Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

English as an inequitable literacy: Cognitive and environmental predictors of reading in Malay and English among Malaysian biliterate children

Tze Peng Wong
University of Nottingham Malaysia Campus
Rachel Pye
University of Reading
Daisy Powell
d.a.powell@reading.ac.uk

University of Reading

Research Article

Keywords: biliteracy, reading development, home literacy environment, cross-language associations, bilingual reading

Posted Date: November 12th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11550343/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License. Read Full License

Additional Declarations: No competing interests reported.

Abstract

Purpose

Educational inequity in multilingual contexts is a growing concern, yet little is known about how cognitive and environmental factors jointly shape literacy outcomes in low- and middle-income countries (LMICs). This study examined cognitive-linguistic and environmental predictors of reading in English and Malay among bilingual Malaysian children, and whether these relationships differ across two orthographies of contrasting depth.

Method

Ninety-seven English–Malay bilingual children (mean age 7.80 years) were assessed on phonological awareness (PA), rapid automatized naming (RAN), and receptive vocabulary in both languages. Parents completed a home literacy environment questionnaire capturing shared reading, parental teaching, book availability, and socioeconomic status (SES). Word reading accuracy and fluency were measured in each language. Hierarchical regression models were used for fluency outcomes; generalized linear mixed models fitted to by-item binary data were used for accuracy.

Results

Cross-language associations were asymmetric: Malay PA predicted English reading fluency and accuracy, but English PA did not predict Malay reading. English RAN predicted fluency in both languages, whereas Malay RAN did not. Environmental effects were language- and outcome-specific: SES and home literacy variables uniquely predicted English reading fluency but did not significantly predict English reading accuracy, Malay fluency, or Malay accuracy.

Conclusion

Orthographic depth is associated with differential patterns of both cross-language cognitive associations and environmental sensitivity in biliteracy development. English, as an opaque high-status language, showed greater susceptibility to home environment disadvantage than the more transparent Malay, with implications for educational equity in multilingual LMIC settings.

Introduction

Globally, many children are expected to learn to read in a multilingual context, acquiring literacy skills in more than one language and in orthographies (writing systems) that might differ widely in their structural and linguistic features. Bi- or multiliteracy acquisition thus presents unique cognitive and environmental challenges that are distinct from monolingual literacy development (Hornberger, 1990). English is commonly taught as a second language (L2) in non-English-speaking countries, such as Malaysia where the current research is situated, due to its status as a global lingua franca and its association with socio-economic mobility (Kirkpatrick, 2012; Mackenzie, 2022). In low- and middle-income countries (LMICs) in particular, English skills are often viewed as a pathway to opportunity. However, it has been argued that successful English proficiency in bilingual education settings depends on key factors, such as adequate language immersion at home or school, promotion of cross-cultural attitudes (Torres-Guzmán et al., 2005), and bilingual teaching competencies such as knowledge of bilingual learning and bilingual pedagogy (Heineke & Davin, 2021; Scherzinger & Brahm, 2023). Yet these resources may not always be equitably distributed in LMICs (Nag et al., 2024). Thus, access to English literacy intersects with broader issues of educational equity.

The Malay language is an Austronesian language and is the national language of Malaysia, as well as Indonesia, Brunei, and Singapore. Although Malay and English are both written using the 26-letter Roman alphabet, they differ markedly in orthographic transparency, particularly vowels: while Malay has six vowel phonemes represented by five graphemes, English has approximately 20 vowel phonemes represented by just five vowel letters with highly inconsistent mappings (Yap et al., 2010). Participants were children attending national schools, the largest school type in Malaysia, where Malay is the medium of instruction and English is a compulsory second language. Children were learning literacy simultaneously in both Malay and English. They were predominantly bilingual and biliterate, although more than 120 languages are spoken in Malaysia, and many children also spoke Mandarin, Tamil or other dialects at home, were learning Arabic literacy for religious purposes, or attending mother tongue classes in additional languages.

Despite theoretical frameworks that support cross-linguistic transfer (e.g. Cummins, 1991), bilingual education practices often fail to fully account for how L1 and L2 literacy skills interact (Cummins, 2017). Cummins's (1991) linguistic interdependence hypothesis posits that, with adequate exposure and motivation, L1 skills facilitate L2 development, while growth in L2 further supports L1 development. Koda's transfer facilitation theory (Koda, 2009; Koda & Reddy, 2008) further proposed that metalinguistic awareness, such as phonological, morphological, and orthographic knowledge, can transfer across languages, provided that these skills are sufficiently developed in L1. In terms of the direction of cross-linguistic transfer, some studies report unidirectional transfer from transparent to opaque orthographies, suggesting that consistent grapheme–phoneme mappings support the development of decoding skills that can transfer to more complex systems (D'Angiulli et al., 2001; Geva & Siegel, 2000). However, other research has found evidence for bidirectional or symmetrical transfer, even between orthographically dissimilar languages such as Chinese and English (Pasquarella et al., 2015; X. Tong & McBride-Chang, 2010). Thus, transfer may not only be influenced by structural differences between orthographies, but also by task demands, proficiency, and the sociolinguistic context of bilingual development, as per Koda's (2009) framework. According to Koda (2009), metalinguistic skills may be flexibly accessed across languages once they are sufficiently developed, regardless of modality or direction. Given its opaque orthography, English literacy learning takes considerably longer than in more transparent orthographies (Seymour et al., 2003). Few studies, however, have investigated how orthographic transparency interacts with cognitive and environmental predictors of literacy across both L1 and L2 in bilingual contexts.

Cognitive predictors of reading, particularly phonological awareness (PA) and rapid automatized naming (RAN) have been robustly linked to reading outcomes in monolingual children (e.g. Powell & Atkinson, 2021). While PA is known to vary in its predictive strength with orthographic transparency, RAN has been identified as a stable predictor across languages (Landerl et al., 2019), though evidence from bilingual populations is more limited. A recent meta-analysis by Kishchak et al. (2024) found RAN to be a significant predictor across a range of bilingual groups (overall effect sizes: concurrent $r = -.39$, longitudinal $r = -.38$). The influence of specific language pairings and orthographic features remains underexplored, though in one relevant study, O'Brien et al. (2019) investigated whether cognitive predictors of English reading varied across Malay–English, Chinese–English, and Tamil–English bilingual children in Singapore, where English is the main medium of instruction. Onset–rime awareness was the strongest predictor for Chinese–English bilinguals; onset–rime and phonemic awareness predicted reading for Tamil–English bilinguals; and onset–rime and syllable awareness showed similar predictive strength for Malay–English bilinguals. Vocabulary moderated the effects of PA on reading only among the Tamil-English children.

