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Why Are Home Literacy Environment and Children's Reading Skills Associated? What Parental Skills Reveal

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ABSTRACT

Associations between home literacy environment and children's reading ability are often assumed to reflect a direct influence. However, heritability could account for the association between parent and child literacy-related measures. We used data from 101 mother/father/child triads to consider the extent to which associations between home literacy and children's reading fluency could be accounted for by parental reading fluency. Although home literacy correlated significantly with children's reading, no variable predicted significant variance after allowing for parental reading, except the number of books in the home. By incorporating measures of heritable parental traits into studies investigating home environment effects, we can start to identify which variables are correlates of parental traits and which might play a causal role in fostering children's development.

Children's word-reading accuracy and fluency (i.e., decoding) is linked to aspects of the family environment that children grow up in, including parents' educational attainment, how often parents read themselves and to their children, and availability of reading material (Davis-Kean, 2005; Johnson, Martin, Brooks-Gunn, & Petrill, 2008; Kiuru et al., 2013; Leseman & de Jong, 1998; Sénéchal & LeFevre, 2002). Measures of parents' direct teaching about print have shown somewhat larger effects than parents' informal print-related activities such as shared reading (Sénéchal & LeFevre, 2014; Torppa, Poikkeus, Laakso, Eklund, & Lyytinen, 2006). Correlations of home literacy (e.g., shared reading, access to books) and parental education with children's (emergent) reading in kindergarten and first grade are in the order of .2. Few studies focusing on word-level reading and home literacy have included children beyond first grade.

The intuitive and dominant interpretation of associations between children's home-rearing environment and their development is that the family environment causes the child outcome. However, individual differences in reading are due to both environmental and genetic differences, with a substantial heritability of about 70% (e.g., de Zeeuw, de Geus, & Boomsma, 2015; Olson, Keenan, Byrne, & Samuelsson, 2014). Therefore, the association between home literacy and children's reading ability may well be explained (at least partly) by a third variable: genes shared by parents and offspring (see Figure 1). A parent with a genetic predisposition to poor reading may pass this on to the child and may also be disinclined to buy books for the home. More generally, the relationship between home literacy and child outcome might reflect a passive gene–environment correlation. The

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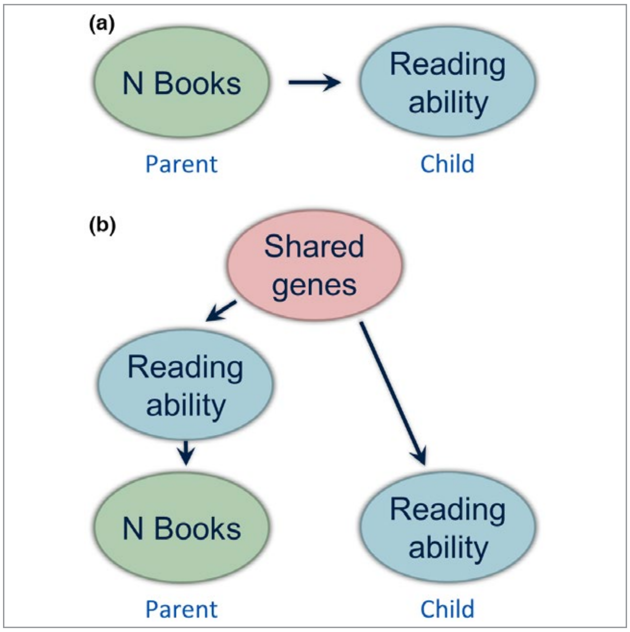
FIGURE 1
Hypothetical Models Explaining the Relation Between a Family Characteristic (Number of Books in the Home) and Child Outcome (Reading Ability)



Note. Panel (a) shows a direct environmental effect of number of books on children's reading ability, called cultural transmission. Panel (b) shows a model explaining the association via a set of genes shared between parents and children, which influences both the number of books and the children's reading ability. This is referred to as a passive gene–environment correlation. According to this model, the family characteristic does not exert an environmental effect on child outcome. Instead, the relation between the family characteristic and child outcome is explained by the genetic link between parents and offspring.

passive form of a correlation between children's genotype and environmental exposure happens because parents pass on their genes and create the home environment. For example, children of avid readers inherit their genes and are raised in an environment that may foster reading development (see Figure 1b). This type of explanation is often discounted because it is thought to imply a fatalistic approach toward reading problems, but as Asbury and Plomin (2014) pointed out, this is not accurate: We need to study genes and environment together to identify how to help those at genetic risk. Here, we will demonstrate how the interpretation of the relationship between family environment and child outcome can be informed by employing measured reading skills in parents.

At first sight, the twin study design seems to be the obvious choice to disentangle genetic and environmental effects on children's reading development. If monozygotic twin pairs are more alike in reading skills than dizygotic pairs, this tells us that individual differences among children are partly due to genetic differences. However, this approach cannot be used to study the association between family environment characteristics and child outcomes, because within each twin pair, the children perfectly resemble each other for family characteristics (e.g., they grow up in the same family with the same number of books), independent of zygosity (Turkheimer, D'Onofrio, Maes, & Eaves, 2005). In conclusion, the nature of the effects of family environment on child outcomes cannot be resolved in the classical twin design.

