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Title: Literacy skills seem to fuel literacy enjoyment, rather than vice versa

Year: 2023

Version: Published version

Received: 2 September 2021 | Revised: 17 June 2022 | Accepted: 15 July 2022

DOI: 10.1111/desc.13325

Developmental Science WILEY

RESEARCH ARTICLE

Literacy skills seem to fuel literacy enjoyment, rather than vice versa

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Funding information
Academy of Finland Center of Excellence in Complex Disease Genetics, Grant/Award Numbers: 213506, 129680; Academy of Finland, Grant/Award Numbers: 100499, 205585, 118555, 308248, 312073; National Institute of Alcohol Abuse and Alcoholism, Grant/Award Numbers: AA-12502, AA-00145, AA-09203; NWO (Dutch Research Council) VENI, Grant/Award Number: 451-15-017; NWO Gravitation, Grant/Award Number: 024.001.003; ZonMw, Grant/Award Number: 531003014; Eunice Kennedy Shriver National Institute of Child Health and Human Development, Grant/Award Number: P50HD052120; Academy Research Fellow by the Academy of Finland, Grant/Award Number: 308698; Academy of Finland, Grant/Award Numbers: 314639, 276239

Abstract

Children who like to read and write tend to be better at it. This association is typically interpreted as enjoyment impacting engagement in literacy activities, which boosts literacy skills. We fitted direction-of-causation models to partial data of 3690 Finnish twins aged 12. Literacy skills were rated by the twins' teachers and literacy enjoyment by the twins themselves. A bivariate twin model showed substantial genetic influences on literacy skills (70%) and literacy enjoyment (35%). In both skills and enjoyment, shared-environmental influences explained about 20% in each. The best-fitting direction-of-causation model showed that skills impacted enjoyment, while the influence in the other direction was zero. The genetic influences on skills influenced enjoyment, likely via the skills→enjoyment path. This indicates an active gene-environment correlation: children with an aptitude for good literacy skills are more likely to enjoy reading and seek out literacy activities. To a lesser extent, it was also the shared-environmental influences on children's skills that propagated to influence children's literacy enjoyment. Environmental influences that foster children's literacy skills (e.g., families and schools), also foster children's love for reading and writing. These findings underline the importance of nurturing children's literacy skills.

KEYWORDS
causality, heritability, literacy enjoyment, literacy skills, print exposure, reading ability

Highlights

- It's known that how much children enjoy reading and writing and how good they are at it correlates ~0.30, but causality remains unknown.
- We tested the direction of causation in 3690 twins aged 12.
- Literacy skills impacted literacy enjoyment, but not the other way around.
- Genetics influence children's literacy skills and how much they like and choose to read and write, indicating genetic niche picking.

1 INTRODUCTION

> "Reading for pleasure is the single biggest factor in success later in life, outside of an education. Study after study has shown that those children who read for pleasure are the ones who are most likely to fulfil their ambitions. If your child reads, they will succeed – it's *that simple.*"
>
> Bali Rai

Proficient literacy skills are essential in our literate society for communication and learning. Unsurprisingly, avid readers tend to have good literacy skills: reading skills correlate ~0.30 with reading enjoyment (Froiland & Oros, 2014; Retelsdorf et al., 2011). Moreover, word reading, reading comprehension, and spelling (together: literacy skills) each correlate ~0.40 with how much children and adolescents read for pleasure, also known as print exposure (Mol & Bus, 2011). Print exposure and reading enjoyment are closely related and have also been subsumed under the term reading engagement (Brozo et al., 2007; Silinskas et al., 2020). Reading enjoyment, for its part, can be defined as the perceived intrinsic value of reading (Eccles et al., 1993). We focused on enjoyment and skills not only in reading but the broader domain of literacy. Regarding literacy enjoyment and literacy skills, we went beyond merely establishing an association, and aimed to investigate what is cause and effect. In what follows, we discuss previous theoretical work, previous empirical work (on print exposure and on literacy enjoyment), genetic and environmental contributions, genetic niche-picking, and the current study's aims, analytical approach, and hypotheses.

Regarding theoretical work, based on general motivation theories, such as expectancy-value theory (Eccles et al., 1993) and self-determination theory (Ryan & Deci, 2000), literacy enjoyment can be theorized to boost literacy skills (i.e., enjoyment→skills). This is because intrinsic motivation would elicit more frequent and focused literacy activities (De Naeghel et al., 2012; Wigfield & Guthrie, 2000). This could be represented as motivation/enjoyment→print exposure→skills. Indeed, intrinsic reading motivation has been found to correlate 0.85 with print exposure (underlining the similarity of these constructs) and 0.38 with reading skills (Becker et al., 2010). However, reading enjoyment is also based on one's perceptions of aptitudes and one's previous experiences (Eccles et al., 1993), which are clearly based on reading skills. Hence, we may expect reciprocal causal effects. In line with this, Vu et al. (2022) recently theorized a motivation-achievement cycle, which would more explicitly predict a reciprocal association between enjoyment and skills (i.e., enjoyment ↔ skills). Finally, the body of literature that operationalizes academic motivation as academic self-concept of ability, supports that academic motivation and achievement are mutually reinforcing (Guay et al., 2003; Luo et al., 2010; Marsh & Martin, 2011).

Regarding empirical work, the correlation between reading engagement and skills is often interpreted unidirectionally, as evidence that book reading boosts literacy. On the contrary, empirical evidence is piling up that, at least for print exposure in childhood, the influence runs from reading skills to print exposure. Thus, good literacy skills boost literacy enjoyment and book reading. Evidence comes from both longitudinal studies and twin studies (Harlaar et al., 2011; Torppa et al., 2020; Toste et al., 2020; van Bergen et al., 2018). Most of these studies focus on the early years of primary school. However, two studies followed (Finnish) children up to adolescence (Torppa et al., 2020; van Bergen et al., 2021). They also accounted for autoregressive effects, to be able to investigate whether one trait influences the change in the other trait (van Bergen et al., 2021). They found that the direction of influences flipped from either reciprocal or unidirectional reading skills→print exposure in the early grades (1–3) to mainly print exposure→reading skills in later grades (4–9) (Torppa et al., 2020; van Bergen et al., 2021). Yet a recent (American) twin study in early adolescence found more support for a reading skills→print exposure influence than for the other direction or bidirectional effects (Erbeli et al., 2020). This was in line with a (Dutch) twin study in young readers (7½ years) who only found a reading skills→print exposure influence (van Bergen et al., 2018). Recall that print exposure in all these studies refers to voluntary reading, outside of school hours.

