Published in final edited form as:

J Pediatr. 2020 January ; 216: 189–196.e3. doi:10.1016/j.jpeds.2019.07.008.

Shared Reading at Age 1 Year and Later Vocabulary: A Gene-environment Study

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Abstract

Objective—To assess the extent to which associations between shared reading at age 1 and child vocabulary at age 3 differ based on the presence of sensitizing alleles in the dopaminergic and serotonergic neurotransmitter systems.

Study design—We conducted a secondary analysis of data from a national urban birth cohort using mother reports in conjunction with child assessments and salivary genetic data. Child vocabulary was assessed using the Peabody Picture Vocabulary Test (PPVT). The primary exposure was mother-reported shared reading. We used data on gene variants that may affect the function of the dopaminergic and serotonergic systems. We examined associations between shared reading and PPVT score using multiple linear regression. We then included interaction terms between shared reading and the presence of sensitizing alleles for each polymorphism to assess potential moderator effects adjusting for multiple comparisons.

Results—Of the 1772 children included (56% black, 52% male), 31% of their mothers reported reading with their child daily. Daily shared reading was strongly associated with child PPVT

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scores in unadjusted ($B=7.9$; 95% confidence interval (CI): 4.3–11.4) and adjusted models ($B=5.3$; 95% CI: 2.0–8.6). The association differed based on the presence of sensitizing alleles in the dopamine receptor 2 and serotonin transporter genes.

Conclusions—Among urban children, shared reading at age 1 was associated with greater vocabulary at age 3. Although children with sensitizing alleles on the dopamine receptor 2 and serotonin transporter genes were at greater risk when not read to, they fared as well as children without these alleles when shared reading occurred.

Keywords

Child development; language; Fragile Families and Child Wellbeing Study; birth cohort

The American Academy of Pediatrics recommends that parents read aloud with their children from birth. (1) Shared reading with toddlers and preschoolers is associated with improved language and literacy outcomes (2–5) as well as activation of brain areas that support comprehension and imagery. (6) Studies have demonstrated improved language outcomes for children exposed to shared reading during infancy. (7–9) Although consistently replicated and important, the benefits of early shared reading on later language outcomes are relatively modest. (2–4)

Gene-environment studies offer novel insight into the heterogeneity of children's responses to their environments. (10) A growing number of studies have documented that sensitizing alleles in the dopaminergic and serotonergic neurotransmitter systems, which are implicated in learning, attention, and behavior, play a role in a child's response to the environment. (11–15) Two prominent models serve as organizing frameworks. (16) The diathesis-stress model posits that certain types of genetic variation confer risk and that children with certain genetic polymorphisms have poor outcomes in harsh environments. (17) Scientists have proposed and empirically tested the differential susceptibility model, which posits that children with certain polymorphisms do worse in harsh environments but have even better outcomes compared with peers without these polymorphisms under positive environments. (18)

There are several reasons to expect that children respond differently to shared reading based on genetic characteristics. In one study, the effect of responsive parenting on later academic performance was moderated by the presence of the short allele of the 5-HTTLPR polymorphism on the serotonin transporter gene. In this study, children with the 5-HTTLPR short allele had worse outcomes when exposed to low parent responsiveness but fared no worse when exposed to highly responsive parenting compared with children without the short allele, which is consistent with the diathesis-stress model. (19) With regard to literacy specifically, children in kindergarten with a sensitizing allele on the dopamine receptor 4 gene fared worse than children without the allele when not exposed to a literacy instruction intervention but better when exposed to the intervention, which is consistent with the differential susceptibility model. (20, 21) Despite these findings, no study has directly examined the extent to which the presence of sensitizing alleles in the dopaminergic and serotonergic systems result in different responses to shared reading.

To address this gap, we used data from a national, urban birth cohort study with robust behavioral and genetic measures. We hypothesized that sensitizing alleles in the dopaminergic and serotonergic neurotransmitter systems would moderate the association between shared reading in infancy and child vocabulary at age 3 years.