Instead, as proposed by the intergenerational multiple deficit model (van Bergen, van der Leij, & de Jong, 2014b), a simple design for studying associations between family environment and child skills is one that includes parental skills. In effect, we treat reading skills of the parents as an indicator of children's familial liability or potential (or the more neutral term, *familial effect*). The familial effect is a combination of the genetic and environmental influences transmitted from parent to child. We reasoned that if an environmental measure is still significantly associated with children's reading after controlling for parental reading, the environmental measure exerts an effect on children's reading that is partly independent of the familial effect. This is consistent with the environmental measure exerting a true environmental effect (i.e., cultural transmission) rather than just a masked genetic effect (i.e., gene–environmental correlation; see Figure 1). It is important to identify variables that represent a true environmental effect, as those are the variables that we can potentially manipulate to improve children's achievement.

What does the effect of an environmental measure over and above parental skills signify? For this, we first need to consider what shapes the parent–offspring resemblance. In the current study, we assessed reading ability in children and their parents. It is important to note that this design cannot distinguish genetic and cultural transmission. However, we can consider the strength of the association between parents and children found in our study in the light of behavioral-genetic studies. If parent–offspring resemblance reflected shared genetic influences (and if the same genes were implicated in the two generations), the correlation would be half the heritability of reading. Because the heritability is ~.65 (e.g., Olson et al., 2014), the correlation would be ~.33. It would be higher if cultural transmission or a shared environmental confound played a role. An example of the latter is belonging to a religious community that reads a lot.

Direct evidence on the ratio of genetic and cultural transmission comes from two independent studies employing different designs: a U.S. adoption study (Wadsworth, Corley, Hewitt, Plomin, & DeFries, 2002) and a Dutch twin-family study (Swagerman et al., 2015). Resemblance between parents and adopted children can only come about through cultural transmission. However, parent–offspring reading correlations in

Wadsworth et al.'s study were modest in biological families but absent in adoptive families, which suggests that transmission of reading skills from one generation to the next is mainly genetic in nature. The same conclusion was reached by Swagerman et al., who studied resemblance for reading fluency among twins, siblings, and parents. The path for cultural transmission in their model was very small (standardized: .006) and nonsignificant. Thus, current evidence suggests that the parent–offspring relation in reading primarily reflects genetic, not cultural, transmission. Therefore, if we consider the relation between home literacy and children's reading, adjusting for parental skills mainly controls for genetic transmission.

Earlier studies that accounted for familial risk (including shared genes) have followed the progress of children born into families with a dyslexic parent (Snowling & Melby-Lervåg, 2016). Note that in these studies, familial risk for dyslexia is based on the dyslexia status of one parent rather than the reading skills (on a continuum) of both parents. In general, these studies have not found associations between home literacy environment (e.g., shared reading, access to reading material, parental print exposure), or socioeconomic status (SES), and children's reading status in primary school (Snowling, Muter, & Carroll, 2007; Torppa et al., 2007; van Bergen, de Jong, Maassen, & van der Leij, 2014a), but this could reflect the homogeneity of the samples or the fact that parents who volunteer to take part are an unusually motivated sample. Moreover, although findings of familial risk studies are of relevance to our understanding of disorders, they cannot be readily generalized to the general population covering the full range of reading ability.

The intergenerational multiple deficit model (van Bergen et al., 2014b) explicitly includes both parents, as they can both affect their offspring's behavior and skills via genetic and cultural transmission. Paternal and maternal effects are usually not distinguished in research on the effects of home literacy: Questionnaires are filled out by "the parents." Open questions are whether paternal and maternal effects differ in magnitude and whether they overlap or add up. For shared reading and prekindergartners' vocabulary, for instance, effects of fathers and mothers seem to be equal and additive (Malin, Cabrera, & Rowe, 2014).

Including both parents in the study also offers the possibility to estimate the correlation between spouses' skills, known as assortative mating. It is important to know about assortative mating, as it can distort estimates of heritability in twin studies (Plomin, DeFries, McClearn, & McGuffin, 2008; van Leeuwen, van den Berg, & Boomsma, 2008). Wadsworth and colleagues (2002) reported for reading accuracy in a U.S. sample an assortative mating of .26, and Swagerman et al. (2015) reported for reading fluency in a Dutch sample an assortative mating of .38. Furthermore, where there is significant assortative mating, offspring of a dyslexic parent may be particularly vulnerable because parents cannot compensate for each other's poor reading skills (Swagerman et al., 2015).

The Current Study

Our study examines reading fluency in a sample of children (beyond the emergent reading phase) and their parents. We focused on decoding skills because (a) they form the basis for reading comprehension skills, and (b) a decoding deficit is the primary criterion for dyslexia, making our study clinically relevant. Readers of relatively transparent orthographies, such as Dutch or Spanish, make few reading errors (de Jong & van der Leij, 2003; Verhoeven & van Leeuwe, 2009). For that reason, both clinicians and researchers typically assess reading fluency, which is a combination of decoding accuracy and speed (Blomert, 2006; Verhoeven & van Leeuwe, 2009).

As measures of the family environment, we studied parental education and home literacy. Home literacy is thought to be more proximal to children's reading than parental education. In line with this, home literacy still predicts children's (emergent) literacy after controlling for parental education (Foster, Lambert, Abbott-Shim, McCarty, & Franze, 2005; van Steensel, 2006). For all family variables, we asked the same question: Do they exert a true environmental effect on child reading (as in Figure 1a), or is the relation due to the genetic link between parents and children (as in Figure 1b)?