For enjoyment (rather than print exposure), studies have mostly looked at the enjoyment→skills direction only. When controlling for Grade 5 reading skills, reading enjoyment had very little or no effect on Grade 8 reading skills (Froiland & Oros, 2014; Retelsdorf et al., 2011, respectively). In a large British longitudinal twin study, Malanchini et al. (2017); see their supplement) did a test and find a bidirectional effect. Between ages 9½ and 12, they found the bidirectional effects between reading (comprehension) skills and reading enjoyment to be similar and moderate (0.22–0.23). Taking all these studies together, the mixed findings seem to be due to differences in the studied age group, chosen statistical approach, traits and measures (e.g., print exposure or enjoyment), or country of study and hence differences in orthographic transparency and educational system.

Twin studies also shed light on the degree to which individual trait differences are due to genetic and environmental differences (Hart et al., 2021). The overall picture is that individual differences in literacy skills are mainly genetic in origin, while individual differences in literacy enjoyment and voluntary reading (i.e., print exposure) are due to both genetic differences and shared-environmental differences (Erbeli et al., 2020; Harlaar et al., 2014; van Bergen et al., 2018). Shared-environmental influences are those environmental influences that make children growing up together more alike, such as how many books there are in the home and whether they see their parents reading. In the Malanchini study (2017), they could also study the genetic and environmental contributions to the bidirectional effects: the cross-lagged link from skills to enjoyment was fully genetic in origin, while the link from enjoyment to skills was explained by genetic and non-shared environmental influences. Non-shared environmental effects are difficult to interpret because they could reflect true environmental influences that make twin siblings less alike, like influences of an accident, separate friends, or individual experiences, but non-shared environmental influences also include measurement error. But we can conclude, perhaps counterintuitively, that environmental influences shared between siblings and making them more alike, like the home-literacy environment, did not contribute to the bidirectional effects. That the link from skills to enjoyment was fully genetic (Malanchini et al., 2017), fits with the genetic skills-to-print-exposure link found by van Bergen et al. (2018). In van Bergen et al., the sources of individual differences in the latent trait 'reading skills' were 87% genetic and 13% non-shared environment, so no influences of the shared environment. Thus, the path from reading skills to print exposure was almost fully driven by genetic influences on reading skills.

Heritable influences on skills that subsequently influence reading behaviours can be interpreted as an active gene-environment correlation, or in other words, as genetic niche-picking: Innate child factors influence children's talent for effortless reading (or lack thereof) and, subsequently, those innate factors influence whether a child after school picks up a book or rather chose something else to do, like kicking a ball. Note that reading ability is just one of the many factors that influence reading behaviours. For example in van Bergen et al. (2018), reading ability explained 16% of the variance in print exposure. The remaining print-exposure variance was due to genetic and shared-environmental influences, in equal shares.

In the current study, we aim to test uni- and bidirectional causation between literacy skills and literacy enjoyment. Additionally, we study the sources of individual differences in skills and enjoyment, in terms of genetic, shared and non-shared environmental sources. In the bigger picture, we extend a triangulated set of recent studies that probe possible causal relations between literacy skills and engagement using different cohorts and designs. The current study, on 12-year-old Finnish twins, employs the direction-of-causation design (Duffy & Martin, 1994; Heath et al., 1993) used in two previous twin studies (one American: Erbeli et al., 2020; one Dutch: van Bergen et al., 2018).

The direction-of-causation design tests competing hypotheses about why two traits correlate (Duffy & Martin, 1994; Heath et al., 1993). These would be for literacy skills and literacy enjoyment: (a) common genetic influences, (b) common environmental influences, (c) both common genetic and common environmental influences, (d) skills influencing enjoyment, (e) enjoyment influencing skills, and (f) reciprocal influences. Models a to c explain the correlation by shared influences, while models d to e explain the correlation by causal influences. Cross-sectional twin data allow the testing of these hypotheses because the different hypotheses give rise to different "cross-trait cross-twin" correlations. Cross-trait cross-twin correlations in our case are the correlation between skills of twin 1 (i.e., the first-borns) with the enjoyment of twin 2 (i.e., their co-twins) and the correlation between enjoyment of twin 1 with skills of twin 2. Similarly, in longitudinal studies what helps to infer the direction of influences are "cross-wave cross-trait" correlations. In the direction-of-causation twin design, discriminating between the different models works best if the traits are reasonably correlated (Duffy & Martin, 1994, recommend >0.25), the traits differ in heritability, and the traits are modeled as latent variables to reduce measurement error (Duffy & Martin, 1994; Heath et al., 1993).

The current study is methodologically a replication of the two twin studies (Erbeli et al., 2020; van Bergen et al., 2018), but set in a different country and using broader definitions of literacy skills (not just reading) and literacy enjoyment (rather than print exposure). We test whether our findings are in line with the direction-of-causation twin studies (which found reading skills→print exposure) or whether they are in line with the longitudinal studies (one British and two Finnish, which found in adolescence, reading skills ↔ print exposure). Being a methodological replication of the Dutch and American twin studies, but set in the same country as two of the previous longitudinal studies, can explore if a similar methodology may lend similar results or if a similar sample may lend similar results. Based on the previous twins studies, we expect to find support for a unidirectional model (i.e., literacy skills→literacy enjoyment). However, based on the two longitudinal Finnish studies, we may expect reciprocal associations in adolescence (i.e., literacy skills ↔ literacy enjoyment), if the context is critical.

