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Environmental influences on the longitudinal covariance of expressive vocabulary: measuring the home literacy environment in a genetically sensitive design

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Abstract

Background—Despite the well-replicated relationship between the home literacy environment and expressive vocabulary, few studies have examined the extent to which the home literacy environment is associated with the development of early vocabulary ability in the context of genetic influences. This study examined the influence of the home literacy environment on the longitudinal covariance of expressive vocabulary within a genetically sensitive design.

Methods—Participants were drawn from the Western Reserve Reading Project, a longitudinal twin project of 314 twin pairs based in Ohio. Twins were assessed via three annual home visits during early elementary school; expressive vocabulary was measured via the Boston Naming Test (BNT), and the Home Literacy Environment (HLE) was assessed using mothers' report.

Results—The heritability of the BNT was moderate and significant at each measurement occasion, h^2 = .29–.49, as were the estimates of the shared environment, c^2 = .27–.39. HLE accounted for between 6–10% of the total variance in each year of vocabulary assessment. Furthermore, 7–9% of the total variance of the stability over time in BNT was accounted for by covariance in the home literacy environment.

Conclusions—These results indicate that aspects of the home literacy environment, as reported by mothers, account for some of the shared environmental variance associated with expressive vocabulary in school aged children.

Keywords

Expressive vocabulary; home literacy environment; twins; genetics; environments

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Expressive vocabulary, which can be defined as a set of words a person is able to define, describe, or explain either orally or in writing, is a language-based skill that is important to early reading acquisition (Whitehurst & Lonigan, 1998). Given the large body of words known by most typical children, vocabulary is acquired not only by direct instruction, but also by indirect instruction and learning (National Reading Panel, 2000). Gaining a further understanding of the indirect learning environment is crucial for an appreciation of how children learn vocabulary. The home literacy environment is one aspect of indirect instruction that has been implicated in the development of expressive vocabulary. More specifically, the home literacy environment is defined as participation in literacy activities in the home, and includes both exposure to and frequency of parental activities such as joint book reading, modeling of independent reading and support of literacy-related activities, providing books, and going to the library (see Griffin & Morrison, 1997).

There is substantial support for a significant association between expressive vocabulary and the home literacy environment when measured concurrently (e.g., Postlethwaite & Ross, 1992; Payne, Whitehurst, & Angell, 1994). Longitudinal investigations have also indicated that a richer early home literacy environment is associated with enhanced vocabulary ability in early and middle childhood (van Steensel, 2006). Also, research has suggested that early measures of the home literacy environment significantly predict later vocabulary skills for children in pre-kindergarten and kindergarten (Roberts, Jurgens, & Burchinal, 2005), first grade (van Steensel, 2006), and second grade (Griffin & Morrison, 1997). This research in total indicates that success in early vocabulary performance is at least partially dependent on previous literacy exposure in the home (Dale & Crain-Thoreson, 1999).

Although these findings have shown a statistically significant relationship between vocabulary and the home literacy environment (e.g., van Steensel, 2006), the role of genetic and environmental influences is confounded in these previous studies. In particular, the relationship between the environment and outcome is confounded by the fact that biologically related family members living in the same home share both genes and aspects of the environment. For example, parents who engage in more literacy-based activities with their children may be providing an enriched literacy environment, but they could also be sharing genetic influences for stronger literacy skills. Thus it is unclear whether the correlation between home literacy environment and vocabulary is a function of environmental pathways, gene–environment pathways, or both.

Quantitative genetic methodology is in a unique position to examine this issue. Specifically, twin studies estimate the proportion of variance attributable to genetic influences (or heritability; h^2), shared environmental influences (i.e., non-genetic influences that make siblings more similar; c^2), and nonshared environmental influences (i.e., non-genetic effects that make siblings different, plus error; e^2). On average, previous twin studies have reported significant estimates of genetic and environment influences for vocabulary (h^2 = .32–.46 and c^2 = .40–.60 respectively; Byrne et al., 2006; DeThorne et al., 2008).