Methods

We conducted a secondary analysis of data from the Fragile Families and Child Wellbeing Study (FFCWS), a population-based urban birth cohort that includes nearly 5,000 children born between 1998 and 2000 in 75 hospitals located in 20 large US cities. (22, 23) The FFCWS drew a stratified random sample of all 77 U.S. cities with populations of 200,000 or more. In 18 cities, all hospitals with maternity wards were included; in the two largest cities, hospitals with maternity wards were randomly sampled. Within hospitals, births were randomly sampled, with oversamples of births to unmarried parents. While still in the hospital after giving birth, mothers were approached by a professional survey interviewer and screened for eligibility. If eligible, they were asked to participate in a national survey about the conditions and capabilities of new parents, their relationships, and their children's well-being. A mother was eligible for the study if both she and the infant's father were at least 18 years old or, if they were minors, the hospital allowed recruitment of minors into the study; if she was able to complete the interview in either English or Spanish; if the father of the newborn was living; and if the parents were not planning to place the child for adoption. The fathers were also asked to participate in an interview. Informed consent was obtained.

A total of 4,898 mothers (3,712 unmarried; 1,186 married) were interviewed after they gave birth. Parents were re-interviewed over the telephone at 1, 3, 5, 9, and 15 years following the birth. At the 3-, 5-, and 9-year follow-ups, trained interviewers also administered in-home assessments of child development. Salivary DNA was collected from 2,482 children at the 9-year follow up.

Study population

We limited the analytic sample to 1,772 children who completed the Peabody Picture Vocabulary Test (PPVT) third edition in English at age 3 and for whom salivary DNA samples were collected at age 9.

Outcome

Child vocabulary—The PPVT is a validated measure of receptive vocabulary that has been used previously to examine the effects of shared reading on child vocabulary. (7, 24) The mean standard score in our relatively disadvantaged sample was 86.2 with standard deviation of 16.2. PPVT scores for children with available salivary DNA were 2 points higher than for children without ($p=0.014$).

Exposure

Shared reading—At the age 1 interview, mothers were asked, in a typical week “How many days a week do you usually read stories to (child)?” Based on the distribution of the data and past work examining shared reading among very young children, (8) we created a 3

level ordinal variable that included “never” defined as 0 days/week as well as “some shared reading” defined as >0–6 days/week, and “daily shared reading” defined as 7 days/week. In separate models we assessed whether our findings were sensitive to alternate specifications with shared reading frequency as a binary variable (never reading versus any reading) and as a 4-level ordinal variable (never reading, reading >0–3 times/week, reading 4–6 times/week, and daily reading).

Genetic markers

Detailed information regarding the collection and processing procedures are summarized elsewhere. (15) Briefly, saliva samples were collected using the Oragene DNA Self-Collection Kit from the child at the 9 year home visit. Several candidate polymorphisms believed to influence child development through interactions with children’s environment were genotyped.

We used data on 3 gene variants that have been shown to affect the function of the dopaminergic system and that we hypothesized would moderate the association between shared reading and later vocabulary: (1) The Taq1A single nucleotide polymorphism of the dopamine receptor 2 gene (*DRD2*, 11q23, rs1800497). The presence of a thymine (T) allele for this polymorphism has been linked to addictive behaviors and poor executive control. (12) Although the Taq1A polymorphism is structurally located in the nearby *ANKK1* gene it still influences *DRD2* expression. (25) (2) The variable number tandem repeat (VNTR) in the third exon of the dopamine receptor 4 gene (*DRD4*, 11p15.5). The presence of the 7-repeat allele for this polymorphism has been associated with attention deficit hyperactivity disorder (ADHD) (12) (3) A polymorphism of the dopamine transporter gene (*DAT1*, 5p15.3, rs40184). The *DAT1* gene has been linked to ADHD. (26)

We also included a length polymorphism 5-HTTLPR of the serotonin transporter gene (*5-HTT*, *SLC6A*, 17q11.2) of the serotonergic system as a potential moderator. The short allele of 5-HTTLPR has been associated with reduced transcription of the serotonin transporter gene and diminished reuptake of serotonin potentially resulting in reduced pre-synaptic stores of this neurotransmitter and influencing mental health outcomes. (27) As noted above, the short allele of the 5-HTTLPR polymorphism was previously found to moderate the association between responsive caregiving and academic performance. (19) Rare alleles of 5-HTTLPR were present in 3% of our sample and recoded. In supplementary models we excluded cases with these rare alleles to assess the sensitivity of our findings. DNA samples were analyzed using PCR or qPCR to distinguish alleles previously identified as sensitizing in the literature.

We created binary variables for each polymorphism indicating the presence of the sensitizing allele versus homozygous non-sensitizing genotype (Table I; available at www.jpeds.com). Genotype results were consistent with Hardy-Weinberg Equilibrium within racial/ethnic groups for the entire sample of FFCWS with genetic data. Allele frequencies differed by race in our analytic sample.