Environmental predictors of literacy development, particularly the home literacy environment (HLE) and socio-economic status (SES), have also been widely studied. According to Sénéchal and LeFevre's (2002) home literacy model, two dimensions of HLE, informal exposure (e.g., shared storybook reading) and formal instruction (e.g., parent teaching of letters), are key factors underlying children's reading development in monolingual children. Subsequent research has consistently shown that HLE and SES are associated with early literacy outcomes, particularly in alphabetic languages with opaque orthographies like English (Frijters et al., 2000; Levy et al., 2006). However, the strength and nature of these associations may differ in bilingual contexts. Lower-SES households have been reported to provide a less rich home literacy environment, with fewer opportunities for shared book reading, more limited access to books and print materials, and less frequent supportive adult-child literacy interaction (Bradley & Corwyn, 2002). An implication of this is that orthographic depth may interact with environmental factors: because of the extended period required to master word reading in the opaque English orthography, children are likely to remain more reliant on scaffolding and feedback from a more skilled reader, typically a parent or caregiver, for a longer period. This suggests that HLE and SES may exert stronger effects on reading development in English than in more transparent orthographies such as Malay.

Furthermore, the strength and nature of the associations between environmental factors and literacy development may differ in bilingual contexts. In Hong Kong, for example, Liu et al. (2016) found that SES predicted L2 (English) proficiency but not L1 (Chinese) in Chinese-English bilingual children. In the same context, C. K. Y. Tong et al. (2023) showed that parental literacy skills were significant predictors of children's reading outcomes, controlling for SES, but that while SES was positively associated with English reading, it was negatively related to Chinese reading, perhaps because in higher SES families, English reading was prioritized at the expense of Chinese. Evidence from LMICs is more limited and has produced mixed findings. Dulay et al. (2019) demonstrated that family literacy engagement played an important role in reading development among Filipino children. However, a recent meta-analysis (Nag et al., 2024) of studies in 43 LMICs found that while the effect of the HLE on reading outcomes was significant, it was considerably smaller than in Western contexts ($r = .08$ vs $r = .22$). The authors suggested that the reliance on culturally mismatched, often Anglophone measures, could lead to an underestimate of the role of home environments on reading in such contexts.

Taken together, the research points to the importance of both cognitive-linguistic and environmental factors in biliteracy development, yet two significant gaps remain. First, the great majority of research on cross-linguistic transfer and the cognitive predictors of biliteracy has been conducted in Western, high-income contexts, using well-studied language pairs such as Spanish–English or Chinese–English. The Malay–English pairing, involving two typologically distinct alphabetic orthographies that differ markedly in transparency, has received comparatively little systematic investigation, despite its relevance to multilingual education across South and Southeast Asia, given the prevalence of Malay, which is spoken by around 300 million people as a first or second language. Second, the interaction between orthographic depth and environmental predictors of reading in bilingual contexts remains largely unexplored, particularly in LMICs. Recent findings that HLE effects on reading were substantially smaller in LMICs than in Western contexts (Nag et al., 2024) raise questions about whether this reflects genuine differences in the role of home environment or an artefact of culturally mismatched measurement, questions that can only be addressed through primary research in specific LMIC contexts.

This study addresses both gaps. By examining cognitive and environmental predictors of reading fluency and accuracy in both Malay and English, in the same Malaysian primary school children developing literacy simultaneously in both languages, we are able to test whether patterns of cognitive and environmental prediction differ across the two orthographies. By including both within-language and cross-language predictors alongside language-specific HLE measures, we contribute primary evidence from an under-represented LMIC context to the international literature on biliteracy development, and speak directly to the equity implications of how orthographic depth may interact with environmental resources to shape children's reading trajectories.

To address these aims, we investigate the following research questions:

1. To what extent do cognitive skills (phonological awareness, rapid automatized naming, and vocabulary) and environmental factors (home literacy environment and socio-economic status) predict reading fluency and accuracy in each language (English and Malay)?
2. Are there cross-linguistic associations, such that cognitive/linguistic skills in one language are associated with reading outcomes in the other—and are these associations symmetrical or asymmetrical?
3. Given the difference in orthographic transparency between Malay and English, are environmental factors (the HLE and SES) equally predictive of reading development in Malay and English, after accounting for cognitive/linguistic predictors?

Method

Participants

A total of 185 bi/multilingual children comprising 97 boys (52.4%) and 88 girls (47.6%) were recruited for a larger longitudinal study. This paper reports the data from the 97 children (47.4% boys; mean age = 7.80; *SD* age = 0.34) whose parents completed the home literacy questionnaire.

Children were recruited from three Malaysian public primary schools in the main city of a southern state in Malaysia. All schools used the Malay language as the main medium of instruction, and English was taught as the second language for about five hours a week. Children received daily literacy instruction in both Malay and English. Some children also gained additional language and literacy exposure during school time: Arabic for religious education, and weekly Mandarin or Tamil classes for heritage language maintenance. Parents also provided information via questionnaires about language use at home, reporting conversational exposure to four languages: Malay, English, Chinese, and Tamil. Most children (69%) were exposed to two languages, 18% to three, and 13% to only one (Malay, English, or Chinese only). Malay was most often the dominant language (70% of families), while English was most often the second language (64%) spoken at home.

Materials and measures

Selecting appropriate measures for bilingual research in a Malaysian context presents particular challenges. As Nag et al. (2024) note, the overwhelming majority of cognitive and literacy assessment tools used in LMICs have been developed and normed in Western, high-income settings, and very few validated instruments exist for Malaysian populations. We therefore aimed to follow a principled hierarchy in task selection: where instruments had been developed for and validated with Malaysian populations with adequate reported reliability, these were prioritized; where no Malaysian measures were available, we drew on instruments developed for the Singaporean context, which shares important linguistic and cultural features with Malaysia; and where no suitable instrument existed in either context, we developed new tasks modelled on the equivalent English measures used in this study. Given this approach, reliability estimates for all measures are reported from our own sample, rather than citing published norms derived from different populations. The two Malay cognitive tasks developed for this study, a phonological awareness sound matching task and a rapid automatized naming task, are made openly available via the University of XXX Research Data Archive (DOI: XXX).

Home literacy environment (HLE) and socio-economic status (SES)

Parents completed a questionnaire in either Malay or English, which was based on a home literacy questionnaire by Atkinson et al. (2014). A composite SES score was calculated by averaging the Z scores of mother's education and household income (following e.g. Bradley & Corwyn, 2002). Questionnaire data were used to create sub-measures of relevant HLE constructs based on Sénéchal and LeFevre's (2002) model, for both Malay and English: amount of shared storybook reading; parent teaching of reading and reading-related skills; child's active engagement during shared reading; number of books at home (child and adult).

Receptive vocabulary

The children's receptive vocabulary in English and Malay was measured with the receptive vocabulary scales of the Bilingual Language Assessment Battery (BLAB; Sze & Rickard Liow, 2009). The BLAB was developed in Singapore, a context that shares similar language variation and culture with Malaysia. The English and Malay tests comprise different items and have good reliability of $\alpha = .884$ and .917 respectively. Each test was administered to a group of children using pen and paper; the researcher named 80 distinct word sets in the English and Malay assessment in turn, and children circled the correct picture from four. Accuracy scores were recorded with a maximum of 80 per language.