Home literacy is conceptualized as a multifaceted construct. For example, Sénéchal and LeFevre (2002) differentiated informal and formal literacy activities, that is, storybook exposure and parent tutoring about literacy. Leseman and de Jong (1998) distinguished opportunity, instruction, cooperation, and socioemotional quality. The most studied aspect of home literacy is opportunity, including the access to written material and how much family members read. Opportunity is an important element of home literacy. Simple questions about parents' level of education and parents' print exposure have been found to capture 50% of the variance of the observed quality of parent–child book-reading interactions (Leseman & de Jong, 1998; see their Table 3). The current study aimed to shed light on the nature of the opportunity aspect of home literacy. As indicators, we used parents' print exposure and availability of magazines, newspapers, and books in the home.

We also investigated the nature of the association between child reading and parental education. Parental education is a ubiquitously used general index of parents' achievement beliefs and stimulating home behaviors. Subsequently, these are thought to mediate the relation between parents' educational level and children's academic achievement (Davis-Kean, 2005). Importantly, explaining the effect of parental education on child outcome purely in terms of environmental effects ignores the fact that parents' educational attainment is partly heritable (Rietveld et al., 2013). As a result, transmission of genetic material could (partly) account for the observed associations between parental education and child outcome.

We assessed several measures of the home environment, separately for fathers and mothers. For environmental measures that were significantly associated with children's reading, we tested whether they still related to children's reading fluency after controlling for the reading fluency of both parents. That is, we ran regression analyses predicting children's reading outcome, with parental reading fluency added in the first step and the measure of environment in the second step. The critical question was whether the second step was significant. Because heritability of children's reading ability has been found to differ as a function of parents' educational level (Friend, DeFries, & Olson, 2008; Friend et al., 2009), we explored the interaction between parental reading fluency and other environmental measures in explaining children's reading fluency. We show how parental skills can shed light on why children's skills correlate with the home environment.

Methods

Participants

The families took part in the Familial Influences on Literacy Abilities (FIOLA) Project (van Bergen, Bishop, van Zuijen, & de Jong, 2015). The FIOLA sample consists of families visiting the science museum in Amsterdam, The Netherlands,[1] who agreed to take part in a one-off test session with at least one parent and one child. Data collection took place during school holidays over two consecutive years. The primary data set consisted of participants who participated in the first year of data collection, as home literacy environment was assessed only in the first year. The data of the second year of testing were only used to cross-validate an interaction effect (see the Results section).

Year 1 Sample

In the first year, 613 people from 191 families took part. To allow for the regression analyses in the current article, only families with data of both parents were selected. This resulted in 111 mother/father/child families. Subsequently, three families were excluded because the child was an adult. Then, five families were excluded because the parents' native language was not Dutch or because they had not received Dutch education. Finally, two families were excluded because the children were being educated abroad. This left us with 101 families.

Thus, the primary data of the current study include the 101 families of which both (biological) parents and at least one child took part during year 1.[2] If more than one child per family participated, the data of the oldest were selected. All 101 fathers (age: mean [*M*] = 43.99 years, standard deviation [*SD*] = 3.85 years), 101 mothers (age: *M* = 42.19 years, *SD* = 3.42 years), and 101 children (age: *M* = 10.92 years, *SD* = 2.21 years, range = 7–17 years; 70 girls) were native speakers of Dutch, and all participants had attended or were still attending Dutch mainstream education. The children were at least in grade 2 and had completed at least 14 months of formal reading instruction[3] (*M* = 51.03 months, *SD* = 21.61 months, range = 14–114 months).

Year 2 Sample

In the second year, 622 people from 195 families participated. Following the same exclusion steps as described for the year 1 data, we were left with 89 mother/father/child families with complete data for reading fluency and parental level of education (necessary for cross-validating the interaction effect described in the Results section). The year 2 sample was very similar to the year 1 sample (age of fathers: *M* = 43.12 year, *SD* = 3.37 years; age of mothers: *M* = 41.31 years, *SD* = 3.60 years; age of children: *M* = 10.65 years, *SD* = 1.80 years, range = 6–15 years; and 44 out of 89 children were girls). Parental level of education (see the Measures section) was also very similar to that reported in Table 1 for the year 1 sample (fathers: *M* = 5.79, *SD* = 1.87; mothers: *M* = 5.44, *SD* = 1.76; see Appendix A for the full 9-point scale).

Unless stated otherwise, figures from here on refer to the year 1 data set.

Representativeness

We have three indicators of representativeness of the sample. For children in grades 2–7 (*N* = 83), national norm scores for the reading fluency tests (see the Measures section) were available, which indicated that performance of these children is ~0.5 *SD* above the national average. Second, the social status score of the neighborhoods where our participants live were looked up in the database of The Netherlands Institute for Social Research (Sociaal en Cultureel Planbureau, 2012). The social status score of a neighborhood (defined by the four digits of the postal codes) is based on the inhabitants' level of education, occupation, and income. The

TABLE 1
Descriptive Statistics of the Participants (*N* = 101 mother/father/child triads)