Covariates

To address potential confounding, we controlled for maternal race, ethnicity, education, and relationship status with the child's father, all measured at postpartum interview, and maternal depressive symptoms and material hardship measured at age 1. Maternal depressive symptoms were assessed with the Composite International Diagnostic Interview-Short Form (CIDI- SF), which categorizes respondents as having experienced a depressive episode in the past year based on Diagnostic and Statistical Manual of Mental Disorders criteria. (23) Household material hardship was assessed with 9 questions that addressed financial problems related to food, housing, and health care access (eg: "In the past year, were you evicted from your home?"). These questions were derived from the Survey of Income and Program Participation. (23) We also controlled for the child's sex.

Analyses

We first summarized child and maternal characteristics, both overall and by the presence of shared reading. We tested for statistically significant differences based on the presence of shared reading using chi square analysis. We also tested whether shared reading was associated with presence of each of the sensitizing alleles using chi square analysis. We then used linear regression in unadjusted and adjusted models to assess the extent to which shared reading at age 1 was associated with child vocabulary at age 3. Finally, we added interactions between shared reading and presence of sensitizing alleles for each polymorphism to the adjusted models to assess moderating effects. We then calculated the predicted PPVT value based on the frequency of shared reading and genotype, for significant interactions. We applied the false discovery rate control method to determine statistical significance with a maximum false discovery rate of 0.05 for analyses that included the interaction terms. (28, 29) Missing data for each of the exposure, moderators, and covariates was 3% for the analytic sample and we used complete case analysis. In exploratory analyses, we further stratified analyses by race (white and black) given evidence that gene-environment interactions may vary by race. (11) We also conducted a number of supplementary analyses to assess sensitivity of our findings to alternate model specifications. Specifically, we estimated models that included interaction terms between all independent variables and the sensitizing alleles and that controlled for maternal singing with the child at age 1, storytelling to the child at age 1, spanking of the child at age 1, maternal PPVT score, and maternal genotype to assess whether our findings were sensitive to the fully-interactive specification and to controlling for markers of nurturing parenting, harsh parenting, maternal vocabulary, and the presence of maternal sensitizing alleles. We performed the analyses using STATA 15 (StataCorp LP, College Station, TX).

The Rutgers Biomedical Health Sciences Institutional Review Board determined that this study was exempt.

Results

Maternal and child characteristics are summarized in Table 2; 56% of children were African American and 52% were male. Two-thirds of mothers had at least a high school education. Only about one-quarter of the parents were married (because the study oversampled non-

marital births), over one-third were cohabiting, and about 7% had infrequent or no contact with the father of their child. Six percent of mothers reported never reading to their child and 32% reported reading daily. Racial, ethnic, and education distributions differed significantly by shared reading frequency (Table 2). Shared reading was not correlated with the presence of any of the sensitizing alleles

As expected based on previous studies, shared reading at age 1 was associated with higher vocabulary scores at age 3 in both unadjusted and adjusted models. In unadjusted analyses, both some shared reading ($B=5.4$; 95% CI: 2.0 to 8.8) and daily shared reading ($B=7.9$; 95% CI: 4.3 to 11.4) were significantly associated with increased PPVT score. Although adjusting for the potential confounders resulted in an approximately one-third reduction in the estimates, the associations remained significant with increases in PPVT standard scores of 3.7 and 5.3 points for children exposed to shared reading sometimes and daily, respectively (Table 3). Maternal college education had the strongest association with PPVT score, with a 14-point increase in PPVT score. Results when treating shared reading as a binary or 4-level ordinal variable were consistent with those presented here (Results not shown).

