The mental health effects of pet death during childhood: Is it better to have loved and lost than never to have loved at all?

Katherine M Crawford, BS, Yiwen Zhu, MS, Kathryn A Davis, MA, Samantha Ernst, BS, Kristina Jacobsson, Kristen Nishimi, MPH, Andrew D.A.C. Smith, PhD, Erin C. Dunn, ScD, MPH

Center for Genomic Medicine, Massachusetts General Hospital, Boston, MA, Katherine M Crawford, BS
research coordinator

Center for Genomic Medicine, Massachusetts General Hospital, Boston, MA, Yiwen Zhu, MS
data analyst

Center for Genomic Medicine, Massachusetts General Hospital, Boston, MA, Kathryn A Davis, MA
research coordinator

Center for Genomic Medicine, Massachusetts General Hospital, Boston, MA, Samantha Ernst, BS
research assistant

Center for Genomic Medicine, Massachusetts General Hospital, Boston, MA, Kristina Jacobsson
research assistant

Center for Genomic Medicine, Massachusetts General Hospital, Boston, MA, Department of Social and Behavioral Sciences, Harvard T.H. Chan School of Public Health, MA, Kristen Nishimi, MPH
doctoral student

Applied Statistics Group, University of the West of England, UK, Andrew D.A.C. Smith, PhD
senior lecturer

Center for Genomic Medicine, Massachusetts General Hospital, Boston, MA, Department of Psychiatry, Harvard Medical School, Boston, MA, Center on the Developing Child at Harvard University, Cambridge, MA, Erin C. Dunn, ScD
assistant professor

Corresponding author: Erin C. Dunn, ScD, MPH, Psychiatric and Neurodevelopmental Genetics Unit, Center for Human Genetic Research, Massachusetts General Hospital, 185 Cambridge Street, Simches Research Building 6th Floor, Boston, MA 02114; Email: edunn2[at]mgh[dot]harvard[dot]edu. Phone: 617-726-9387; Fax: 617-726-0830; Website: www.thedunnlab.com

Abstract

Background: Pet ownership is common. Growing evidence suggests children form deep emotional attachments to their pets. Yet, little is known about children's emotional reactions to a pet's death.

Aims: To describe the relationship between experiences of pet death and risk of childhood psychopathology and determine if it is "better to have loved and lost than never to have loved at all".

Method: Data came from the Avon Longitudinal Study of Parents and Children, a UK-based prospective birth cohort (n=6260). Children were characterized based on their exposure to pet ownership and pet death from birth to age 7 (*never loved*; *loved without loss*; *loved with loss*). Psychopathology symptoms at age 8 were compared across groups using multivariable linear regression.

Results: Psychopathology symptoms were higher among children who had *loved with loss* compared to those who had *loved without loss* (β=0.35, p=0.013; 95% CI=0.07, 0.63), even after adjustment for other adversities. This group effect was more pronounced in males than in females. There was no difference in psychopathology symptoms between children who had *loved with loss* and those who had *never loved* (β=0.20, p=0.31, 95% CI =-0.18, 0.58). The developmental timing, recency, or accumulation of pet death was unassociated with psychopathology symptoms.

Conclusions: Pet death may be traumatic for children and associated with subsequent mental health difficulties. Where childhood pet ownership and pet bereavement is concerned, Tennyson's pronouncement may not apply to children's grief responses: it may *not* be "better to have loved and lost than never to have loved at all".

Introduction

Pet ownership is common. Roughly half of households in developed countries own at least one pet [1, 2]. For example, 31% of United Kingdom households report owning a dog and 26% report owning a cat, with smaller but substantial percentages reporting ownership of other household animal types [3, 4]. Since the 1980's, an accumulating body of research into human animal interaction (HAI) and human animal bonding (HAB) suggests that people can form complex bonds to animals [5]. This research has often focused on children, given the particularly high prevalence of pet ownership during childhood [4, 6] as well as the development of child-oriented interventions that capitalize on the developmental benefits of HAI and HAB. From this literature, there is increasing evidence that children often form deep emotional attachments to their pets. These attachments can resemble secure human attachment relationships [6-8] in providing several key resources, such as affection, protection, and reassurance [6, 9]. Previous studies have shown children often turn to pets for comfort and to discuss emotional experiences [10, 11]. Childhood pet ownership and attachment has, in turn, been linked to a number of positive developmental consequences associated with healthy attachment, such as increased empathy [12, 13], self-esteem [14, 15], and greater social competence [16, 17].

Unfortunately, one consequence of the high prevalence of childhood pet ownership is that many children are exposed to the death of a pet. The two most common pet types – dogs and cats – live an average of 12 and 15 years, respectively [18]. Thus, many youth living in households with a pet will experience the death of that pet sometime during childhood. Although relatively little research has been done to empirically study children's emotional reactions to a pet's death, children's grief in response to the loss of other important attachment relationships

has been well-documented [19-21]. Though children's grief responses may be distinct from those of adults—with bereaved children displaying infantile behaviors, fearfulness [22], and somatic reactions, including headaches and stomach aches [23]—their grief may be no less intense [20, 24]. In general, the death of a family member has been associated with an increased risk of childhood psychopathology symptoms [25], including anxiety [26], post-traumatic stress symptoms [27], and depressive symptoms [27]. It has also been shown that although grief reactions for most children abate over time following the death of a loved one, some children can exhibit a high, prolonged grief response known as complicated grief. Complicated grief is a particularly potent predictor of depression in children and adolescents as far as three years after the loss [19].

Despite the prevalence of pet death as a potentially traumatic loss during childhood, very little research has examined the mental health consequences of children's exposure to the death of a pet. The few cross-sectional and retrospective studies that have explored this topic have primarily studied psychopathology symptoms in adults [28], among whom pet death has been associated with increased risk for neurotic [29] and depressive symptoms [30], though risk for major psychopathology following pet death is low [31]. Prior case reports and empirical studies have found that compared to adults, children's grief responses to a pet's death can be profound [32, 33], and can have greater intensity and duration [34].

To our knowledge, no previous studies have explored childhood mental health problems following the death of a pet. Thus, it remains unclear whether pet death is associated with psychopathology symptoms, and if the known positive effects of owning a pet outweigh any negative consequences associated with pet bereavement. In the words of British poet Alfred Lord Tennyson, the question remains: is it "better to have loved and lost than never to have loved

at all"? [35]. The current study aimed to answer this question by using data from a deeply characterized prospective longitudinal population-based birth-cohort study, containing serial measures of household pet ownership and child exposure to pet death. With these data, we explored the association between pet death and subsequent psychopathology symptoms during childhood, focusing on differences between non-pet owners (*never loved*), pet owners who never experienced the death of a pet (*love without loss*), and pet owners who experienced a pet death (*love with loss*).

Methods

Sample and Procedures

Data came from the Avon Longitudinal Study of Parents and Children (ALSPAC), a prospective, longitudinal birth cohort of children born to pregnant mothers who were living in the county of Avon England (120 miles west of London) with estimated delivery dates between April 1991 and December 1992 [36, 37]. Approximately 85% of eligible pregnant women agreed to participate (N=14,541), and 76% of eligible live births (N=14,062) who were alive at 12 months of age (N=13,988 children) were enrolled. Response rates to data collection have been good (75% have completed at least one follow-up), with 56% (N=7912) of the original sample participating in the age 8 assessment. Ethical approval for the study was obtained from the ALSPAC Ethics and Law Committee and the Local Research Ethics Committee. More details are available on the ALSPAC website, including a fully searchable data dictionary: http://www.bristol.ac.uk/alspac/researchers/our-data/.

Measures

142 *Pet Ownership and Exposure to Pet Death*

143 Pet ownership and exposure to pet death were determined through mailed questionnaires
144 completed by the mothers.

145 Pet ownership was assessed in a questionnaire about living arrangements, where the
146 mother indicated if she owned a pet and if so, how many. This questionnaire was completed at
147 five time periods, when the child was 8 months, 21 months (1.75 years), 33 months (2.75 years),
148 47 months (3.9 years), and 84 months (7 years) of age.

149 Children's exposure to pet death was determined through an item in a stressful life events
150 inventory, asking the mother to indicate whether or not the child had been exposed to pet death
151 since the last questionnaire. This questionnaire was completed at six time periods, when the
152 child was 18 months (1.5 years), 30 months (2.5 years), 42 months (3.5 years), 60 months (5
153 years), 72 months (6 years), and 84 months (7 years) of age. Age of exposure was defined as the
154 age of the child at the time the mother completed the questionnaire indicating her child had
155 experienced pet death. For example, if the mother indicated at the age 30 month assessment that
156 the death of a pet had occurred at some time since the previous assessment (at 18 months), the
157 age of exposure was coded as 30 months.

158 We used these data to categorize children into one of three mutually exclusive groups:
159 *never loved*, meaning children who were non-pet owners throughout the entire time period; *love*
160 *with loss*, meaning children who were pet owners and experienced the death of at least one pet
161 (in a time period subsequent to the report of pet ownership); and *love without loss*, meaning
162 children who were pet owners who did not experience the death of a pet.

163 Given that the focus of ALSPAC is on children and their development rather than pet
164 ownership specifically, these survey measures did not allow us to identify certain relevant

details, such as the type of pet that died or the strength of the child's attachment to that pet. These child-centric measures were, however, unparalleled in their attention to the timing of exposure and measurement of co-occurring adversities. The limitations of these measures are addressed in further detail in the Discussion section.