2 | METHODS

2.1 | Participants

Participants for this study were twin pairs from a longitudinal population-based Finnish Twin Cohort study, FinnTwin12 (Kaprio, 2013; Kaprio et al., 2002). In Finntwin12, 5600 twins and their families (~90% of those invited) were enrolled from nationwide birth cohorts born 1983–1987. Some data-collection waves targeted the full sample and some investigated selected sub-samples. The data reported here is based on teacher-report (on literacy skills) and self-report (on literacy enjoyment) at baseline when the twins were 11–12 years old. Twin pairs that had different teachers filling out the questionnaire were omitted from the sample (96 pairs). Teacher data were available for 3690 twins: monozygotic twins (MZ) $n = 1304$, dizygotic same-sex twins (DZ) $n = 1222$, and dizygotic opposite-sex twins (DOS) $n = 1154$. Self-report data were available for a subsample of 1639 twins (MZ $n = 647$, DZ $n = 506$, and DOS $n = 486$). Thus, we focused on a sample of twins with teacher data, of whom almost half had also self-report data. The twins who returned the self-report (pupil questionnaire) had similar literacy skills as the twins who did not: reading fluency ($F(1, 3674) = 1.19$, $p = 0.28$, Cohen's $d = 0.05$), reading comprehension ($F(1, 3674) = 1.11$, $p = 0.29$, Cohen's $d = 0.04$), spelling ($F(1, 3674) = 1.03$, $p = 0.31$, Cohen's $d = 0.03$), and writing ($F(1, 3670) = 1.44$, $p = 0.23$, Cohen's $d = 0.04$).

The FinnTwin12 study protocol was approved by the Helsinki and Uusimaa Hospital District ethical review board and the Institutional Review Board of Indiana University, Bloomington. Parents gave permission to assess their children and to contact their teachers. FinnTwin12 data are available through the Institute for Molecular Medicine Finland Data Access Committee for authorized researchers who have IRB/ethics approval and an institutionally approved study plan. For more details, please contact the Data Access Committee (fimm-dac@helsinki.fi).

2.2 | Measures

2.2.1 | Literacy skills

Teachers were asked to evaluate the literacy skills of each of the twins: "Please evaluate the student's performance in the following skills in comparison to the grade average level." There were four items on literacy: oral reading fluency, reading comprehension, spelling, and writing. Five response options were given 1 (*performs considerably worse than average*), 2 (*performs slightly worse than average*), 3 (*average performance*), 4 (*performs slightly better than average*), and 5 (*performs considerably better than average*. Cronbach alpha for the items was 0.92, showing excellent internal reliability. External validity of teacher reports could not be assessed within this Finnish sample, but from British and Dutch samples we know that teacher reports correlate highly (~0.70) with test scores (Rimfeld et al., 2019; van Bergen et al., 2018). Moreover, teacher reports and test scores were equally heritable, stable, and predictive of later exam grades and university enrolment (Rimfeld et al., 2019). There is no reason why Finnish teacher reports would be less valid.

2.2.2 | Literacy enjoyment

Twins were asked to evaluate their literacy enjoyment with two items; "Do you like reading?" and "Do you like writing?" Three response options were given: 1 (*No*), 2 (*Sometimes*), 3 (*Yes*). Cronbach's alpha for the items was 0.60.

2.3 | Analytical approach

First, a phenotypic two-factor measurement model was estimated with one latent variable for the teacher evaluations on twins' literacy skills (four indicators) and another latent variable for the twins' self-reported literacy enjoyment (two indicators; Figure 2). We modelled an equality constraint on the two indicators of literacy enjoyment, to ensure that both indicators would contribute equally to the latent variable. Without an equality constraint, one of the two indicators may get a factor loading close to one, so that the latent factor basically only represents that one indicator. The measurement model served as the basis for the correlational and the direction-of-causation behavioural genetic models.

Next, we tested several levels of factorial invariance in the two-factor model to test whether the factors are invariant across the five twin groups. That is, whether the measurement model is the same for each twin group. Apart from plausible mean differences between boys and girls, there is no reason to believe that the measurement model would be different across twin groups (e.g., different factor loading for girls and boys, or different factor loadings for MZ and DZ twins). Still, in twin modelling it is good to check that the invariance assumption holds across the twin groups. If measurement invariance across groups does not hold, the measurement is not similar for the groups, which makes the interpretation of the model unclear. The factorial invariance in the two-factor model was tested with the following successive stages: First, factor loadings were set equal across the five twin groups (i.e., MZ males, MZ females, DZ males, DZ females, DOS). Next, factor loadings and intercept of observed variables were set equal across the five twin groups. Finally, factor loadings, intercepts and residual variances of observed variables were set equal across five twin groups.

Smaller Root Mean Square Error of Approximation (RMSEA) values indicate better model fit. Because of the model complexity and large sample, the chi-square difference test is too sensitive for testing models with successively stricter invariance. Therefore, changes in RMSEA (ΔRMSEA) was used as an index for model fit in the model comparisons. According to Chen (2007), invariance holds if the RMSEA does not increase more than 0.015.

Next, we fitted the behavioural-genetic correlational model. Here we investigated the relative contributions of genes and environments on the phenotypic variances and covariance of literacy skills and literacy enjoyment. The twin method exploits data on MZ and DZ twin pairs who are raised together. MZ twins are genetically identical; DZ twins share on average 50% of their segregating genes. The total variance of each trait was decomposed into an additive genetic (A), a shared or common environment (C), and an unshared-environment component (E). The C component reflects environmental influences that twins share and that make them more similar to one another (e.g., family and school effects), while the E component reflects environmental influences that twins do not share (e.g., an accident or unique perceptions). The E-component also includes measurement error, although the amount of measurement error is reduced in a latent-variable approach. The latent factor will not include measurement error that is specific to one indicator, but it will include measurement error that is common among indicators (like teacher-specific variance in the case of teacher report). The phenotypic twin correlations indicate the underlying twin model: If the MZ twin correlation is larger than the DZ twin correlations, the phenotype is genetically influenced.

