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Research article

Does developmental timing of exposure to child maltreatment predict memory performance in adulthood? Results from a large, population-based sample☆

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ABSTRACT

Although maltreatment is a known risk factor for multiple adverse outcomes across the lifespan, its effects on cognitive development, especially memory, are poorly understood. Using data from a large, nationally representative sample of young adults (Add Health), we examined the effects of physical and sexual abuse on working and short-term memory in adulthood. We examined the association between exposure to maltreatment as well as its timing of first onset after adjusting for covariates. Of our sample, 16.50% of respondents were exposed to physical abuse and 4.36% to sexual abuse by age 17. An analysis comparing unexposed respondents to those exposed to physical or sexual abuse did not yield any significant differences in adult memory performance. However, two developmental time periods emerged as important for shaping memory following exposure to sexual abuse, but in opposite ways. Relative to non-exposed respondents, those exposed to sexual abuse during early childhood (ages 3–5), had better number recall and those first exposed during adolescence (ages 14–17) had worse number recall. However, other variables, including socioeconomic status, played a larger role (than maltreatment) on working and short-term memory. We conclude that a simple examination of "exposed" versus "unexposed" respondents may obscure potentially important within-group differences that are revealed by examining the effects of age at onset to maltreatment.

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Child maltreatment, like other childhood adversities, has been linked in both youth and adults to numerous immediate and long-term consequences, spanning multiple domains of health (McLaughlin et al., 2010, 2012), premature mortality, suicidality, and risky behavior (Felitti et al., 1998), adverse education and employment outcomes (Cicchetti & Toth, 2005; Gilbert et al., 2009), and both structural and functional changes in the brain (De Bellis et al., 1999; De Bellis, Woolley, & Hooper, 2013; Porter, Lawson, & Bigler, 2005; Teicher et al., 2003). These findings are concerning given current epidemiological estimates suggesting that 4.1% of youth have experienced some type of sexual maltreatment and as many as one in 10 youth have experienced physical abuse (Finkelhor, Turner, Shattuck, & Hamby, 2013; McLaughlin et al., 2012).

Relatively little is known, however, about the effects of child maltreatment on cognitive functioning, especially working memory (i.e., the temporary storage, manipulation and retrieval of limited amount of information) and short-term memory (i.e., the temporary storage for limited amount of information; see Cowan, 2008 for a review). The lack of research on this association is problematic, as the ability to retain, manipulate and retrieve information is essential to everyday functions, such as multitasking and adaptation to changing task demands (Morgan et al., 2013) and may be one of the many adverse consequences of exposure to maltreatment. Indeed, many have hypothesized that child maltreatment is a negative contributor to memory performance, as higher-order cognition, such as executive function and memory, is subserved primarily by the prefrontal cortex and hippocampus, both of which are stress-sensitive brain regions (Gunnar & Quevedo, 2007). However, to date, empirical findings have been mixed. Some studies, including those from convenience samples of children (DePrince, Weinzierl, & Combs, 2009), studies of maltreated children identified by Child Protective Services (Augusti & Melinder, 2013), clinical studies of adult survivors of abuse (Bremner et al., 1995; Stein, Hanna, Vaerum, & Koverola, 1999), and population-based samples of adults (Majer, Nater, Lin, Capuron, & Reeves, 2010) have found deficits in aspects of working memory and short-term memory, including spatial recognition, verbal learning and memory, visual memory, and spatial and pattern recognition memory, among those exposed to maltreatment. In some studies, sexual abuse exerts a stronger effect (De Bellis et al., 2013; Gould et al., 2012) on working or short-term memory relative to physical abuse or neglect.

However, other studies using convenience samples of adult women (Navalta, Polcari, Webster, Boghossian, & Teicher, 2006; Pederson et al., 2004) or samples of adults with documented cases of maltreatment have found no differences or even *enhanced* working or short-term memory when assessing memory among those exposed to maltreatment (Nolin & Ethier, 2007; Porter et al., 2005), especially sexual abuse. For example, one population-based study of older adults found child sexual abuse was associated with *better* immediate recall of emotionally neutral words (Feeney, Kamiya, Robertson, & Kenny, 2013). These findings parallel research in other aspects of memory, including autobiographical memory and recall of negative memories or emotionally-valenced words, which have also observed memory deficits among some maltreated children and enhanced memory among others (Goodman, Quas, & Ogle, 2010; Howe, Cicchetti, & Toth, 2006; Pollak, Cicchetti, & Klorman, 1998).