Child Psychopathology

Child psychopathology symptoms were assessed using the Strengths and Difficulties Questionnaire (SDQ) [38, 39], which mothers completed by mail when the child was 8 years old. The SDQ is one of the most commonly used dimensional rating scales of child psychopathology in epidemiology studies and has excellent psychometric properties [40, 41]. The SDQ contains 25 items, rated on a three-point scale (0=not true, 1=somewhat true, or 2=certainly true), capturing the child's behavior and feelings within the past six months. We calculated a total SDQ score by summing across items on the first four subscales (conduct problems; emotional symptoms; hyperactivity; peer problems; range 0-40), with higher scores indicating more emotional and behavioral difficulties (α=0.82). This total score has been shown in studies from across the globe to correlate highly with questionnaire and interview measures of psychopathology, including the Child Behavior Checklist as well as clinician-rated diagnoses of child mental disorder [42, 43].

Covariates

We controlled for the following baseline covariates, measured at the time of the child's birth: child sex; child race/ethnicity; number of previous pregnancies; maternal marital status; highest level of maternal education; maternal age; homeownership; parent social class; singleton

or multiple birth; and maternal depression, as assessed by the Edinburgh Postnatal Depression Scale (EPDS) [44] . Covariates were selected for inclusion because they were found to be potential confounders in our sample, or because they have been included routinely in longitudinal birth cohorts when studying child mental health outcomes [45-47]. For example, prior studies have found higher levels of pet ownership among families with lower education levels [4, 48] and lower parent social class (as defined by occupation) [4, 49]. Adjustment for maternal depression allowed us to reduce potential impacts of common rater bias [50], as mothers reported about both their child's exposure to pet death as well as their child's emotional and behavioral problems, and maternal mood or other factors may influence reports of adversity exposure [51] and psychopathology [52, 53].

Recognizing that childhood adversities often co-occur, and that the effects of pet death on psychopathology could be confounded by experiences of other adversities, we additionally adjusted for exposure to three major types of childhood adversity: financial hardship, caregiver physical or emotional abuse, and physical or sexual abuse by anyone (see **Supplemental Materials** for details).

Primary Analyses

To reduce potential bias and minimize loss of power due to attrition [54, 55], we conducted all analyses using multiply imputed datasets, where missing exposure (i.e., pet ownership and pet death) and covariate information were imputed using the MICE package in R [55] (see **Supplemental Materials**).

Our analysis was based on an analytic sample of 6260 children out of a possible 7912 (79%) who completed the age 8 assessment, which was the last time point of data examined in

the current analysis. The analytic sample met two inclusion criteria. First, given that methods for imputation of missing outcomes may induce additional noise [56], we restricted our analyses to children who had a completed outcome measure. This criterion omitted 436 children from the sample who participated in the age 8 assessments. Second, in the interest of deriving exposure groups that were as homogenous as possible, we omitted children from our primary analysis whose mothers reported that the child had experienced the death of a pet although no pet had been indicated to reside in the household in prior assessments (n=1216; 16%) **Supplemental Figure 1**). The experience of pet loss in the absence of pet ownership was likely due to the child experiencing a pet loss outside of the home (e.g., at a grandparent's home or in a school classroom, where children often encounter pets with whom they may bond [57, 58]). Further details can be found in **Supplemental Materials**.

We began the analysis by running univariate and bivariate analyses to examine the distribution of baseline covariates in the total analytic sample and by our three exposure groups. We then used multivariable linear regression to compare child psychopathology symptom scores across the three exposure groups (*never loved*, *love without loss*, and *love with loss*), after adjustment for baseline covariates (Model 1). To ensure these results were not explained by exposure to other types of adversities, we ran a set of models – building from Model 1 – to additionally adjust for the role of exposure to financial hardship (Model 2), caregiver physical or emotional abuse (Model 3), physical or sexual abuse by anyone (Model 4), and all three adversities considered simultaneously (Model 5).

Secondary Analyses

We conducted three sets of secondary analyses. First, given documented differences between girls' and boys' grief responses to pet death [59], as well sex differences in psychopathology symptoms [60, 61], we reran the primary analyses stratified by sex.

Second, based on evidence from life course theory that the effects of childhood adversity on risk for childhood psychopathology may vary depending on the characteristics of the exposure, including when it occurs in development, how many times it occurs, and how recently it occurred [62, 63], we capitalized on the availability of the repeated measures of pet death and pet ownership to examine the potential time-dependent effects of pet death on childhood psychopathology symptoms. Specifically, we used a structured life course modeling approach grounded in least angle regression [64, 65] to evaluate which of the three life course theoretical models explained the most variability in child psychopathology symptoms, as determined by r^2 values [66]. The life course models tested were: (1) a sensitive period model [66]; (2) an accumulation model [67]; and (3) a recency model [68] (see **Supplemental Materials**).

Third, recognizing that the experience of pet death may still be impactful for children who lost non-household animals, we examined the effects of being ever exposed to pet death without differentiating between explicit and ambiguous pet ownership. Thus, we reran all models to include the 1216 children who likely experienced pet loss outside of home and were excluded from our primary analysis. These results are reported as Models 6-10.

Results

Sample Characteristics and Distribution of Exposure to Pet Death

The analytic sample was sex-balanced (50.7% male) and comprised of predominately White (97.0%) children from families whose parents were married and owned their home (**Table**

1). Pet death was common in this sample, with most children experiencing the death of a pet at some point in their lives (52.7%; N=3296). A large percentage of children had pets that were still living (*love without loss* group N=1682; 26.9%), with only 808 children (12.9%) belonging to the *never loved* group. These three subgroups differed on some demographic characteristics. Specifically, children in the *love with loss* group were more likely to be female (p=0.001), non-White (p<0.001), from families with less parental education (p<0.001) and lower parental social class (p<0.001), and were exposed to other forms of childhood adversity (**Table 1**). Among children in this *love with loss* group, the most frequent age at first exposure to the death of a pet was 4.75 years (24%) (**Figure 1**).

Primary Analyses: Association between Pet Death and Child Psychopathology Symptoms

As shown in **Table 2** and **Figure 2** for Model 1, there were no differences observed in psychopathology symptoms between children in the *love without loss* group and the children who *never loved* (p=0.45) after adjustment for baseline covariates. Similarly, there were also no differences in psychopathology symptoms observed between the *love with loss* group and the *never loved* group (p=0.31).

However, psychopathology symptom scores were higher among children who experienced pet death (*love with loss*), compared those who had pets that were still living (*love without loss*) (β=0.35, p=0.013; 95% CI=0.07,0.63). This relative increase in psychopathology symptoms persisted, though was slightly attenuated, after adjustment for financial hardship (Model 2), caregiver physical or emotional abuse (Model 3), and physical or sexual abuse by anyone (Model 4). When all three types of adversity were included simultaneously as covariates (Model 5), the difference in psychopathology symptoms associated with pet loss was marginally

279 statistically significant (β=0.26; p=0.06). Notably, in visually examining the magnitude of the
280 difference in psychopathology symptoms between the *love with loss* group compared to the *love*
281 *without loss group*, we can see across Models 2-5 that this effect was at least one third as large as
282 the magnitude of having ever been exposed to each of the adversity covariates (**Table 2**).
283
284 Secondary Analyses: Association between Pet Death and Child Psychopathology Symptoms
285 **Figure 3** shows that the increase in psychopathology symptoms in the *love with loss*
286 group compared to the *love without loss* group was more pronounced in males than in females
287 (Model 1: β_{male}=0.45, p_{male}=0.035; β_{female}=0.28, p_{female}=0.14). The patterns of between-group
288 differences in males were similar to the results from the primary analysis; however, we did not
289 observe any group effect in females.
290 There were no meaningful differences in risk for psychopathology symptoms based on
291 the developmental timing, recency, and accumulation of exposure to pet death. That is, all life
292 course theoretical models were weak and inconclusive predictors of child psychopathology in
293 both the full sample and among the sample of pet owners (p>0.05; **Supplemental Table 1**).
294 As shown in **Table 3**, children exposed to the death of a pet, whether that pet resided in
295 their household or not, had psychopathology symptoms scores that were slightly higher than their
296 peers who did not experience a pet death (β=0.26; 95% CI=0.03, 0.50; p=0.03), after adjustment
297 for covariates (Model 6). This effect was still observed after accounting for exposure to financial
298 hardship (Model 7), but no longer statistically significant after adjustment for the other two
299 abuse-related adversities (Model 8-10). Compared to the primary analyses, where subgroups
300 were defined based on pet loss and pet ownership status, the effect sizes in this model associated

with the ever versus never exposed analyses were smaller, suggesting that defining the pet loss experience with more precision allowed us to see more meaningful patterns.

Discussion

To our knowledge, the current study is the first to test the association between exposure to a pet's death and psychopathology symptoms in childhood. Three main findings emerged from this prospective study. First, we found that pet ownership was common, with most children (88%) in our sample having owned a pet at some point in childhood. Second, pet death was also a common childhood experience, with a substantial proportion (63%) of children having lost a pet during the first seven years of life. Third, we found that these experiences of pet death were associated with elevated psychopathology symptoms. This association was observed even after accounting for other adverse factors known to increase child risk for poor mental health, such as low socioeconomic status, maternal history of depression, and exposure to child abuse. These findings align with previous work in adult grief documenting increased neurotic and depressive symptoms following the death of a pet [28-30]. Our findings also align with the few case reports and empirical studies exploring the psychological sequelae of pet bereavement in childhood [33, 34], which have found that children's grief responses to a pet's death can surpass adults' responses in intensity and duration [34]. Most previous studies of pet bereavement in children and adults have not accounted for the potential psychological benefits of pet ownership. From what we can determine, this is the first study to compare groupings of pet ownership in this manner and thus our findings regarding the differences between *love with loss* and *love without loss* are novel.