Phonological awareness

Phonological Awareness (PA) was measured using the sound matching and elision subscales of the Comprehensive Test of Phonological Processes 2 (CTOPP-2; Wagner et al., 2013) in English and matching tasks in Malay. The English sound matching task (CTOPP-2) comprised 26 items, with 13 items requiring matching of the first sounds of words, and 13 items requiring matching of the final sounds of words. We developed a Malay sound matching task (DOI: XXX) by mirroring the structure of the English task, with 26 Malay items selected to be high frequency, familiar to children, and to be representative of a broad range of phonemes in the language. Sound matching reliability was $\alpha = .933$ and .921 for English and Malay respectively.

The elision subscale of CTOPP-2 comprised a total of 34 items that tested the children's elision of syllables (14 items), then phonemes (20 items), in English. Malay elision ability was assessed using a task developed by Yee (2009) comprising 25 items requiring syllable elision of two- and three-syllable words, and 10 items requiring the elision of individual phonemes from single-syllabic words. Given a significant correlation between subtasks, a composite score of PA was created for each language by calculating Z scores for each task across the sample, then taking an average of Z scores. Elision reliability was $\alpha = .94$ for English and .918 for Malay.

Rapid automatized naming

Rapid Automatized Naming (RAN) was measured using the object naming and digit naming subscales of the CToPP-2 (Wagner et al., 2013). Each subscale contained 36 items, presented in four rows of nine items, and the children named the object or digit from left to right, top to bottom, as quickly and as accurately as possible. The time taken to name the items was recorded; each naming error incurred a 5-second *penalty* (as in Powell & Atkinson, 2021). We developed a matched version suitable for the Malay context, with the same format but different objects and digits. The Malay RAN tests comprised six highly familiar items (1-2-5-6-7-8 for digit naming and car-desk-door-moon-mouse-scissors for object naming), with each item repeated six times, presented in four rows of nine items, consistent with the format of the CTOPP-2 RAN tasks used.

Word reading accuracy

English word reading accuracy was measured using all subscales from the Diagnostic Test of Word Reading Processes (DTWRP; Forum for Research in Language and Literacy, 2012) namely regular words (30 items), irregular words (30 items), and nonwords (30 items). A total score (maximum 90) was calculated. Cronbach's alpha was .981 for the overall DTWRP score, and .954, .962 and .941 for the Nonword, Regular and Irregular subscales respectively.

Malay word reading accuracy was measured using a scale developed by Lee (2008). The children read 50 root and affixed words of increasing difficulty, i.e., basic two-syllable root words to four-syllable words with affixes (α = .979), and 20 nonwords (α = .883), also of increasing difficulty and from two to four-syllables in length.

Word reading fluency

English word reading fluency was measured using the word (108 items) and nonword (66 items) subscales of Test of Word Reading Efficiency – Second Edition (TOWRE-2; (Torgesen et al., 2012). For each subscale, the children read as many words as they could within 45 seconds. Their English word/nonword reading score was number of items read correctly divided by 45, providing a measure of items read correctly per second.

Malay word reading fluency scores were derived from Lee's (2008) word reading scale, which also records the total time used to read all words. Each child's Malay word reading fluency scores for the word and non-word subscales was the number read correctly divided by the time used to read all words in the list.

Procedure

The schools and parents provided written consent while children gave their verbal assent prior to the start of the study. Children's vocabulary measures were conducted in a group setting. PA, RAN and reading scores were measured individually across two sessions. English and Malay tasks where carried out in different sessions. Task and language presentation order was counter-balanced for each child. All measures were conducted within one week. Ethical approval was obtained from the Ethics Committee of the Faculty of Arts and Social Sciences, University of XXX, and the Malaysian Ministry of Education.

Results

Data were analyzed using R (R Core Team, 2022) and RStudio (Posit Team, 2023); code is available via the University of XXX Research Data Archive.

Reading accuracy analyses used generalized linear mixed models (GLMMs) fitted to by-item binary response data (0 = incorrect, 1 = correct), with crossed random effects for participants and items. Reading fluency analyses used ordinary least squares regression, as fluency measures did not generate by item data. School was examined as a potential random effect but produced boundary singular fit in every model (estimated variance = 0), likely due to the small number of schools ($N = 3$) with highly unequal group sizes; school was therefore excluded from all models. Data screening revealed some multivariate outliers with high leverage: one participant was therefore removed from the English fluency and accuracy analyses, and two participants were excluded from Malay accuracy analyses.

Descriptive statistics for all variables and bivariate correlations are shown in Table 1. As expected, PA and RAN were moderately to strongly (Cohen, 1988) correlated with reading (accuracy and fluency) in both languages. Malay PA appeared more strongly related to English reading than English PA was to Malay reading, an asymmetry that foreshadows the regression findings. Vocabulary was also moderately correlated with reading scores, but only within-language correlations were significant.

Moving to environmental variables, correlational relationships appeared stronger for English than Malay. The composite SES measure was significantly correlated with reading accuracy and fluency in English, but only with reading fluency in Malay. None of the HLE variables were related to reading in Malay. With regard to reading in English, children's active engagement during reading and the number of English language children's books at home were significant correlates of reading fluency, while these variables as well as the amount of parent literacy teaching and the number of English language adult books at home were significant correlates of English reading accuracy.

Bivariate correlations guided decisions about which predictors to include in models, with only those variables significantly correlated with outcome measures included in analyses. As random effects in GLMMs absorb between-participant variance and reduce the apparent size of fixed effects, a more stringent criterion, of an at least moderate correlation ($r \geq .30$; Cohen, 1988) as well as $p < .05$, was applied for GLMM predictors. The variables selected as Step 3 predictors were as follows. For English reading fluency (OLS regression): SES, active engagement, and English children's book count; for English reading accuracy (GLMM), SES and active engagement. For Malay reading fluency (OLS regression): SES only. For Malay reading accuracy (GLMM): no environmental predictors met the threshold.

Predictors of English reading fluency

Results of the hierarchical linear model for English reading fluency are summarized in Table 2. In Model 1, English-language cognitive predictors were entered. The model was significant, and English PA and English RAN were significant unique predictors.

Adding Malay cognitive predictors in Model 2 resulted in a significant increase in R^2. Malay PA emerged as a significant positive predictor while English PA was no longer a significant unique predictor, indicating that Malay phonological awareness had displaced English PA in predicting English fluency. English vocabulary also became a significant predictor in Model 2. Malay RAN was not a significant unique predictor.

Environmental variables were added in Model 3, resulting in a further significant increase in R^2. SES was a significant positive predictor. English children's book count was a significant negative predictor. Active engagement did not reach significance as a unique predictor. In the final model, English RAN, Malay

PA, and SES were the significant unique predictors of English reading fluency. Sensitivity analysis revealed a minimum detectable effect size at 80% power given this design (8 predictors, $N = 78$) was Cohen's $f^2 = 0.215$. Observed $f^2 = 2.15$, substantially exceeding this threshold and suggesting that the analysis was adequately powered.

