



Gender differences in reading medium, time, and text types: Patterns of student reading habits and the relation to reading performance

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Abstract

Reading habits play an active role in promoting students' reading skills and making them prepared to participate in modern society. Gender differences regarding students' habits in the use of reading medium, amount of time spent on leisure reading, and the frequency of school-related reading and of leisure reading were examined. The relation between these habits and the level of student reading performance was further explored. Data on 439,847 15-year-old students in 61 countries/regions were extracted from the most recent database of the Programme for International Student Assessment. Descriptive statistics showed that female students preferred print reading and multiformat use, that they spent more time on leisure reading, and that they read fiction and magazines more often than male students. Then, 3-level hierarchical linear modeling was conducted. The results indicated that the use of a paper format, the school-related reading of texts with tables or graphs and of fiction, and the leisure reading of fiction and nonfiction positively influenced reading performance among members of both gender groups and that a small amount of leisure reading of magazines and newspapers only showed a significant, albeit small, positive impact among members of the female group. Additionally, more than 2 h of leisure reading a day brought greater benefits for female students, while 1 to 2 h a day seemed to be more effective for male students. The practical implications for the cultivation of reading habits by students as well as those for the implementation of educational interventions were further discussed.

Keywords Reading habits · Gender differences · Programme for International Student Assessment (PISA) · PISA reading · HLM

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Introduction

Reading habits generally refer to customary reading behaviors (e.g., Chu et al., 2020; Ouellette & Wood, 1998), which embody several aspects, such as the frequency of reading (e.g., Leppänen et al., 2005), time spent reading (e.g., Karim & Hasan, 2007), and choice of reading medium (e.g., Parodi et al., 2019). According to the construction-integration (CI) model (Kintsch, 1988), comprehending a text requires two core processes: one is construction, i.e., information activation derived from the current text and the reader's prior knowledge, and the other is integration, i.e., the continuous spread of activations resulting in the successful construction of a network of nodes representing surface structure, text-base, and situational models. Playing an active role in the accumulation of lexicon and background knowledge (e.g., Duncan et al., 2016; Torppa et al., 2020) as well as in the improvement of the automaticity of comprehension processes (e.g., decoding skills, use of reading strategies, etc.) and reading self-efficacy (e.g., Pfof et al., 2013), students' habitual reading practices exert influences on their performance in reading assessments, which has been heatedly discussed. Meanwhile, gender has been considered to be an important contextual factor influencing students' learning and development (e.g., Logan & Johnston, 2010). A considerable number of empirical studies have observed evident gender differences in the behavioral aspect of reading, such as time spent reading and the frequency of reading different types of texts (e.g., Duncan et al., 2016; Kauderer & Randler, 2013; Loh et al., 2020; McGeown et al., 2015), which makes gender differences in reading habits a nonnegligible topic. Hence, the following part reviewed the literature on different reading habits from the perspectives of gender differences and the habits' relation to reading performance.

Gender differences in the use of reading medium and its relation to reading performance

Concerning the use of reading medium, previous investigations have demonstrated that print reading is more prevalent among females, whereas digital reading and multiformat use are more prevalent among males (e.g., Schwabe et al., 2022; Zhang & Kudva, 2014). A comprehension advantage has been revealed in print reading (e.g., Delgado et al., 2018). When reading in a traditional paper format, students have a greater sense of immersion rather than disruption (e.g., Clinton-Lisell, 2022; Hou et al., 2017), they practice reading strategies more skillfully (e.g., Yang & Hu, 2022), and they achieve better reading outcomes (e.g., Pfof et al., 2013). Meanwhile, e-book reading has been found to be positively associated with the growth of phonological awareness and vocabulary (e.g., López-Escribano et al., 2021) and its advantages of portability, access to multiple resources, etc., enable students to make their own reading choices, which might strengthen their language learning motivation (e.g., Schneider et al., 2018) and further improve their general reading performance.

Gender differences in the amount of time spent reading and its relation to reading performance

In terms of time spent reading, previous studies have suggested that the female group tends to spend more time reading than the male group (e.g., Kauderer & Randler, 2013), especially on leisure reading (e.g., Nippold et al., 2005; Rees, 2017). Despite the hypothesis that claims “the more, the better” (e.g., Locher & Pfof, 2020), the findings on the relationship between time spent reading and student reading performance were inconsistent. On the one hand, previous research has shown that time spent reading mediates the influence of reading motivation and has a significant positive effect on students’ reading comprehension (e.g., Stutz et al., 2016); on the other hand, some studies have found an unexpected ineffectiveness resulting from extra reading (e.g., Baye et al., 2019). Recently, considering the difference among age cohorts, Locher and Pfof (2020) found a statistically significant positive correlation between time spent on leisure reading and reading comprehension ($\beta \approx 0.20$) among children and adolescents; however, in the adult cohort, this correlation decreased to a low level ($\beta \approx 0.07$), and the predictive role of occupation-related reading stood out ($\beta = 0.13 - 0.23$).