We speculate that there are three possible explanations for the mixed results among prior studies. First, prior studies have used a variety of measures to assess working memory, making it difficult to discern whether mixed results are an artifact of differential measurement. Second, prior studies have not consistently adjusted for co-occurring mental health symptoms, leaving open the possibility that observed memory deficits are secondary to a psychiatric condition, rather than being a consequence of maltreatment itself (Hart & Rubia, 2012). Third, and more importantly, there has been a lack of attention to age-related differences in the effect of exposure to specific types of maltreatment – or the possibility of "sensitive periods" in development. Sensitive periods are windows of time when the developing brain is highly "plastic" and therefore especially malleable to environmental influence (Bailey, Bruer, Symons, & Lichtman, 2001; Knudsen, 2004). While the existence of sensitive periods has been established for the visual (Hensch, 2004), and auditory systems (McMahon, Wintermark, & Lahav, 2012), knowledge about sensitive periods for cognition is more limited and mixed (Lupien, McEwen, Gunnar, & Heim, 2009). Although some previous studies suggest a sensitive period for cognitive development occurs before age 2 (Nelson et al., 2007), others find the time of greatest plasticity for some aspects of cognition may be during adolescence (Blakemore & Choudhury, 2006; Somerville & Casey, 2010). For instance, Andersen and Teicher found that greater levels of sexual abuse starting at 3–5 or 11–13 were associated with lower hippocampal volume in adult women and that greater levels of abuse starting at ages 14–16 was associated with lower frontal gray matter volume (Andersen et al., 2008). These findings underscore the possibility that there may be multiple sensitive periods corresponding to different brain regions and associated cognitive functions throughout the lifespan.

In the current study, we sought to overcome these gaps in knowledge by using data from a large, nationally representative epidemiological sample of young adults to examine the association between exposure to physical and sexual abuse with memory. Our use of a population-based study is a major strength, as few population-based studies of cognition have been conducted; see for example (Anda et al., 2006; Majer et al., 2010; Mills et al., 2011). The lack of data on the relationship between maltreatment and lifespan cognition in epidemiological studies is an important gap, as children in referred samples (who are identified in administrative records, including CPS), represent only a fraction of all children with maltreatment experiences, perhaps as few as 5–8% of physically or sexually abused children, respectively (MacMillan, Jamieson, & Walsh, 2003). Our primary aim was to disentangle the effect of type and timing of exposure to child maltreatment on working memory. In so doing, we aimed to better understand how the features of maltreatment predict memory, which could be used to guide the investment of resources to public health interventions that can reduce the consequences of exposure to maltreatment.

Methods

Sample and Procedures

Data came from the National Longitudinal Study of Adolescent to Adult Health (Add Health), formerly known as the National Longitudinal Study of Adolescent Health, which is one of the only nationally representative longitudinal surveys of US adolescents in the United States. As described in detail elsewhere (Harris, 2013), Add Health recruited a school-based sample of U.S. adolescents in grades 7 through 12 in 1994. Wave 1 (1994–1995) utilized a multi-stage sampling design to enroll adolescents. A systematic random sample of high schools along with feeder schools (i.e., middle schools whose students matriculate at the selected high school) was selected. A total of 134 schools (79%) participated, with 90,118 students completing the in-school survey and 20,745 participating in a more detailed in-home interview (75.6% and 79.5% of eligible students, respectively). Add Health investigators prospectively followed these Wave 1 respondents over three additional waves of data collection into young adulthood (Waves 2, 3, and 4).

In this study, we used data from the Wave 1, 3 and 4 interviews. Wave 3 (2001–2002) interviews included 15,197 in-home Wave 1 respondents (aged 18–26), and Wave 4 (2008–2009) follow-up interviews were completed with 15,701 of these respondents (aged 24–32; 77.4% and 80.3% of eligible respondents, respectively). We focused our analyses on an analytic sample of 10,788 respondents who had complete data on all study variables. This analytic sample was ascertained after removing 4,882 youth who were either missing data on covariates, both exposures, the outcome measures, or most commonly the survey weighting variable. Respondents included in our analytic sample were more likely than those who were excluded to be female (54.05% included sample vs. 51.23% in excluded sample; $\lambda^2 = 10.77$; $p < 0.001$), and younger (16.05 mean age included vs. 16.22 mean age excluded; t-test = −5.67; $p < 0.001$).

Measures

Exposure to Physical and Sexual Abuse. Respondents answered questions about experiences of two types of child maltreatment at Wave 3. Physical abuse was ascertained by the item: "Before your 18th birthday, how often did a parent or adult caregiver hit you with a fist, kick you, or throw you down on the floor, into a wall, or down stairs?" Sexual abuse was ascertained with the item: "How often did a parent or other adult caregiver touch you in a sexual way, force you to touch him or her in a sexual way, or force you to have sexual relations?" Response options were: 1 = one time; 2 = two times; 3 = three to five times; 4 = six to ten times; 5 = more than ten times; and 6 = this never happened. We used information from this variable to determine whether or not the participant had been exposed (0 = non-exposed; 1 = exposed) to either adversity.