Predictors of English reading accuracy

English reading accuracy was modelled using a GLMM fitted to 7020 observations (78 participants × 90 items) with crossed random effects for participants and items. Results are summarized in Table 3. Random effect variances were substantial in Model 1 (item SD = 1.64, participant SD = 1.61), confirming that both item difficulty and individual differences contributed meaningfully to response variability.

In Model 1, English-language cognitive predictors were entered. English PA and English RAN were significant unique predictors; vocabulary was not. Adding Malay cognitive predictors in Model 2 resulted in a significant improvement in fit. Malay PA

was a strong positive predictor, while English PA was no longer significant, consistent with the fluency findings. English RAN remained significant though Malay RAN did not.

Environmental predictors (SES, active engagement) were added in Model 3. The addition of environmental predictors did not significantly improve model fit over Model 2. Individually, neither SES nor active engagement was a significant unique predictor of English reading accuracy. The conditional and marginal R^2 for the final model were .696 and .305 respectively, indicating that fixed and random effects together accounted for a substantial proportion of variance in item-level responses.

Simulation-based diagnostics (DHARMa) indicated adequate model fit: the Kolmogorov-Smirnov test for uniformity of scaled residuals was non-significant ($D = 0.009$, $p = .561$), and the dispersion test was also non-significant (dispersion statistic = 1.003, $p = .764$). To evaluate statistical power, sensitivity was assessed via simulation using powerSim() (simr package; Green & MacLeod, 2016), varying each environmental coefficient across a range of plausible values and estimating power at each point (200 simulations per value). The study had 80% power to detect SES effects of OR ≥ 1.73 (log-odds ≥ 0.55) and active engagement effects of OR ≥ 1.11 (log-odds ≥ 0.10). The observed SES coefficient was log-odds 0.25 (OR = 1.28) and the observed active engagement coefficient was log-odds 0.05 (OR = 1.05), both smaller than their respective minimum detectable effects, indicating the study was underpowered for effects of the magnitude observed. For the Model 2 vs 3 comparison, 80% power required effects approximately 1.5 times the observed magnitude.

Predictors of Malay reading fluency

Results of the hierarchical linear model for Malay reading fluency are summarized in Table 4. No participants were excluded as outliers; listwise

Table 1

Means, standard deviations, and correlations between all variables

Variable	*M*	*SD*	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Eng read flu	0.85	0.32													
2. Mal read flu	0.52	0.25	.77**												
3. Eng read acc	16.30	7.51	.89**	.64**											
4. Mal read acc	0.12	0.81	.69**	.80**	.65**										
5. Eng vocab	39.30	7.71	.37**	.14	.38**	.10									
6. Mal vocab	55.24	8.61	.15	.33**	.01	.26*	− .11								
7. Eng PA	0.02	0.76	.48**	.37**	.52**	.43**	.26*	.11							
8. Mal PA	0.16	0.74	.68**	.70**	.70**	.73**	.16	.35**	.52**						
9. Eng RAN	-0.12	0.74	− .61**	− .47**	− .57**	− .28**	− .27**	.03	− .27**	− .39**					
10. Mal RAN	-0.14	0.49	− .57**	− .59**	− .51**	− .50**	.08	− .24*	− .27**	− .52**	.57**				
11. SES	-0.01	0.87	.45**	.30**	.44**	.18	.40**	.09	.37**	.33**	− .28**	− .21*			
12. Eng read to	5.57	5.12	.15	− .04	.16	− .01	.32**	− .10	.08	.02	− .21*	.09	.17		
13. Mal Read to	5.79	4.19	− .06	− .07	− .09	.01	− .23*	.20	− .21*	− .11	.09	.01	− .21	.50**	
14. Eng parent tch	6.48	3.02	.14	− .03	.25*	− .01	.29**	− .29**	.11	− .04	− .23*	.03	.26*	.58**	.22*
15.Mal parent tch	6.92	2.64	− .06	.10	− .04	.05	− .31**	.18	− .09	− .03	.09	− .15	− .19	.17	.48**
16. Eng actv eng	15.73	5.80	.38**	.10	.35**	.10	.41**	− .22	.19	.09	− .37**	− .14	.35**	.50**	.09
17. Mal actv eng	17.18	4.45	− .07	− .03	− .18	.00	− .08	.31**	.05	− .16	.06	.01	− .21	.21*	.44**
18. Eng kids bks	1.76	1.24	.26*	.13	.31**	.07	.37**	− .10	.32**	.16	− .25*	− .11	.50**	.41**	− .04
19. Mal kids bks	1.61	1.05	.12	.09	.10	.06	− .07	.09	.22*	.09	− .12	− .11	.11	.07	.24*
20. Eng bks home	1.93	1.30	.17	.01	.23*	.02	.44**	− .21	.28**	.09	− .25*	.00	.47**	.54**	.04
21. Mal bks home	1.90	1.22	.05	− .04	− .01	− .03	− .10	.10	.11	− .01	− .13	− .05	.04	.14	.37**

Note. Eng = English; Mal = Malay; flu = fluency (words per second); acc = accuracy; vocab = vocabulary; PA = phonological awareness composite score(z); RAN = rapid automatized naming composite score (z); SES = socio-economic status; read to = amount read to; parent teach = amount of parent teaching; actv eng = active engagement during shared reading; Kids bks = total number of children's books at home; bks home = total number of books at home; *M* and *SD*. * indicates $p < .05$. ** indicates $p < .01$.

deletion yielded $N = 82$. In Model 1, Malay cognitive predictors were entered. The model was significant. Malay PA was the only significant unique predictor; vocabulary and Malay RAN were not significant predictors.

Table 2
Summary of regression analysis for variables predicting English reading fluency

Variable	Model 1			Model 2			Model 3		
	B	*SE(B)*	*t*	*B*	*SE(B)*	*t*	*B*	*SE(B)*	*t*
Intercept	0.609	0.144	4.23***	0.494	0.121	4.10***	0.547	0.129	4.23***
Eng vocab	0.005	0.004	1.34	0.007	0.003	2.41*	0.005	0.003	1.51
Eng PA	0.139	0.035	3.94***	0.029	0.035	0.83	0.038	0.035	1.09
Eng RAN	−0.288	0.050	−5.78***	−0.204	0.044	−4.67***	−0.188	0.044	-4.29***
Mal PA				0.179	0.041	4.41***	0.161	0.040	4.06***
Mal RAN				−0.050	0.030	−1.66	−0.052	0.029	-1.78
SES							0.070	0.031	2.24*
Act eng							0.008	0.005	1.76
KidsBks							−0.045	0.022	-2.04*
R^2 (Adj R^2)	.514 (.494)			.680 (.657)			.716 (.683)		
F for ΔR^2	$F(3, 74) = 26.08$, $p < .001$			$F(2, 72) = 18.60$, $p < .001$			$F(3, 69) = 2.92$, $p = .040$		

Note. Eng = English; Mal = Malay; vocab = vocabulary; PA = phonological awareness (z); RAN = rapid automatized naming (z); SES = socioeconomic status (z); Act eng = active engagement during English shared reading; KidsBks = number of English children's books. *$p < .05$. **, $p < .01$, ***$p < .001$.