Gender differences in the frequency of reading diverse types of texts and its relation to reading performance

Concerning the practices of reading diverse types of texts, a common assumption within academia is that male students read more nonfiction, whereas female students read more fiction (e.g., Jabbar & Warraich, 2022; Loh et al., 2020; Mar et al., 2009; Scholes et al., 2021; Topping, 2015; Topping et al., 2008). Some research also found a larger amount of comic-book reading (e.g., Duncan et al., 2016; Torppa et al., 2018) and newspaper reading (e.g., Karim & Hasan, 2007) among male students and a greater amount of magazine reading among female students (e.g., Torppa et al., 2018). Furthermore, the experiences of reading different types of texts exerts mixed influences on student reading performance, and the frequency of leisure reading by genre (e.g., fiction, nonfiction, newspapers, etc.) has been a major focus. Specifically, a consistent “fiction” effect has been found in the development of student literacy abilities, which might promote better student performance in reading assessments (e.g., Jerrim & Moss, 2019; Mar & Rain, 2015; Martin-Chang et al., 2020, 2021; McGeown et al., 2015; Scholes, 2021; Spear-Swerling et al., 2010). However, the frequent reading of nonfiction, newspapers, magazines, and comics was sometimes found to exert nonsignificant or negative effects on reading performance (e.g., Jerrim & Moss, 2019; Jerrim et al., 2020; Roni & Merga, 2019; Spear-Swerling et al., 2010). In addition to traditional printed reading materials, digital texts are now numbered among adolescents’ typical reading choices (e.g., Duncan et al., 2016). Much research attention has been dedicated to investigating whether the reading experience of digital texts in daily life promotes the development of reading competence. Some scholars have argued that the informative use of digital texts is

positively related to navigation skills (e.g., Naumann, 2015) and comprehension in internet reading (e.g., Salmerón et al., 2018). Nevertheless, some research has found a nonsignificant relation between reading practices of digital texts and word reading skills, summarization skills, etc. (e.g., McGeown et al., 2015) and even a significant negative link between the consumption of digital texts and student print reading comprehension (e.g., Torppa et al., 2020).

Overall, previous studies have highlighted notable gender differences in reading habits and the mixed influences of these habits on students' reading performance. However, there are still some research gaps needing to be filled. First, the above-mentioned inconsistent findings as well as some less-studied reading habits (e.g., the frequency of school-related reading) need to be further investigated. Second, insufficient attention has been given to the heterogeneous effects of reading habits on reading performance between different gender groups. Since some scholars have found that the influence of reading attitude on the development of reading skills is more significant for male students than it is for female students (e.g., Logan & Johnston, 2009), it could be that the effects of behavioral features of reading (e.g., reading habits) vary by gender, which requires further research to verify. Third, several relevant studies are limited to single-country/region samples, while empirical studies within the context of large-scale international surveys might produce more generalizable results.

The present study

In an attempt to fill these gaps, the present study aims to provide insights into the tailored cultivation of reading habits for both female and male students, and to better prepare them for active participation in modern society. Reading habits between secondary school female students and male students were compared, and three-level hierarchical linear modeling (HLM) was separately constructed for each group to explore these habits' influences on the reading performance of each group (see Fig. 1), based on data of 439,847 secondary school students in 61 countries/regions that participated in the latest Programme for International Student Assessment (PISA 2018). It is worth noting that the present study followed the call of Locke (2007) encouraging the use of the inductive approach in social sciences. The motives for exploring the gender differences regarding reading habits and the influence of these habits on student reading performance were mainly derived from previous research focus and the existing research gaps.

Specifically, the following questions are addressed:

1. Do gender differences exist in students' reading habits, including the use of reading medium (paper or digital format), total time spent on leisure reading, the frequency of school-related reading, and the frequency of leisure reading? If so, how?
2. Does the use of reading medium influence the reading performance of female and male students? If so, how?