	Descriptives			Correlations								
Variable	*M*	*SD*	Range	1	2	3	4	5	6	7	8	9
Reading fluency[a]												
1. Child	0	1	−2.45–2.04	—								
2. Father	0	1	−2.09–2.37	.32**	—							
3. Mother	0	1	−3.09–1.99	.29**	.10	—						
Socioeconomic status[b]												
4. Father’s education	5.61	2.00	2–9	.22*	.47***	.34***	—					
5. Mother’s education	5.29	1.89	2–9	.23*	.31**	.38***	.47***	—				
Home literacy environment												
6. Father’s reading frequency	3.09	0.96	1–5	.21*	.45***	.12	.48***	.19*	—			
7. Mother’s reading frequency	2.99	0.96	1–5	.02	.02	.22*	.13	.25*	.07	—		
8. Magazine/newspaper subscriptions[c]	0	1	−1.51–1.91	.14	.26**	.25**	.41***	.30**	.19	.06	—	
9. Number of books estimated in the home	4.31	1.74	1–6	.36***	.34**	.24*	.40***	.47***	.26**	.25*	.20*	—

Note. M = mean; SD = standard deviation. Raw scores for fathers: $M = 1.45$, $SD = 1.03$; raw scores for mothers: $M = 1.21$, $SD = 0.95$.
[a]Standardized composite of word- and pseudoword-reading fluency. The children’s scores are corrected for linear and quadratic age effects. [b]See Appendix A for the full 9-point scale. [c]Standardized composite of the father’s and mother’s scores.
*$p < .05$. **$p < .01$. ***$p < .001$.

mean social status score of the FIOLA sample appeared ~0.45 *SD* above the national average. Third, the level of education of the FIOLA sample ranged from primary school only to post-master’s degree. The sample’s average was 0.49 *SD* above the national average (van Bergen et al., 2015). In sum, higher SES and skill level were somewhat overrepresented, but the sample included all socioeconomic strata and skill levels.

Measures

We assessed the following measures of the home environment: parental level of education, parental reading frequency, magazines and newspapers in the home, and access to books. Parents and children were tested on the same reading fluency tests.

Parental Education

The level of education of the parents was measured on a scale ranging from 1 (*primary school only*) to 9 (*post-master’s degree*; see Appendix A for the full scale).

Home Literacy Environment

Parents rated their own reading frequency using these two questions: How many hours per week do you read on average for study/work? How many hours per week do you read on average for pleasure? The alternatives ranged from 1 (*<1*) to 5 (*>10*). The first question also included a “not applicable” option for unemployed parents (4% of fathers; 13% of mothers). This option was rescored as 1. One mother had a missing score for reading for pleasure; this was replaced by the group mean. From the scores for questions 1 and 2, *z*-scores were computed (separately for fathers and mothers), which were averaged to give the total reading frequency scores for fathers and mothers. The *z*-scores correlated .23 for fathers and .17 for mothers. Low correlations were expected: For instance, a stay-at-home parent does not read for study or work (score of 1) but may read a great deal for pleasure.

Furthermore, fathers and mothers indicated whether they had subscriptions to magazines or newspapers (*no*, *1*, *2*, or *≥ 3*). Their scores correlated .57. *Z*-scores were computed, averaged, and standardized across parents. Finally, parents estimated the number of books at home (range = 1, *<25*, to 6, *>225*; one question per family). All questions relevant to the current study are listed in Appendix B.

Reading Fluency

The fluency (i.e., accuracy and speed) of reading was tested for both words (One-Minute Test: Brus & Voeten, 1972) and pseudowords (Klepel: van den Bos, Lutje Spelberg, Scheepstra, & de Vries, 1994). Participants were asked to correctly read as many items as possible within one minute (word-reading fluency) or two minutes (pseudoword-reading fluency). The original test versions consist of a list of 116 items of increasing difficulty. To avoid a ceiling effect in adults, the lists were extended by adding the last column of its parallel test, resulting in a list of 145 items. Reliability for children of different ages ranges from .76 to .96 for word reading and from .89 to .95 for pseudoword reading. To obtain reliability estimates for adults, we tested an independent sample (N = 50) on parallel forms, which yielded reliability coefficients of .96 for word reading and .94 for pseudoword reading.

Procedure

Ethical approval for this study was provided by the University of Amsterdam's Ethics Committee. Written informed consent was obtained from parents. Family members were tested individually in separate rooms by research assistants. The research assistants were trained and supervised by van Bergen (first author) and van Zuijen (second author). The museum provided two rooms for participant testing. The rooms had partial glass walls, so parents and children could see each other. Testing lasted 15 minutes and included more tests than reported here. Both parents completed a questionnaire that included questions on the home environment. Together, the parents filled in a short questionnaire that included a question on whether any of the participating family members (had) attended special education (which was an exclusion criterion) and another question on the number of books in the family home.

Results

Descriptive Statistics

Descriptive statistics are presented in Table 1 and raw reading scores in Appendix C. To control for the effect of children's age on their reading scores and, closely related, the effect of amount of schooling, we regressed out the effect of months of instruction (which correlates .96 with age). For children's word reading, both the linear and the quadratic effect of months of instruction were significant and were removed.[4] For pseudoword reading, only the linear effect was significant and was removed. The standardized residuals of these regressions were saved, which yields z-distributed child reading scores without amount of schooling (or age) effects. For parents, raw reading scores were transformed to z-scores. The word and pseudoword z-scores correlated .84 for children, .74 for fathers, and .67 for mothers. For all family members, a reading fluency score was formed by averaging the z-scores of word and pseudoword reading. This average was again normalized, yielding reading fluency scores with a mean of 0 and *SD* of 1.

Two out of 101 fathers had a missing value for word-reading fluency. For them, only their pseudoword reading score was used to calculate their reading fluency score. All other data were present. Hence, all regression analyses included all 101 families.