For both items, respondents also indicated how old they were the first time the event happened. Consistent with prior research (Kaplow & Widom, 2007), we categorized respondents according to the age when they were first exposed to each adversity: infancy (ages 0–2), early childhood (ages 3–5), middle childhood (ages 6–8), late childhood (ages 9–10), early adolescence (ages 11–13), or adolescence (ages 14–17).

Memory. Memory was assessed at Wave 4 using two interviewer-administered tasks capturing memory for numbers (working memory) and memory for words (short-term memory).

Memory for Numbers. Interviewers read a string of numbers and asked respondents to repeat those numbers in backwards order (e.g., in the reverse order from which they were presented). There were a total of 7 possible number sets administered. Each number set at the same length contained two trials. The first trial set had three numbers with each trial set increasing one number in length. Basal performance was established when respondents had two correct responses in the same number set. The task ended at the level at which the respondent could not correctly respond to both trials at the same length. The total score, or the total number of correct numbers recalled, was calculated by assigning one point if the respondent answered each number set correctly (mean = 4.15; SE = 0.04; min = 0; max = 7). This task is adapted from the backward digit span task in the Wechsler Adult Intelligence Scale, Third edition (WAIS-3), which is the most widely used measure of working memory (Wechsler, 1997). This memory assessment task has been commonly used in psychology research as well as other large-scale epidemiological surveys, including the Midlife in the United States (MIDUS; http://midus.wisc.edu) and has been shown to be reliable and valid across cohort and large diverse samples (Gignac, 2015).

Memory for Words. Participants completed the Rey Auditory-Verbal Learning Test, which assesses recall of lexical items as well as other memory processes, including immediate memory, retention of information, memory inhibition and memory recognition, and verbal learning (Lezak, 2004; Rey, 1964; Taylor, 1959). In this task, interviewers read 15 unrelated and emotionally-neutral, but common words (each word separated by a 1-s interval) and asked respondents to recall as many of them as possible, in any order (Rey, 1964; Taylor, 1959). The task ended after 90 s, or when the respondent failed to recall any further words (whichever came sooner). The total score, or the total number of correct answers recalled, was calculated by assigning one point for each correct word (mean = 6.73; SE = 0.05; min = 0; max = 15). Examples of words included were: drum, school, and farmer.

Covariates. All models controlled for the following covariates, taken from the Wave 1 interview: sex, age (continuous), parental education (highest level attained by either mother or father; 1 = less than high school; 2 = GED or high school diploma; 3 = business, trade, or vocational school post-high school; 4 = some college; 5 = college; 6 = more than college) and parental occupation (1 = professional/manager; 2 = technical, officer worker, or sales; 3 = industry, construction, transportation, or military) as measures of socioeconomic status, and self-reported race/ethnicity (1 = white; 2 = black; 3 = Asian; 4 = Hispanic; 5 = native American; 6 = other; 7 = multi-racial). These constructs were important to include, as they have been shown in prior research to be associated with exposure to adversity or domains of executive functioning (Gur et al., 2012).

As prior studies have also revealed that the effects of maltreatment on executive functioning may depend on previous or current psychopathology, see for example (see for example Bremner et al., 1995; Goodman et al., 2010), we adjusted for levels of concurrent (past-week) depressive symptoms, measured at Wave 4, using the 9-item version of the Center for Epidemiological Studies of Depression Scale (CES-D) (Radloff, 1977). We also adjusted for ADHD diagnosis, determined by a question at Wave 4 that asked "Has a doctor, nurse or other health care provider ever told you that you have or had: attention problems or ADD or ADHD". ADHD diagnosis was only adjusted in the analysis of memory for words, as this variable was unrelated to memory for numbers in our analytic sample ($p = 0.36$).

Data Analyses

We fit a set of linear regression models that examined, separately for physical abuse and sexual abuse, the association between exposure to adversity as well as its timing on memory for words and memory for numbers after adjusting for covariates. Model 1 examined the effect of being exposed (exposed vs. non-exposed). Model 2 examined the effect of timing of exposure. We used survey procedures in Stata 13 (StataCorp, College Station, TX) to adjust for survey design, sample weights, and non-response.

Results

Table 1 presents descriptive statistics on the total analytic sample and basic bivariate analyses for average number and word recall. In our analytic sample, 16.50% of respondents reported having been exposed to physical abuse and 4.36% to sexual abuse by age 17. A total of 19.61% experienced at least one of these adversities and 2.04% experienced both (correlation = 0.40). Among children exposed to physical abuse, the majority of were first exposed during adolescence (33.90%), whereas for sexual abuse, the majority reported being first exposed during early childhood (28.28%).

The sample was balanced with respect to sex (50.55% female). The sample was predominately White (69.28%), and socioeconomically diverse (9.6% of respondents had a parent with less than a high school education; 12% had a parent with more than a college degree). Mean values of memory for numbers and memory for words in each exposure and covariate group are also shown in Table 1.