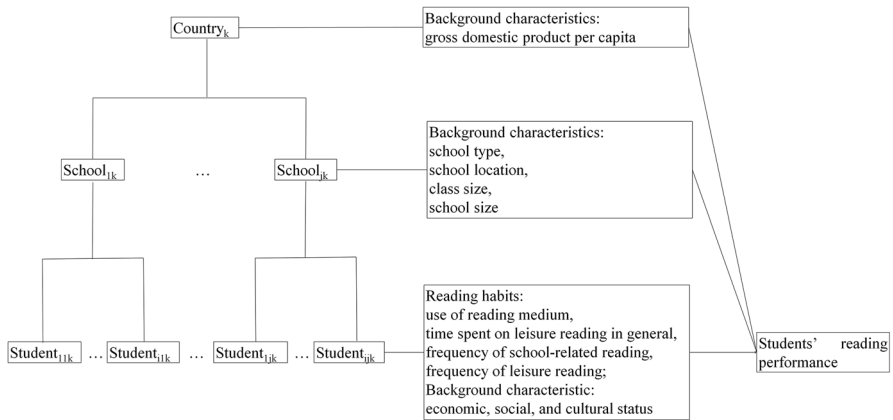


Fig. 1 three-level HLM for the present study. Since no consensus has been reached on the conceptualization of reading habits, the coverage of reading habits in this study is mainly based on previous literature and relevant questionnaire items in PISA 2018, which corresponds to the inductive approach (Toledo et al., 2011)

3. Does the time spent on leisure reading in general influence the reading performance of female and male students? If so, how?
4. Does the frequency of school-related reading, including that of texts with diagrams or maps, fiction, texts with tables or graphs, and digital texts with links, influence the reading performance of female and male students? If so, how?
5. Does the frequency of leisure reading, including magazines, comic books, fiction, nonfiction books, and newspapers, influence the reading performance of female and male students? If so, how?

Methodology

Data collection

The major data source for the present study was the database of PISA 2018 (<https://www.oecd.org/pisa/data/2018database/>), from which student- and school-level data were extracted. PISA is a triennial large-scale international survey initiated by the Organization for Economic Cooperation and Development (OECD) in 2000, and in the latest cycle, its dominant focus was on reading. In addition to most countries/regions assessing student reading performance via computers, PISA also used questionnaires to collect statistics on student reading habits and student background information (OECD, 2019). Concerning the country/region-level data, the indicator of gross domestic product (GDP) per capita was retrieved from the World Bank's database (<https://databank.worldbank.org/source/world-development-indicators>). All countries or regions participating in the PISA 2018 reading assessment via

advanced computer-based design, demonstrating no controversial reading performance,¹ and providing data for the variables of interest were chosen. Specific sampling information is presented in Table 1. It is worth noting that there were 445,492 students from 16,017 schools in the selected 61 countries/regions participating in the PISA 2018 computer-based reading assessment; however, due to the inconsistency of school type between some school principals' reports and official records, the statistics of 5,645 students from 161 schools were deleted, which resulted in 439,847 students from 15,856 schools comprising the final research sample. Thus, in the present study, the gender categories refer to the female and the male students, which were provided by the PISA 2018 database.

Variables

The dependent variable in the present study was student reading performance, i.e., the competence to understand, use, and evaluate single-source and multiple-source texts and reflect on and engage with those texts to better prepare oneself to participate in society (OECD, 2019). To measure it, PISA designed a broad array of tasks (e.g., Manu et al. 2021) requiring students to read single-source text, i.e., a single piece of text, or multiple-source text, i.e., several pieces of text, and to provide a selected response or short constructed response. Specifically, 25% of the tasks were designed for the cognitive process of locating information: 15% for scanning the content to retrieve words, phrases, etc., and 10% for searching for and selecting relevant text; 45% of the tasks were used to test the cognitive process of understanding: 15% for representing literal meaning and 30% for integrating and generating inferences; 30% of the tasks were used for the cognitive process of evaluating and reflecting: 20% for assessing quality and credibility and reflecting on content and form, and 10% for corroborating and handling contradictions across texts (OECD, 2019). Reading fluency was also taken into consideration, and the column "PISA Test" on the PISA official website (<https://www.oecd.org/pisa/test/>) offered some sampling tasks. Additionally, PISA implemented adaptive testing, i.e., the reading assessment for each student changed with his or her performance in prior tasks, and a graded response Rasch model was adopted to compute 10 plausible values (PVs), each with a mean of 500 and a standard deviation of 100 to determine the reasonable range of students' performance (OECD, 2009). Guided by previous research (e.g. Hu et al., 2018), 10 PVs were simultaneously considered as dependent variables.

Students' reading habits concerning the use of reading medium, the time spent on leisure reading, and the frequency of school-related reading and of leisure reading were taken as independent variables. Specifically, ST168Q01HA in the PISA 2018 student questionnaire collected information concerning student use of paper and digital media while reading any topics (recoded as "MEDIUM" in

¹ "No controversial reading performance" here refers to the situation that rapid and patterned responses were found in Spanish sample in the PISA 2018 reading assessment (OECD, 2019) and that sample was not included in the present study to avoid potential bias.