Next, we tested our hypothesis that the presence of sensitizing alleles in the dopaminergic and serotonergic systems would moderate associations between shared reading at age 1 and child vocabulary at age 3. Of the 3 sensitizing alleles in genes involved in the dopaminergic system that we hypothesized would moderate the effect of shared reading on PPVT score, one had an interaction with daily shared reading with a p-value less than 0.05. Specifically, the presence of the T allele of the Taq1A polymorphism on DRD2 moderated the association between daily shared reading and child vocabulary but not between some shared reading and child vocabulary. After applying the false discovery rate correction, the main effects for some and daily shared reading, the sensitizing alleles, and the interaction term (*daily shared reading x DRD2*) were statistically significant (Table 4 and Table 5 [available at www.jpeds.com]). Figure 1 (available at www.jpeds.com) shows the difference in predicted PPVT scores for children exposed to shared reading compared with the reference group (children with the sensitizing allele who were not read to). Among children with the sensitizing allele, children who were exposed to daily shared reading had PPVT scores 8 points higher than children who were not exposed to shared reading. In contrast, we found only a one point difference in PPVT scores between children without the sensitizing allele who were exposed to daily shared reading and those who were exposed to no shared reading. Results of analyses stratified by race can be found Table 6 (available at www.jpeds.com). The regression coefficient for the *some shared reading x DRD2* interaction was larger for white race ($B=-7.3$) than black race ($B=-5.8$) but the regression coefficients for the *daily shared reading x DRD2* interaction terms were similar.

The interactions between shared reading and presence of the short sensitizing allele of 5-HTTLPR were statistically significant after applying the false discovery rate control, as were the main effects of shared reading (Table 5 and Table 7). Figure 2 (available at www.jpeds.com) shows the difference in predicted PPVT scores for children exposed to different levels of shared reading compared with the reference group. Among children with the short sensitizing allele, children who were exposed to daily shared reading had PPVT

scores 9 points higher than those of children who were not exposed to shared reading, compared with a 1 point difference between children without the sensitizing allele who were exposed and not exposed to daily shared reading. Analyses stratified by race and ethnicity can be found in Table 8 (available at www.jpeds.com). For the *daily shared reading x 5-HTTLPR* interaction term, the regression coefficient was substantially larger for white race (−14.2) than black race (−3.7) as well as *the some shared reading x 5-HTTLPR* interaction term ($B = -15.8$ versus $B = -2.1$) suggesting that the differential effects of shared reading on child vocabulary based on the presence of the sensitizing allele of *5-HTTLPR* are more pronounced among whites.

The full interaction models, excluding rare alleles for *5-HTTLPR*, and alternately controlling for maternal singing, storytelling, spanking, PPVT score, and genotype did not substantially alter our findings.

Discussion

In a national, population-based sample of children born in large US cities, we found that reading with children at age 1 was associated with increases in child vocabulary at age 3—an important indicator of school readiness and later academic attainment—even when controlling for a robust set of confounders. We also found evidence of differential responses to shared reading based on genotype. Specifically, we found that the presence of the short allele of the *5-HTTLPR* polymorphism of the serotonin transporter gene and the T allele of the *Taq1a* polymorphism of *DRD2* moderated the association between shared reading and child vocabulary. Although children with these sensitizing alleles had worse vocabulary scores than their peers at age 3 in the absence of shared reading, they fared as well when exposed to shared reading. For the *5-HTTLPR* polymorphism, this effect appeared to be most pronounced among children with Caucasian mothers. By focusing on shared reading, a positive exposure, and vocabulary, an indicator of healthy development, our work contributes to the growing literature on gene–environment interactions on child development that has largely focused on adverse exposures and unfavorable outcomes. (16) Our findings also have implications for understanding the effects of shared reading and other literacy-promoting behaviors on child outcomes.

Several studies have underscored the deleterious effects of early adversity on child development, health, and overall wellbeing. (30, 31–37) Although the literature is growing, far fewer studies have focused on identifying factors associated with resilience when children face such adversity. (34, 38, 39) The negative effects of poverty and low maternal education on child development, and in particular language development, are well documented. (40) In our relatively disadvantaged sample, average vocabulary scores were below typical norms. Our findings align with the diathesis-stress model in that the presence of the *5-HTTLPR* and *DRD2* sensitizing alleles placed children at greater risk for poor vocabulary outcomes, but we also found that shared reading, a positive exposure, appeared to mitigate this risk. When children with the sensitizing allele were exposed to shared reading, their predicted vocabulary scores at age 3 were equivalent to those of children without this allele. Although it is possible that maternal reports of shared reading are an indicator of other language-rich interactions or warm nurturing parenting activities in the

home that we were not able to capture, the role of shared reading and specific aspects of this experience in promoting children's resilience warrant additional study.