We also examined bivariate associations between each of the covariates and exposure to physical and sexual abuse (Table 2). Reports of exposure to physical abuse differed by race and SES. Physical abuse was also associated with an ADHD diagnosis and depressive symptoms. Respondents exposed to sexual abuse also varied across parental employment and education, and were more likely to report depressive symptoms.

Physical Abuse and Memory

Table 3 presents results from the multiple linear regression models examining exposure to physical abuse after adjusting for covariates. Respondents exposed to physical abuse did not differ from unexposed respondents on the memory for numbers task ($\beta = 0.05$; $p = 0.34$; Model 1). No differences in memory for numbers were detected when comparing youth first exposed during different developmental periods to unexposed respondents (see Model 2).

On the memory for words task, *better* word recall was detected among those exposed to physical abuse compared to those who were non-exposed ($\beta = 0.13$; $p = 0.05$; Model 1). This effect appeared to be driven by *higher* levels of word recall among those first exposed to physical abuse during late childhood (ages 9–10) compared to unexposed ($\beta = 0.45$; $p = 0.03$).

Sexual Abuse and Memory

Table 4 presents results from the multiple linear regression models for sexual abuse. Respondents exposed to sexual abuse did not differ from unexposed respondents on either the memory for numbers ($\beta = 0.03$; $p = 0.76$) or memory for words task ($\beta = -0.05$; $p = 0.69$; Model 1). However, recall for numbers differed among children exposed to sexual abuse at different ages, with children first exposed in early childhood (ages 3–5) having *better* number memory task performance ($\beta = 0.32$; $p = 0.02$) and those first exposed during adolescence (ages 14–17) having *worse* number memory task performance ($\beta = -0.44$; $p = 0.05$) (Model 2).

Table 1
Descriptive statistics in total sample (N = 10,788) and by average memory for numbers and words.

	Total sample		Memory for numbers		Memory for words	
	%	*N*	Mean	SE	Mean	SE
Exposure to physical abuse						
Exposed	16.50	1,852	4.19	0.05	6.72	0.07
Unexposed	83.50	8,936	4.23	0.03	6.74	0.05
Timing of physical abuse						
Infancy (ages 0–2)	3.65	48	3.80	0.28	6.42	0.41
Early childhood (ages 3–5)	13.37	246	4.38	0.14	6.64	0.16
Middle childhood (ages 6–8)	17.66	305	4.30	0.11	6.81	0.17
Late childhood (ages 9–10)	10.01	207	4.36	0.14	7.02	0.20
Early adolescence (ages 11–13)	21.49	344	4.09	0.11	6.65	0.14
Adolescence (ages 14–17)	33.83	580	4.06	0.08	6.63	0.10
Exposure to sexual abuse						
Exposed	4.36	484	4.11	0.10	6.66	0.13
Unexposed	95.64	10,304	4.23	0.03	6.74	0.05
Timing of sexual abuse						
Infancy (ages 0–2)	6.93	28	3.70	0.32	5.90	0.38
Early childhood (ages 3–5)	28.17	129	4.43	0.15	7.01	0.21
Middle childhood (ages 6–8)	22.05	113	4.26	0.22	6.79	0.24
Late childhood (ages 9–10)	12.89	59	4.10	0.21	6.70	0.28
Early adolescence (ages 11–13)	15.83	79	4.09	0.21	6.56	0.23
Adolescence (ages 14–17)	14.13	64	3.59	0.22	6.23	0.33
	Mean	SE	Mean	SE	Mean	SE
Covariates						
Age at Wave 1 (continuous)	15.86	0.12	–	–	–	–
Depressive symptoms	5.03	0.07	–	–	–	–
	%	*N*	Mean	SE	Mean	SE
Female	50.56	5,831	4.18	0.04	7.00	0.05
Race/ethnicity						
White	69.31	6,034	4.36	0.03	6.92	0.05
Black	12.66	1,948	3.77	0.08	6.09	0.09
Asian	2.91	658	4.29	0.12	6.70	0.13
Hispanic	9.83	1,472	3.88	0.07	6.34	0.08
Native American	0.35	49	3.84	0.22	6.70	0.29
Other	0.69	75	4.29	0.20	6.73	0.28
Mixed	4.24	552	4.20	0.08	6.57	0.11
Parental education						
Less than high school	9.60	1,082	3.63	0.06	6.14	0.09
High school diploma/GED	31.88	3,171	4.03	0.05	6.48	0.06
Business/trade/vocational post HS	7.60	761	4.22	0.08	6.67	0.08
Some college	14.31	1,569	4.37	0.05	6.86	0.06
College	24.40	2,693	4.37	0.04	6.93	0.06
More than college	12.21	1,512	4.74	0.06	7.36	0.09
Parental occupation						
Service	37.02	3,894	3.94	0.04	6.45	0.05
Industry/transportation/construction/military	27.53	2,855	4.29	0.04	6.69	0.06
Professional/manager	35.45	4,039	4.47	0.04	7.07	0.06
ADHD diagnosis	4.76	513	4.11	0.11	6.40	0.11

Social Determinants of Memory

Overall, socioeconomic status and race/ethnicity appeared to play a larger role in shaping memory performance than did exposure to child maltreatment. Across all models, there was a clear gradient indicating better memory performance on both number and word tasks among youth with parents who had more education and higher status occupations. Respondents from racial/ethnic minority groups, namely Black and Hispanic youth, were also more likely to have lower memory task performance relative to youth who were White.