Table 1 Demographic statistics of the selected sample

N (student)	N (female)	N (male)	N (school)	Country/region
19,100	9311	9789	749	United Arab Emirates
17,084	8302	8782	592	Kazakhstan
14,273	7075	7198	763	Australia
13,818	6996	6822	471	United Kingdom
13,677	6883	6794	185	Qatar
12,059	6222	5837	396	Indonesia
11,957	5732	6225	358	B-S-J-Z (China)
10,930	5274	5656	500	Italy
10,678	5473	5205	596	Brazil
8515	4639	3876	287	Thailand
7621	3814	3807	254	Chile
7608	3861	3747	263	Russian Federation
7542	3759	3783	340	Denmark
7455	3829	3626	245	Colombia
7237	3784	3453	284	Mexico
7191	3849	3342	186	Philippines
7179	3594	3585	204	Costa Rica
7019	3518	3501	333	Czech Republic
6890	3396	3494	186	Turkey
6831	3352	3479	360	Lithuania
6828	3383	3445	55	Brunei Darussalam
6814	3262	3552	179	Morocco
6777	3231	3546	193	Baku (Azerbaijan)
6676	3277	3399	166	Singapore
6666	3240	3426	61	Montenegro
6650	3191	3459	188	Korea
6623	3544	3079	174	Israel
6609	3311	3298	183	Croatia
6609	3272	3337	187	Serbia
6480	3148	3332	213	Bosnia and Herzegovina
6401	2993	3408	345	Slovenia
6364	3164	3200	240	Greece
6354	3164	3190	326	Albania
6308	3078	3230	252	France
6239	3159	3080	252	Panama
6109	3120	2989	183	Japan
6037	2955	3082	152	Hong Kong (China)
5978	3080	2898	187	Malaysia
5916	2897	3019	329	Peru
5889	2919	2970	274	Portugal
5803	2772	3031	234	Belarus
5755	2755	3000	226	Switzerland

Table 1 (continued)

N (student)	N (female)	N (male)	N (school)	Country/region
5649	2772	2877	214	Finland
5625	2857	2768	240	Poland
5577	2777	2800	157	Ireland
5572	2682	2890	321	Georgia
5534	2806	2728	230	Dominican Republic
5519	2745	2774	350	Slovak Republic
5451	2525	2926	223	Germany
5315	2650	2665	229	Estonia
5303	2685	2618	308	Latvia
5294	2533	2761	197	Bulgaria
5263	2732	2531	189	Uruguay
5132	2605	2527	238	Hungary
5121	2542	2579	43	Luxembourg
5058	2457	2601	211	Kosovo
4838	2376	2462	164	United States
4765	2330	2435	156	Netherlands
3691	1829	1862	44	Macao (China)
3296	1656	1640	142	Iceland
3295	1544	1751	49	Malta

Countries or regions were ordered based on their total number of students participating in the PISA 2018

the present study). ST175Q01IA in the PISA questionnaire concerned the amount of time that students spent on leisure reading in general (“JOYTIME”) and the answers were based on a five-point Likert scale ranging from “do not read for enjoyment” to “more than 2 h a day”. PISA 2018 used four items (ST150Q01IA to ST150Q04HA) to gather students’ school-related reading frequency of texts with diagrams or maps (“DIAMAPSCH”), fiction (“FICSCH”), texts with tables or graphs (“TABGRASCH”), and digital texts with links (“DIGITXT”) during the last month and students responded to the items with options from “many times” to “not at all”. Additionally, ST167Q01IA to ST167Q05IA concerned the frequent leisure reading of magazines (“MEGAZINEJOY”), comics (“COMICJOY”), fiction (“FICTIONJOY”), nonfiction books (“NONFICJOY”), and newspapers (“NEWSJOY”), and the responses ranged from “never or almost never” to “several times a week.” The detailed proportion of students’ responses to these items are presented in the Descriptive statistics section.

Additionally, in line with previous studies (e.g., Areepattamannil & Khine, 2017; Wang et al., 2023), background characteristics were employed as control variables, including student economic, social, and cultural status index (ESCS); school location (SCHLOC, 1 to 5 represent the categories “village, hamlet or rural area,” “small town,” “town,” “city,” and “large city,” respectively), school

type (SCHTYPE), average class size (CLSIZE), school size (SCHSIZE), and the logarithm of GDP per capita (LnGDP).

Analysis procedures

Data preprocessing

Prior the main analysis, data preprocessing, including the handling of missing values and the data transformation, was conducted. First, the missing cases of all variables of interest were checked, among which the variable SCHSIZE had the highest missing proportion at 9.2%. Thus, multiple imputation (MI) was employed to impute missing values 10 times through a predictive mean matching model, which obtained 99% efficiency for 10% of the missing values (Schafer & Olsen, 1998). Based on the principle of predicting the distribution of both continuous and categorical variables and imputing several plausible values for each missing value, MI has been broadly applied in previous studies (e.g., Tabachnick & Fidell, 2013). Then, each imputed dataset was coupled with the PVs of students' reading performance in accordance with the same sequential tag (e.g., MI1 with PV1, MI2 with PV2). Additionally, since the study focused on the contribution of different reading habits to the reading performance of female and male students separately, each imputed dataset was split into two groups, one for the female students and one for the male students. The following data transformation and HLM analysis were conducted in each imputed dataset for each group, and the final HLM results for each group were combined via Rubin's rule (Rubin, 1987).