Three additional findings were observed as well. First, the association between pet death and elevated psychopathology symptoms was stronger in male children than in female children, which was somewhat unexpected given previous research in adolescents suggesting that females reported a more intense grief response to a pet's death than did males [59]. Additionally, this association was stronger for household pets versus non-household pets; however, even in the case of the death of a non-household pet, children still showed an increase in psychopathology symptoms. Finally, the strength of this association did not vary as a function of when the pet's death occurred during childhood, how many times it occurred, or how recently it occurred. This finding was somewhat surprising in light of emerging work suggesting that exposure to adversity in the first five years of life may be especially important in shaping risk for psychopathology symptoms in childhood [62] and beyond [69, 70]. We did not, however, find evidence to suggest similar timing effects here.

This study had three major strengths. First, despite the ubiquity of pet ownership [1, 2] and the fact that a pet's death is likely the first major loss a child will encounter [59], few studies have systematically explored the effect of pet death on children's risk for experiencing psychopathology symptoms. Our study therefore addresses an important, but understudied issue. Second, we addressed this issue by analyzing data from a large, longitudinal, and population-based sample of children, who were followed from birth and whose mothers had provided repeated measures that allowed us to track experiences of pet ownership and pet loss across time. These serial measurements enabled us to capture events during childhood without relying on retrospective reporting, which is commonplace among studies examining the consequences of childhood adversities. The depth of measurement in ALSPAC also allowed us to adjust for other important potential confounders, notably experiences of co-occurring adversity. Third, we could

346 characterize experiences of pet death in ways that moved beyond the simple classification of
347 children as ever versus never exposed.
348 Several limitations are noted. Although ALSPAC contains rich data collected from
349 parents and children, the study was not designed to investigate pet ownership and pet death
350 experiences, thus these measures of these constructs lacked some granularity. For example,
351 while there was information available about the type of pet the child had, there was no data
352 available to identify which of the pets had died. Moreover, we were unable to examine the
353 effects of pet death for specific types of pets, including cats or dogs. This was a limitation
354 because prior studies have shown that children tend to form stronger bonds with dogs and cats,
355 and less strong attachments with pet birds or fish [6, 71]. Future studies could extend these
356 findings by examining the role of the type of pet death to elucidate differences that may emerge
357 from different types of animal bonding. Additionally, while earlier child psychopathology may
358 be linked to pet ownership and later psychopathology symptoms, we did not adjust for
359 psychopathology symptoms before age 8, as this would prove difficult for maintaining
360 temporality in the exposure-disease association. In brief, our first indicator of exposure to pet
361 death at age 18 months occurred before the first assessment of psychopathology symptoms in
362 ALSPAC. Thus, inclusion of psychopathology measured after this time point would create
363 temporal ambiguity with respect to our exposure-outcome association. That is, while
364 psychopathology symptoms were assessed at 48 months, adding this measure as a covariate
365 would be problematic as it would likely mediate the relationship between exposure to pet
366 ownership and pet death that occurred before 48 months and psychopathology symptoms at age
367 8. We hope future studies will be able to more carefully account for time-varying covariates so
368 that the prospective and longitudinal association between pet death and child psychopathology

can be studied. Finally, the high prevalence of pet death (above 50%) in the analytic sample indicated that the classification likely covered a wide range of experiences spanning in severity. In future studies, the experience of pet death could be further characterized to capture more subtle distinctions within the *love with loss* group, which likely reflect not only different pet types but different durations of pet ownership and the strength of attachments between children and their pets.

In conclusion, Tennyson's pronouncement may not, in fact, apply to children's grief responses to pet bereavement: where childhood pet ownership is concerned, it may *not* be "better to have loved and lost than never to have loved at all". Our study results suggest that pet death may be traumatic for children and that children who have pets may show signs of mental health difficulties if their pet dies. Especially when pets feel like members of the family and children are attached to their pets, parents and other caregivers may find it beneficial to recognize children's short- and long-term psychological reactions, which may mimic responses to the loss of other important human attachments. The death of a pet should be treated as the loss of other strong emotional attachments, and parents and physicians should be prepared to treat it as such.

Funding Statement and Acknowledgments: We are extremely grateful to all the families who took part in this study, the midwives for their help in recruiting them, and the whole ALSPAC team, which includes interviewers, computer and laboratory technicians, clerical workers, research scientists, volunteers, managers, receptionists and nurses. The UK Medical Research Council and the Wellcome Trust (Grant ref: 102215/2/13/2) and the University of Bristol provide core support for ALSPAC. A comprehensive list of grants funding is available on the ALSPAC website (http://www.bristol.ac.uk/alspac/external/documents/grant-acknowledgements.pdf). This publication is the work of the authors, each of whom serve as guarantors for the contents of this paper. This work was conducted with support from the National Institutes of Health Award K01MH102403 and R01MH113930. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health. The authors thank Janine Cerutti for her assistance in preparing this manuscript for publication.

Conflict of Interest Statement: On behalf of all authors, the corresponding author, states that there is no conflict of interest. All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf and declare: no support from any organization for the submitted work; no financial relationships with any organizations that might have an interest in the submitted work in the previous three years; no other relationships or activities that could appear to have influenced the submitted work.

Ethical approval: Ethical approval for the study was obtained from the ALSPAC Ethics and Law Committee and the Local Research Ethics Committee. Informed consent for the use of data collected via questionnaires and clinics was obtained from participants following the recommendations of the ALSPAC Ethics and Law Committee at the time. More details are available on the ALSPAC website (www.bristol.ac.uk/alspac), including a fully searchable data dictionary.

Transparency statement: Dr. Erin C. Dunn, the manuscript's senior author and grantor, affirms that this manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

References

1. Voith, V.L., *The Impact of Companion Animal Problems on Society and the Role of Veterinarians.* Veterinary Clinics of North America: Small Animal Practice, 2009. **39**(2): p. 327-345.

2. Utz, R., *Walking the Dog: The Effect of Pet Ownership on Human Health and Health Behaviors.* Social Indicators Research, 2014. **116**(2): p. 327-339.

3. Murray, J.K., et al., *Number and ownership profiles of cats and dogs in the UK.* Veterinary Record, 2010. **166**(6): p. 163.

4. Westgarth, C., et al., *Family Pet Ownership during Childhood: Findings from a UK Birth Cohort and Implications for Public Health Research.* International Journal of Environmental Research and Public Health, 2010. **7**(10): p. 3704-3729.

5. Hosey, G. and V. Melfi, *Human-animal interactions, relationships and bonds: a review and analysis of the literature.* 2014.

6. Hawkins, R.D., J.M. Williams, and A. Scottish Society for the Prevention of Cruelty to, *Childhood Attachment to Pets: Associations between Pet Attachment, Attitudes to Animals, Compassion, and Humane Behaviour.* International Journal of Environmental Research and Public Health, 2017. **14**(5): p. 490.

7. Beck, L. and E.A. Madresh, *Romantic Partners and Four-Legged Friends: An Extension of Attachment Theory to Relationships with Pets.* Anthrozoös, 2008. **21**(1): p. 43-56.

8. Carr, S. and B. Rockett, *Fostering secure attachment: experiences of animal companions in the foster home.* Attachment & Human Development, 2017. **19**(3): p. 259-277.

9. Zilcha-Mano, S., M. Mikulincer, and P.R. Shaver, *Pets as safe havens and secure bases: The moderating role of pet attachment orientations.* Journal of Research in Personality, 2012. **46**(5): p. 571-580.

10. Bryant, B.K., *The neighborhood walk: Sources of support in middle childhood.* Monographs of the Society for Research in Child Development, 1985. **50**(3): p. 122-122.

11. Covert, A.M., et al., *Pets, Early Adolescents, and Families.* Marriage & Family Review, 1985. **8**(3-4): p. 95-108.

12. Poresky, R.H. and C. Hendrix, *Differential Effects of Pet Presence and Pet-Bonding on Young Children.* Psychological Reports, 1990. **67**(1): p. 51-54.

13. Vidović, V.V., V.V. Štetić, and D. Bratko, *Pet Ownership, Type of Pet and Socio-Emotional Development of School Children.* Anthrozoös, 1999. **12**(4): p. 211-217.

14. Poresky, R.H., et al., *Young Children's Companion Animal Bonding and Adults' Pet Attitudes: A Retrospective Study.* Psychological Reports, 1988. **62**(2): p. 419-425.

15. Poresky, R.H., et al., *Children's pets and adults' self-concepts. (Tennessee Self Concept Scale, Companion Animal Bonding Scale).* The Journal of Psychology, 1988. **122**(5): p. 463.

16. Guttman, G., M. Predovic, and M. Zemanek, *Influence of pet ownership on non-verbal communication and social competence in children*, in *Proceedings of the International Symposium on the Human–Pet Relationship*. 1983: Vienna. p. 58-63.

17. Endenburg, N. and D.B. Baarda, *The roles of pets in enhancing human well-being: effects on child development*, in *The Waltham Book of Human–Animal Interaction: Benefits and Responsibilities of Pet Ownership.*, I. Robinson, Editor. 1995, Pergamon: Exeter. p. 1-17.

18. Grimm, D., *Why we outlive our pets.* Science, 2015. **350**(6265): p. 1182-1185.

19. Melhem, N.M., et al., *Grief in Children and Adolescents Bereaved by Sudden Parental Death.* Archives of General Psychiatry, 2011. **68**(9): p. 911-919.