Within this context, it becomes possible to identify whether the home literacy environment accounts for a portion of the c^2 in concurrent measures of vocabulary. For example, the home literacy environment can be measured, and quantified, as a specific aspect of the more general shared environment (unless under the influence of an active gene–environment correlation, which may serve to inflate the h^2; see Oliver, Dale, & Plomin, 2005). Walker, Petrill, and Plomin (2005) accounted for a proportion of the shared environmental effects of school achievement with various measured aspects of the environment, such as class size, in twins from the UK. This method can also be extended to examine measured aspects of the environment within a longitudinal framework; thus allowing an examination of how a measured aspect of the shared environment influences the development of cognitive skills (e.g., Petrill, Pike, Price, & Plomin, 2004). For example, Hart, Petrill, Deater-Deckard, and Thompson (2007) examined whether a measure of chaos in the home accounted for a proportion of the shared environmental variance in twins general cognitive ability across two years of assessment. They found that chaos in the home accounted for a significant proportion of the shared environmental variance at each year of analysis, and it further contributed to the longitudinal covariance of general cognitive ability across the two years.

The influence of the home literacy environment on expressive vocabulary has yet to be examined within a genetically sensitive design (see McGrath et al., 2007, for an example of the influence of the home literacy environment on the genetics of general reading and language disability). The home literacy environment is consistently correlated with vocabulary, and vocabulary knowledge has been shown in previous twin research to be strongly influenced by the shared environment (e.g., Byrne et al., 2006). Thus, the assessment of the relationship between home literacy environment and vocabulary is particularly promising. For example, research has highlighted the importance of varied and repetitive word use in the home, an example of the shared environment, showing a positive correlation between number of words heard and vocabulary in young children (Hart & Risley, 1995; Weizman & Snow, 2001).

This study has two major goals. First, we examine whether the home literacy environment accounts for a significant proportion of the shared environmental influences on concurrent measures of expressive vocabulary. Second, we are interested in whether the home literacy environment can account for a proportion of the longitudinal covariance, or the stability over time, of expressive vocabulary in school-aged twins. From this, we estimate whether the home literacy environment measured at different time points in development can uniquely predict different proportions of the longitudinal covariance of expressive vocabulary, or if one baseline measure accounts for all the variance predicted by the home literacy environment.

Methods

Participants

Participants were drawn from the Western Reserve Reading Project (WRRP), an ongoing longitudinal twin project of 314 pairs of monozygotic (MZ; $N = 128$) and same-sex dizygotic (DZ; $N = 175$) twins in Ohio (see Petrill, Deater-Deckard, Thompson, DeThorne, & Schatschneider, 2006). Twins are first assessed upon their enrollment in the project, and are further evaluated annually for a total of five reading visits. Recruitment of the twins occurred through school nominations, in which schools were asked to send a packet of information to parents in their school system with twins who were enrolled in kindergarten but had not yet finished first grade. Families who returned a postcard stating their interest were enrolled in the project. Enrollment occurs throughout the year.

The present analyses are based on data available from the first three years of home visits. The twins were approximately 6 years old in year 1 (age $M = 6.09$ yrs, SD = .69 yrs, range = 4.33–8.25 yrs), 7 years old in year 2 (age $M = 7.17$ yrs, SD = .67 yrs, range = 6.00–8.83 yrs) and 8 years old in year 3 (age $M = 8.32$ yrs, SD = .74 yrs, range = 6.92–10.00 yrs). Twins' zygosity was determined using DNA analysis via a cheek swab. For the cases where parents did not consent to genotyping ($n = 76$), zygosity was determined using a parent questionnaire on twins' physical similarity (Goldsmith, 1991). Parent education levels varied widely and were similar for fathers and mothers: 12% high school or less, 18% some college, 30% bachelor's degree, 24% some post-graduate education or degree, 5% not specified. The educational attainment of the sample is similar to the general population, although the present sample is overrepresented for bachelor's degree and higher (US Census Bureau, 2007). Most families were two-parent married households (92%) and nearly all were White (92% of mothers, 94% of fathers).

Measures

Psychometric batteries of reading ability and language, including expressive vocabulary, were administered via annual home visits. In total, in-home testing took approximately 90 minutes per child for each year of data collection, and a separate tester in a separate room was used for each child. Also, around the time of the home visit, parents were mailed questionnaires to complete, taking approximately 20 minutes. Present analyses are based on maternal report. All parents completed a parental consent form and twins completed a child assent form before testing.