We found that the 5-HTTLPR and DRD2 sensitizing alleles moderated associations between shared reading at age 1 and child vocabulary at age 3. These findings align with prior work that found that a population-based literacy promotion intervention had a small effect overall (Cohen $d=0.05$), but that the average effect masked a larger effect for children with reactive temperaments (Cohen $d=0.46$) which have been linked to sensitizing alleles. (41) Together, this work illustrates the heterogeneity in children's responses to their environments. It also demonstrates the limitations of focusing solely on average effects and highlights the importance of identifying how and why children respond differently to early childhood environments. (42) The presence of the short allele of 5-HTTLPR is thought to reduce pre-synaptic stores of serotonin and may also lead to developmental changes in serotonin receptor function which in turn influences learning and mental health outcomes. (43) Prior work also indicates that individuals with the short allele display increase amygdala activation during aversive stimuli. (44) In contrast, the long allele has been associated with reduced variability in how individuals respond to their environments. Along these lines, the T allele of the Taq1A polymorphism of DRD2 has been associated with poor executive control. (12) It is possible that the focused joint attention around a book and responsive interactions offered by shared reading are especially beneficial for these groups during infancy given the high degree of neuroplasticity during this developmental stage. Additional work is needed to more fully understand mechanisms that underlie the heterogeneity in children's responses to environmental exposures including shared reading.

Our work is subject to certain limitations. First, although we analyzed data from a population-based national urban birth cohort, our findings still may not generalize to all settings. Second, given the observational study design we cannot assume causal relationships. Third, we used a mother-reported measure of shared reading that may be subject to social desirability bias. Six percent of our sample reported never reading to their child which is consistent with a nationally representative survey conducted during the same time period. (45) Although this measure is commonly used in research studies, (7) shared reading may be over-reported, which would reduce variability in our primary exposure measure and bias our results toward the null hypothesis of no difference in vocabulary outcomes based on shared reading. (2) Similarly, we were unable to assess the quality of shared reading, which could account for the observed differences. Although our findings are consistent with the diathesis-stress model, future work that incorporates a measure of the quality of shared reading, which may be even more strongly associated with improved outcomes than reading frequency, may elucidate a role for the differential susceptibility model. Overall, more precise measures of reading exposure will strengthen future work. Fourth, like other gene-environment studies, we cannot rule out the possibility of a gene-environment correlation, namely, that children's genetic makeup determines whether their parents read to them or whether they are born into environments associated with shared reading. (46) Furthermore, the child's genetic architecture reflects, in part, the mothers. Thus, differences in the shared reading environment could reflect allelic effects in the mother, although our models that controlled for the mothers' genotype do not suggest that this is the case. Fifth, although our findings suggest that differences in the interaction

between shared reading and 5-HTTLPR were largest for children with Caucasian mothers, additional confirmatory work with larger samples is needed given the exploratory nature. Of note, our findings are consistent with previous work studying gene-environment interactions involving 5-HTTLPR, which demonstrates that these interactions differ for individuals from Caucasian backgrounds compared with others. Kochanska et al demonstrated that the association between responsive parenting and academic performance was moderated by 5-HTTLPR took place among a largely Caucasian sample. (19) Sixth, not all of the hypothesized interactions we examined were statistically significant, as has been the case in previous studies of gene-environment interactions. (47) Finally, it is unlikely that individual gene variants could completely explain responses to a complex and dynamic exposure such as shared reading; it is more likely that the polymorphisms we identified work in concert with other genes. Future research is needed to more fully understand the relevant biosocial pathways.

The findings from this study support previous research demonstrating that shared reading in infancy improves vocabulary outcomes and indicate that the presence of sensitizing alleles in the dopaminergic and serotonergic systems moderate this association, such that children with the sensitizing alleles are at greater risk than their peers for poor outcomes when not read to but fare as well as their peers when exposed to shared reading. Our findings support the critical policy insight that by modifying children's environments in a positive way, those who are vulnerable can do as well as their peers. They also serve as a cautionary tale for relying solely on average effects of early childhood environments and interventions in interpreting their impact on children, because average effects may bury the fact that some children benefit disproportionately for heretofore unexplained reasons.

Acknowledgments

Support for the Child Health Institute of New Jersey is provided in part by the Robert Wood Johnson Foundation (67038 and 74260). The views expressed here do not necessarily reflect the views of the Foundation. The project described was supported in part by Award Numbers R25HD074544, P2CHD058486, 5R01HD076592, and 5R01HD036916 awarded by the *Eunice Kennedy Shriver* National Institute of Child Health & Human Development. The content is solely the responsibility of the authors and does not necessarily represent the official views of the *Eunice Kennedy Shriver* National Institute of Child Health & Human Development or the National Institutes of Health. M.J. is supported by the Robert Wood Johnson Foundation Harold Amos Medical Faculty Development Program (73308). The authors declare no conflicts of interest.