20. Wolraich, M., et al., *The pediatrician and childhood bereavement. American Academy of Pediatrics. Committee on Psychosocial Aspects of Child and Family Health.* Pediatrics, 2000. **105**(2): p. 445.

21. Bugge, K., et al., *Young Children's Grief: Parents' Understanding and Coping.* Death Studies, 2014. **38**(1): p. 36.

22. Dowdney, L., *Childhood bereavement following parental death: annotation.* Journal of Child Psychology and Psychiatry and Allied Disciplines, 2000. **41**(7): p. 819-830.

23. Sood, A., et al., *Children's reactions to parental and sibling death.* Current Psychiatry Reports, 2006. **8**(2): p. 115-120.

24. Schultz, K., *Bereaved children.* Canadian Family Physician, 1999. **45**: p. 2914-2921.

25. Brent, D., et al., *The Incidence and Course of Depression in Bereaved Youth 21 Months After the Loss of a Parent to Suicide, Accident, or Sudden Natural Death.* American Journal of Psychiatry, 2009. **166**(7): p. 786-794.

26. Kranzler, E.M., et al., *Early Childhood Bereavement.* Journal of the American Academy of Child & Adolescent Psychiatry, 1990. **29**(4): p. 513-520.

27. Kaplow, J.B., K.H. Howell, and C.M. Layne, *Do Circumstances of the Death Matter? Identifying Socioenvironmental Risks for Grief-Related Psychopathology in Bereaved Youth.* Journal of Traumatic Stress, 2014. **27**(1): p. 42-49.

28. Brown, O.K. and D.K. Symons, *"My Pet Has Passed": Relations of Adult Attachment Styles and Current Feelings of Grief and Trauma after the Event.* Death Studies, 2015. **40**(4).

29. Kimura, Y., H. Kawabata, and M. Maezawatype: Full Paper, *Frequency of Neurotic Symptoms Shortly after the Death of a Pet.* The Journal of Veterinary Medical Science, 2014. **76**(4): p. 499.

30. Hunt, M., H. Al-Awadi, and M. Johnson, *Psychological Sequelae of Pet Loss Following Hurricane Katrina.* Anthrozoös, 2008. **21**(2): p. 109-121.

31. Adrian, J., A. Deliramich, and B. Frueh, *Complicated grief and posttraumatic stress disorder in humans' response to the death of pets/animals.* Bulletin of the Menninger Clinic, 2009. **73**(3): p. 176-187.

32. Sharkin, B.S. and D. Knox, *Pet Loss: Issues and Implications for the Psychologist.* Professional Psychology: Research and Practice, 2003. **34**(4): p. 414-421.

33. Kaufman, K. and N. Kaufman, *And then the dog died.* Death Studies, 2006. **30**(1): p. 61-76.

34. Jarolmen, J., *A Comparison of the Grief Reaction of Children and Adults: Focusing on Pet Loss and Bereavement.* OMEGA — Journal of Death and Dying, 1998. **37**(2): p. 133-150.

35. Tennyson, A.T., *In memoriam*. 1852, Boston.

36. Boyd, A., et al., *Cohort profile: The 'Children of the 90's'- the index offspring of the Avon Longitudinal Study of Parents and Children.* International Journal of Epidemiology, 2012.

37. Fraser, A., et al., *Cohort profile: The Avon Longitudinal Study of Parents and Children: ALSPAC mothers cohort.* International Journal of Epidemiology, 2012.

38. Goodman, R., *The strenghts and difficulties questionnaire: A research note.* Journal of Child Psychology and Psychiatry, 1997. **38**: p. 581-586.

39. Goodman, R., *Psychometric properties of the strenghts and difficulties questionnaire.* Journal of the American Academy of Child and Adolescent Psychiatry, 2001. **40**: p. 1337-1345.

40. Ezpeleta, L., et al., *Psychometric properties of the strengths and Difficulties Questionnaire3–4 in 3-year-old preschoolers.* Comprehensive Psychiatry, 2013. **54**(3): p. 282-291.

41. Muris, P., C. Meesters, and F. van den Berg, *The Strengths and Difficulties Questionnaire (SDQ)--further evidence for its reliability and validity in a community sample of Dutch children and adolescents.* European Child & Adolescent Psychiatry, 2003. **12**(1): p. 1-8.

42. Goodman, A., D.L. Lamping, and G.B. Ploubidis, *When to use broader internalizing and externalizing subscales instead of the hypothesized five subscales on the strengths and difficulties questionnaire (SDQ); Data from British parents, teachers, and children.* Journal of Abnormal Child Psychology, 2010. **38**: p. 1179-1191.

43. Goodman, A. and R. Goodman, *Population mean scores predict child mental disorder rates: validating SDQ prevalence estimators in Britain.* Journal of Child Psychology and Psychiatry, 2011. **52**(1): p. 100-8.

44. Cox, J.L., J.M. Holden, and R. Sagovsky, *Detection of postnatal depression. Development of the 10-item Edinburgh Postnatal Depression Scale.* The British Journal of Psychiatry, 1987. **150**: p. 782-6.

45. Hibbeln, J.R., et al., *Maternal seafood consumption in pregnancy and neurodevelopmental outcomes in childhood (ALSPAC study): An observational cohort study.* The Lancet, 2007. **369**(9561): p. 578-585.

46. Suren, P., et al., *Parental obesity and risk of autism spectrum disorder.* Pediatrics, 2014. **133**(5): p. e1128-38.

47. Oliver, B.R., et al., *Social Cognition and Conduct Problems: A Developmental Approach.* Journal of the American Academy of Child & Adolescent Psychiatry, 2011. **50**(4): p. 385-394.

48. Parslow, R.A., et al., *Pet Ownership and Health in Older Adults: Findings from a Survey of 2,551 Community-Based Australians Aged 60–64.* Gerontology, 2005. **51**(1): p. 40-47.

49. Mullersdorf, M., et al., *Aspects of health, physical/leisure activities, work and socio-demographics associated with pet ownership in Sweden.* Scandinavian Journal Of Public Health, 2010. **38**(1): p. 53-63.

50. Podsakoff, P.M., et al., *Common method biases in behavioral research: a critical review of the literature and recommended remedies.* Journal of Applied Psychology, 2003. **88**(5): p. 879-903.

51. Holt, S., H. Buckley, and S. Whelan, *The impact of exposure to domestic violence on children and young people: a review of the literature.* Child Abuse & Neglect, 2008. **32**(8): p. 797-810.

52. Chilcoat, H.D. and N. Breslau, *Does psychiatric history bias mothers' reports? An application of a new analytic approach.* Journal of the American Academy of Child and Adolescent Psychiatry, 1997. **36**(7): p. 971-9.

53. Ringoot, A.P., et al., *Parental depression and child well-being: young children's self-reports helped addressing biases in parent reports.* Journal of Clinical Epidemiology, 2015. **68**(8): p. 928-38.

54. van Buuren, S., H.C. Boshuizen, and D.L. Knook, *Multiple imputation of missing blood pressure covariates in survival analysis.* Statistics in Medicine, 1999. **18**(6): p. 681-94.

55. van Buuren, S. and K. Groothuis-Oudshoorn, *mice: Multivariate Imputation by Chained Equations in R.* Journal of Statistical Software, 2011. **45**: p. urn:issn:1548-7660.

56. White, I.R., P. Royston, and A.M. Wood, *Multiple imputation using chained equations: issues and guidance for practice.* Statistics in Medicine, 2011. **30**(4): p. 377-399.

57. Rud, A.G. and A.M. Beck, *Companion animals in Indiana elementary schools.* Anthrozoös, 2003. **16**(3): p. 241-251.

58. Uttley, C., *Animal Attraction: Including Animals in Early Childhood Classrooms.* YC Young Children, 2013. **68**(4): p. 16-21.

59. Brown, B.H., H.C. Richards, and C.A. Wilson, *Pet Bonding and Pet Bereavement Among Adolescents.* Journal of Counseling & Development, 1996. **74**(5): p. 505-509.

60. Eme, R.F., *Sex differences in childhood psychopathology: A review.* Psychological Bulletin, 1979. **86**(3): p. 574.

61. Nolen-Hoeksema, S. and J.S. Girgus, *The emergence of gender differences in depression during adolescence.* Psychol Bull, 1994. **115**(3): p. 424-443.

62. Keiley, M.K., et al., *The timing of child physical maltreatment: a cross-domain growth analysis of impact on adolescent externalizing and internalizing problems.* Dev Psychopathol, 2001. **13**(4): p. 891-912.

63. Dunn, E.C., et al., *What life course theoretical models best explain the relationship between exposure to childhood adversity and psychopathology symptoms: recency, accumulation, or sensitive periods?* Psychological Medicine, 2018. **48**(15): p. 2562-2572.

64. Simpkin, A.J., et al., *Longitudinal analysis of DNA methylation associated with birth weight and gestational age.* Hum Mol Genet, 2015. **24**(13): p. 3752-63.

65. Smith, A.D., et al., *A structured approach to hypotheses involving continuous exposures over the life course.* Int J Epidemiol, 2016. **45**(4): p. 1271-1279.

66. Ben-Shlomo, Y. and D. Kuh, *A life course approach to chronic disease epidemiology: conceptual models, empirical challenges, and interdisciplinary perspectives.* International Journal of Epidemiology, 2002. **31**: p. 285-293.

67. Evans, G.W., D. Li, and S.S. Whipple, *Cumulative risk and child development.* Psychological Bulletin, 2013. **139**(1): p. 342-396.

68. Shanahan, L., et al., *Child-, adolescent- and young adult-onset depressions: differential risk factors in development?* Psychological Medicine, 2011. **41**(11): p. 2265-74.