Regarding co-variation, the phenotypic correlation between the skills and enjoyment factors was decomposed into genetic (r_A) and environmental correlations (r_C and r_E). If significantly correlated, they represent shared aetiological influence. Finally, we fitted the three main direction-of-causation models (Duffy & Martin, 1994; Heath et al., 1993) to determine the influence from literacy skills to enjoyment and/or vice versa. Finally, we fitted one additional model to test whether the found causal path holds over and beyond genetic pleiotropy (i.e., a shared genetic influence: r_A).

All models were estimated using Mplus version 8.0 (Muthén & Muthén, 2017). The models were estimated using the full information maximum likelihood method, which uses all the available information in the data and assumes that missingness is random. As shown above, this is supported as twins who returned the self-report questionnaire had similar literacy skills as the twins who did not. We decided to retain the half of the sample with only literacy skills data. Although this subsample does not contribute to estimating the enjoyment variance components and the skills-enjoyment covariance components, it does contribute to estimating more precise skills variance components. For the reported chi-square difference tests in the direction-of-causation models, we used the Satorra-Bentler scaled chi-square difference test (Satorra, 2000). Our Mplus files with the scripts and output can be downloaded from OSF (https://osf.io/5anpy/).

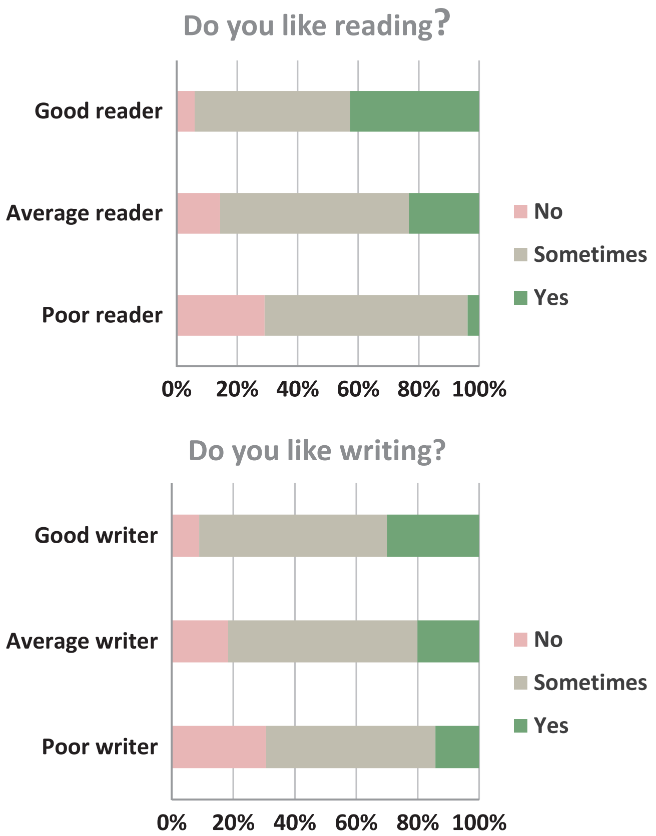

FIGURE 1 Enjoyment of reading and writing per skill level. *Note*. Good skills: values 4.5 or higher (18.8% of the sample), Average skills: values between 1.5 and 4.5 (76.0% of the sample), and poor skills: values 1.5 or lower (5.2% of the sample).

3 | RESULTS

3.1 | Descriptive statistics, gender differences, and correlational analysis

Figure 1 depicts the distributions of literacy enjoyment as a function of literacy skills. Descriptive statistics and gender differences for the study variables are reported in Table 1. Girls scored higher on all measures (all *ps* < 0.001), with moderate to large effects sizes. Correlations are provided in Table 2. The intra-class correlations (ICC), calculated separately for the MZ and DZ twins, were consistently stronger for MZ twins than DZ twins, suggesting genetic influences on individual differences. The cross-twin-cross-trait correlations were also consistently higher for MZ twins, suggesting a genetic correlation (i.e., r_A) between literacy skills and enjoyment.

3.2 | Measurement model

First, a common two-factor model with factors for literacy skill and literacy enjoyment was estimated. This measurement model (Figure 2), with two factors, one for the four teacher-reported literacy skills and one for the two self-reported literacy enjoyment items, fitted the data well: X^2 (9) = 179.79, $p < 0.001$, RMSEA = 0.07, CFI = 0.98, SRMR = 0.04. Next, the model invariance among the five twin groups was examined: The measurement model for the five twin groups (MZ girls, MZ boys, DZ girls, DZ boys, and DOS) was specified and the invariance of its estimates across groups was tested. In the base model, all parameters were set equal within the same-sex twin pairs but allowed to differ among the twin groups. The base-model fitted the data well: $X^2(297) = 469.05$, $p < 0.001$, RMSEA = 0.04, CFI = 0.99, SRMR = 0.06. Next, factor loadings were set equal across the five twin groups. The model fitted the data well: $X^2(323) = 500.50$, $p < 0.001$, RMSEA = 0.04, CFI = 0.99, SRMR = 0.07. The ΔRMSEA = -0.002 indicated that factor loadings were equal across the groups.