Even after age-standardizing children's reading scores, it could be that the relationship between child reading and home literacy changes across development. Therefore, we divided the group into families with younger and older child participants via a median split on age (at 132 months). The correlations between child reading and home literacy for the two age bands are reported in Appendix D. Although correlations seem to be higher for the younger group for some variables, statistical testing showed no significant differences. Hence, we further looked at the correlations in the entire sample.

Table 1 shows that children's reading fluency correlated with parental reading fluency, parental educational level, fathers' reading frequency (but not mothers'), and the number of books at home. The magazine/newspaper subscriptions variable was not significantly related to child reading and therefore not considered further. The correlation of parents' educational level was stronger with their own (.47/.38) than with their children's reading fluency (.22/.23). Child reading did not differentially correlate with fathers' and mothers' reading (.32/.29) or education (.22/.23). For reading frequency, the effects seemed to differ, but confidence intervals (CIs) overlapped (fathers: .21, 95% CI [0.02, 0.39]; mothers: .02, 95% CI [−0.18, 0.21]).

Data Analysis Plan

Significant correlations were followed up by sequential multiple regressions, presented in Table 2. In these regressions, children's reading fluency is the dependent variable, and the parental and home characteristics are the independent variables (predictors). We tested how much variance environmental measures can explain in child reading (models 1a, 2a, and 3a). Subsequently, we tested whether environmental measures explained variance in child reading after parental reading had been taken into account (models 1b, 2b, and 3b). This was achieved by entering parental reading fluency in step 1 and the environmental measure in step 2. Because we did not have a priori hypotheses about differential effects for fathers and mothers, father and mother variables were analyzed together, resulting in fewer and more conservative tests.

Regarding power, Tabachnick and Fidell (2007) recommended a sample size of the number of predictors plus 104 if one is interested in individual predictors. In our case, this ranges from 105 (one predictor in model 3a) to 110 (six predictors in model 1b). Because our sample size of 101 families is slightly smaller, we should be careful in drawing conclusions based on the significance of individual

TABLE 2
Hierarchical Regression Models Predicting Children's Reading Fluency

Model	Step	Predictor	ΔR^2	*F*-change	(df_1, df_2)	*p*	β[a]
1. Parental education[b]							
1a	1	Father's education	.07*	3.69	2, 98	.029	.15
		Mother's education					.16
1b	1	Father's reading fluency	.17***	9.78	2, 98	<.001	.28*
		Mother's reading fluency					.22*
	2	Father's education	.00	0.16	2, 96	.850	.01
		Mother's education					.05
	3	Father's reading fluency × education	.04	2.60	2, 94	.079	.21*
		Mother's reading fluency × education					−.06
2. Parental reading frequency							
2a	1	Father's reading frequency	.04	2.17	2, 98	.120	.21*
		Mother's reading frequency					.01
2b	1	Father's reading fluency	.17***	9.78	2, 98	<.001	.26*
		Mother's reading fluency					.27**
	2	Father's reading frequency	<.01	0.26	2, 96	.770	.06
		Mother's reading frequency					−.04
3. Number of books estimated in the home							
3a	1	Number of books	.13***	14.76	1, 99	<.001	.36***
3b	1	Father's reading fluency	.17***	9.78	2, 98	<.001	.21*
		Mother's reading fluency					.21*
	2	Number of books	.05*	5.84	1, 97	.018	.24*

[a]Reported βs pertain to the model after the final step (all predictors included). [b]See Appendix A for the full 9-point scale.
*$p < .05$. **$p < .01$. ***$p < .001$.

predictors (βs). However, the significance of each of the steps in the regression analyses (see Table 2) is more robust.

Testing the assumptions of regressions can be done by examining the scatterplots of the predicted child reading values against the residuals (Tabachnick & Fidell, 2007). Residuals should scatter around zero across the range of predicted values. For the regressions reported next, no deviations were visible in these scatterplots. Also, none of the standardized residuals exceeded |3| *SD*s.

Predicting Children's Reading Fluency From Parental Education

In model 1 in Table 2, we tested how much of the variance in child reading can be explained by parental education (model 1a) and whether parental education still explains a significant amount of variance in child reading after parental reading had been entered in step 1 (model 1b). Model 1a showed that parental education explains 7% of the variance in child reading. Step 1 of model 1b (but also step 1 of models 2b and 3b) revealed that paternal and maternal reading fluency explain independent and similarly large proportions of variance in children's reading fluency, as can be seen from the significant and comparable βs for fathers and mothers. Together, parental reading fluency explained 17%. Note that parental education predicted children's reading fluency (R^2 = 7%; model 1a) but not over and above parental reading (model 1b, step 2).

Finally, we tested in step 3 of model 1b the interaction between parental reading and education, after controlling for the main effects in steps 1 and 2. This interaction term for fathers related to child outcome, explaining an additional 4% (model 1b, step 3). Drawing regression lines for fathers with an educational level 1 *SD* above or below average revealed a positive association between fathers' and children's reading fluency for fathers with more education, whereas this association was absent for fathers with less education.