69. Dunn, E.C., et al., *Developmental timing of child maltreatment and symptoms of depression and suicidal ideation in young adulthood: results from the National Longitudinal Study of Adolescent Health.* Depression and Anxiety, 2013. **30**(10): p. 955-64.

70. Teicher, M.H., C.M. Anderson, and A. Polcari, *Childhood maltreatment is associated with reduced volume in the hippocampal subfields CA3, dentate gyrus, and subiculum.* Proceedings of the National Academy of Science, 2012. **109**(9): p. E563-E572.

71. Westgarth, C., et al., *Pet ownership, dog types and attachment to pets in 9-10 year old children in Liverpool, UK.* BMC Veterinary Research, 2013. **9**: p. 102.

Table 1. Distribution of covariates in the total ALSPAC analytic sample and by the three subgroups defined by pet ownership and pet death

	Total sample (N=6260)	Love with Loss (N=3296)	Love without Loss (N=1682)	Never Loved (N=808)	*P*-value
	N (%)	N (%)	N (%)	N (%)	
Sex					0.001
Males	3175 (50.7)	1609 (48.8)	877 (52.1)	451 (55.8)	
Females	3085 (49.3)	1687 (51.2)	805 (47.9)	357 (44.2)	
Race					<0.001
Non-White	184 (3.0)	67 (2.1)	58 (3.5)	42 (5.3)	
White	5884 (97.0)	3134 (97.9)	1582 (96.5)	751 (94.7)	
Maternal education					<0.001
less than O-level	1290 (21.0)	697 (21.5)	340 (20.5)	109 (13.6)	
O-level	2174 (35.3)	1234 (38.1)	533 (32.1)	252 (31.5)	
A-level	1668 (27.1)	880 (27.1)	473 (28.5)	217 (27.1)	
Degree or above	1023 (16.6)	431 (13.3)	315 (19.0)	222 (27.8)	
Maternal marital status					0.326
Never Married	764 (12.4)	384 (11.8)	212 (12.7)	86 (10.7)	
Widowed/Divorced/Separated	304 (4.9)	171 (5.3)	72 (4.3)	35 (4.4)	
Married	5115 (82.7)	2700 (82.9)	1380 (82.9)	680 (84.9)	
Home ownership					<0.001
Mortgage/own home	5149 (83.8)	2691 (83.1)	1400 (84.7)	697 (88.3)	
Rent home	828 (13.5)	446 (13.8)	215 (13.0)	87 (11.0)	
Other	164 (2.7)	100 (3.1)	37 (2.2)	5 (0.6)	
Age of mother at child birth					0.029
Ages 15-19	99 (1.6)	47 (1.4)	29 (1.7)	3 (0.4)	
Ages 20-35	5616 (89.7)	2971 (90.1)	1503 (89.4)	720 (89.1)	
Age >35	545 (8.7)	278 (8.4)	150 (8.9)	85 (10.5)	
Parental social class (occupation)					<0.001
Professional	909 (14.5)	399 (12.1)	277 (16.5)	185 (22.9)	
Managerial and technical	2424 (38.7)	1261 (38.3)	663 (39.4)	335 (41.5)	
Skilled, non-manual	1354 (21.6)	760 (23.1)	347 (20.6)	144 (17.8)	
Skilled, manual	348 (5.6)	209 (6.3)	93 (5.5)	22 (2.7)	

Semi-skilled, manual	103 (1.6)	63 (1.9)	25 (1.5)	5 (0.6)	
Unskilled, manual or other	1122 (17.9)	604 (18.3)	277 (16.5)	117 (14.5)	
Number of previous pregnancies					<0.001
0	2782 (45.5)	1314 (40.9)	786 (47.8)	464 (58.7)	
1	2222 (36.4)	1195 (37.2)	624 (37.9)	253 (32.0)	
2	837 (13.7)	533 (16.6)	181 (11.0)	54 (6.8)	
3+	267 (4.4)	174 (5.4)	54 (3.3)	20 (2.5)	
Singleton vs. multiple birth					0.156
Singleton	6128 (97.9)	3239 (98.3)	1645 (97.8)	786 (97.3)	
Multiple birth	132 (2.1)	57 (1.7)	37 (2.2)	22 (2.7)	
Financial hardship					<0.001
Never exposed	4092 (69.4)	2073 (66.7)	1237 (75.7)	634 (78.7)	
Exposed	1802 (30.6)	1033 (33.3)	397 (24.3)	172 (21.3)	
Caregiver physical or emotional abuse					0.029
Never exposed	4444 (83.0)	2295 (81.6)	1329 (84.4)	656 (84.3)	
Exposed	908 (17.0)	519 (18.4)	246 (15.6)	122 (15.7)	
Physical or sexual abuse by anyone					0.002
Never exposed	4533 (87.5)	2370 (86.0)	1500 (89.2)	659 (89.4)	
Exposed	645 (12.5)	385 (14.0)	182 (10.8)	78 (10.6)	
	Mean (SD)	Mean (SD)			0.012
Maternal depression	5.16 (4.54)	5.27 (4.55)	5.00 (4.50)	4.81 (4.39)	0.041

Note. The groups reported here were determined *before* imputation using complete-case data, meaning any child who had complete pet ownership and pet death exposure data (n=5786). The actual group proportions varied slightly across the 20 imputed datasets. The p-values corresponded to chi-squared tests when the covariate was a categorical variable (testing the null hypothesis that the covariates were equally distributed among the three exposure subgroups). For maternal depression (continuous), ANOVA was performed and the corresponding p-value was reported. Since most covariates and the pet death exposure variables had missingness, the cell counts do not sum to the total sample size.

Table 2. Results of linear regression models examining difference in child psychopathology symptom scores between groups in the ALSPAC analytic sample (N=6260), after adjustment for covariates and exposure to other childhood adversities.

	Beta	SE	P-value	95% CI
Model 1: Baseline covariates only				
Exposure				
Never loved vs. Love with Loss	0.20	0.19	0.311	(-0.18, 0.58)
Never loved vs. Love without loss	-0.15	0.20	0.452	(-0.56, 0.25)
Love without loss vs. Love with Loss	0.35	0.14	0.013*	(0.07, 0.63)
Model 2: Model 1 + Financial hardship				
Exposure				
Never loved vs. Love with Loss	0.13	0.19	0.507	(-0.25, 0.51)
Never loved vs. Love without loss	-0.19	0.20	0.358	(-0.59, 0.21)
Love without loss vs. Love with Loss	0.32	0.14	0.025*	(0.04, 0.59)
Covariate				
Never vs. ever exposed to financial stress	0.72	0.14	<.001**	(0.45, 1)
Model 3: Model 1 + Caregiver physical or emotional abuse				
Exposure				
Never loved vs. Love with Loss	0.17	0.19	0.369	(-0.21, 0.55)
Never loved vs. Love without loss	-0.15	0.20	0.476	(-0.54, 0.25)
Love without loss vs. Love with Loss	0.32	0.14	0.023*	(0.04, 0.59)
Covariate				
Never vs. ever exposed to phys/emo abuse	1.39	0.17	<.001**	(1.05, 1.72)
Model 4: Model 1+ Physical or sexual abuse by anyone				
Exposure				
Never loved vs. Love with Loss	0.14	0.19	0.485	(-0.24, 0.51)
Never loved vs. Love without loss	-0.17	0.20	0.401	(-0.57, 0.23)
Love without loss vs. Love with Loss	0.31	0.14	0.029*	(0.03, 0.58)
Covariate				
Never vs. ever exposed to phys/sex abuse	1.56	0.19	<.001**	(1.19, 1.94)
Model 5: Model 1+ All three childhood adversities				
Exposure				
Never loved vs. Love with Loss	0.07	0.19	0.722	(-0.31, 0.45)
Never loved vs. Love without loss	-0.19	0.20	0.351	(-0.59, 0.21)
Love without loss vs. Love with Loss	0.26	0.14	0.066	(-0.02, 0.53)
Covariate				
Never vs. ever exposed to financ. hardship	1.35	0.19	<.001**	(0.97, 1.73)
Never vs. ever exposed to phys/emo abuse	0.59	0.14	<.001**	(0.31, 0.86)
Never vs. ever exposed to phys/sex abuse	1.17	0.17	<.001**	(0.83, 1.51)

Note. In these analyses, the first group listed, meaning before the vs., was the referent group. The names of the models indicate what variables were adjusted for when estimating the effects of the pet ownership and exposure status in the regression analyses. The covariate and exposure to other adversity variables are described in the Methods section.

* The corresponding beta estimate was significantly different from 0 at $p<.05$.

** The corresponding beta estimate was significantly different from 0 at $p<.0001$.

Table 3. Results of linear regression models examining difference in child psychopathology symptom scores between those ever versus never exposed to pet death regardless of pet ownership (N=7476), after adjustment for covariates and exposure to other major childhood adversities.

