p<0.001), such that children with missing outcome data were more likely to have mothers with lower levels of education, and to be non-white (λ2=68.05, p<0.001).

Multiple Imputation

Following van Buuren et al.[5, 6], imputation with chained equations[7] was implemented with the *mice* package in R. The variables used for the imputation model included all covariates, all exposures, paternal depression and anxiety diagnoses, maternal anxiety diagnoses, and other mother-reported adversity measures (e.g. not feeling safe in neighborhood). Variables that were not correlated with the missing variable (r<0.10) were dropped from the imputation model[5, 6]. Both exposures and covariates were imputed; we did not impute outcome variables, to avoid noise in the estimation of effect estimates[8]. Imputation was performed 20 times for both males and females with 25 iterations each. Following imputation, we assessed the convergence of the imputation model and the distribution of imputed data in comparison to the observed data for each adversity. The first stage of the SLCMA (the LARS stage) depends only on the covariance structure of the exposures, outcome and covariates. We estimated this covariance structure within each of the 20 multiply imputed datasets and pooled estimates across datasets using Rubin's rules (2, 5). For the purposes of software compatibility (as the *lars* R package will accept only data as an input, not a covariance structure) we used the

Cholesky decomposition to construct a single dataset with exactly the same covariance structure as the pooled estimate. This single dataset was used only for the purposes of model selection in the first stage of the SLCMA and for application of the covariance test to the selected model(s). For the second stage of the SLCMA (effect estimation stage) we performed a linear regression of the theoretical model chosen on each of the 20 multiply imputed datasets and pooled effect estimates (regression coefficients) and standard errors across datasets using Rubin's rules [6, 9]. We used the p-value from the covariance test to calculate unbiased confidence intervals for the effect estimates.[10, 11]

Correlations between exposures

Tetrachoric correlations within and between childhood maltreatment types (N=3474)								
		Harsh Physical Discipline				Neglect		
		Age 3	Age 5	Age 9		Age 3	Age 5	Age 9
Within	Age 3	1	---	---	Age 3	1	---	---
	Age 5	0.55	1	---	Age 5	0.38	1	---
	Age 9	0.41	0.57	1	Age 9	0.26	0.34	1
	Average	0.51	---	---	Average	0.33		
Between	0.28							

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Table S1. Distribution of covariates in the total sample, by childhood maltreatment (N=3474)					
	Total Sample		Exposed To Maltreatment		
	N	%	N	%	*p*-value
Sex					.005
Males	1803	51.9	940	54.3	
Females	1671	48.1	791	45.7	
Maternal Race					<.001
White	758	21.9	266	15.4	
Black	1744	50.3	1014	58.7	
Hispanic	845	24.4	392	22.7	
Other	120	3.5	57	3.3	
Maternal Education					<.001
Less than high school	1100	31.7	578	33.5	
High school	1111	32.0	580	33.6	
Some college	871	25.1	417	24.1	
College or graduate school	387	11.2	153	8.9	
Marital Status					<.001
Married/Cohabiting	2080	59.9	944	54.5	
Unmarried	1394	40.1	787	45.5	
Public Assistance/Welfare					<.001
Received	1247	36.2	700	40.6	
Didn't receive	2194	63.8	1025	59.4	
Maternal Depression					<.001
Present	475	14.7	304	18.4	
Absent	2748	85.3	1351	81.6	
Maternal Substance Use					<.001
Present	265	8.2	176	10.6	
Absent	2958	91.8	1479	89.4	

	Total Sample		Exposed To Maltreatment	
	Mean	SD	*F*-statistic	*p*-value
Mother Age at Child's Birth	25.14	6.04	16.49	<.001

Table S2. Tetrachoric correlations within and between childhood maltreatment types (N=3474)

		Harsh Physical Discipline				Neglect		
		Age 3	Age 5	Age 9		Age 3	Age 5	Age 9
Within	Age 3	1	---	---	Age 3	1	---	---
	Age 5	0.55	1	---	Age 5	0.38	1	---
	Age 9	0.41	0.57	1	Age 9	0.26	0.34	1
	Average	0.51	---	---	Average	0.33		
Between				0.28				