Concerning data transformation, to enhance the interpretability of intercepts (e.g., Hofmann & Gavin, 1998) and limit the possibility of multicollinearity (e.g., Mathieu & Taylor, 2007), student-level continuous explanatory variables were centered by group mean and school-level and country/region-level continuous explanatory variables were centered by grand mean, which is in line with previous research (e.g., Chen & Cui, 2020). Additionally, the categorical variables were dummy coded with values of 0 s and 1 s. In linear regression analysis, dummy coding is necessary as predictors for those categorical variables (Field, 2013). Specifically, for each categorical variable, one of its categories was chosen as the baseline group, and then the first dummy variable was created by assigning the value of 1 for the first group compared to the baseline group and assigning the value of 0 for all the other groups. This process was repeated for the rest of the groups, and the number of dummy variables was equal to the number of categories minus one. In the current study, students who selected "rarely or never read books," "do not read for enjoyment," "not at all," and "never or almost never" were used as the baseline groups for the independent variables MEDIUM, JOYTIME, DIAMAPSCH to DIGITXTSCH, MAGAZINEJOY to NEWSJOY, respectively. For control variables, "village, hamlet, or rural area" and "private" were taken as the baseline groups for SCHLOC and SCHTYPE, respectively. Hence, the coefficient of each dummy variable was

equal to the mean reading performance in the group that this dummy variable represents minus the mean performance in the baseline group when controlling for other variables.

Construction of three-level HLMs

To address the nested structure of international survey data, i.e., students were clustered in schools and schools were clustered in countries, three-level HLM was applied in the *Hierarchical Linear & Nonlinear Modeling 8.2* software (HLM 8.2, ID: 13437) (Raudenbush et al., 2019). HLM assesses the dependence of sample students within the same school in the same country/region and has been popularly adopted in PISA-related studies (e.g., OECD, 2009). Following step-by-step procedures (Hox, 2010), the building of the HLM proceeded as follows:

First, Model 1, i.e., the unconditional intercept-only model, was constructed:

$$READ_{ijk} = \gamma_{000} + \varepsilon_{ijk} + r_{jk} + u_k \quad (1)$$

where $READ_{ijk}$ refers to the reading performance of Student i from School j in Country/Region k ; γ_{000} refers to the fixed intercept; ε_{ijk} , r_{jk} , and u_k refer to the estimated residuals at student, school, and country/region levels, respectively.

Intraclass correlation (ICC) at the school level and country/region level was computed to examine the necessity of applying three-level HLM:

$$ICC_{school} = \frac{\sigma_{r_{jk}}^2}{\sigma_{\varepsilon_{ijk}}^2 + \sigma_{r_{jk}}^2 + \sigma_{u_k}^2} \quad (2)$$

$$ICC_{country/region} = \frac{\sigma_{u_k}^2}{\sigma_{\varepsilon_{ijk}}^2 + \sigma_{r_{jk}}^2 + \sigma_{u_k}^2} \quad (3)$$

Accordingly, if the school-level ICC and country/region-level ICC values are greater than 0.1 and the corresponding design effect, i.e., $1 + [n(\text{average cluster size}) - 1] \times ICC$, is larger than 2, then it indicates the necessity of three-level analysis (e.g., Marôco, 2021; Snijders & Bosker, 2012).

Then, all control variables concerning student-, school-, and country/region-level background characteristics were added into the model simultaneously and those that had statistical significance were retained, while other nonsignificant variables were excluded stepwise starting with the largest p value (Model 2).

After that, independent variables at each level were integrated into the model and the filtering of nonsignificant variables was reconducted (Model 3). Given the computational complexity, in line with previous research (e.g., Marôco, 2021), the final model (Model 3) was set as random intercepts and fixed slopes:

$$READ_{ijk} = \gamma_{000} + \gamma_{a00} Student_{ijk} + \gamma_{0b0} School_{jk} + \gamma_{00c} Country/Region_k + \varepsilon_{ijk} + r_{jk} + u_k \quad (4)$$

where similar to formula(1), $READ_{ijk}$ refers to students' reading performance, γ_{000} is the model's fixed intercept, ε_{ijk} , r_{jk} , and u_k refer to the estimated residuals at each level; γ_{a00} , γ_{0b0} , and γ_{00c} represents the estimated fixed slopes of variables at student, school, and country/region levels, respectively.