Expressive vocabulary—Expressive vocabulary was measured by the Boston Naming Test (BNT), a test of object naming from line drawings (Goodglass & Kaplan, 2001). The BNT is 60 items long, with each item increasing in difficulty, quantified by the inverse of frequency of use. Each year of measurement of the BNT was residualized for age and sex prior to analysis. It should be noted that age and grade are confounded in US schools. However, we have previously reported that age and grade correlate $r = .88$ in our sample (Petrill et al., 2006; Petrill, Deater-Deckard, Thompson, Schatschneider, & DeThorne, 2007). Additional multilevel modeling analyses have found that grade adds no additional explained variance beyond age in these data (available from the first author).

Home literacy environment—The home literacy environment (HLE) was measured via a parental survey of adult and child reading behaviors in the home (Griffin & Morrison, 1997). This portion of the HLE is 6 items long, assessing various family-level literary activities in the home, with a maximum score of 11 (see Appendix A). Higher scores correspond to endorsement of items that indicate better home literacy environments. Each year of measurement of the HLE indicated a normal distribution of scores, with all possible total scores represented (except for year 3, where a score of 0 is not represented). Given that the HLE is a family-level measure incorporating numerous individuals with different sexes and ages, raw data only was used for analysis.

Results

Descriptive statistics

Descriptive statistics of all three years of the Boston Naming Test (BNT) and the home literacy environment (HLE) are presented in Table 1. Mean scores for each year of the BNT and the HLE show a general increase across the years. Pearson correlations among the three years of the BNT and the HLE are displayed in Appendix B. Within the BNT, cross-year correlations are high and significant ($r = .80$–$.83$), suggesting substantial longitudinal covariance. Within the three years of the HLE, moderate and significant correlations ($r = .59$–$.67$) also suggesting covariance for the HLE across ages (and moderate test–retest reliability). Correlations between the BNT and the HLE were modest and significant within and across years ($r = .15$–$.39$).

Model fitting

Structural equation modeling simultaneously estimates the general additive genetic (or heritability; h^2), shared environment (c^2), nonshared environment (e^2) effects for each year of the BNT, as well as the shared environmental variance directly associated with the HLE (the ‘expanded univariate model’; see Table 2; Plomin, DeFries, McClearn, & McGuffin, 2008). As such, univariate estimates can be derived for this ‘expanded model’ using each year of the BNT with the HLE included as a specific environmental measure, allowing for estimates of the influences of HLE on each year of the BNT (see Hart et al., 2007, for more information). In this case, ‘HLE^2’ (Table 2), refers to the proportion of total variance in the BNT associated with shared environmental variation attributable to the HLE. Because the HLE is a family-level and not a twin-specific measure, it can only account for the variance from the shared environment. If HLE was not in the model, such as with a standard univariate analyses (Neale & Cardon, 1992), the variance associated with the HLE would be incorporated into the general shared environmental variance. These models were fitted to the data separately for years 1, 2, and 3. From these models, 95% confidence intervals were obtained for all parameter estimates. All analyses were conducted using all available raw data in Mx (Neale, Boker, Xie, & Maes, 2006).

Expanded univariate models—Point estimates for the expanded univariate model of the BNT, which includes the HLE as a measured aspect of the shared environment, are displayed in Table 2. The univariate estimates of the BNT including the HLE in the model suggest moderate and significant estimates of heritability (h^2 = .29–.49), shared environment (c^2 = .27–.42) and nonshared environment (plus error; e^2 = .14–.25). In addition, the variance associated with the HLE at each year of analysis for the BNT accounted for 6–10% of the total variance in the BNT, or 13–27% of the general shared environmental variance.

Expanded longitudinal model—This method can be expanded to examine the covariance between the HLE and the BNT across all three years of analysis. This extension of the expanded univariate model allows for a better understanding of the genetic and environmental overlap among the three years of the BNT, as well as allowing for an examination of the association of each year of the HLE to the covariance of the BNT across years (see Figure 1). More specifically, this model partitions the covariance between all three years of the BNT into estimates of genetic, shared environmental and nonshared environmental overlap (A_1, C_1, and E_1, respectively). Also, the model estimates the genetic and environmental overlap (A_2, C_2, and E_2, respectively) between years 2 and 3 that is independent from the year 1 assessment. Finally, the A_3, C_3, and E_3 factors represent the genetic and environmental variance associated with year 3 BNT independent from years 1 and 2. The longitudinal expanded model also measures the covariance between the BNT and the HLE. The first HLE factor ('HLE years 1, 2 and 3') represents the covariance among all three years of the HLE measure, as well as all three years of the BNT. The second HLE factor ('HLE years 2 and 3') accounts for the covariance among years 2 and 3 of the HLE and the BNT that is independent from the first HLE factor which includes covariation with year 1. Finally, the third factor ('HLE year 3') represents the covariance between year 3 HLE and BNT which is independent from the covariance associated with the previous two factors.