To examine the equality of intercepts next, the factor loadings and also intercepts were set equal across the five twin groups. Factor mean differences between girls and boys were still allowed. Model fit worsened: $X^2(351) = 847.58$, $p < 0.001$, RMSEA = 0.06, CFI = 0.96, SRMR = 0.08. The ΔRMSEA = 0.023 also indicated sex differences in the intercepts. In the next model the intercepts of girls and boys were allowed to differ, but factor loadings were set equal across the five twin groups. This model fitted the data well: X^2 (347) = 537.13, $p < 0.001$, RMSEA = 0.04, CFI = 0.98, SRMR = 0.08 and ΔRMSEA < 0.001. Finally, residual variances were set equal across twin groups. Model fitted the

TABLE 1 Descriptive statistics

	Total				Boys			Girls			
	N	Range	*M*	*SD*	*N*	*M*	*SD*	*N*	*M*	*SD*	*d*
Literacy skills											
Reading fluency	3676	1–5	3.49	1.07	1817	3.21	1.06	1859	3.76	1.00	0.53
Reading comprehension	3672	1–5	3.45	1.10	1813	3.26	1.09	1859	3.63	1.08	0.34
Spelling	3680	1–5	3.33	1.19	1817	2.94	1.16	1863	3.71	1.10	0.68
Writing	3680	1–5	3.24	1.09	1818	2.82	1.00	1862	3.65	1.00	0.83
Literacy enjoyment											
Liking reading	1639	1–3	2.12	0.61	830	1.94	0.59	809	2.31	0.58	0.63
Liking writing	1627	1–3	2.04	0.62	824	1.82	0.58	803	2.27	0.57	0.78

Note: *d* = Effect size Cohen *d* with pooled standard deviations.

TABLE 2 Phenotypic, intraclass and cross-twin cross-trait correlations

	Phenotypic correlations					Twin correlations					
Variables	1.	2.	3.	4.	5.	1.	2.	3.	4.	5.	6.
Literacy skills (teacher-reported)											
1. Reading fluency	–					0.85/0.55	0.48	0.43	0.46	0.15	0.05
2. Reading comprehension	0.75	–				0.69	0.86/0.57	0.44	0.47	0.10	0.04
3. Spelling	0.73	0.76	–			0.63	0.61	0.87/0.58	0.47	0.12	0.04
4. Writing	0.71	0.74	0.81	–		0.68	0.68	0.65	0.88/0.59	0.13	0.03
Literacy enjoyment (self-reported)											
5. Reading enjoyment	0.22	0.21	0.27	0.28		0.23	0.24	0.16	0.22	0.28/0.31	0.16
6. Writing enjoyment	0.12	0.09	0.20	0.22	.43	0.07	0.08	0.03	0.03	0.19	0.25/0.20

Note: Phenotypic correlations were calculated across all participants. The twin correlations include intraclass correlations on the diagonal (MZ value/DZ value). Cross-twin-cross-trait correlations are off the diagonal (lower triangle MZ; upper triangle DZ). All correlations were statistically significant at $p < 0.001$.

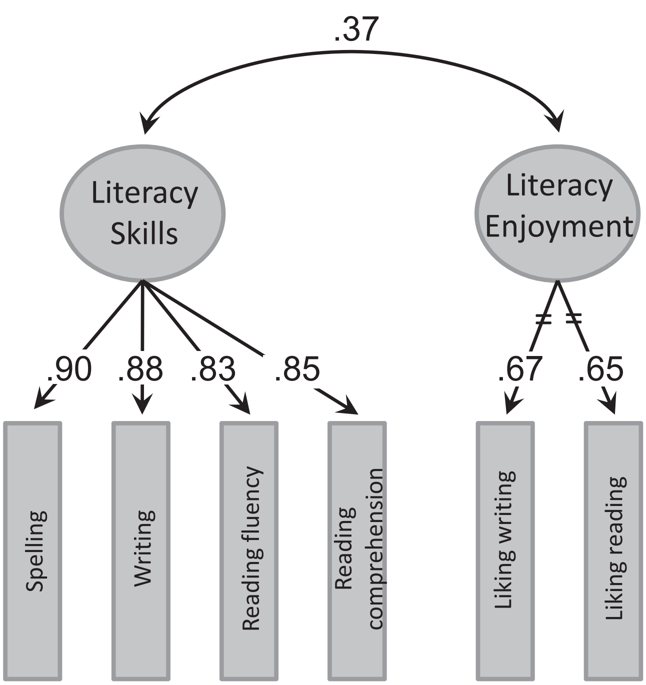

FIGURE 2 The measurement model

data well: $X^2(377) = 609.72$, $p < 0.001$, RMSEA = 0.04, CFI = 0.98, SRMR = 0.08. The ΔRMSEA = 0.002 indicated that also invariance of the residual variances holds. Thus, apart from girls having higher means than boys (see also Table 1), no other invariances were found. Thus, the two reading constructs were measured in a similar way, independent of sex and zygosity.

3.3 | Two-factor common pathway model

Figure 3 depicts the two-factor common pathway model (also known as a bivariate twin model). It fitted the data well $X^2(400) = 641.67$, $p < 0.001$, RMSEA = 0.04, CFI = 0.98, SRMR = 0.09. Literacy skills were mostly explained by genetic influences (70%) while the shared environment explained 21% of the variance. Of literacy enjoyment, on the other hand, about one third (36%) was explained by genetic influences and 24% by shared-environmental influences. The genetic influences for literacy skills and enjoyment correlated moderately ($r_A = 0.36$) while the shared-environmental influences correlated weakly ($r_C = 0.24$).