Discussion

The current study used data from a large, population-based epidemiological sample of young adults (between ages 24 and 32) to examine the relationship between exposure to two types of childhood maltreatment (physical and sexual abuse)

Table 2
Distribution of covariates by those reporting exposure to physical and sexual abuse.

		Physical abuse	χ^2	*p*-Value	Sexual abuse	χ^2	*p*-Value
		N = 1,852 (17.17%)			*N* = 484 (4.49%)		
Sex	Male	904 (18.24)	1.49	0.39	376 (2.18)	122.96	<0.001
	Female	948 (16.26)			108 (6.45)		
Race	White	989 (16.39)	41.21	<0.001	256 (4.24)	8.17	0.51
	Black	309 (15.86)			96 (4.93)		
	Asian	123 (18.69)			21 (3.19)		
	Hispanic	277 (18.82)			68 (4.62)		
	Native	11 (22.45)			6 (12.24)		
	Other	15 (20.00)			3 (4.00)		
	Mixed	128 (23.19)			34 (6.16)		
Parental education	Less than HS	215 (19.87)	47.87	<0.001	58 (5.36)	36.29	<0.001
	HS diploma/GED	564 (17.79)			164 (5.17)		
	Business/TRADE	138 (18.13)			31 (4.07)		
	Some college	293 (18.67)			84 (5.35)		
	College	404 (15.00)			91 (3.38)		
	More than college	238 (15.74)			56 (3.70)		
Parental occupation	Service	724 (18.59)	19.32	0.007	211 (5.42)	34.64	<0.001
	Industry/transportation	491 (17.20)			139 (4.87)		
	Professional/manager	637 (15.77)			134 (3.32)		
ADHD Diagnosis	No diagnosis	1,722 (16.76)	9.37	0.024	454 (4.42)	0.01	0.942
	Diagnosis	130 (25.34)			30 (5.85)		

	Physical abuse	*t*	*p*-Value	Sexual abuse	*t*	*p*-Value
Age at Wave 1	16.06	0.98	0.33	16.09	1.79	0.08
Depressive symptoms	6.25	10.81	<0.001	7.01	7.34	<0.001

Note: The percent entries by physical and sexual abuse represent proportions within each level of categorical covariate. Cell entries for age and depressive symptoms denote mean values for those exposed to physical and sexual abuse, respectively.

and memory for numbers and memory words. Though few have been reported previously, population-based studies provide more generalizable estimates of the effects of adversity on cognition, as they do not rely on clinical or referred samples where the effects of adversity on memory could be over- or underestimated.

Three findings emerged from this research. First, we found that a crude analysis comparing exposed to unexposed respondents did not yield any meaningful differences in either working and short-term memory performance. However, subsequent analyses examining maltreatment timing did reveal important differences. These results suggest that a simple group comparisons of "exposed" versus "unexposed" respondents may obscure potentially important within-group differences and underscores the need for future studies to examine characteristics of the maltreatment experience.

Second, we found differences with respect to timing of exposure, particularly for sexual abuse. Two developmental time periods appeared to be important for shaping memory following exposure to sexual abuse, but in opposite ways. Compared to those who were never exposed, exposure to sexual abuse during early childhood (ages 3–5) predicted *better* number recall. In contrast, those first exposed to sexual abuse during adolescence (ages 14–17) had *worse* number recall compared to non-exposed respondents. Though the direction of effect for these associations was in the opposite direction, the magnitude of the effect was similar. However, the effect of timing of exposure to sexual abuse was limited to memory for numbers; we did not detect similar associations when examining memory for words. In addition, we also found that exposure to physical abuse during late childhood (ages 9–10) was predictive of *better* performance on the memory for words task compared to unexposed respondents. No consistent differences were found when comparing those exposed at different ages to those who were unexposed on the memory for numbers task. Although, to our knowledge, no prior studies have directly tested timing of adversity exposure using our age groups and these two specific memory measures, our results appear to be consistent with previous studies focusing on timing of exposure to adversity. For example, among young adult women who were exposed to sexual abuse around age 6, Navalta et al. (2006) found higher global and visual short-term memory scores compared to women who were not exposed. However, other studies, including one by Porter et al. (2005), observed no differences in memory recall by whether or not the sexual abuse began before or after age 5.