Table 3
Summary of generalized linear mixed model analysis for variables predicting English reading accuracy

Variable	Model 1			Model 2			Model 3		
	B (log-odds)	SE	z	B	SE	z	B	SE	z
Intercept	−1.350	1.040	−1.30	−2.089	0.865	−2.42*	−2.032	0.927	−2.19*
Eng vocab	0.025	0.026	0.98	0.040	0.021	1.91	0.020	0.023	0.89
Eng PA	0.925	0.258	3.59***	0.076	0.256	0.30	0.050	0.254	0.20
Eng RAN	−1.950	0.367	−5.31***	−1.385	0.320	−4.33***	−1.218	0.321	−3.80***
Mal PA				1.454	0.291	5.00***	1.415	0.284	4.98***
Mal RAN				−0.163	0.241	−0.68	−0.157	0.234	−0.67
SES							0.248	0.199	1.25
Act eng							0.048	0.031	1.56
AIC	6145.4			6118.9			6118.4		
Model comp	-			$\chi^2(2) = 30.48$, $p < .001$			$\chi^2(2) = 4.50$, $p = .105$		
Cond. R^2 / Marg. R^2	.699/ .215			.696 / .296			.696 / .305		

Note: Eng = English; Mal = Malay; vocab = vocabulary; PA = phonological awareness composite score(z); RAN = rapid automatized naming composite score (z); SES = socio-economic status; Act eng = active engagement during English shared reading; Cond. R^2 = conditional R^2; Marg. R^2 = marginal R^2; Model comp = Model comparison; *$p < .05$. **, $p < .01$, ***$p < .001$.

Cross-language English predictors were added in Model 2, yielding a significant increase in R^2. English RAN was a significant predictor, indicating cross-linguistic influence on Malay fluency; English PA was not significant. Malay PA remained significant.

SES was added in Model 3 (the only environmental variable meeting the $p < .05$ threshold for this outcome) but was not a significant unique predictor. R^2 was identical across Models 2 and 3. Thus, although SES was positively correlated with Malay fluency at the bivariate level ($r = .30$, $p = .006$), it contributed no unique variance once cognitive predictors were included, in contrast with the English fluency result. The minimum detectable effect size at 80% power for the final model (6 predictors, $N = 82$) was Cohen's $f^2 = 0.180$; the observed $f^2 = 0.97$, confirming adequate power.

Predictors of Malay reading accuracy

Malay reading accuracy was modelled using a GLMM fitted to 6,439 observations (92 participants × 70 items; two participants were excluded as outliers), with crossed random effects for participants and items. Results are summarized in Table 5. In Model 1, Malay cognitive predictors were entered. Malay PA and Malay RAN were significant unique predictors; vocabulary was not. In Model 2, English PA was added as a cross-language predictor (English RAN was omitted because its bivariate correlation with Malay accuracy, r = − .28, did not meet the r ≥ .30 criterion). The model comparison did not reach significance. The individual English PA coefficient was positive and marginally significant ($z = 1.90$, $p = .057$), providing weak and inconclusive evidence of cross-linguistic

transfer from English to Malay reading accuracy at this stage of development. As no environmental predictors met the $r \geq .30$ threshold for this outcome, no Step 3 model was fitted.

Table 4
Summary of regression analysis for variables predicting Malay reading fluency

Variable	Model 1			Model 2			Model 3		
	B	***SE(B)***	***t***	***B***	***SE(B)***	***t***	***B***	***SE(B)***	***t***
Intercept	0.339	0.145	2.34*	0.188	0.147	1.28	0.188	0.148	1.27
Mal vocab	0.002	0.003	0.94	0.005	0.003	1.88	0.005	0.003	1.87
Mal PA	0.179	0.036	4.99***	0.133	0.040	3.32**	0.134	0.041	3.27**
Mal RAN	−0.056	0.030	−1.87	−0.034	0.030	−1.13	−0.033	0.030	−1.12
Eng PA				0.032	0.033	0.99	0.032	0.033	0.97
Eng RAN				−0.129	0.044	−2.93**	−0.129	0.045	−2.84**
SES							−0.001	0.026	−0.02
R^2 (Adj R^2)	.471 (.450)			.531 (.500)			.531 (.493)		
F for ΔR^2	*F(3, 78)* = 23.12, *p* < .001			*F*(2, 76) = 4.84, *p* = .010			*F*(1, 75) < 0.001, *p* = .983		

Note: Eng = English; Mal = Malay; vocab = vocabulary; PA = phonological awareness composite score(z); RAN = rapid automatized naming composite score (z); SES = socio-economic status. * = *p* < .05, ** = *p* < .01, *** = *p* < .001.

Table 5
Summary of generalized linear mixed model analysis for variables predicting Malay reading accuracy

Variable	Model 1			Model 2		
	***B* (log-odds)**	***SE***	***z***	***B***	***SE***	***z***
Intercept	1.039	0.838	1.24	0.932	0.824	1.13
Mal vocab	0.017	0.015	1.11	0.019	0.015	1.29
Mal PA	1.286	0.203	6.34***	1.106	0.220	5.03***
Mal RAN	−0.901	0.291	−3.10**	−0.874	0.285	−3.07**
Eng PA				0.353	0.186	1.90
AIC	4235.1			4233.5		
Model comp	-			$\chi^2(1) = 3.51$, *p* = .061		
Cond. R^2 / Marg. R^2	-			.566 / .227		

Note: Eng = English; Mal = Malay; vocab = vocabulary; PA = phonological awareness composite score(z); RAN = rapid automatized naming composite score (z). * = *p* < .05, ** = *p* < .01, *** = *p* < .001.

Simulation-based diagnostics (DHARMa) indicated adequate model fit: the Kolmogorov-Smirnov test for uniformity of scaled residuals was non-significant ($D = 0.006$, $p = .954$), and the dispersion test was also non-significant (dispersion statistic = 1.003, $p = .872$). Sensitivity analysis for the English PA cross-language effect in Malay accuracy indicated that 80% power required a log-odds coefficient of ≥ 0.55 (OR ≥ 1.73); the observed coefficient was 0.35 (OR = 1.42), suggesting modest underpowering for an effect of this magnitude.