Abbreviations

ADHD	Attention Deficit Hyperactivity Disorder
DAT1	Dopamine transporter gene
DRD2	Dopamine receptor 2 gene
DRD4	Dopamine receptor 4 gene
FFCWS	Fragile Families Child Wellbeing Study
PPVT	Peabody Picture Vocabulary Test

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Figure 1:
Difference in Peabody Picture Vocabulary Test Scores at Age 3 Years Based on Frequency of Shared Reading at Age 1 year and Presence of DRD2 Thymine (Sensitizing) Allele

Figure 2:
Difference in Peabody Picture Vocabulary Test Scores at Age 3 Years Based on Frequency of Shared Reading at Age 1 year and Presence of 5HTTLPR Short (Sensitizing) Allele

Table 1:

Genotype distribution

Neurotransmitter system	Gene/polymorphism	Sensitizing allele	%(n) sensitizing allele present ^a
Dopaminergic system	Dopamine receptor 4 variable number tandem repeat (VNTR)	7 repeat	42.9 (755)
	Dopamine receptor 2 Taq1a	T	54.1 (955)
	Dopamine transporter gene	C	79.6 (1,408)
Serotonergic system	Serotonin transporter gene- 5-HTTLPR ^b	Short	54.4 (954)

^aIndicates presence of at least one sensitizing allele

^bRare alleles of 5-HTTLPR were present in 3% of our sample and recoded as short or long.

Table 2:

Sample characteristics

	Overall (n=1772)	Read 0 days per week (n=97) ^a	Reading sometimes (n=1,075)	Daily Reading (n=546)	p-value
Variable	% (No.)	% (No.)	% (No.)	% (No.)	
Child Sex					
Female	48.1 (853)	47.4 (46)	46.8 (503)	50.9 (278)	0.29
Male	51.9 (919)	52.6 (51)	53.2 (572)	49.1 (268)	
Maternal Race					
White	29.4 (513)	24.5 (23)	29.0 (306)	32.4 (175)	<0.001
African American	56.1 (978)	46.8 (44)	55.5 (587)	57.0 (308)	
Other	14.6 (254)	28.7 (27)	15.5 (164)	10.6 (57)	
Maternal Ethnicity					
Not Latino	79.1 (1392)	62.5 (60)	77.8 (832)	84.1 (456)	<0.001
Latino	21.0 (369)	37.5 (36)	22.2 (237)	15.9 (86)	
Maternal education ^a					
< High School diploma	31.9 (564)	40.6 (39)	31.3 (336)	30.5 (166)	<0.001
High School diploma	32.0 (566)	38.5 (37)	32.0 (343)	31.6 (172)	
Some college	26.2 (464)	16.7 (16)	28.4 (305)	23.1 (126)	
College	9.8 (174)	4.2 (4)	8.3 (89)	14.9 (81)	
Parents' relationship status ^a					
Married	22.3 (395)	19.6 (19)	21.1 (227)	25.1 (137)	0.46
Cohabiting	36.6 (649)	37.1 (36)	37.3 (401)	34.3 (187)	
Visiting	28.6 (506)	26.8 (26)	28.9 (311)	28.6 (156)	
Friends	5.8 (103)	7.2 (7)	5.4 (58)	6.6 (36)	
Infrequent contact ^b	6.7 (119)	9.3 (9)	7.3 (78)	5.5 (30)	
Depressive symptoms ^{c, d}					
Present	12.3 (211)	12.4 (12)	12.1 (130)	12.6 (69)	0.95
Not present	87.8 (1511)	87.6 (85)	87.9 (945)	87.4 (477)	
Material hardship ^{c, e}					
Present	49.2 (847)	52.6 (51)	50.9 (547)	45.1 (246)	0.07
Not present	50.8 (875)	47.4 (46)	49.1 (528)	55.0 (300)	

Source: Fragile Families and Child Wellbeing Study

^aAt birth of child^bIncludes mothers who responded that they "hardly talk" with the biological father, "never talk" talk with the biological father or the biological father is unknown^cAt age 1 year^dMaternal depressive symptoms were assessed with the Composite International Diagnostic Interview-Short Form (CIDI-SF)

^eMaterial hardship was assessed with 9 questions that addressed financial problems including food, housing, and access to care (e.g. In the past year, were you evicted from your home?) that were derived from the Survey of Income and Program Participation