Note that although the interaction's β was significant, step 3 as a whole (ΔR^2) was not. Because all relevant variables were also present in the year 2 data set (see the Participants section), we had the opportunity to cross-validate this regression in the year 2 data. Following the steps in model 1b, step 1 (parental reading fluency) was significant, R^2 = 26%, $F(2, 86) = 14.75$, $p < .001$; but step 2 (parental education) and step 3 (interaction between parental reading and education) were not, $\Delta R^2 < 1\%$, $F(2, 84) < 1$, $p = .808$ and $\Delta R^2 < 1\%$, $F(2, 82) < 1$, $p = .896$, respectively. Thus, the large effect of parental reading fluency (step 1) and the absence of an effect of educational level on top of that (step 2) were replicated, but the interaction effect (step 3) was not. Regarding the interaction, the questionable evidence from the primary data and the clear null result from the cross-validation led us to not consider the interaction further.

Predicting Children's Reading Fluency With Parental Reading Frequency

Next, we continued our analyses of the primary data set, now testing the effect of how much parents read. Fathers' reading frequency was a significant correlate of children's reading (significant β), but together with mother's reading frequency did not account for a significant amount of variance in children's reading (model 2a: R^2 = 4%, nonsignificant), nor did parental reading frequency predict beyond parental reading fluency (model 2b, step 2: $\Delta R^2 < 1\%$, nonsignificant).

Predicting Children's Reading Fluency With Access to Books

We finally investigated the effect of access to books in the home in model 3. Interestingly, the number of books at home predicted children's reading fluency (R^2 = 13%; model 3a), and this effect remained significant after controlling for parental reading fluency (accounting for an additional 5% of variance; model 3b, step 2).

None of the other possible interactions between parental reading fluency and an environmental measure were significant.

Discussion

This study demonstrates how employing parental characteristics gives insight into interpreting observed associations between children's heritable characteristics and aspects of the home environment (see Figure 1). Next, we will discuss the observed associations and the key question, Why are literacy environment and literacy levels associated?

Home Literacy Correlations

We extended previous findings by showing that aspects of the home environment also relate to children's reading skills beyond the emergent reading phase. However, parental education and parental reading frequency did not predict children's reading fluency over and above parental reading fluency. That is, the reason why these aspects of the home environment were connected with children's reading seemed to be because good reading parents tend to have good reading children, as well as high educational attainment and highly literate homes, and vice versa for poor reading parents. Effects of parental education, reading frequency, and reading fluency on children's reading fluency did not differ in magnitude between fathers and mothers. The strongest correlate of child reading appeared to be the number of books in the home. This predicted child reading over and above parental reading fluency.

Family Correlations

Reading fluency among family members was robustly correlated. The correlation between spouses (i.e., assortative mating) was .10 and not significant. For comparison, assortative mating for educational level was .47. Correlations between parents' and children's reading were similar in magnitude for fathers and mothers and acted additively: Because of low assortative mating, they made independent contributions to children's reading. Our estimate of assortative mating is lower than previously reported (Swagerman et al., 2015; Wadsworth et al., 2002). Importantly, our observed parent–offspring correlations (~.35 across both samples) are in line with Swagerman et al.'s and Wadsworth et al.'s findings of just genetic transmission (without cultural transmission) of reading ability from parent to offspring.

We would like to add two qualifications to the conclusion that parent–offspring resemblance seems to reflect just genetic transmission. First, note that this conclusion does not imply that parental behavior makes no difference. It would only mean that growing up with caretakers of a certain reading level is not a risk or protective factor; nonetheless, other parenting practices may still be. Second, bear in mind that this paragraph and its conclusion pertain to parent–offspring resemblance, whether that is due to genetic or environmental transmission. It is not about to which degree parents' reading is influenced by their own environmental experiences and genotype.

It has generally been assumed that correlations between child and parent reading arises through cultural transmission; if this were so, then by intervening with parents, we should be able to also affect children (McAdams et al., 2014; Swagerman et al., 2015). The absence of cultural transmission, however, implies that modifying parental reading skills may not be an effective intervention strategy for children at high familial risk of dyslexia. A case can be made for offering extra literacy support at school to all low-achieving children (Asbury & Plomin, 2014). It is possible that those at family risk may benefit from a qualitatively different approach to reading instruction, rather than just increased quantity. For instance, it may be beneficial to control the timing of instruction and support to ensure that the child has underlying phonological skills firmly in place before introducing written language.

Why Are Literacy Environment and Literacy Levels Associated?

From the evidence that transmission of reading ability is genetic in nature, it follows that a home literacy aspect that predicts child outcome after accounting for parental skills suggests a genuine environmental effect. Here, this would apply to the number of books in the home. How many books a family possesses could indicate the value that is placed on literacy and of parents' support in developing the child's literacy. The number of books is indeed related to how often parents read to their prereading children (Myrberg & Rosen, 2009), which is related to children's emergent reading skills (Mol & Bus, 2011), which subsequently predicts later reading levels (de Jong & van der Leij, 1999). In an impressive study across 27 nations, Evans, Kelley, Sikora, and Treiman (2010) showed that growing up in homes with many books is related to later educational success across all studied nations. We note that the discussion of this article is an example of the fallacy also noted by Bishop (2014): The association is solely explained in terms of an environmental cause (e.g., "each addition to a home library helps the children get a little farther in school"; Evans et al., 2010, p.187). In our study, the book variable had an effect, but this was quite modest once parental skills had been controlled for, consistent with a mixture of cultural and genetic transmission.