Table 3 displays the results of this expanded longitudinal model. The diagonal elements for each matrix represent, with confidence intervals, the univariate genetic (A; h^2 = .32–.54), shared environmental (C; c^2 = .26–.42), nonshared environmental (E; e^2 = .15–.24) and home literacy environment (HLE^2 = .04–.08) influences as described before in the expanded univariate models. The off-diagonal elements of Table 3 display the genetic, shared, and nonshared environmental contributions to the correlation between the longitudinal assessments of the BNT. Additionally, this table also presents the contribution of the measured HLE to the correlation of the BNT across the annual measurement occasions.

More specifically, by summing the standardized genetic, shared environmental, nonshared environmental and the HLE specific pathways between year 1 and year 2 of the BNT from the expanded longitudinal model, the estimated total phenotypic correlation between expressive vocabulary years 1 and 2 is calculated ($r_{estimated}$ = .35 + .39 + .06 + .05 = .85). From this r = .85, the extent to which genetics influence the covariance between years 1 and 2 is .35, or 41% of the overlap between expressive vocabulary from years 1 and 2 (41% = .35/.85 * 100). Using the same logic, shared environmental and nonshared environmental influences not attributable to the HLE account for 46% (.39) and 7% (.06) of the correlation between expressive vocabulary from years 1 to 2 respectively. Finally, the HLE accounted for 6% (.05) of the covariance of the BNT from year 1 to year 2. This same set of calculations can be used to examine the magnitude of the sources of covariance across other measurement occasions. Genetic influences account for 49% (.40) of the covariance from year 1 to year 3 of the BNT, and 52% (.44) between year 2 and 3. Shared environmental influences accounted for 33% (.27) of the covariance between year 1 and year 3, and 33% (.28) of the correlation between years 2 and 3. The nonshared environment accounted for 9% (.07) and 7% (.06) of the correlation between years 1 and 3, and years 2 and 3, respectively. Lastly, the HLE accounts for 9% (.07) of the covariance between year 1 and year 3 BNT, and 7% (.06) of the covariance between year 2 and year 3 of the BNT.

Although the 95% confidence intervals around each parameter estimate suggests statistical significance for the influence of the HLE in general on the covariance of multiple measures of the BNT, it cannot be determined from Table 3 how the individual years of measurement of the HLE influences this covariance. In particular, it could be the case that the three assessments of the HLE load on one general factor which influences the BNT across measurement occasions or that there is time-specific prediction of the HLE which independently accounts for the variance in the BNT. To test this question, we used the full expanded longitudinal model as the null model for all tests of model fit to asses the influence of the BNT on the HLE. Therefore, four submodels were tested within the expanded longitudinal model (see Table 4). The first submodel (titled ‘Drop all HLE factors’) dropped all the HLE pathways to all years of the BNT. This model tested the most basic issue; whether the HLE is important to the fit of the overall model. This submodel resulted in a significant decrease in model fit from the full model, ($\chi^2_{change} = 40.83$, $\Delta df = 6$, $p < .05$). Dropping the pathways from year 2 and year 3 HLE to BNT (titled ‘Drop HLE year 2 and HLE year 3’) tested whether variance in the HLE related to year 2 and year 3 independent from year 1, is necessary (see Figure 1). This model resulted in a significant decrease in model fit ($\chi^2_{change} = 11.04$, $\Delta df = 3$, $p < .05$). Moreover, dropping year 2 HLE (titled ‘Drop HLE year 2’) also resulted in a significant decrease in model fit ($\chi^2_{change} = 11.04$, $\Delta df = 2$, $p < .05$). However, dropping year 3 HLE (titled ‘Drop HLE year 3’) did not ($\chi^2_{change} = .00$, $\Delta df = 1$, *ns*).

Discussion

The goals of this study were twofold. The first was to examine whether the home literacy environment accounted for a significant proportion of the shared environment associated with expressive vocabulary. The second was to test whether the home literacy environment accounted for a proportion of the covariance in expressive vocabulary across early childhood. From this, the extent to which each individual year of measurement of the home literacy environment uniquely predicted the covariance across the years of expressive vocabulary was estimated.