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Table 3:

Multivariable linear regression model examining the association between shared reading and child Peabody Picture Vocabulary Test scores at age 3 controlling for other factors

Variable	B	95% confidence interval	p
Shared reading at age 3 ^a			
(No shared reading)			
Some shared reading	3.7	0.5 to 6.8	0.021
Daily shared reading	5.3	2.0 to 8.6	0.002
Sex			
(Female)			
Male	-1.9	-3.3 to -0.5	0.009
Race			
(White)			
African American	-8.5	-10.4 to -6.6	<0.001
Other	-4.6	-7.2 to -2.1	<0.001
Latino			
(Not Latino)			
Latino	-3.8	-6.2 to -1.4	0.002
Maternal education ^b			
(< High school diploma)			
High school diploma	-1.2	-2.9 to 0.6	0.20
Some college	5.3	3.4 to 7.2	<0.001
College	14.1	11.1 to 17.1	<0.001
Relationship status ^b			
(Married)			
Cohabiting	0.2	-2.0 to 2.4	0.841
Visiting	-0.6	-3.0 to 1.7	0.595
Friends	1.4	-2.1 to 4.9	0.433
Infrequent contact ^c	-1.7	-5.0 to 1.6	0.308
Depressive symptoms ^{a, d}			
(Not present)			
Present	-1.4	-3.6 to 0.8	0.204
Material hardship ^{a, e}			
(Not present)			
Present	1.5	0.04 to 3.0	0.044

^a At age 1 year

^b At birth of child

^c Includes mothers who responded that they “hardly talk” with the biological father, “never talk” talk with the biological father or the biological father is unknown

^d Maternal depressive symptoms were assessed with the Composite International Diagnostic Interview-Short Form (CIDI- SF)

^e Material hardship was assessed with 9 questions that addressed financial problems including food, housing, and access to care (e.g. In the past year, were you evicted from your home?) that were derived from the Survey of Income and Program Participation

Table 4:

Estimated coefficients from linear regression of Peabody Picture Vocabulary Test scores at age 3 years by shared reading at age 1 year and presence of sensitizing allele on **Dopamine Receptor 2 (DRD2)** controlling for potential confounders (n=1674) ^a

Variable	Coefficient (95% CI)	p-value
Shared reading frequency at age 1 ^b (ref.= No days/week)		
Some shared reading (SomeSR)	5.7 (1.7 to 9.8)	0.005
Daily shared reading (DailySR)	8.5 (4.3 to 12.7)	<0.001
Presence of sensitizing allele on DRD2 (ref.=Sensitizing allele DRD2 present)		
Sensitizing allele DRD2 not present	7.7 (1.5 to 13.8)	0.014
Interactions: Shared reading frequency and DRD2		
SomeSR_DRD2	-5.5 (-11.9 to 0.9)	0.091
DailySR_DRD2	-8.3 (-14.9 to -1.7)	0.014

Source: Fragile Families and Child Wellbeing Study

^a Adjusted for child sex, race, ethnicity, maternal education, and parent relationship status at baseline as well as presence of material hardship and maternal depression at age 1

^b Parent-reported shared reading: "No shared reading" = 0 times per week; "Some shared reading" = 1–6 times per week; "Daily shared reading" = 7 times per week

False discovery rate control method for multiple tests of main effects of shared reading, sensitizing polymorphisms, and interaction terms between shared reading and sensitizing polymorphisms of the dopaminergic and serotonergic neurotransmitter systems

Table 5:

Sorted p values	<0.001 [*]	<0.001 [*]	0.001 [*]	0.005 [*]	0.005 [*]	0.011 [*]	0.014 [*]	0.014 [*]	0.022 [*]	0.024 [*]	0.024 [*]	0.04	0.051	0.091	0.305	0.467	0.488	0.575	0.928	0.945
Significance level ^d	0.003	0.005	0.008	0.01	0.013	0.015	0.018	0.02	0.023	0.025	0.028	0.03	0.033	0.035	0.038	0.04	0.043	0.045	0.048	0.05
Model ^b	2	4	4	2	3	1	2	2	4	1	4	3	4	2	1	1	1	3	3	3
Variable ^c	SR2	SR2	SR1	SR1	SR2	SR2	DRD2	SR2X DRD2	SR1 x 5HTTLPR	SR1	SR2X 5HTTLPR	SR1	5HTTLPR	SR1X DRD2	SR1X DRD4	DRD4	SR2X DRD4	DAT	SR2X DAT	SR1X DAT