Discussion

Our findings make three key contributions to the literature on literacy development in multilingual contexts. First, in relation to research question 1, phonological awareness (PA) and rapid automatized naming (RAN) were significant predictors of reading in both languages, consistent with prior research in monolingual and bilingual populations (Kishchak et al., 2024; Landerl et al., 2019). However, in addressing research question 2 we found notable asymmetries in the direction and strength of these relationships. Specifically, PA in Malay (the more transparent orthography) predicted both Malay and English reading proficiency, whereas English PA did not significantly predict Malay reading. English RAN predicted English reading fluency and accuracy, and was an unexpected significant predictor of Malay reading fluency, while Malay RAN was not. Malay RAN was, however, a significant predictor of Malay reading accuracy. Findings provide some support for the linguistic interdependence hypothesis (Cummins, 1991) and Koda's (2009) transfer facilitation model, suggesting that foundational skills developed in a simpler orthography are associated with stronger reading in a more opaque one. These asymmetries indicate the importance of considering orthographic transparency in cross-linguistic research on reading.

Second, in relation to research question 3 we found that environmental predictors relating to the home literacy environment (HLE) and socio-economic status (SES) were more strongly associated with English than Malay reading. In the regression analysis examining predictors of English reading fluency, there was a

significant change in R^2 when environmental variables were added, with SES accounting for additional unique variance. Interestingly, the number of children's books at home was a negative predictor of English reading fluency, a pattern consistent with a suppressor effect whereby, after accounting for SES and active engagement, residual variation in book count may reflect compensatory purchasing by parents of lower-performing children rather than an enriched reading environment. The association of environmental variables with English reading fluency aligns with findings from other bilingual contexts showing stronger environmental influences on L2, often English, compared to L1 (e.g., Liu et al., 2016). This environmental effect was specific to reading fluency: environmental predictors did not significantly account for additional variance in English reading accuracy, suggesting that the influence of home environment may be most pronounced for fluency-based outcomes where extended home-based practice has most opportunity to accumulate. Findings showing that environmental effects predicted English reading fluency but not Malay reading accuracy or fluency may reflect the additional support required for children to become literate in English, a language with an opaque orthography which requires more sustained input at home and in school (Mackenzie, 2022). It may of course be true that acquiring literacy in any second language, not just English, is more heavily dependent on environmental factors than a first language. However, it is likely that Malay's consistent orthography reduces the burden on both cognitive and environmental resources, allowing children to successfully develop reading skills through school instruction alone. Further research in a multilingual context where the second language was more transparent than the first would shed further light on this issue.

Third, our results suggest that the cognitive and environmental predictors of reading are not only language-specific but also language-pair dependent. The asymmetric transfer patterns between Malay and English support the idea that transfer is shaped by the relative difficulty of the two languages and the proficiency level achieved in each. A further cross-language asymmetry emerged in the RAN findings: English RAN was a significant predictor of Malay reading fluency, whereas Malay RAN was not. The absence of a within-language RAN effect is consistent with the orthographic transparency of Malay: it has been argued that in highly consistent orthographies, phonological decoding skill is acquired quickly, reducing the unique predictive contribution of rapid naming once phonological awareness is accounted for (Landerl et al., 2019; Ziegler & Goswami, 2005). The cross-language English RAN effect may reflect a domain-general processing speed advantage: children who retrieve phonological codes rapidly in the more demanding English orthographic context appear to benefit in Malay reading fluency, suggesting cross-language generalization of processing efficiency rather than language-specific phonological knowledge. This is consistent with the view that PA and RAN represent separable contributors to reading (Powell & Atkinson, 2021; Wolf & Bowers, 1999), and with the fact that RAN is particularly related to reading fluency. Both reading fluency and RAN index processing automaticity, suggesting that even purportedly universal predictors show differential patterns across orthographic contexts and proficiency levels, with the more opaque English orthography appearing to drive a generalizable processing speed advantage. Like PA, RAN showed complex, language-dependent relationships: English RAN predicted fluency in both languages, whereas Malay RAN predicted fluency in neither.

Taken together, these findings speak to the issue of inequities in biliteracy development. English, as a language with high social and economic value but challenging orthographic properties, appeared in this sample to be more sensitive to environmental variation. This raises concerns about how bilingual education systems might rely on children's home environments to support L2 literacy acquisition, potentially exacerbating existing inequalities. If environmental factors such as SES drive proficiency in English but not in Malay, then English may function as an inequitable language, disproportionately rewarding those with access to literacy-rich environments and resources. Programs that encourage reading through school-based or community-led initiatives may be a potentially fruitful approach to ensure all children, including those from families with lower income, are supported in acquiring English literacy skills. Our findings are also in line with broader critiques of English-dominant literacy research, assessments and instructional policies that may overstate the role of environment in literacy development, due to an over-reliance on studies conducted in opaque orthographies, particularly English (Share, 2008).

This study is not without limitations. First, the final sample represented a self-selecting subgroup of families who returned the parent questionnaire. It is likely that families who are more invested in literacy development were over-represented, potentially limiting the generalisability of findings. This limitation reflects recurrent issues in research on the role of the home environment in children's development, where even research targeting low-income communities report a selection bias towards the more well-resourced families in the area (e.g., Burgoyne et al., 2025). Indeed, this selection bias may also underlie the findings that interventions to enhance the home literacy environment, e.g. through increasing the quality and quantity of shared storybook reading at home, produce negligible effect sizes, particularly where robust methods (e.g. randomized controlled trials) with an active control group are used (Noble et al., 2019). A linked issue is that our final sample was small; while sensitivity analyses suggested that we had a sufficient sample for some analyses, other analyses were underpowered (e.g. the test relating to the predictive role of environmental effects on English reading accuracy). Further research is needed to validate these findings.

Second, our findings are correlational and cross-sectional, limiting causal inference. While our models indicate which variables predicted reading outcomes, longitudinal research is needed to trace the directionality of cross-language influences over time. A further longitudinal study could clarify whether early skills in Malay consistently predict English reading development, or whether the reverse relationship strengthens as English proficiency grows. Additionally, formal language × predictor interaction models would provide a stronger test of whether predictive patterns differ across languages; the present analyses demonstrate that cognitive and environmental predictors show different patterns in each language, but do not constitute a direct test of language moderation.

Third, although we focused on bilingual literacy in this study, we did not account for other languages spoken or read in our sample, such as Chinese and/or Tamil. The sample were all recruited from national schools where the instructional language is Malay and English is taught as a compulsory L2. It is therefore likely that most of our sample spoke other languages at home but were not proficient readers of these languages, as separate Chinese- and Tamil-medium schools are available across Malaysia. It is possible that these more nuanced linguistic backgrounds could have influenced our results, and studies explicitly accounting for language and literacy groupings beyond Malay and English would be a useful addition to the literature.

Finally, the questionnaire used to assess the home literacy environment was based on a measure developed in a UK context rather than an instrument designed for or validated within Malaysian multilingual households. As Nag et al. (2024) argued, measures derived from Western HLE models tend to foreground shared storybook reading and formal literacy instruction as the primary pathways to reading development, and may be insensitive to the home literacy activities most relevant in LMIC settings, potentially underestimating the true contribution of home environments to children's literacy development. This is a plausible partial explanation for the relatively modest HLE effects observed in the present study, and future research should prioritize culturally responsive instruments, or qualitative and mixed-methods approaches, to better capture the ways in which families in multilingual Malaysian households support their children's biliteracy development. As a partial step towards building the necessary assessment infrastructure in this context, the Malay cognitive tasks developed for this study, a phonological awareness sound matching task and a rapid automatized naming task, are made openly available, for use and adaptation by future researchers working in Malay-speaking contexts.