Nonetheless, our findings suggest that children's reading levels are influenced by the size of the home library partly via the environment. This could be due to the importance of the number of books in itself, or the number of books could be a proxy for how much value the family places on reading. It is important to identify family characteristics that have an effect after parceling out genotypic effects and that can be manipulated. After all, these variables are good candidates for intervention work. The key question here from a scientific perspective would be whether merely providing families with more books would enhance children's reading. From an educational view, it makes more sense to try to boost reading by providing books and encouraging families to engage in family literacy practices, such as shared reading and/or direct tutoring of decoding. For boosting reading comprehension, one may also think of tutoring text comprehension through reading strategies, and engaging in discussions about books. A meta-analysis showed that family literacy programs in which parents increase literacy activities at home and teach specific skills indeed enhance children's code-related and comprehension-related reading skills, but short-term effects are small (Cohen's $d = 0.18$; van Steensel, McElvany, Kurvers, & Herppich, 2011) and might not be lasting (van der Leij, 2013).

Correlations between children's reading fluency and other measures of home literacy could all be accounted for in terms of passive gene–environment correlations. Recall that how much parents read and their level of education were correlated with children's reading outcome (see Table 1) but no longer after parceling out parents' reading ability (see Table 2). In light of our reasoning, the explanation for their associations seems as follows: On average, good reading parents read more and are more educated. They also pass on a genetic proclivity to good reading. Meanwhile, their children grow up in a high-SES family where they see their parents reading regularly. The crux of the matter is the reason that their children are likely to become good readers: This appears not to be because of the parents' education and reading habits. These indicators of the home-rearing environment appear to be related to children's reading outcome through a masked genetic effect, that is, a passive gene–environment correlation (see Figure 1b).

It would, however, be rash to conclude that that is all: It is possible that causal environmental effects might be seen with a larger sample and/or different methods. If there were a small environmental confound or modest cultural transmission of reading ability, our method would be too conservative. However, the observed parent–offspring correlations are in agreement with values predicted by solely genetic transmission. We found robust associations with home literacy measures, which were based on a short questionnaire. We would expect the associations to be even more robust had we used home observations.

A study that controlled for passive gene–environment correlations is the adoption study of Petrill, Deater-Deckard, Schatschneider and Davis (2005). They found small effects on child reading ability of parental school involvement and the child's reading enjoyment (combined measure) and of how many library books children bring home. Not related were mothers' educational attitudes, book reading, and expected time spent on homework. Noteworthy, the two environmental measures for which an effect was found may well reflect environments that children seek out themselves, creating an active gene–environment correlation. *Active gene–environment correlation* refers to children seeking out environments that fit their genotype. For example, children with a genetic propensity for good reading may choose to read a lot.

Turning to parents' education, we found significant correlations between parental educational level and children's reading, although these were relatively weak, as reported previously (Kiuru et al., 2013; Manolitsis, Georgiou, & Parrila, 2011). In the current and cross-validation samples, they were not statistically significant when parental reading was taken into account. It seems that the family's educational level that the child experiences is associated with his or her reading skills through parental reading skills.

Our method allows for testing interactions. We did not find solid effects of parents' education × reading on child reading. Friend et al. (2008) reported higher heritability for dyslexia among children of more highly educated parents. In contrast, the opposite pattern (higher heritability for less educated parents) was found for reading ability at the high end (Friend et al., 2009). Taken together, this suggests higher heritability for performance that is unexpected against the backdrop of the educational attainment of one's parents (Friend et al., 2009). This would be a nonlinear interaction across the range of abilities, whereas we only tested a linear interaction. This topic deserves further research before firm conclusions can be drawn.

Figure 1a shows the situation where growing up surrounded by books acts as a protective factor. An alternative possibility that we cannot test is that the arrow in Figure 1a points in the opposite direction, for instance, with able and avid reading children causing the home library to grow by asking for books. However, this kind of evocative gene–environment correlation (i.e., a child's heritable behavior, such as effortless reading, evokes certain environmental responses) is much less plausible for the other independent variables. That is, children's reading ability is not likely to influence the educational attainments or reading preferences of parents.

Future Research

We proposed a study design that is easy to implement, compared with proper genetically informative family designs. The study design is of interest more broadly: Parents' heritable traits can aid interpreting associations between children's heritable traits and the environment they grow up in. This design can be translated to at least two lines of future research: first, to study the nature of the effects of other domains of home literacy. A wider range of variables through survey or observation should be studied to test for environmental effects after parceling out genetic effects. Identifying such variables will also inform future intervention work. Examples of general family-characteristic and home literacy domains that could be considered are household order/chaos, digital media use, and parent–child interactions. The type of parent–child interaction considered may differ over development: shared reading in the prereading or emergent reading phase, tutoring of literacy-related skills during the early school years, and assisting with higher level reading and writing skills in older children. The research question would test whether the frequency and quality of such parent–child interactions add to child outcome beyond what can be attributed to parents' own literacy skills.

Second, the design that we demonstrated can be transferred to investigate the nature of the effect of home characteristics on other heritable traits, such as children's spoken language, reading comprehension, arithmetic, and attention deficit/hyperactivity disorder (ADHD) and autism symptoms. The same methods can be applied as we showed for reading fluency if measures are obtained of the home characteristics and similar assessments of the trait under study in both generations. For instance, if the focus of the study is the effects of home characteristics on children's ADHD symptoms, the effect that should be partialed out first is parental ADHD symptoms. Whenever possible, both fathers and mothers should be assessed, as both contribute to genetic and cultural transmission. If, say, the mother–child resemblance is larger than the father–child resemblance, this may point to the presence of cultural transmission. By assessing both parents, assortative mating can be estimated in addition. The advantage of applying our method to reading fluency is that we know from previous work that parent–child resemblance seems to be due to genetics. Such information may be lacking for other traits. However, it might be stated that if there is both genetic and cultural transmission, it will be harder to find an environmental effect when the parental trait is controlled. More generally, if the relationship between an environmental factor and the child trait disappears after controlling for the parental trait, this might be due to cultural transmission that captures the environmental effect. However, if we find an environmental effect after accounting for the parental trait, this suggests a true environmental effect, even in the presence of cultural transmission.