Moreover, to guarantee the reliability of HLM analysis, assumptions for the statistical model (Field, 2013) were investigated. Variance inflation factors (VIFs) were computed to examine the multicollinearity problem (see Table S1 in Supplementary Materials). Quantile-quantile (Q-Q) plots of residuals were drawn to check normality and scatterplots of fitted values by residuals were constructed to explore the linearity at each level and the homoscedasticity at the student level (see Figs S1 to S10 in Supplementary Materials). In addition, the proportion of explained variance at each level, represented by f^2 , was calculated to demonstrate model effects:

$$f^2 = \frac{Variance_{baseline} - Variance_{conditional}}{Variance_{baseline}} \quad (5)$$

where $Variance_{baseline}$ represents the respective random variance at the three levels in the unconditional intercept-only model and $Variance_{conditional}$ represents the remained random variance at each level after adding the explanatory variables. Accordingly, small, medium, and large effect sizes were obtained when the value of f^2 reached 0.02, 0.15, and 0.35 respectively (Cohen, 1988).

Results

Descriptive statistics

Since all independent variables (reading habits) used in the present study were categorical variables, the proportion of each category is presented in Table 2.

As shown in Table 2, gender differences were mainly observed in the use of reading medium (MEDIUM), time spent on leisure reading (JOYTIME), and the frequency of the leisure reading of magazines (MAGAZINEJOY) and fiction (FICTIONJOY). Specifically, over half of female students were more often either print readers or multiformat users (MEDIUM_2 or MEDIUM_4), spent at least 30 min a day on leisure reading (JOYTIME_3 to JOYTIME_5), and read fiction for enjoyment at least several times a month (FICTIONJOY_4 and FICTIONJOY_5); however, the proportions of male students that had these reading habits were only 44.2%, 34.9%, and 30.1%, respectively. In addition, almost 40% of male students reported that they never or almost never read magazines for enjoyment, whereas nearly 75% of female students tended towards the leisure reading experience of magazines.

HLM results

By building HLMs, patterns of reading habits that significantly influenced student reading performance were identified, and the final results are summarized in Table 3.

Table 2 Descriptive statistics of students' reading habits

Variable	Value label for each category	Proportion (%) in the female group	Proportion (%) in the male group
MEDIUM	1: Never or rarely read books	18.6	32.9
	2: More often in paper format	37.0	27.8
	3: More often through digital devices	21.3	23.0
	4: Equally often in paper format and through digital devices	23.1	16.4
JOYTIME	1: Do not read for enjoyment	22.7	39.4
	2: < 30 min a day	24.2	25.6
	3: 30~60 min a day	22.0	18.2
	4: 1~2 h a day	18.5	11.0
	5: > 2 h a day	12.5	5.7
DIAMAPSCH	1: Many times	27.4	28.3
	2: Two or three times	32.9	31.9
	3: Once	19.2	19.0
	4: Not at all	20.5	20.8
FICSCH	1: Many times	38.9	31.6
	2: Two or three times	32.1	32.5
	3: Once	18.0	20.6
	4: Not at all	11.0	15.3
TABGRASCH	1: Many times	29.3	29.9
	2: Two or three times	32.1	31.6
	3: Once	18.9	19.3
	4: Not at all	19.7	19.3
DIGITXTSCH	1: Many times	23.1	24.1
	2: Two or three times	26.1	25.6
	3: Once	19.4	19.6
	4: Not at all	31.5	30.8
MAGAZINEJOY	1: Never or almost never	26.7	39.7
	2: A few times a year	30.3	25.0
	3: About once a month	19.6	15.8
	4: Several times a month	16.3	12.7
	5: Several times a week	7.1	6.8
COMICJOY	1: Never or almost never	45.3	38.3
	2: A few times a year	22.0	23.7
	3: About once a month	11.9	13.8
	4: Several times a month	11.8	13.6
	5: Several times a week	9.0	10.7
FICTIONJOY	1: Never or almost never	11.7	26.8
	2: A few times a year	20.3	23.8
	3: About once a month	19.7	19.3
	4: Several times a month	25.3	17.5
	5: Several times a week	23.0	12.6

Table 2 (continued)

Variable	Value label for each category	Proportion (%) in the female group	Proportion (%) in the male group
NONFICJOY	1: Never or almost never	26.9	30.3
	2: A few times a year	24.9	22.6
	3: About once a month	19.3	18.0
	4: Several times a month	18.1	17.9
	5: Several times a week	10.7	11.2
NEWSJOY	1: Never or almost never	38.3	34.9
	2: A few times a year	21.9	19.5
	3: About once a month	15.2	15.1
	4: Several times a month	13.9	16.0
	5: Several times a week	10.7	14.5

In the following analysis, in consideration of the conciseness of expression, underscores, i.e., “_”, were used to link the abbreviation of each categorical variable with the numerical labels of its categories, e.g., “MEDIUM_1” refers to student group choosing “never or rarely read books” in the categorical variable MEDIUM

According to Table 3, the school- and country/region-level variance were significant ($p < 0.001$); ICC values at the two levels in Model 1 were larger than 0.1, i.e., 0.249 and 0.268 for female students, and 0.261 and 0.231 for male students; and the corresponding design effects were larger than 2. Thus, it was necessary to construct three-level HLM.