Conclusion

This study set out to examine how cognitive and environmental factors jointly shape biliteracy development in Malaysia, where children learn to read simultaneously in a highly transparent (Malay) and a highly opaque (English) orthography. Three findings stand out. First, cross-linguistic associations were asymmetrical: phonological awareness in Malay predicted reading in both languages, while English phonological awareness did not significantly predict Malay reading at this early stage of development, consistent with theoretical accounts that suggest that the direction of transfer is moderated by relative orthographic complexity and relative proficiency.

Second, environmental factors, particularly SES, contributed to English reading fluency over and above cognitive predictors, but showed no comparable effect on English accuracy or Malay reading. This is an important finding, suggesting that environmental sensitivity is both language-specific and outcome-specific, and most pronounced where the demands of the orthography are highest, as is the case with English. Third, these findings were obtained in a LMIC context that has been largely absent from the international biliteracy literature, and included cognitive assessment tasks developed specifically for the Malay language that are made openly available to support future research in the region.

Finally, this study demonstrates the analytical value of assessing reading and reading-related skills in both languages simultaneously. The cross-language asymmetries identified here, in phonological cross-language associations, in the role of RAN, and in the specificity of environmental influences, would have been invisible in a single-language design. This illustrates the importance of collecting data across languages when working in multilingual contexts, even where one language is the primary focus, as the contrasts between languages can illuminate processes that within-language designs cannot detect.

Together, these results carry implications that extend beyond Malaysia. English, as a language with high economic and social value but a demanding orthographic system, emerges here as more sensitive to the quality of children's home literacy environments than the more transparent Malay. Because those environments are themselves unequally distributed by socioeconomic status, English functions, in this sample at least, as a language that amplifies existing inequalities. Theoretical models and assessment tools developed in Western, high-income contexts have long shaped literacy policy and practice across the Global South; these findings are a reminder that orthographic properties are not educationally neutral, and that the particular demands English makes on home environments may make it a systematically inequitable language in multilingual societies where access to those environments is itself unequal.

Declarations

Author Contribution

All authors contributed to the conception of the study, data curation, and the writing and revision of the manuscript. In addition, T.P.W. and D.P. designed the methodology and jointly secured funding, supervised, and administered the project. T.P.W. took prime responsibility for collecting the data, provided the resources and validated the measures. D.P. contributed to managing data collection, wrote the analysis code, conducted the statistical analyses, validated the results and prepared the tables. All authors read and approved the final manuscript.

Acknowledgement

We thank the three participating schools, and the children who participated and their parents

Data Availability

The data analysed in this study are not publicly available because participants' parents did not give consent for their data to be shared beyond the research team. The Malay phonological awareness and rapid automatized naming tasks developed for this study, and the R analysis code, are openly available in the the University of Reading Research Data Archive (https://doi.org/10.17864/1947.001576).

References

1. Atkinson, L., Powell, D., Slade, L., & Levy, J. (2014). Investigating the influence of home literacy practices on the developmental pathways of early reading comprehension [Paper presentation]. Society for the Scientific Study of Reading 21st Annual Meeting, Santa Fe, USA.