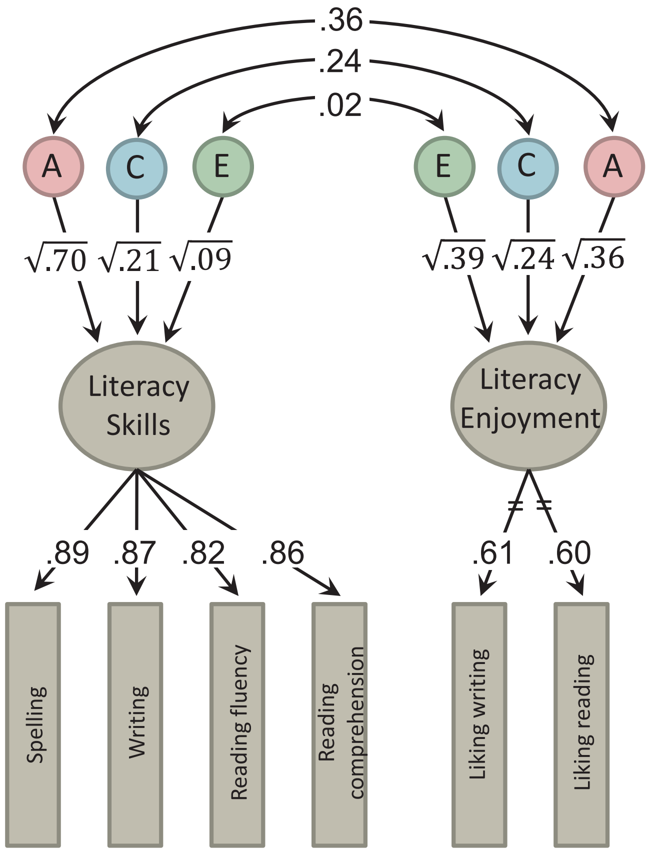

FIGURE 3 The common pathway model (or bivariate twin model)

3.4 | Direction-of-causation models

Two of the three main direction-of-causation models are depicted in Figure 4. In the first, the correlations between the A, C, and E components were dropped and two unidirectional paths were added: one from literacy skills to enjoyment and another from literacy enjoyment to skills (top left panel of Figure 4). Despite the increase of one degree of freedom, the model fit stayed almost identical to that of the common pathway model. $X^2(401) = 642.13$, $p < 0.001$, RMSEA = 0.04, CFI = 0.98, SRMR = 0.09.

To examine the direction of causation we next fitted two reduced models. The (non-significant) path from enjoyment to skills was dropped first. This reduced model (right panel of Figure 4) fitted the data well $X^2(402) = 642.97$, $p < 0.001$, RMSEA = 0.04, CFI = 0.98, SRMR = 0.09 and the model fit did not deteriorate significantly from the full direction of causality model, $\Delta X^2(1) = 1.11$, $p = 0.292$. This suggests that the path from enjoyment to skills was not needed for explaining the correlations. In the second reduced model (not depicted), we dropped the path from skills to enjoyment. This model fitted the data reasonably well $X^2(402) = 653.52$, $p < 0.001$, RMSEA = 0.04, CFI = 0.98, SRMR = 0.09, but the chi-square difference test revealed that the model fit deteriorated significantly in comparison to the full direction of causality model, $\Delta X^2(1) = 33.45$, $p < 0.001$. Therefore, the most parsimonious representation of the data is the direction-of-causality model with a unidirectional path from literacy skills to literacy enjoyment (right panel).

Finally, to see whether the causal (skills to enjoyment) path holds beyond genetic pleiotropy, we fitted a model including that causal path from skills to enjoyment and, in addition, a correlation between the genetic influences on skills and enjoyment (Figure 4, bottom left). This model fitted the data well, $X^2(401) = 642.13$, $p < 0.001$, RMSEA = 0.04, CFI = 0.98, SRMR = 0.09. In this model, that allows for genetic pleiotropy (r_A), the skills-enjoyment link is mainly explained by the genetic correlation ($r_A = 0.30$, $p < 0.001$) and less so by the causal phenotypic path (.08, $p = 0.669$; but note the large confidence interval). This would mean that the phenotypic association is almost fully due to shared genetic effects. But given that adding the r_A did not significantly improve model fit ($\Delta X^2(1) = 0.60$, $p = 0.435$), the most parsimonious model is still the one without the added r_A and just the skills to enjoyment path (Figure 4; right panel). The model including the r_A does, however, show that the causal path does not hold over and above shared genetic effects.

4 | DISCUSSION

Reading enjoyment is often found to be correlated with reading skills (Becker et al., 2010; De Naeghel et al., 2012). Theory suggests that the correlation between reading enjoyment and reading skills represents a reciprocal association between reading enjoyment and reading skills (Eccles et al., 1993; Vu et al., 2022). Children with a high interest in reading are likely to engage more in leisure reading and are reading considerably more than their less motivated peers, which is thought to lead to better reading (Baker & Wigfield, 1999; Wigfield & Guthrie, 1997). In addition, children who are interested in reading will invest more time and energy in reading also the more challenging texts, which may further increase the impact of reading activities on reading skills through repeated exposure to novel words in print (Becker et al., 2010; Castles et al., 2018). However, a growing literature using longitudinal and twin designs, which give some evidence of causal directionality, has found that the relationship between engagement with texts (defined as print exposure) and reading skills is due to a unidirectional causal relation of reading skills to engagement. Therefore, we sought to complete a methodological replication of the two previous (direction-of-causation) twin studies using a different sample (with another language and culture), with a broader measurement of literacy skills (not just reading) and literacy enjoyment (rather than print exposure).

Our models suggest that there is a causal direction from skills to enjoyment, which is largely mediated by genetic effects (the big A effect on skills going, via the causal path, to enjoyment). However, we cannot compellingly distinguish between this causal model (with genetic mediation) and a genetic-pleiotropy model, which would suggest that the association between literacy skills and enjoyment is due to shared genetic effects. It is indeed known that it is statistically difficult to discriminate between a genetic-pleiotropy and a causal model in which the high-heritability trait causes the low-heritability trait (as in our