Of note, our results also mirror studies examining sensitive periods for psychopathology, which have also found mixed results regarding whether earlier or later exposure is associated with worse outcomes. For instance, among studies examining sensitive periods for depression, some find no effects by timing of age at first sexual abuse, others find earlier abuse (before age 12 or even earlier) increases risk (Schoedl et al., 2010), others find later abuse (after age 12) increases risk (Thornberry, Ireland, & Smith, 2001), and others find multiple periods of elevated risk compared to non-exposed respondents (Dunn, McLaughlin, Slopen, Rosand, & Smoller, 2013).

Table 3
Adjusted association between exposure to physical abuse, timing, and frequency on memory for numbers and words in the total sample ($N = 10{,}788$) and among exposed ($N = 1852$).

	Memory for numbers						Memory for words					
	Model 1			Model 2			Model 1			Model 2		
	Beta	SE	*p*-Value	Beta	SE	*p*-Value	Beta	SE	*p*-Value	Beta	SE	*p*-Value
Exposure to physical abuse												
Exposed to physical abuse												
Exposed	0.05	0.05	0.34				0.13	0.06	0.05			
Unexposed	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*
Timing of physical abuse												
Infancy (ages 0–2)				−0.31	0.28	0.28				−0.01	0.41	0.98
Early childhood (ages 3–5)				0.20	0.13	0.14				0.03	0.16	0.85
Middle childhood (ages 6–8)				0.15	0.11	0.17				0.24	0.15	0.12
Late childhood (ages 9–10)				0.22	0.13	0.11				0.45	0.20	0.03
Early adolescence (ages 11–13)				−0.03	0.10	0.77				0.08	0.14	0.59
Adolescence (ages 14–17)				−0.07	0.08	0.34				0.01	0.10	0.92
Covariates												
Age at Wave 1 (continuous)	−0.03	0.01	0.02	−0.03	0.01	0.02	−0.04	0.02	0.01	−0.04	0.02	0.01
Depressive symptoms (continuous)	−0.02	0.01	<0.01	−0.02	0.01	<0.01	−0.04	0.01	<0.01	−0.04	0.01	<0.01
Female	−0.07	0.04	0.09	−0.06	0.04	0.13	0.57	0.05	<0.01	0.57	0.05	<0.01
Race/ethnicity												
White (referent)	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*
Black	−0.47	0.07	<0.01	−0.47	0.07	<0.01	−0.71	0.08	<0.01	−0.71	0.08	<0.01
Asian	−0.07	0.11	0.55	−0.07	0.11	0.53	−0.21	0.12	0.08	−0.22	0.13	0.09
Hispanic	−0.26	0.07	<0.01	−0.26	0.07	<0.01	−0.34	0.09	<0.01	−0.35	0.09	<0.01
Native American	−0.44	0.22	0.05	−0.43	0.23	0.06	−0.07	0.31	0.83	−0.05	0.31	0.87
Other	−0.05	0.20	0.81	−0.04	0.20	0.86	−0.17	0.28	0.55	−0.16	0.28	0.57
Mixed	−0.10	0.08	0.22	−0.12	0.08	0.15	−0.30	0.10	<0.01	−0.30	0.10	<0.01
Parent education												
Less than high school	−0.83	0.09	<0.01	−0.81	0.09	<0.01	−0.88	0.13	<0.01	−0.87	0.13	<0.01
High school diploma/GED	−0.55	0.07	<0.01	−0.54	0.07	<0.01	−0.64	0.10	<0.01	−0.65	0.10	<0.01
Business/trade/vocational post HS	−0.41	0.11	<0.01	−0.40	0.11	<0.01	−0.55	0.11	<0.01	−0.57	0.11	<0.01
Some college	−0.28	0.08	<0.01	−0.27	0.08	<0.01	−0.35	0.09	<0.01	−0.36	0.10	<0.01
College	−0.33	0.07	<0.01	−0.33	0.07	<0.01	−0.35	0.09	<0.01	−0.37	0.09	<0.01
More than college (referent)	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*
Parent occupation												
Service	−0.22	0.05	<0.01	−0.22	0.05	<0.01	−0.26	0.08	<0.01	−0.25	0.08	<0.01
Industry/transportation/construction/military	−0.02	0.06	0.77	−0.02	0.06	0.73	−0.19	0.07	0.01	−0.19	0.07	<0.01
Professional/manager (referent)	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*
ADHD Diagnosis	–	–	–	–	–	–	−0.32	0.10	<0.01	−0.33	0.10	<0.01

Table 4
Adjusted association between exposure to sexual abuse, timing, and frequency on memory for numbers in the total sample ($N = 10{,}788$) and among exposed ($N = 484$).