	Beta	SE	P-value	95% CI
Model 6: Baseline covariates only				
Never vs. ever exposed to pet death	0.26	0.12	0.029*	(0.03,0.5)
Model 7: Model 6 + Ever/never exposed to financial hardship				
Never vs. ever exposed to pet death	0.24	0.12	0.047*	(0,0.48)
Never vs. ever exposed to financial stress	0.53	0.13	<.001**	(0.27,0.79)
Model 8: Model 6 + Ever/never exposed to caregiver physical or emotional abuse				
Never vs. ever exposed to pet death	0.23	0.12	0.052	(0,0.47)
Never vs. ever exposed to caregiver physical or emotional abuse	1.32	0.18	<.001**	(0.97,1.66)
Model 9: Model 6 + Ever/never exposed to physical or sexual abuse by anyone				
Never vs. ever exposed to pet death	0.21	0.12	0.076	(-0.02,0.45)
Never vs. ever exposed to physical or sexual abuse by anyone	1.56	0.18	<.001**	(1.19,1.92)
Model 10: Model 6 + Ever/never exposed to all three major childhood adversities				
Never vs. ever exposed to pet death	0.18	0.12	0.138	(-0.06,0.41)
Never vs. ever exposed to financial hardship	1.36	0.19	<.001**	(0.99,1.73)
Never vs. ever exposed to caregiver physical or emotional abuse	0.36	0.13	0.005	(0.11,0.62)
Never vs. ever exposed to physical or sexual abuse by anyone	1.11	0.18	<.001**	(0.76,1.46)

Note. In these analyses, the never exposed group was the referent. The names of the models indicate what variables were adjusted for when estimating the effects of exposure to pet death in the regression analyses. The covariate and exposure to other adversity variables are described in the Methods section.

* The corresponding beta estimate was significantly different from 0 at p<.05.

** The corresponding beta estimate was significantly different from 0 at p<.0001.

Figure 1. Child age at first exposure to pet death and number of occasions exposed among the *Love with Loss* group, meaning children who were pet owners and experienced pet death

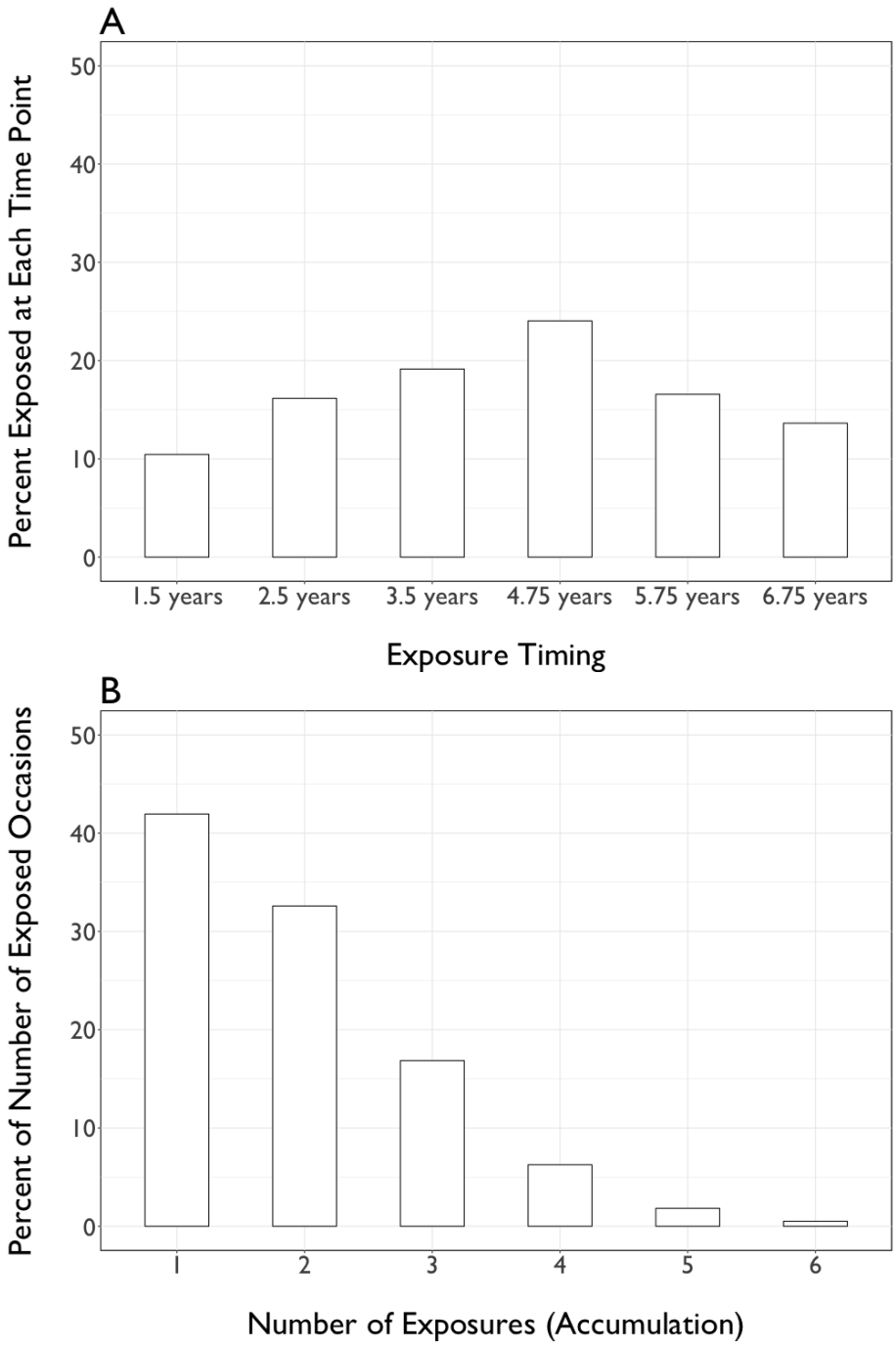
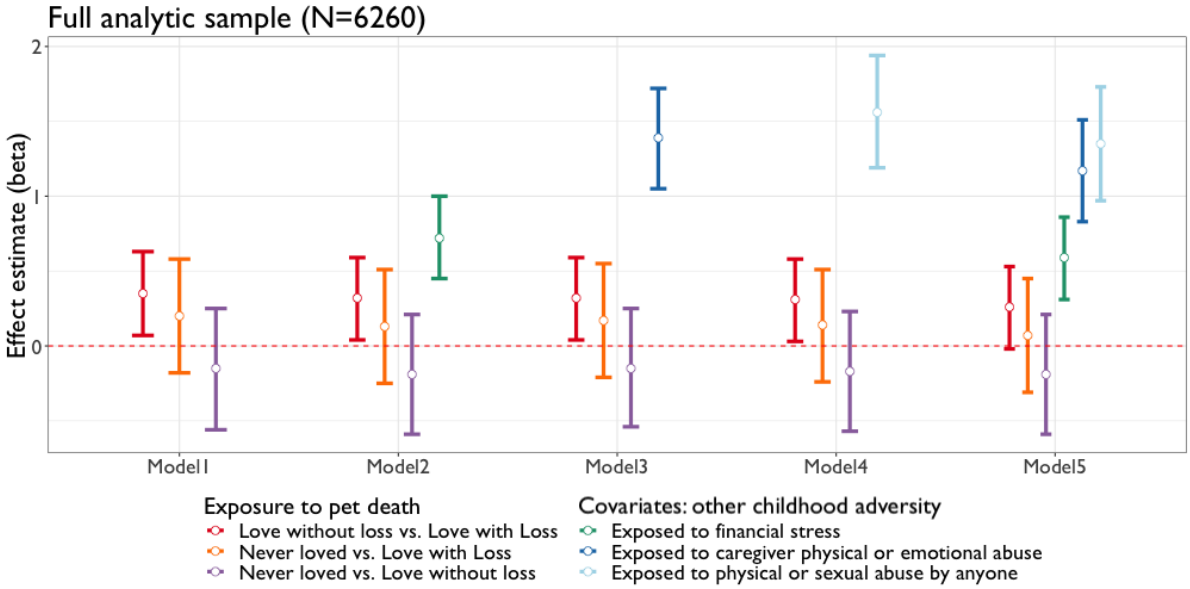
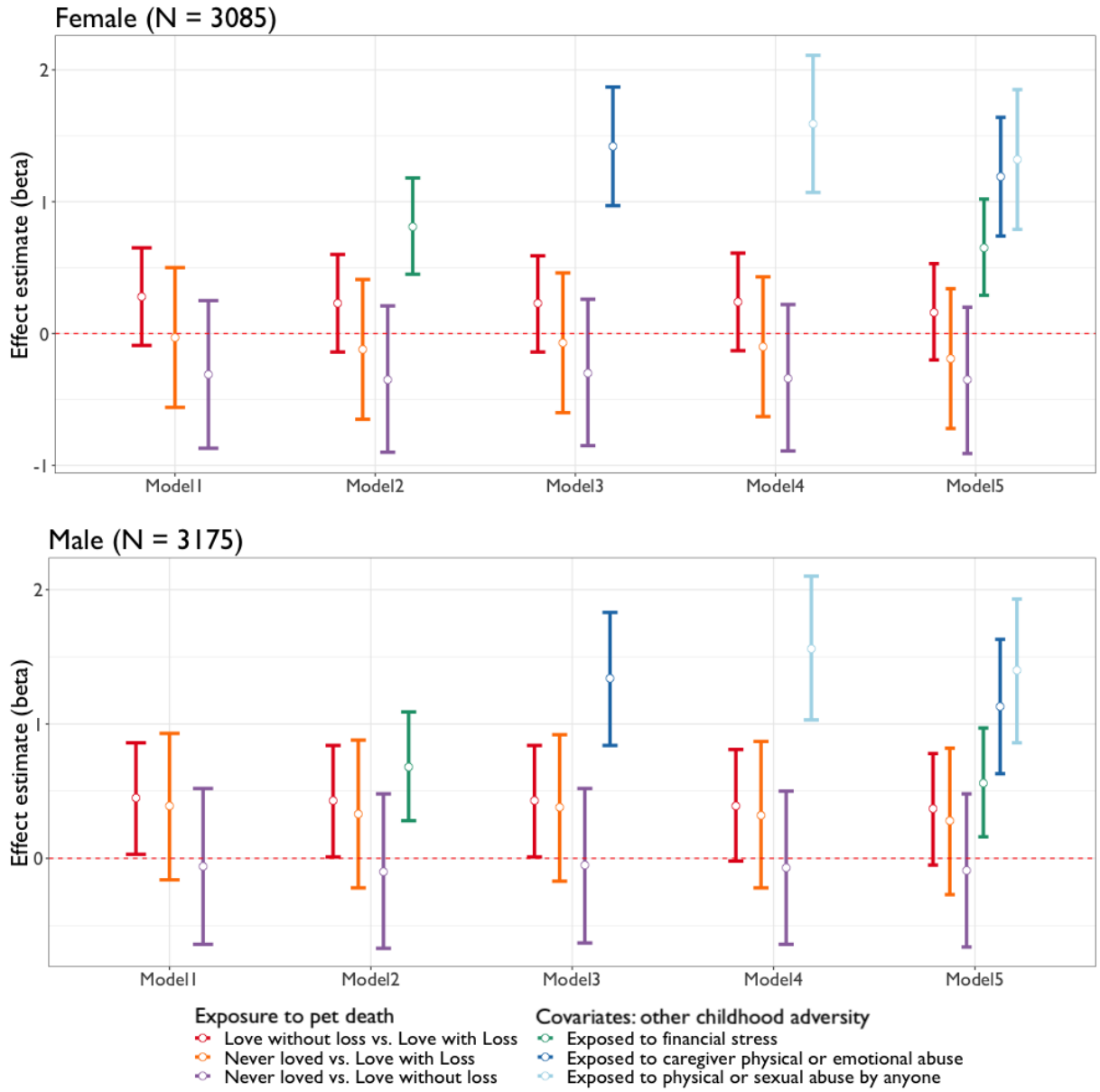