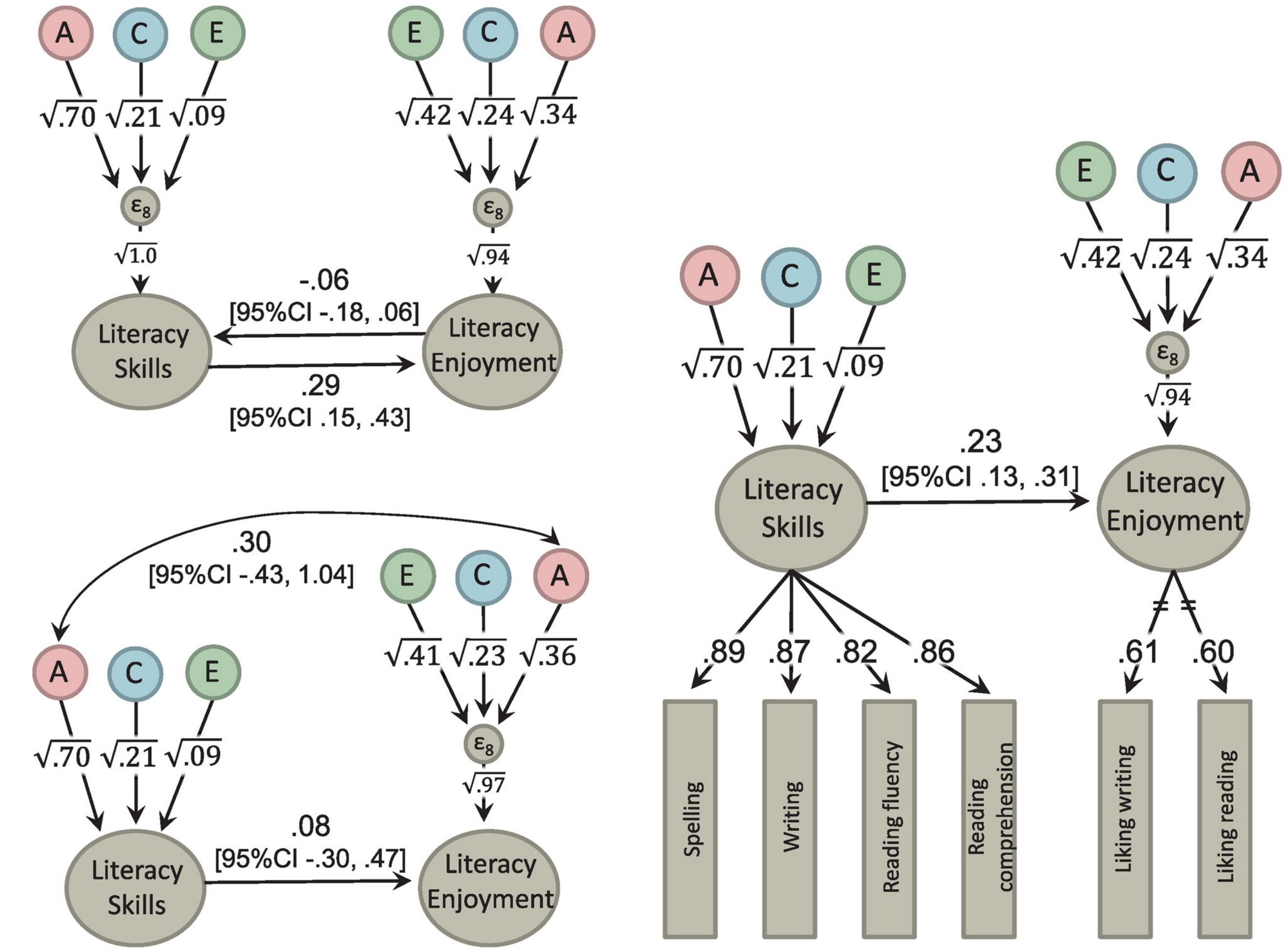

FIGURE 4 The direction of causation models. For the models on the left, the indicators are not depicted to avoid clutter. The path from enjoyment to skills (top left panel) was non-significant and could be dropped, resulting in the model on the right. The bottom left model shows that the causal path from skills to enjoyment does not hold over and above genetic pleiotropy (the $r_A = 0.30$). The model on the right, without r_A, is the best fitting model.

case; Duffy & Martin, 1994). In our data, these two models fitted the data equally well, in which case the most parsimonious model is preferred. According to this preferred model, we found that literacy skills drive enjoyment, so that young adolescents who are more skilled, then because of that, also liked reading and writing more.

The current findings are remarkable in their consistency with the two previous twin studies, which used the same statistical method in different twin samples (along with different countries, cultures, and orthographies) and different, but related, constructs (Erbeli et al., 2020; van Bergen et al., 2018). Given this building up of literature supporting a unidirectional influence of literacy skills on enjoyment, we are left with two conclusions. The first is the obvious causal conclusion: Better readers are more motivated by reading, including finding reading enjoyable and engaging in reading more often. The second conclusion is methodological. We were struck by the fact that so far (direction-of-causation) twin studies support a unidirectional effect, all in the same direction. However, the longitudinal studies support a bidirectional relationship: Three longitudinal studies using (random-intercept) cross-lagged panel models and relatively similar constructs have supported, in part, a bidirectional effect over time between reading motivation and reading skills (Malanchini et al., 2017; Torppa et al., 2020; van Bergen et al., 2021). Reconciling twin and longitudinal findings, a recent meta-analysis on longitudinal studies observed bidirectional associations (controlled for the autoregressor) between reading skills and motivation, with early skills being a stronger predictor of later motivation than vice versa (Toste et al., 2020). It may be that something about the twin direction-of-causation method makes finding a unidirectional causal relation more likely, especially above a bidirectional relation, which costs an extra degree of freedom in the model. Similarly, in longitudinal studies, the cost of an extra degree of freedom to allow bidirectionality may outweigh the better fit to the data. However, that extra path in the (direction-of-causation) twin studies from reading behaviours to skills, was in all three studies small, non-significant, and negative, so actually in the opposite effect of what would be considered plausible (Erbeli et al., 2020; van Bergen et al., 2018, and the current study). Although we are left supporting both possible conclusions, what we can be certain about is the accumulating evidence for a causal effect from reading skills to reading engagement:

how well children read impacts their amount and enjoyment of reading. The evidence for a causal effect in the opposite direction is currently mixed.