	Memory for numbers						Memory for words					
	Model 1			Model 2			Model 1			Model 2		
	Beta	SE	*p*-Value	Beta	SE	*p*-Value	Beta	SE	*p*-Value	Beta	SE	*p*-Value
Exposure to sexual abuse												
Exposed to sexual abuse												
Exposed	0.03	0.09	0.76				−0.05	0.12	0.69			
Unexposed	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*
Timing of sexual abuse												
Infancy (ages 0–2)				−0.38	0.30	0.21				−0.64	0.38	0.10
Early childhood (ages 3–5)				0.32	0.14	0.02				0.25	0.18	0.17
Middle childhood (ages 6–8)				0.24	0.19	0.21				0.22	0.21	0.30
Late childhood (ages 9–10)				−0.10	0.21	0.64				−0.21	0.27	0.41
Early adolescence (ages 11–13)				0.00	0.22	0.99				−0.26	0.23	0.26
Adolescence (ages 14–17)				−0.44	0.22	0.05				−0.39	0.33	0.23
Covariates												
Age at Wave 1 (continuous)	−0.03	0.01	0.02	−0.03	0.01	0.02	−0.04	0.02	0.01	−0.04	0.02	0.01
Depressive symptoms	−0.02	0.01	<0.01	−0.02	0.00	<0.01	−0.03	0.01	<0.01	−0.04	0.01	<0.01
Female	−0.07	0.04	0.08	−0.07	0.04	0.08	0.60	0.05	<0.01	0.57	0.05	<0.01
Race/ethnicity												
White (referent)	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*
Black	−0.47	0.07	<0.01	−0.47	0.07	<0.01	−0.71	0.08	<0.01	−0.71	0.08	<0.01
Asian	−0.06	0.11	0.56	−0.06	0.11	0.56	−0.21	0.12	0.09	−0.21	0.12	0.09
Hispanic	−0.25	0.07	<0.01	−0.26	0.07	<0.01	−0.34	0.09	<0.01	−0.35	0.09	<0.01
Native American	−0.44	0.23	0.05	−0.45	0.23	0.05	−0.06	0.31	0.85	−0.06	0.31	0.84
Other	−0.05	0.20	0.81	−0.05	0.20	0.80	−0.17	0.28	0.54	−0.17	0.27	0.53
Mixed	−0.10	0.08	0.24	−0.10	0.09	0.26	−0.29	0.10	<0.01	−0.29	0.10	<0.01
Parent education												
Less than high school	−0.83	0.09	<0.01	−0.82	0.09	<0.01	−0.87	0.13	<0.01	−0.86	0.13	<0.01
High school diploma/GED	−0.54	0.07	<0.01	−0.54	0.07	<0.01	−0.64	0.10	<0.01	−0.64	0.09	<0.01
Business/trade/vocational post HS	−0.41	0.11	<0.01	−0.40	0.11	<0.01	−0.55	0.11	<0.01	−0.55	0.11	<0.01
Some college	−0.28	0.08	<0.01	−0.27	0.08	<0.01	−0.34	0.09	<0.01	−0.34	0.09	<0.01
College	−0.33	0.07	<0.01	−0.33	0.07	<0.01	−0.35	0.09	<0.01	−0.35	0.09	<0.01
More than college (referent)	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*
Parent occupation												
Service	−0.22	0.05	<0.01	−0.22	0.05	<0.01	−0.26	0.08	<0.01	−0.26	0.08	<0.01
Industry/transportation/construction/military	−0.02	0.06	0.76	−0.02	0.06	0.69	−0.19	0.07	0.01	−0.19	0.07	0.01
Professional/manager (referent)	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*	*ref*
ADHD Diagnosis	–	–	–	–	–	–	−0.32	0.10	<0.01	−0.32	0.10	<0.01

Third, we found that the indicators of race/ethnicity and socioeconomic status had a larger role in predicting adult memory performance than did exposure to child maltreatment. Specifically, we found that Black youth recalled almost one fewer word, on average, compared to their White counterparts, even after adjusting for socioeconomic status. We also observed a clear socioeconomic gradient illustrating better memory performance on both memory tasks for every additional gain in education or occupation level. Prior studies have also shown an inverse relationship between duration of childhood poverty and adult working memory (Evans & Schamberg, 2009) and higher levels of memory performance among White compared to minority children (Jensen & Figueroa, 1975). These findings likely illustrate the long-term effects of exposure to other childhood adversities, such as discrimination, parent death, parental imprisonment, and exposure to neighborhood violence, which are more commonly experienced by racial/ethnic minority children and children from low socioeconomic backgrounds (Addy, Engelhardt, & Skinner, 2013; National Survey of Children's Health, NSCH 2011/2012; Slopen et al., 2015). Our findings therefore illustrate the need to consider child maltreatment along with other social-environmental risk factors in order to understand the constellation of risk factors experienced during childhood that may confer memory deficits in adulthood.