Figure 2. Results of linear regression models examining difference in child psychopathology symptom scores between groups in the full ALSPAC analytic sample, adjusting for covariates and exposure to other adversity.



Note. Each vertical line represents point estimates and the corresponding confidence interval. The psychopathology symptoms in the *love with loss* group, compared to the *love without loss* group were significantly higher in Models 1-4, although the magnitude of effect was not as large as the effects of other major types of childhood adversity.

Figure 3. Results of linear regression models examining difference in child psychopathology symptom scores between groups stratified by sex, adjusting for covariates and exposure to other adversity.



Note. Each vertical line represents a point estimate and the corresponding confidence interval. After stratifying by sex, the effects of the *love with loss* group relative to the *love without loss* group were no longer significant in girls, but they were still observed in Models 1-3 in boys.

Supplemental Materials

Measures

We controlled for the following covariates, measured at the time of the child's birth: *child sex* (1=female ; 2=male) *child race/ethnicity* (0=non-White; 1=White); *number of previous pregnancies* (between 0-3+); *maternal marital status* (0=never married; 1=widowed/divorced/separated; 2=married); *highest level of maternal education* (1=less than O-level, 2=O-level, 3=A-level, 4=Degree or above); *maternal age* (0=ages 15-19, 1=ages 20-35, 2=age>35); *homeownership* (0=mortgage/own home; 1=rent home; 2=other); *parent social class* (i.e. the highest social class of either parent: 1=professional; 2= managerial and technical; 3=skilled, non-manual; 4=skilled, manual; 5=semi-skilled, manual; 6=unskilled, manual or other); and *maternal depressive symptoms* (measured by total scores on the Edinburgh Postnatal Depression Scale scores ranged from 0-30 with higher scores indicating higher levels of depressive symptoms).

Children were coded as being exposed to financial hardship if at any time point before age 7, their mothers indicated that being able to afford necessity was at least fairly difficult (the 3rd point on a 4-point Likert-type scale, ranging from not difficult to very difficult) for three or more out of the five types of necessity assessed (housing, heating, clothing, food, or items for the child). Children were determined to be exposed to physical or emotional abuse if the mother, partner, or both reported themselves or the other caregiver as being physically or emotionally cruel to the child. Exposure to sexual or physical abuse was defined based on the mother's answer to one item asking whether or not the child had been exposed to either sexual or physical abuse from anyone. All three types of adversity were repeatedly measured on at least five occasions up to age 8. Exposure to each type of adversity was defined as being exposed at one or more time points before age 8.

Data Selection

Out of ALSPAC's 14,763 initially enrolled children, there were 7912 children who had a measurement of childhood psychopathology. With this base set of 7912 children, we then applied our exclusion criteria to identify the analytic sample, as summarized in **Supplemental Figure 1**.

Multiple Imputation

In the current study, missingness was handled using multiple imputation to reduce potential bias and minimize loss of power due to attrition. Logistic regression or multinomial logistic regression was performed to impute the missing values on variables encoding exposure to pet loss/ownership or covariates. All children with complete outcome data were included and the procedure generated 20 datasets with 25 iterations. Following the guidance of van Buuren and colleagues [1, 2] as well as prior research with imputation in the ALSPAC dataset [3, 4], the following predictors were allowed to enter the imputation models: all covariates, exposures, the outcome, and measurements of other forms of childhood adversity such as family instability or neighborhood disadvantaged. Among these, predictors uncorrelated with the missing variable ($r<0.10$) were excluded from the imputation model [1, 2]. Imputation was performed with chained equations [5] using the *mice* package in R [2]. Because prior studies have found that imputing the outcome would likely induce noise in the estimates, we did not impute the outcome [6].

All reported results described were obtained by aggregating estimates from 20 multiply imputed datasets. Group status (*never loved*; *love without loss*; *love with loss*) was determined after imputation. Notably, because a single set of descriptive statistics cannot be generated from imputed data, we report descriptive statistics on exposure status from the observed data and as estimated from the imputed data. We confirmed the convergence of the imputation model and the distribution of imputed data as compared to the observed data, making sure that all data generated were plausible.

Structured Life Course Modeling Approach

In the secondary analysis, we used a structured life course modeling approach (SLCMA) to systematically compare life course theories describing time-dependent effects of exposures to pet death. The SLCMA was originally proposed by Mishra [7]. Smith and colleagues [8] later extended the approach by making use of a least angle regression (LARS) procedure [9]. The approach allows us to identify the life course theory that explains the most variation in the outcome and yields unbiased estimates.

First, we generated three sets of variables: (1) a single variable denoting the total number of time points of exposure to pet loss (coded as 0-6), encoding the theory that the total number of exposure occasions is linearly associated with psychopathology symptoms; (2) a set of variables indicating presence vs. absence of the exposure to pet loss at a specific time point, to test the sensitive period hypothesis, which posits that pet loss during a particular developmental period is most harmful; and (3) a single variable encoding the total number of developmental periods of exposure linearly weighted by the age (in months) of the child at the time of assessment, which assumed more recent pet death experiences were associated with higher symptoms than distally-occurring ones.

We then assessed the relative importance of these variables in the SLCMA. We followed the approach of Smith [8] and entered the set of variables described previously into a Least Angle Regression (LARS) procedure in order to identify the variable (or potentially more than one variables) that explained the most variability in the outcome, i.e., levels of psychopathology symptoms. To determine which model is selected and whether the selection is sufficiently supported by the observed data, we used an elbow plot (**Figure 2**) and a covariance test [10]. The covariance test has been shown to produce unbiased estimates even after comparing and testing multiple hypotheses and selecting the one having the strongest association [10]. To adjust for potential confounding, we regressed each encoded variable on the covariates and implemented LARS on the regression residuals [11].

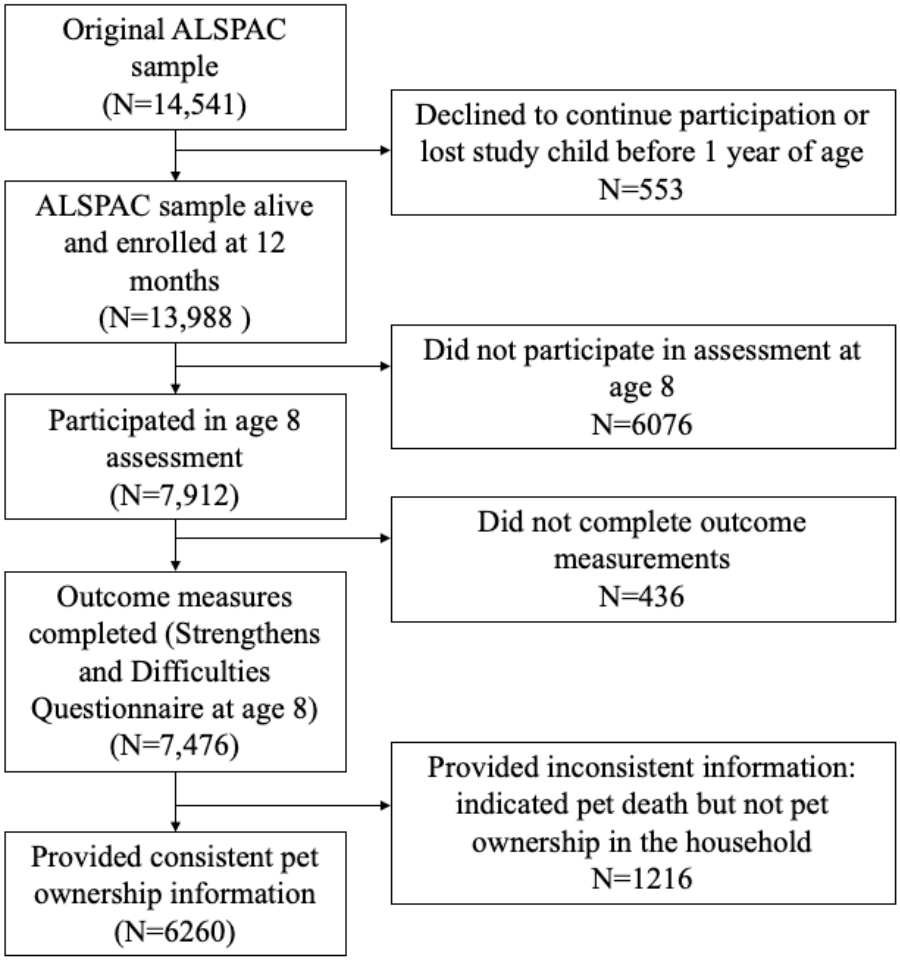
Of note, since missingness in this study was handled using multiple imputation, we estimated the covariance structure across all 20 multiply imputed datasets and implemented LARS on the aggregated covariance structure. The approach allowed us to avoid potential inconsistencies arising from different model selections across multiply imputed datasets [12].