Interventions work well when they combine reading instruction with motivational components, like enhancing student interest and self-regulation. A recent meta-analysis concluded that interventions that target both skills and motivation improve both, with $g = 0.20$ and $g = 0.30$, respectively (McBreen & Savage, 2021). "What works" is the most important question for policymakers and teachers, but for our question on causality we would need clean intervention studies that strictly target either skills or motivation/enjoyment, and then assess both as outcome measures. What is known, is that just making children in the classroom read more independently has no effect (Erbeli & Rice, 2022). In the absence of feedback, practice apparently does not make perfect (Hattie & Timperley, 2007; Kim, 2007; Reitsma, 1988). Regarding gender differences in literacy, boys perform poorer and enjoy it less (average Cohen's *d*s 0.60 and 0.71, respectively; Table 1). This is in line with international PISA studies and studies showing that reading impairment is more often identified among boys than girls (OECD, 2019; Quinn & Wagner, 2015; Torppa et al., 2018). Hence, more boys than girls need remedial teaching.

Although we believe there is considerable evidence suggesting that better readers are more motivated to read to themselves and enjoy reading more, there are some limitations to this work. Most generally, the motivation—reading ability relationship seems to be only present in children and adolescents (i.e., not adults) (Locher & Pfost, 2020) and only in high-achieving countries (i.e., not countries with poor reading ability, as measured by PISA) (Cheema, 2018). The current and discussed studies were conducted in alphabetic writing systems. Reading skills and behaviours in non-alphabetic writing systems, where a larger set of characters needs to be learned, remain under-researched (McBride et al., 2022). Specific to the current work, we were limited to using only teacher assessment of literacy skills, and not a direct measure of literacy skills. Directly measuring literacy skills is ideal, but a different twin study has found that teachers are able to rate their pupil's reading skills as well as direct assessment (Rimfeld et al., 2019). Less than half of our sample (1639 out of 3690 children) had complete data on both traits, but this subsample with complete data was still substantial and did not differ in literacy skills from the subsample without complete data (Cohen's $d \leq 0.05$).

Some strengths of this study are that it included a large twin sample that allowed for using a unique twin method to evaluate whether an association between two traits is likely to be causal or likely to be due to shared genetic and environmental correlates. Moreover, we modelled our two traits as latent variables to reduce measurement error. Had we had the same reporter for both traits, then the same response style (rater bias) could have inflated the trait correlation and led to biased results (non-shared environmental confounding; Rasmussen et al., 2019). However, we had two different reporters, teachers for literacy skills, and the twins themselves for reading enjoyment, to keep measurement error uncorrelated in the model. Note that even though the current Finnish data were collected in the late 90s, findings converged with the more recent Dutch and American twin studies (Erbeli et al., 2020; van Bergen et al., 2018). The possibility of digital reading nowadays seems unrelated to literacy skills: the amount of digital reading does not or negatively correlate with literacy skills (Torppa et al., 2020).

Individual differences in how easy it is for a child to learn to read, spell, and write show strong genetic and small but significant shared-environmental influences (de Zeeuw et al., 2015; Little et al., 2017). The ease to which a child learns such literacy skills then predicts how much they will enjoy it and choose to do it. This gives support to the idea of (genetic) niche picking (more formally called an active gene-environment correlation; Plomin et al., 1977; Scarr & McCartney, 1983), in that readers create the reading environment around them best correlated with their abilities. This means that better readers choose to read more and enjoy it more. However, on the other end of that correlation, it means that those who struggle with reading will likely choose to avoid it. Actually, we could not convincingly reject a model in which the link between literacy skills and literacy enjoyment is the result of shared genetic effects (Figure 4, bottom left). We caution against any conclusion that unnecessarily blames children who are struggling to read for "not reading to themselves more." Instead, we put the focus on providing high-quality reading instruction and intervention to all, so that all children can find enjoyment with reading to themselves.

To get back to Bali Rai's quote at the start: it's not that simple. From the idea that those who read for pleasure do better in life (Bavishi et al., 2016) we cannot simply label literacy enjoyment as causal. In fact, our findings suggest that literacy enjoyment follows from good literacy skills.

ACKNOWLEDGMENT

FinnTwin12 data collection was supported by the Academy of Finland Center of Excellence in Complex Disease Genetics (grants 213506, 129680), the Academy of Finland (grants 100499, 205585, 118555, 308248, and 312073), National Institute of Alcohol Abuse and Alcoholism (grants AA-12502, AA-00145, and AA-09203). Elsje van Bergen was supported by VENI grant 451-15-017, NWO Gravitation grant 024.001.003, and ZonMw grant 531003014. Sara Hart was supported by funding from the Eunice Kennedy Shriver National Institute of Child Health and Human Development grant P50HD052120. Antti Latvala was supported as Academy Research Fellow by the Academy of Finland (grant 308698). Eero Vuoksimaa was supported as Academy Research Fellow by the Academy of Finland (grant 314639). Minna Torppa was also supported as Academy Research Fellow by the Academy of Finland (grant 276239). Views expressed herein are those of the authors and have neither been reviewed nor approved by the granting agencies.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

DATA AVAILABILITY STATEMENT

FinnTwin12 data are available through the Institute for Molecular Medicine Finland (FIMM) Data Access Committee for authorized researchers who have IRB/ethics approval and an institutionally approved study plan. For more details, please contact the FIMM Data Access Committee (fimm-dac@helsinki.fi).

ETHICS APPROVAL STATEMENT

The FinnTwin12 study protocol was approved by the Helsinki and Uusimaa Hospital District ethical review board and the Institutional Review Board of Indiana University, Bloomington. Parents gave permission to assess their children and to contact their teachers.

SCRIPTS AVAILABILITY STATEMENT

We have uploaded our Mplus files with the scripts and output on OSF (https://osf.io/5anpy/) to increase replicability and transparency in light of the Open Science movement.

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How to cite this article: van Bergen, E., Hart, S. A., Latvala, A., Vuoksimaa, E., Tolvanen, A., & Torppa, M. (2022). Literacy skills seem to fuel literacy enjoyment, rather than vice versa. *Developmental Science*, e13325. https://doi.org/10.1111/desc.13325