As was predicted by the previous quantitative genetic literature on expressive vocabulary, the present results indicated genetic and shared environmental influences contribute significantly to each year of measurement of expressive vocabulary (e.g., Byrne et al., 2006). It is also worth noting that the present analyses suggested an increase in heritability estimates for expressive vocabulary across development, further corroborating a common finding in the quantitative genetic literature in cognition (see Plomin et al., 2008, for review). Also, the literature has suggested a moderate and significant association between the home literacy environment and expressive vocabulary (e.g., Griffin & Morrison, 1997). Given this precedent, it was not surprising to find that the measured home literacy environment accounted for a significant proportion of the shared environmental variance at each year of analysis of the BNT (6% to 10% of the total variance of the model) after controlling for genetic influences associated with expressive vocabulary. This is equivalent to 13–27% of the variance associated with the general shared environment, a significant, but not a major proportion, of the variance.

Additionally, an expanded longitudinal model was examined to determine the influence of the home literacy environment on expressive vocabulary in the context of a longitudinal genetically sensitive design. The model suggested that the home literacy environment influenced the longitudinal covariance of vocabulary, accounting for between 6–9% of the total variance across measurements, attributable to measurable shared environmental effects. Furthermore, the comparison of nested models allowed for an examination of the influence of each specific year of measurement of the home literacy environment on the longitudinal covariance of expressive vocabulary. Therefore, when all years of the home literacy environment were examined individually, it was determined that year 3 was accounted for by previous years of the home literacy environment. However it remains plausible that the year 3 home literacy variable may be related to vocabulary measures at later ages not measured presently.

There is some question in the literature as to whether individual differences in the home literacy environment remain stable, despite the child's age or level of schooling (Griffin & Morrison, 1997). For example, it could be the case that multiple measures of the home literacy environment only serve to act together as one general factor of the home environment, regardless of time of measure. The present results suggest a more complex picture. Specifically, the mean score for the home literacy environment from year 1 was significantly different from year 2 (t-test = –4.77, $p < .05$), but year 2 was not significantly different from year 3 (t-test = −.762, *ns*). The phenotypic correlations between the years was moderate (r = .59–.67), suggesting some overlap, but also independence across the years. Most telling, however, was the comparison of nested models, indicating that not only was the first year of measurement of the HLE an important contributor to the covariance across the years of the BNT, but also the second year of measurement, beyond that accounted for by the first year. This suggests that there was some independent variance of the HLE when the children were around 7 years old that is associated with expressive vocabulary independent from the HLE as measured one year earlier. At this age, children are generally in their second year of formalized education, suggesting that the transition to school is still affecting these children to the extent their expressive vocabulary is related to their home literacy environment. It may be the case that the increased complexities of vocabulary required for school, compared to what children need before going to school, is being reflected in the home literacy environment. For example, more books may be taken out from the library. This was not true for year 3, however, suggesting that there may be some stabilization in the impact of the home literacy environment on expressive vocabulary. Therefore, although the home literacy environment at year 3 is important for expressive vocabulary measured at that same year, it is not independent from the influence of the previous two years of measurement of the home environment. In other words, what is affecting expressive vocabulary as it relates to the home literacy environment in year 3 is stable from the previous years. This may also be due to education: by the year 3 assessments, most of the children have experienced at least 3 years of formal schooling. With increased years in the classroom, the home literary practices measured by the HLE may become stable as compared to those not presently measured in the home (e.g., vocabulary homework assigned), or from vocabulary influences in school which supersede those at home (e.g., peers and teachers). Or, it could simply be the case that there is no significant difference in measured home literacy activities after two previous years of measurement.

There are several limitations to the conclusions that can be drawn from this study. First, it may be the case that the present measure of the home literacy environment does not fully characterize literacy practices in the home. However, the measure of the home literacy environment is a standard measure of the home environment, and has been previously shown to be a strong and independent predictor of vocabulary performance (Griffin & Morrison, 1997). An additional limitation is the use of a single measure to represent expressive vocabulary via object naming. Given the complexity of this construct, findings may vary based on the form of measure use, such as a measure of vocabulary from a conversational language sample (see

DeThorne et al., 2008). Related to this, a broader measure of the general language performance incorporating other parts of speech other than just object naming might have resulted in different results as described presently.