Conclusion

We showed that children's basic reading skill is related to several aspects of the home literacy environment, but most seem to be masked genetic effects. That is, they seem to correlate with child reading because children inherit from their parent both a genetic tendency for a certain reading level and the home environment they are exposed to. An exception to this seems to be the number of books children grow up with, which may also exert a true environmental effect on their reading outcome. In general, the research design that we propose opens up an avenue for a new line of research investigating the nature of nurture.

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Van Bergen, van Zuijen, and de Jong developed the FIOLA Project and this article's study design. Testing and data collection were performed under the direction of van Bergen and van Zuijen, both of whom performed the data analyses. Van Bergen drafted the manuscript, and Bishop and de Jong provided critical revisions.

[1] This research is part of Science Live, the innovative research program of NEMO Science Museum that enables scientists to carry out real, publishable, peer-reviewed research using NEMO visitors as volunteers.

[2] We included one child per family to simplify analyses. We opted for the oldest participating child because as children age, reading ability stabilizes and the reading task becomes more similar for adults and children. We started asking about birth order halfway through the first data wave. Of the included children, 90% in year 1 and 85% in year 2 were the oldest child of their families.

[3] Counted as 10 months of instruction per educational year.

[4] Cf. Verhoeven and van Leeuwe's (2009) Figure 1a: For the development of (Dutch) word-reading fluency, a curvilinear model fits better than a linear one.

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APPENDIX A

Level of Education on a 9-Point Scale

Point(s)	Dutch	English translation
1	• Basisonderwijs	• Primary school
2	• VMBO/VBO/MAVO • MBO-1	• Secondary education level 1 • Vocational education level 1
3	• MBO-2	• Vocational education level 2
4	• HAVO • MBO-3	• Secondary education level 2 • Vocational education level 3
5	• VWO • MBO-4 • Propedeuse HBO/WO	• Secondary education level 3 • Vocational education level 4 • First year toward bachelor's degree
6	• HBO	• Professional vocational bachelor's degree
7	• WO bachelor of kandidaats	• Bachelor's degree
8	• HBO/WO master/doctoraal • Korte postdoctorale opleiding (b.v. 1e graads leraarsopleiding)	• Professional vocational or master's degree • Short graduate degree (e.g., teaching degree for secondary education level 3)
9	• Doctorsgraad • Lange postdoctorale opleiding (twee jaar of langer; b.v. specialisatie arts)	• PhD • Long graduate degree (at least two years; e.g., physician's specialist training)

APPENDIX B

English Translations of the Questions Relevant to the Current Study

Relevant item on the individual questionnaire	Alternatives
• What is your highest obtained degree?	Nine alternatives, as listed in Appendix A
• How many hours do you usually spend reading? (Think about books, magazines, newspapers, and the Internet.)	
• For school/study/work?	• Less than 1 hour per week • 1–3 hours per week • 4–6 hours per week • 7–10 hours per week • More than 10 hours per week • I'm not studying and don't have a job.
• For pleasure?	• Less than 1 hour per week • 1–3 hours per week • 4–6 hours per week • 7–10 hours per week • More than 10 hours per week
• Do you have a subscription to a magazine or newspaper?	• No • Yes, 1 subscription • Yes, 2 subscriptions • Yes, 3 or more subscriptions

(*continued*)

English Translations of the Questions Relevant to the Current Study (*continued*)

Relevant item on the family questionnaire	Alternatives
• How many books do you have in the home? (For divorced parents, in the family home where the children spend most of their days)[a]	• Less than 25 • 25–75 • 75–125 • 125–175 • 175–225 • More than 225

Note. Both parents filled out the individual questionnaire. Together, they filled out the family questionnaire.
[a]This addition was irrelevant for the current study, as only cohabiting parent couples were included.

APPENDIX C

Raw Scores on the Reading Fluency Tests

	Words			Pseudowords		
Participant	Mean	Standard deviation	Range	Mean	Standard deviation	Range
Child	76.79	15.53	33–120	66.08	19.49	27–125
Father	99.85	17.34	66–145	88.86	22.80	36–144
Mother	100.60	14.83	54–134	95.41	20.05	37–142

APPENDIX D

Correlations Between Child Reading and Home Literacy for Younger and Older Children Separately

	Age band			
	7–10 years (*n* = 52)	11–17 years (*n* = 49)	Difference	
Variable	*r*	*r*	*z*	*p*
Socioeconomic status[a]				
Father's education	.35	.09	1.31	.190
Mother's education	.40	.07	1.71	.087
Home literacy environment				
Father's reading frequency	.34	.07	1.37	.171
Mother's reading frequency	−.05	.11	−0.75	.453
Magazine/newspaper subscriptions	.17	.11	0.31	.757
Number of books estimated in the home	.40	.33	0.42	.675

[a]See Appendix A for the full 9-point scale.