The results of Model 2 showed that all control variables, including students’ economic, social, and cultural status (ESCS), school location (SCHLOC_1 to SCHLOC_4), school type (SCHTYPE), class size (CLSIZE), school size (SCHSIZE), and the logarithm of gross domestic product per capita (LnGDP), were statistically significant. Thus, these variables were retained in the construction of the final model.

In Model 3, because dummy variables were integral constituents of categorical variables (Field, 2013), the series of dummy variables for each categorical variable were retained if at least one of them had statistical significance. Among female students, the final model explained 10.883% of the student-level variance, 29.219% of the school-level variance, and 53.499% of the country/region-level variance; among male students, the proportions of variance explained at the three levels were 7.044%, 26.388%, and 47.753%, respectively. The effect sizes of both final models were small at the student level, medium at the school level, and large at the country/region level. Concerning the influences of reading habits on reading performance, similarities and differences were found between the two gender groups:

In regard to similarities, both female and male students who used the paper format (MEDIUM_2) more often obtained better reading performance than the other groups. The school-related reading of texts with tables or graphs many times (TABGRASCH_1) and that of fiction at least two or three times (FICSCH_2 in the female group, FICSCH_1 in the male group) during the last month seemed to help students

Table 3 Results for HLMs

Variable	The female group						The male group					
	Model 1		Model 2		Model 3		Model 1		Model 2		Model 3	
	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE
<i>Fixed effects</i>												
Intercept	461.380***	7.209	505.671***	6.050	456.247***	6.116	437.164***	6.939	484.426***	5.974	460.998***	6.666
<i>Student-level variables</i>												
MEDIUM_2					25.690***	1.276					21.062***	1.471
MEDIUM_3					7.866***	1.202					8.347***	1.283
MEDIUM_4					21.567***	1.140					16.242***	1.501
JOYTIME_2					11.160***	1.257					9.437***	1.416
JOYTIME_3					17.654***	1.317					14.881***	1.666
JOYTIME_4					20.746***	1.453					16.910***	2.026
JOYTIME_5					27.150***	1.667					13.750***	1.922
DIAMAPSCH_1					0.351	1.683					-7.838***	2.030
DIAMAPSCH_2					1.944	1.050					-1.341	1.389
DIAMAPSCH_3					-3.991***	0.848					-6.516***	0.980
FICSCH_1					2.026	1.865					6.203**	1.945
FICSCH_2					2.834*	1.401					6.183***	1.571
FICSCH_3					0.565	1.195					3.835**	1.302
TABGRASCH_1					5.850***	1.506					10.006***	1.656
TABGRASCH_2					3.214**	1.074					4.434***	1.099
TABGRASCH_3					-2.678**	1.009					-4.306***	0.862
DIGITXTSCH_1					-7.906***	1.799					-14.119***	2.217
DIGITXTSCH_2					-7.643***	1.273					-11.620***	1.413
DIGITXTSCH_3					-9.518***	0.858					-12.299***	0.913
MAGZINEJOY_2					4.671***	0.864					1.415	0.891

Table 3 (continued)

Variable	The female group						The male group					
	Model 1		Model 2		Model 3		Model 1		Model 2		Model 3	
	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE
MAGZINEJOY_3					0.345	1.278					-1.447	1.499
MAGZINEJOY_4					-1.966	1.544					-4.244*	1.880
MAGZINEJOY_5					-15.989***	1.913					-19.862***	2.511
COMICJOY_2					-4.155***	0.937					-5.451***	1.003
COMICJOY_3					-11.233***	1.302					-11.215***	1.514
COMICJOY_4					-9.180***	1.457					-8.163***	1.654
COMICJOY_5					-10.122***	1.995					-9.530***	2.000
FICTIONJOY_2					14.308***	1.149					14.280***	1.114
FICTIONJOY_3					15.619***	1.387					9.943***	1.472
FICTIONJOY_4					22.024***	1.527					14.886***	1.706
FICTIONJOY_5					30.613***	1.964					18.951***	2.500
NONFICJOY_2					7.976***	1.021					9.024***	0.886
NONFICJOY_3					6.913***	1.511					10.098***	1.207
NONFICJOY_4					7.238***	1.886					14.191***	1.689
NONFICJOY_5					3.355	2.354					16.924***	2.433
NEWSJOY_2					1.830**	0.678					-3.632***	0.817
NEWSJOY_3					0.315	1.126					-5.305***	1.191
NEWSJOY_4					1.340	1.395					-4.268**	1.577
NEWSJOY_5					-5.797**	1.883					-11.669***	2.213
ESCS (control)					13.876***	1.029					11.090***	1.034
<i>School-level variables</i>												
SCHLOC_1 (control)					-38.676***	4.609					-42.900***	4.590
											-40.765***	4.662