Abbreviations: SR1, some shared reading; SR2, daily shared reading

^a Calculated using the procedure described by Benjamini and Hochberg

^b Model 1 included DRD4; Model 2 included DRD2; Model 3 included DAT1; Model 4 included 5-HTTLPR

^{*} statistically significant

Table 6:

Estimated coefficients from linear regression of Peabody Picture Vocabulary Test scores at age 3 years by shared reading at age 1 year and presence of sensitizing allele on **Dopamine Receptor 2 (DRD2)** controlling for potential confounders by race ^a

Variable	African American (n=930)		Caucasian (n=500)	
	B	p	B	p
Shared reading frequency at age 1 ^b (ref.= No days/week)				
Some shared reading (SomeSR)	2.4	0.384	8.8	0.042
Daily shared reading (DailySR)	5.4	0.063	9.7	0.029
Presence of sensitizing allele on DRD2 (ref.=Sensitizing allele DRD2 present)				
Sensitizing allele DRD2 not present	6.2	0.194	9.9	0.114
Interactions: Shared reading frequency and DRD2				
SomeSR_DRD2	-5.8	0.240	-7.3	0.26
DailySR_DRD2	-8.4	0.096	-8.9	0.18

Source: Fragile Families and Child Wellbeing Study

^a Adjusted for child sex, ethnicity, maternal education, and parent relationship status at baseline as well as presence of material hardship and maternal depression at age 1

^b Parent-reported shared reading: “No shared reading” = 0 times per week; “Some shared reading” = 1–6 times per week; “Daily shared reading” = 7 times per week

Table 7:

Estimated coefficients from linear regression of Peabody Picture Vocabulary Test scores age 3 years by shared reading at age 1 year and presence of sensitizing allele on **5-HTTLPR** controlling for potential confounders (n=1661) ^a

Variable	Coefficient (95% CI)	p-value
Shared reading frequency at age 1 ^b (ref.= No days/week)		
Some shared reading (SomeSR)	6.9 (2.8 to 11.0)	0.001
Daily shared reading (DailySR)	8.6 (4.3 to 12.9)	<0.001
Presence of sensitizing allele on 5-HTTLPR (ref.=Sensitizing allele 5-HTTLPR present)		
Sensitizing allele 5-HTTLPR not present (5-HTTLPR)	6.2 (−0.04 to 12.3)	0.051
Interactions: Shared reading frequency and 5-HTTLPR		
SomeSR_5-HTTLPR	−7.5 (−14.0 to −1.1)	0.022
DailySR_5-HTTLPR	−7.7 (−14.3 to −1.0)	0.024

Source: Fragile Families and Child Wellbeing Study

^a Adjusted for child sex, race, ethnicity, maternal education, and parent relationship status at baseline as well as presence of material hardship and maternal depression at age 1

^b Parent-reported shared reading: “No shared reading” = 0 times per week; “Some shared reading” = 1–6 times per week; “Daily shared reading” = 7 times per week

Table 8:

Estimated coefficients from linear regression of Peabody Picture Vocabulary Test scores age 3 years by shared reading at age 1 year and presence of sensitizing allele on **5-HTTLPR** controlling for potential confounders by race ^a

Variable	African American (n=927)		Caucasian (n=497)	
	B	p	B	p
Shared reading frequency at age 1 ^b (ref.= No days/week)				
Some shared reading (SomeSR)	1.7	0.611	12.1	0.003
Daily shared reading (DailySR)	4.7	0.184	11.5	0.006
Presence of sensitizing allele on 5-HTTLPR (ref.=Sensitizing allele 5-HTTLPR present)				
Sensitizing allele 5-HTTLPR not present	1.7	0.711	12.8	0.045
Interactions: Shared reading frequency and 5-HTTLPR				
SomeSR_5-HTTLPR	-2.1	0.650	-15.8	0.017
DailySR_5-HTTLPR	-3.7	0.435	-14.2	0.035

Source: Fragile Families and Child Wellbeing Study

^a Adjusted for child sex, ethnicity, maternal education, and parent relationship status at baseline as well as presence of material hardship and maternal depression at age 1

^b Parent-reported shared reading: “No shared reading” = 0 times per week; “Some shared reading” = 1–6 times per week; “Daily shared reading” = 7 times per week