Another limitation concerns the potential for passive gene–environment correlations to be spuriously inflating the shared environmental effects (Plomin & Bergeman, 1991). It is the case that the entire family shares the same home literacy environment as measured presently, meaning that it may not be thought of as purely a direct measure of the environment. Rather, there may be shared genes in the family contributing to the resemblance amongst the family members (Plomin & Bergeman, 1991). Therefore, it is not possible to know if the present measure of the home literacy environment is truly capturing 'pure' shared environmental influences that create sibling similarity above and beyond genetic influences (Turkheimer, D'Onofrio, Maes, & Eaves, 2005). However, adoption studies that have tested this potential confound have found little evidence for passive gene–environmental correlations in the links between measured family environment variables and cognitive abilities in early childhood (e.g., Rice, Fulker, & DeFries, 1986). Also, it could be the case that there are active gene–environment correlations at work which cannot be known because the home literacy environment is a family-level measure, so individual-specific measurement is not possible. This may be resulting in genetic effects not being separable from the environmental effects as is assumed here.

Finally, there may be difficulties generalizing the results for twins to the greater population, especially concerning twin language development (e.g., Stromswold, 2006). For example, it has been suggested that twins have a different linguistic profile than singletons, specifically with the greater possibility of delays and impairments (Rutter, Thorpe, Greenwood, Northstone, & Golding, 2003). This may be influencing the estimates of genetic and environmental influences on the present vocabulary measure, by expressly lowering the genetic effects and inflating the environmental effects. Despite this, it has been suggested that any major differences in cognitive performance between singletons and twins become nonsignificant by the age of 5, and would therefore be negligible in the present sample (Evans & Martin, 2000).

Despite these limitations, the present study has suggested that the Home Literacy Environment has a significant role in both the independent influences and the covariance of the Boston Naming Test in early childhood. It is likely that this is just one of many environmental aspects that influence both the direct and indirect instruction of expressive vocabulary. Previous work has suggested a possible influence of order and chaos in the home (e.g., Hart et al., 2007) on general cognitive ability, and future research may find similar effects on vocabulary. Identifying these aspects of the environment is important to gain a better understanding of how children learn the complex abilities that are required early in formal schooling. This is especially true of potential home environments. The home literacy environment is most likely a general indicator of the home (e.g., organization) and parental investment in learning (e.g., spare time invested in literacy), and other such markers of the family environment may also prove to be important aspects of the shared environment. This work allows for a better understanding of the home, and possibly school influences, that contribute to the development and stability of early expressive vocabulary. Identifying these environmental aspects allows for future targeting for cognitive performance-based interventions.

Key points

- A richer home environment is associated with enhanced expressive vocabulary in children.

- Quantitative genetic methodology allows for quantifying the shared environmental influences of expressive vocabulary into specific aspects of the environment, such as the home literacy environment.
- Analyses suggest that the home literacy environment accounts for between 6–10% of the total variance in each year as children go from kindergarten to second grade, but also 7–10% of the covariance of expressive vocabulary across the years.
- These results suggest that the home literacy environment, a proxy for the home environment and parental investment in learning, is a significant aspect in the child's expressive vocabulary ability.

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Abbreviations

HLE	home literacy environment
BNT	Boston Naming Test

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Appendix A

Individual items from the home literacy environment (Griffin & Morrison, 1997)

1. *Does anyone in your home have a library card? (___) yes (___) no. If YES, how often is it used?*

0 points = once a month or less

1 point = more than once a month

2. *Does your family subscribe to newspapers/magazines? (___) yes (___) no.*

a. # Newspapers

0 points = no newspapers

1 point = 1 newspaper

2 points = more than 1 newspaper

b. # Adult magazines

0 points = no adult magazines

1 point = 1 adult magazines

2 points = more than 1 adult magazines

c. # Child magazines

0 points = no child magazines

1 point = 1 child magazines

2 points = more than 1 child magazines

3. *How often do you read to yourself? (___) daily (___) several times a week (___) weekly or less.*

0 points = weekly or less

1 point = several times a week

2 points = daily

3. *How often does your spouse read to himself/herself? (___) daily (___) several times a week (___) weekly or less.*

0 points = weekly or less

1 point = several times a week

2 points = daily

Appendix B

Pearson correlations among years 1, 2, and 3 of the Boston Naming Test (BNT) and the Home Literacy Environment (HLE)