Why might sexual abuse have different effects on working memory depending on when in the course of development it occurred? We posit several explanations. First, our findings are consistent with what is known about the development of memory. The components of working memory – namely the phonological loop, visual-spatial sketchpad, and executive control – have been shown to be present by age 6 and to increase in performance linearly thereafter into adulthood. (Gathercole, Pickering, Ambridge, & Wearing, 2004) Thus, working memory may be more plastic prior to age 6, making maltreatment prior to age 6 potentially less deleterious. Second, exposure to child sexual abuse earlier in the lifespan may promote cognitive performance by fostering higher levels of arousal and vigilance. This hypervigilance, in turn, has been shown to predict the encoding and subsequent memory of negative emotional information (Goodman et al., 2010), which may operate along similar pathways as memory performance more broadly. Third, abuse might be harmful to memory during adolescence, but allow for a resilient effect on memory during early childhood, based on the demands of the environment. The social and physical environments in which adolescents develop require much more cognitive capacity than those surround the very young child. Thus, in a context of inescapable harm (Freyd, DePrince, & Gleaves, 2007), decreasing attention to negative threats may promote coping among young children, but prove more challenging for adolescents. Fourth, our finding that exposure to abuse was especially deleterious to working memory during adolescence may reflect stress-sensitivity in the prefrontal cortex (PFC) during this developmental window. The PFC, which subserves a class of complex cognitive skills including working memory, has a protracted maturation that undergoes significant reorganization during the teenage years (Blakemore & Choudhury, 2006; Lenroot & Giedd, 2006). The notion that the PFC may be especially vulnerable to social stressors during adolescence has wide support in rodents (Leussis & Andersen, 2008; Novick, Miiller, Forster, & Watt, 2013) and, although less studied, in humans (Perlman, Webster, Herman, Kleinman, & Weickert, 2007). Moreover, a recent empirical study has shown that structural changes to the PFC mediate the association between early life stress and working memory performance (Hanson et al., 2012). Future research is needed to further explicate how stress sensitivity in the adolescent brain confers heightened risk for compromised cognitive function.

Findings from this study must be evaluated in light of several limitations. First, our analyses were conducted in the context of a longitudinal study where maltreatment and the outcome measures were assessed at two different times. Although this study design is an advancement over prior studies, which have been largely cross-sectional, more authentic longitudinal studies are needed to investigate the effects of child maltreatment on memory performance. Second, the measures of maltreatment were limited and lacking in detail regarding other characteristics of abuse, including the nature, severity, duration of abuse, how recently it occurred, and the relationship of the perpetrator to the respondent. The physical abuse measure did not fully capture all forms of physical abuse, including spanking for discipline, pushing, grabbing, or shoving, and choking or burning. Ideally, future studies would prospectively and repeatedly collect detailed measures of multiple dimensions of the maltreatment experience so that the effects of type and timing could be teased apart from other characteristics of the abuse. Moreover, exposure to maltreatment was self-reported and obtained retrospectively, making the data more prone than prospectively ascertained data to recall bias, particularly for the age at first exposure. Reporting bias may also be reflected here, if respondents were less likely to disclose traumatic experiences, even when asked privately via a computer-assisted self-interviewing procedure, or if non-responders had better memory performance. Although possible, we think these limitations are unlikely, as our prevalence estimates for abuse were comparable to other nationally-representative studies of adolescents (McLaughlin et al., 2012). In addition, it also possible that some respondents with maltreatment experiences perpetrated by non-parental/caregivers are included in the non-exposed portion of the sample. However, we think this is unlikely as parents alone represent more than 90% of the reported perpetrators of documented cases of maltreatment; the remaining perpetrators are primarily other adult caregivers (e.g., step-parent, other relative) (U.S. Department of Health and Human Services & Administration on Children Youth and Families, 2015). Third, the measures of memory in the present study were rather crude. Memory for words, for instance, could be related to participant's general verbal proficiency (Diaz et al., 2014; Linck, Osthus, Koeth, & Bunting, 2014). For individuals with higher language proficiency, it might be easier for them to encode the verbal information because they have the semantic information of the word to encode information efficiently. Future studies involving a sample could include a language proficiency task. Finally, although we were able to adjust for depressive symptoms and an ADHD diagnosis, we did not have information about other psychiatric diagnoses that might have been informative. Future population-based studies with these measures are needed to increase our understanding of the temporal ordering of adversity and memory impairments.

Taken together, our results suggest that a simple comparison of "exposed" versus "unexposed" respondents may obscure potentially important within-group differences that are revealed when examining developmental timing of exposure to maltreatment. Future studies, especially prospective and longitudinal studies, are needed to better understand how adversity predicts memory performance and when during the course of development interventions could be targeted to reduce the negative effects of exposure to maltreatment.

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