2. Bradley, R. H., & Corwyn, R. F. (2002). Socioeconomic status and child development. *Annual Review of Psychology*, *53*, 371–399. https://doi.org/10.1146/annurev.psych.53.100901.135233
3. Burgoyne, K., Hargreaves, S., Akhter, N., Cramman, H., Eerola, P., Einbeck, J., & Menzies, V. (2025). Lack of effect of a parent-delivered early language intervention: Evidence from a randomized controlled trial completed during COVID-19. *JCPP Advances*, *5*(3), e12279. https://doi.org/10.1002/jcv2.12279
4. Cohen, J. (1988). *Statistical power analysis for the behavioural sciences* (2nd ed.). Lawrence Erlbaum Associates.
5. Cummins, J. (1991). Interdependence of first- and second-language proficiency in bilingual children. In E. Bialystok (Ed.), *Language processing in bilingual children* (pp. 70–89). Cambridge University Press. https://doi.org/10.1017/CBO9780511620652.006
6. Cummins, J. (2017). Teaching for transfer in multilingual school contexts. In O. García, A. Lin, & S. May (Eds.), *Bilingual and multilingual education* (pp. 103–115). Springer International Publishing. https://doi.org/10.1007/978-3-319-02258-1_8
7. D'Angiulli, A., Siegel, L. S., & Serra, E. (2001). The development of reading in English and Italian in bilingual children. *Applied Psycholinguistics*, *22*(4), 479–507. https://doi.org/10.1017/S0142716401004015
8. Dulay, K. M., Cheung, S. K., & McBride, C. (2019). Intergenerational transmission of literacy skills among Filipino families. *Developmental Science*, *22*(5), e12859. https://doi.org/10.1111/desc.12859
9. Forum for Research in Language and Literacy. (2012). *Diagnostic test of word reading processes [Test]*. GL Assessment.
10. Frijters, J. C., Barron, R. W., & Brunello, M. (2000). Direct and mediated influences of home literacy and literacy interest on prereaders' oral vocabulary and early written language skill. *Journal of Educational Psychology*, *92*(3), 466–477. https://doi.org/10.1037/0022-0663.92.3.466
11. Geva, E., & Siegel, L. S. (2000). Orthographic and cognitive factors in the concurrent development of basic reading skills in two languages. *Reading and Writing*, *12*(1–2), 1–30. https://doi.org/10.1023/A:1008017710115
12. Green, P., & MacLeod, C. J. (2016). SIMR: An R package for power analysis of generalized linear mixed models by simulation. *Methods in Ecology and Evolution*, *7*(4), 493–498. https://doi.org/10.1111/2041-210X.12504
13. Heineke, A. J., & Davin, K. J. (2021). Implementing the Seal of Biliteracy: A multiple case study of six high-awarding districts. *The Modern Language Journal*, *105*(2), 395–411. https://doi.org/10.1111/modl.12708
14. Hornberger, N. H. (1990). Creating successful learning contexts for biliteracy. *Penn Working Papers in Educational Linguistics, 6*(1), 2–21.
15. Kirkpatrick, A. (2012). English as an International Language in Asia: Implications for language education. In A. Kirkpatrick & R. Sussex (Eds.), *English as an international language in Asia: Implications for language education* (pp. 29–44). Springer. https://doi.org/10.1007/978-94-007-4578-0_3
16. Kishchak, V., Ewert, A., Halczak, P., Kleka, P., & Szczerbiński, M. (2024). RAN and two languages: A meta-analysis of the RAN-reading relationship in bilingual children. *Reading and Writing*, *37*(5), 1235–1265. https://doi.org/10.1007/S11145-023-10441-3
17. Koda, K. (2009). Learning to read in new writing systems. In M. H. Long, & C. J. Doughty (Eds.), *The handbook of language teaching* (pp. 463–485). Wiley-Blackwell. https://doi.org/10.1002/9781444315783.ch25
18. Koda, K., & Reddy, P. (2008). Cross-linguistic transfer in second language reading. *Language Teaching*, *41*(4), 497–508. https://doi.org/10.1017/S0261444808005211
19. Landerl, K., Freudenthaler, H. H., Heene, M., de Jong, P. F., Desrochers, A., Manolitsis, G., Parrila, R., & Georgiou, G. K. (2019). Phonological awareness and rapid automatized naming as longitudinal predictors of reading in five alphabetic orthographies with varying degrees of consistency. *Scientific Studies of Reading*, *23*(3), 220–234. https://doi.org/10.1080/10888438.2018.1510936
20. Lee, L. W. (2008). Development and validation of a reading-related assessment battery in Malay for the purpose of dyslexia assessment. *Annals of Dyslexia*, *58*(1), 37–57. https://doi.org/10.1007/s11881-007-0011-0
21. Levy, B. A., Gong, Z., Hessels, S., Evans, M. A., & Jared, D. (2006). Understanding print: Early reading development and the contributions of home literacy experiences. *Journal of Experimental Child Psychology*, *93*(1), 63–93. https://doi.org/10.1016/j.jecp.2005.07.003
22. Liu, D., Chung, K. K. H., & McBride, C. (2016). The role of SES in Chinese (L1) and English (L2) word reading in Chinese-speaking kindergarteners. *Journal of Research in Reading*, *39*(3), 268–291. https://doi.org/10.1111/1467-9817.12046
23. Mackenzie, L. (2022). Linguistic imperialism, English, and development: implications for Colombia. *Current Issues in Language Planning*, *23*(2), 137–156. https://doi.org/10.1080/14664208.2021.1939977
24. Nag, S., Vagh, S. B., Dulay, K. M., Snowling, M., Donolato, E., & Melby-Lervåg, M. (2024). Home learning environments and children's language and literacy skills: A meta-analytic review of studies conducted in low- and middle-income countries. *Psychological Bulletin*, *150*(2), 132–153. https://doi.org/10.1037/bul0000417
25. Noble, C., Sala, G., Peter, M., Lingwood, J., Rowland, C., Gobet, F., & Pine, J. (2019). The impact of shared book reading on children's language skills: A meta-analysis. *Educational Research Review*, *28*, 100290. https://doi.org/10.1016/j.edurev.2019.100290
26. O'Brien, B. A., Mohamed, M. B. H., Yussof, N. T., & Ng, S. C. (2019). The phonological awareness relation to early reading in English for three groups of simultaneous bilingual children. *Reading and Writing*, *32*(4), 909–937. https://doi.org/10.1007/s11145-018-9890-1
27. Pasquarella, A., Chen, X., Gottardo, A., & Geva, E. (2015). Cross-language transfer of word reading accuracy and word reading fluency in Spanish-English and Chinese-English bilinguals: Script-universal and script-specific Processes. *Journal of Educational Psychology*, *107*(1), 96–110. https://doi.org/10.1037/A0036966
28. Posit Team. (2023). *RStudio: Integrated Development Environment for R [Computer software]*. Posit Software.
29. Powell, D., & Atkinson, L. (2021). Unraveling the links between rapid automatized naming (RAN), phonological awareness, and reading. *Journal of Educational Psychology*, *113*(4), 706–718. https://doi.org/10.1037/edu0000625
30. R Core Team. (2022). *R: A language and environment for statistical computing [Computer software]*. R Foundation for Statistical Computing.

31. Scherzinger, L., & Brahm, T. (2023). A systematic review of bilingual education teachers' competences. *Educational Research Review*, *39*, 100531. https://doi.org/10.1016/J.EDUREV.2023.100531
32. Sénéchal, M., & LeFevre, J. A. (2002). Parental involvement in the development of children's reading skill: A five-year longitudinal study. *Child Development*, *73*(2), 445–460. https://doi.org/10.1111/1467-8624.00417
33. Seymour, P. H. K., Aro, M., & Erskine, J. M. (2003). Foundation literacy acquisition in European orthographies. *British Journal of Psychology*, *94*(2), 143–174. https://doi.org/10.1348/000712603321661859
34. Share, D. L. (2008). On the Anglocentricities of current reading research and practice: The perils of overreliance on an outlier orthography. *Psychological Bulletin*, *134*(4), 584–615. https://doi.org/10.1037/0033-2909.134.4.584
35. Sze, W. P., & Rickard Liow, S. J. (2009). *Bilingual Language Assessment Battery (BLAB). Unpublished measure*. National University of Singapore.
36. Tong, C. K. Y., Ho, J. C. S., Yang, X., McBride, C., Ng, M. C. Y., & Pan, D. J. (2023). Transfer? Reading, writing, and parental factors in Hong Kong Chinese families across Chinese and English. *Reading and Writing*, *36*(8), 1997–2023. https://doi.org/10.1007/S11145-022-10372-5
37. Tong, X., & McBride-Chang, C. (2010). Chinese-English biscriptal reading: Cognitive component skills across orthographies. *Reading and Writing*, *23*(3), 293–310. https://doi.org/10.1007/S11145-009-9211-9
38. Torgesen, J. K., Wagner, R. K., & Rashotte, C. A. (2012). *Test of Word Reading Efficiency–Second Edition (TOWRE-2)*. Pro-Ed. [Test].
39. Torres-Guzmán, M. E., Kleyn, T., Morales-Rodríguez, S., & Han, A. (2005). Self-designated dual-language programs: Is there a gap between labeling and implementation? *Bilingual Research Journal*, *29*(2), 453–474. https://doi.org/10.1080/15235882.2005.10162844
40. Wagner, R. K., Torgesen, J. K., Rashotte, C. A., & Pearson, N. A. (2013). *Comprehensive test of phonological processing–Second edition (CTOPP-2) [Test]*. Pro-Ed.
41. Wolf, M., & Bowers, P. G. (1999). The double-deficit hypothesis for the developmental dyslexias. *Journal of Educational Psychology*, *91*(3), 415–438. https://doi.org/10.1037/0022-0663.91.3.415
42. Yap, M. J., Liow, S. J. R., Jalil, S. B., & Faizal, S. S. B. (2010). The Malay Lexicon Project: A database of lexical statistics for 9,592 words. *Behavior Research Methods*, *42*(4), 992–1003. https://doi.org/10.3758/BRM.42.4.992
43. Yee, P. H. (2009). *Emergent spelling development in Malay* [Unpublished master's thesis]. National University of Singapore.
44. Ziegler, J. C., & Goswami, U. (2005). Reading acquisition, developmental dyslexia, and skilled reading across languages: A psycholinguistic grain size theory. *Psychological Bulletin*, *131*(1), 3–29. https://doi.org/10.1037/0033-2909.131.1.3