Variable	BNT year 1	BNT year 2	BNT year 3	HLE year 1	HLE year 2	HLE year 3
BNT year 1	1.00					
(*n*)	581					
BNT year 2	.83	1.00				
(*n*)	459	472				
BNT year 3	.80	.82	1.00			
(*n*)	324	299	326			
HLE year 1	.28	.15	.29	1.00		
(*n*)	527	436	304	567		
HLE year 2	.23	.24	.39	.63	1.00	

Variable	**BNT year 1**	**BNT year 2**	**BNT year 3**	**HLE year 1**	**HLE year 2**	**HLE year 3**
(*n*)	487	434	302	487	513	
HLE year 3	.31	.30	.33	.59	.67	1.00
(*n*)	377	342	296	381	375	403

All correlations were significant at two-tailed $p < .01$.

Note. The individuals using all available data from year 1, 2 and 3 cohorts are referred to by *n*.

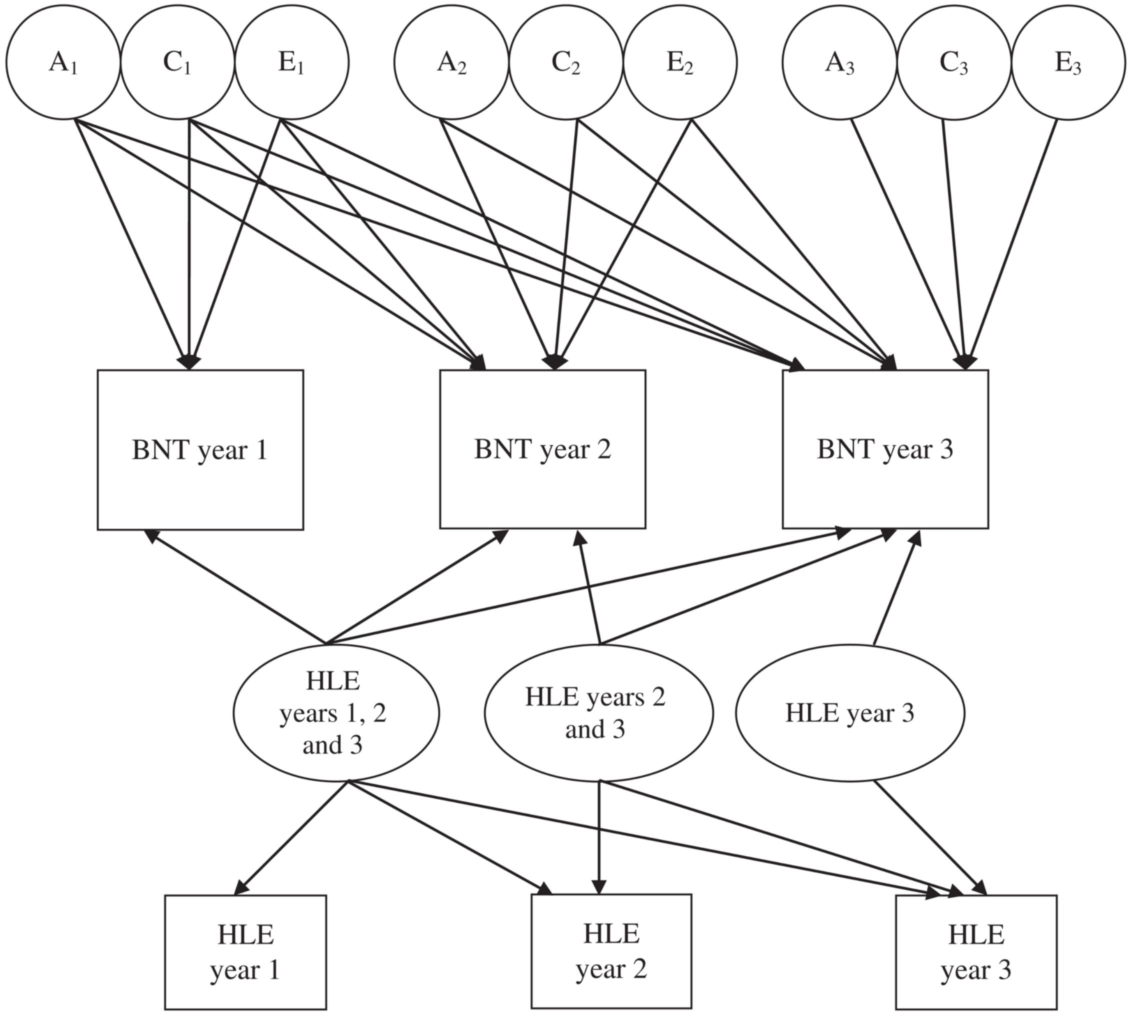

Figure 1.