Table S3. Distribution of covariates in the total sample, by levels of internalizing and externalizing psychopathology at Year 15 (N=3474)

	Internalizing Problems			Externalizing Problems		
	Mean	SD	*p*-value	Mean	SD	*p*-value
Sex			.006			<.001
Males	1.92	2.34		4.73	5.32	
Females	2.14	2.53		4.16	4.90	
Maternal Race			<.001			<.001
White	2.61	2.80		4.02	4.54	
Black	1.79	2.26		4.95	5.60	
Hispanic	1.97	2.35		3.81	4.52	
Other	2.03	2.32		4.60	5.02	
Maternal Education			.032			<.001
Less than high school	2.15	2.43		5.15	5.71	
High school	2.06	2.58		4.58	5.28	
Some college	1.83	2.29		4.06	4.63	
College or graduate school	1.97	2.33		3.03	3.41	
Marital Status			.719			<.001
Married/Cohabiting	2.04	2.43		3.97	4.68	
Unmarried	2.01	2.46		5.18	5.67	
Public Assistance/Welfare			.011			<.001
Received	2.16	2.58		5.41	5.78	
Didn't receive	1.94	2.35		3.92	4.65	
Maternal Depression			<.001			<.001
Present	2.74	2.69		5.98	5.97	
Absent	1.92	2.39		4.25	4.96	
Maternal Substance Use			.002			.029
Present	2.48	2.77		5.17	5.34	
Absent	2.00	2.42		4.44	5.14	

	Pearson's *r*	*p*-value	Pearson's *r*	*p*-value
Mother Age at Child's Birth	-.02	.287	-0.13	<.001

Table S4. Life course theoretical models identified by the LARS as explaining the most variation in child internalizing symptoms, without adjusting for maternal psychopathology (N=3474)

Maltreatment	Model(s) Selected	R^2	Regression coefficient	SE	LCI	UCI
		Girls (n=1671)				
Harsh Physical Discipline	Sensitive Period Year 9	0.81%	0.14	0.04	0.06	0.23
Neglect	Accumulation	1.05%	0.10	0.03	0.06	0.15
		Boys (n=1803)				
Harsh Physical Discipline	Sensitive Period Year 5	0.46%	0.11	0.04	0.04	0.18
Neglect	Accumulation	1.16%	0.09	0.02	0.05	0.14

Note: For sensitive periods models, the regression coefficient is the difference in the z-score for internalizing symptoms for exposed vs unexposed during the sensitive period; for the accumulation model, the regression coefficient is the difference in the z-score for each additional occasion exposed. Confidence intervals are adjusted for model selection, this can cause the intervals to become asymmetrical while maintaining 95% coverage.
LCI: Lower Confidence Interval; UCI: Upper Confidence Interval
LARS: Least Angle Regression variable selection procedure

Table S5. Life course theoretical models identified by the LARS as explaining the most variation in child externalizing symptoms, without adjusting for maternal psychopathology (N=3474)

Maltreatment	Model(s) Selected	R^2	Regression coefficient	SE	LCI	UCI
		Girls (n=1671)				
Harsh Physical Discipline	Sensitive Period Year 9	1.19%	0.22	0.03	0.14	0.28
Neglect	Accumulation	0.38%	0.08	0.02	0.03	0.12
		Boys (n=1803)				
Harsh Physical Discipline	Accumulation	1.64%	0.09	0.01	0.06	0.12
Neglect	Accumulation	1.01%	0.08	0.02	0.05	0.12

Note: For sensitive periods models, the regression coefficient is the difference in the z-score for internalizing symptoms for exposed vs unexposed during the sensitive period; for the accumulation model, the regression coefficient is the difference in the z-score for each additional occasion exposed. Confidence intervals are adjusted for model selection, this can cause the intervals to become asymmetrical while maintaining 95% coverage.
LCI: Lower Confidence Interval; UCI: Upper Confidence Interval
LARS: Least Angle Regression variable selection procedure