Supplemental Table 1. Results of the structured lifecourse modeling approach to examine the relationship between the developmental timing, accumulation, and recency of exposure to pet death on child psychopathology symptoms.

Model(s) selected	Covariance test p-value	Improvement in R2
Analytic sample (N=6260)		
accumulation	0.16	0.05%
pet death 3.5 years	0.55	0.12%
pet death at 5.75 years	0.82	0.14%
pet death at 1.5 years	0.13	0.26%
pet death at 6.75 years	0.91	0.28%
pet death at 4.75 years	0.99	0.28%
pet death at 2.5 years	0.99	0.28%
Pet owners (N=5452)		
accumulation	0.15	0.06%
pet death 3.5 years	0.53	0.15%
pet death at 5.75 years	0.80	0.17%
pet death at 1.5 years	0.11	0.31%
pet death at 6.75 years	0.97	0.32%
pet death at 2.5 years	0.99	0.32%
pet death at 4.75 years	0.98	0.32%
pet death at 4.75 years	0.99	0.32%

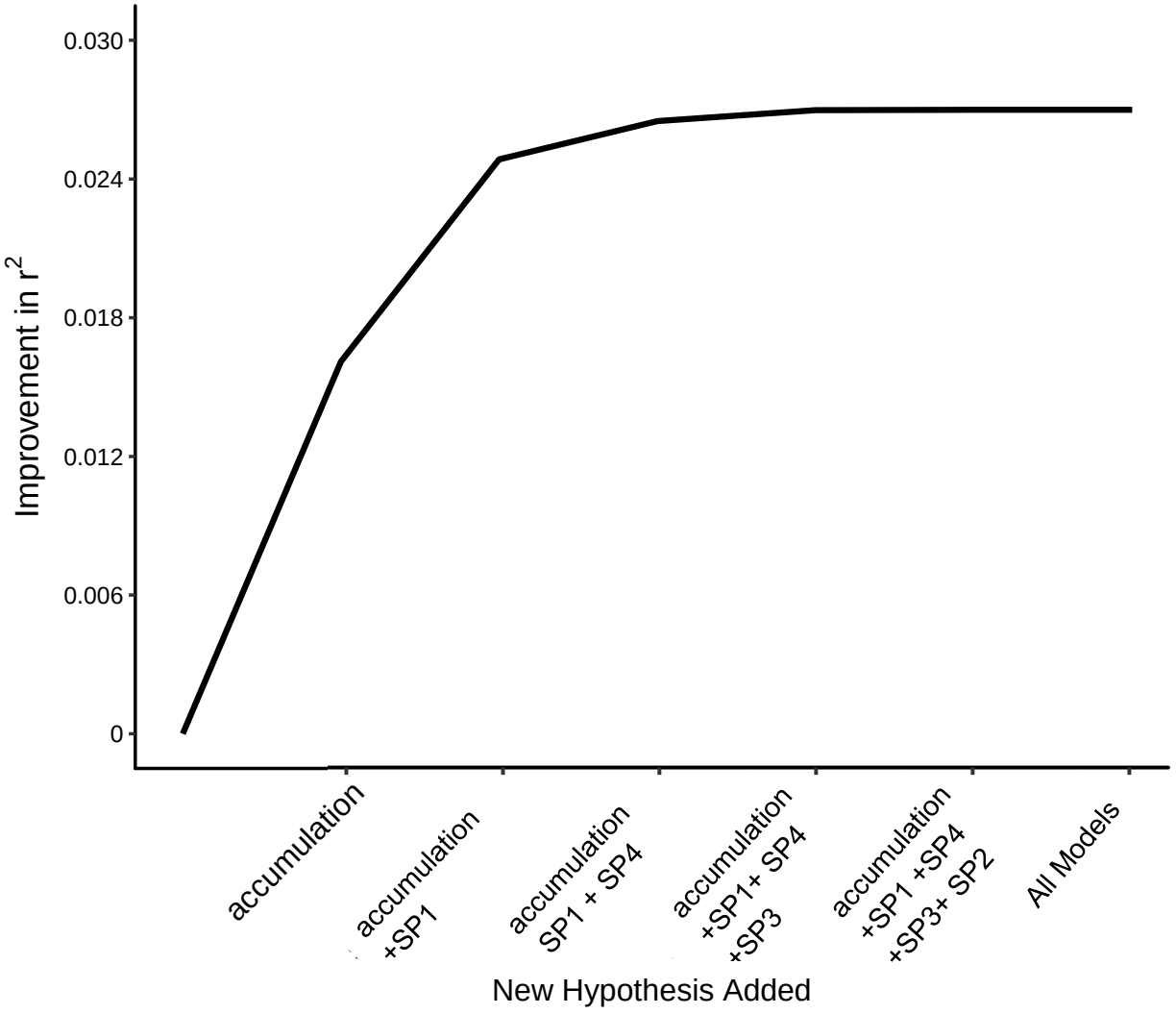
Note. The table indicates the set of theoretical models chosen by the structured lifecourse modeling approach, based on least angle regression and after adjusting for covariates. As the p-values were larger than 0.05 in both the entire analytic sample and the sub-sample of pet owners, no strong lifecourse theoretical models (developmental timing, accumulation, or recency) for psychopathology symptoms were identified. Recency was never selected in any model and thus is not shown.

Supplemental Figure 1. Flow chart to illustrate the selection of participants in our analytic sample



The left hand column represents those children who remained in the ananlysis sample based on the specifc inclusion criteria specified. The numbers in the right hand column represent those removed at each step.

Supplemental Figure 2. Sample elbow plot illustrating LARs variable selection procedure testing two life course models: accumulation and sensitive periods



LARs begins by first identifying the single variable with the strongest association to the outcome; it then identifies the combination of two variables with the strongest association, followed by three variables, and so on, until all variables are included. LARs therefore achieves parsimony by identifying the smallest combination of encoded variables that explain the most amount of outcome variation. In addition to a covariance test, which is calculated at each stage of the LARs procedure and tests the null hypothesis that adding the next encoded variable does not improve r^2, results can also be summarized in an "elbow plot," showing the increase in overall model r^2 as additional predictors are added to the model. The point where this plot levels off indicates the point of diminishing marginal improvement to the model goodness-of-fit from adding additional predictors, suggesting that the predictors included in the model at this point represent an optimal balance of parsimony and thoroughness. In this example, both accumulation and sensitive period 1 were selected in the best fitting models. SP =Sensitive Period.

References

1. van Buuren, S., H.C. Boshuizen, and D.L. Knook, *Multiple imputation of missing blood pressure covariates in survival analysis.* Stat Med, 1999. **18**(6): p. 681-94.

2. van Buuren, S. and K. Groothuis-Oudshoorn, *mice: Multivariate Imputation by Chained Equations in R.* Journal of Statistical Software, 2011. **45**: p. urn:issn:1548-7660.

3. Ramchandani, P.G., et al., *The effects of pre- and postnatal depression in fathers: a natural experiment comparing the effects of exposure to depression on offspring.* J Child Psychol Psychiatry, 2008. **49**(10): p. 1069-78.

4. Evans, J., et al., *The timing of maternal depressive symptoms and child cognitive development: a longitudinal study.* Journal of Child Psychology and Psychiatry, 2012. **53**(6): p. 632-40.

5. Azur, M.J., et al., *Multiple imputation by chained equations: what is it and how does it work?* Int J Methods Psychiatr Res, 2011. **20**(1): p. 40-9.

6. White, I.R., P. Royston, and A.M. Wood, *Multiple imputation using chained equations: Issues and guidance for practice.* Stat Med, 2011. **30**(4): p. 377-99.

7. Mishra, G., et al., *A structured approach to modelling the effects of binary exposure variables over the life course.* International Journal of Epidemiology, 2009. **38**(2): p. 528-37.

8. Smith, A.D., et al., *Model Selection of the Effect of Binary Exposures over the Life Course.* Epidemiology, 2015. **26**(5): p. 719-26.

9. Efron, B., et al., *Least angle regression.* The Annals of Statistics, 2004. **32**(2): p. 407-499.

10. Lockhart, R., et al., *A SIGNIFICANCE TEST FOR THE LASSO.* Ann Stat, 2014. **42**(2): p. 413-468.

11. Smith, A.D., et al., *A structured approach to hypotheses involving continuous exposures over the life course.* Int J Epidemiol, 2016.

12. Wood, A.M., I.R. White, and P. Royston, *How should variable selection be performed with multiply imputed data?* Stat Med, 2008. **27**(17): p. 3227-46.