Expanded longitudinal model estimating genetic, shared environmental, nonshared environmental and identified shared environmental variance of Home Literacy Environment (HLE), for year 1, 2 and 3 Boston Naming Test (BNT). Note that only one twin's pathways are displayed here for simplicity

Table 1

Means and standard deviations (SD) for years 1, 2 and 3 Boston Naming Test (BNT) and home literacy environment (HLE)

Variable	**Mean**	**SD**	**Minimum**	**Maximum**	***n***
BNT year 1	28.04	6.99	8.00	46.00	614
BNT year 2	32.29	7.11	14.00	51.00	530
BNT year 3	37.38	6.68	13.00	52.00	413
HLE year 1	6.20	2.32	0.00	11.00	567
HLE year 2	6.78	2.34	0.00	11.00	513
HLE year 3	7.05	2.24	1.00	11.00	403

Note. The number of individuals using all available data from the year 1, 2 and 3 cohorts are referred to by *n*.

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Table 2

Univariate model fitting for the expanded model, years 1, 2, and 3 Boston Naming Test with years 1, 2 and 3 home literacy environment (HLE) [95% confidence intervals]

	h^2	c^2	e^2	HLE^2	−2ll	*df*
Year 1	.29 [.07–.51]	.39 [.18–.56]	.25 [.19–.34]	.07 [.03–.13]	2579.06	806
Year 2	.36 [.17–.57]	.42 [.21–.58]	.17 [.12–.23]	.06 [.01–.12]	2231.54	698
Year 3	.49 [.28–.75]	.27 [.02–.48]	.14 [.10–.21]	.10 [.03–.19]	1644.61	510

Table 3

Heritability, shared, nonshared, and identified environmental influence (along the diagonals) in Boston Naming Test years 1, 2 and 3 estimated from longitudinal expanded model. The off-diagonals represent parameter estimates of the genetic and environmental contributions to the correlation between longitudinal assessments of the Boston Naming Test [95% confidence intervals]

		Year 1	**Year 2**	**Year 3**
Boston Naming Test				
A	Year 1	.32 [.16–.53]		
	Year 2	.35 [.20–.51]	.37 [.22–.56]	
	Year 3	.40 [.24–.60]	.44 [.28–.63]	.54 [.31–.80]
C	Year 1	.37 [.18–.57]		
	Year 2	.39 [.21–.57]	.42 [.23–.61]	
	Year 3	.27 [.08–.46]	.28 [.09–.47]	.26 [.03–.50]
E	Year 1	.24 [.19–.30]		
	Year 2	.06 [.03–.11]	.17 [.13–.22]	
	Year 3	.07 [.03–.12]	.06 [.02–.10]	.15 [.10–.21]
Home Literacy				
Environment Year 1		.08 [.03–.15]		
	Year 2	.05 [.01–.12]	.04 [.01–.10]	
	Year 3	.07 [.02–.13]	.06 [.02–.12]	.07 [.02–.15]

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Table 4

Model fitting results examining the expanded longitudinal model of years 1, 2, and 3 home literacy environment (HLE) with years 1, 2 and 3 Boston Naming Test (BNT)

Model	−2LL	df	Null χ^2_{change}	NullΔdf	*Null* p_{change}
Full	5461.32	1999			
Drop all HLE factors	5502.15	2005	40.83	6	*
Drop HLE year 2 and HLE year 3	5472.36	2002	11.04	3	*
Drop HLE year 2	5472.36	2001	11.04	2	**
Drop HLE year 3	5461.32	2000	.00	1	NS

Note. The model fit of the full expanded longitudinal model versus a fully saturated model was tested. This resulted in a nonsignificant decrease in model fit ($\chi^2_{change} = 65.28$, $\Delta df = 60$, *ns*), suggesting that the full expanded longitudinal model fit the data as well as the saturated model. Therefore, the null full expanded longitudinal model was used as the full model.

** $p < .05$

* $p < .001$.