Table 3 (continued)

Variable	The female group						The male group					
	Model 1		Model 2		Model 3		Model 1		Model 2		Model 3	
	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE
SCHLOC_2 (control)			-29.630***	4.069	-27.773***	3.882			-32.560***	3.729		
SCHLOC_3 (control)			-19.829***	3.379	-18.299***	3.241			-18.493***	3.220		
SCHLOC_4 (control)			-8.834*	3.261	-8.023**	3.101			-32.207***	5.152		
SCHTYPE (control)			-30.389***	5.055	-28.188***	4.687			-32.207***	5.152		
CLSIZE (control)			0.824***	0.171	0.737***	0.154			0.965***	0.194		
SCHSIZE (control)			0.008***	0.002	0.008***	0.002			0.011***	0.002		
<i>Country/region-level variable</i>												
LnGDP (control)			41.286***	4.691	44.199***	4.549			38.605***	4.666		
Random effects	Variance	ICC	Variance	f^2	Variance	f^2	Variance	ICC	Variance	f^2	Variance	f^2
Student level	5329.823	/	5201.896	2.400%	4749.762	10.883%	6134.495	/	6048.329	1.405%	5702.383	7.044%
School level	2743.485***	0.249	2330.015***	15.071%	1941.855***	29.219%	3151.359***	0.261	2591.484***	17.766%	2319.772***	26.388%
Country/region level	2950.460***	0.268	1487.794***	49.574%	1372.008***	53.499%	2784.177***	0.231	1480.485***	46.825%	1454.655***	47.753%

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. As mentioned in previous section of descriptive statistics, the form "VARIABLE_NUMBER" represents the specific category that the numerical value represents in a certain categorical variable. Specific meanings of the variables with numbers were also presented in the Table S2 in the Supplementary Materials

obtain better reading scores, while the frequent reading of texts with diagrams or maps (DIAMAPSCH_1 to DIAMAPSCH_3) and digital texts with links (DIGITXTSCH_1 to DIGITXTSCH_3) exerted nonsignificant or significantly negative influences. Additionally, the leisure reading of fiction several times a week (FICTIONJOY_5) as well as the leisure reading of nonfiction several times a month in the female group (NONFICJOY_4) and several times a week in the male group (NONFICJOY_5) showed an advantage in reading performance. Frequent leisure reading of comics was negatively correlated with the reading performance in both gender groups.

In terms of the differences, female students' reading performance increased with increasing time spent on leisure reading (JOYTIME_2 to JOYTIME_5), whereas male students who spent 1 to 2 h of leisure reading a day (JOYTIME_4) showed a larger difference from the baseline group than those who spent more than 2 h a day (JOYTIME_5). Although the leisure reading of magazines and newspapers several times a week (MAGAZINEJOY_5 and NEWSJOY_5) showed a significant negative influence on the reading performance of both female and male students, the reading of a small amount of these two genres (MAGAZINEJOY_2 and NEWSJOY_2) demonstrated a significant positive influence among female students.

Discussion

It is well established that those who engage more actively in reading tend to develop better reading competence (e.g., Dylman et al., 2020; Leppänen et al., 2005). Given its role in extending vocabulary, increasing prior knowledge, enhancing reading efficiency, etc. (e.g., Pfost et al., 2013), habitual reading practices in daily life might serve to promote meaning construction and integration processes in reading assessments and help students obtain better reading achievement scores. In the meantime, gender differences in reading habits need to be accounted for (e.g., Duncan et al., 2016), and the heterogeneous effects of these habits in the female group and the male group are still waiting to be probed. With a major focus on the students' behavioral features of reading, the present study attempted to reexamine the gender differences in reading habits, based on the data of the latest global PISA, and made an innovative move to explore the influences of these habits on the reading performance of each group separately. Through descriptive statistics and three-level HLM analysis, differences in secondary school students' reading habits were found between the gender and the mixed influences of these reading habits on female and male students' reading performance were demonstrated, which requires further discussion.

Gender differences in reading habits (responses to RQ1)

The revealed gender differences in leisure reading confirmed the previous claims that female students spent more time on leisure reading (e.g., Rees, 2017) and that they read more fiction (e.g., Topping et al., 2008) and magazines (e.g., Torppa et al.,

2018) than male students. The differences found in the use of reading medium, i.e., female students were more often print or multiformat users, partly corresponded to previous research (e.g., Zhang & Kudva, 2014). Additionally, the present study suggested that school-related reading and the leisure reading of nonfiction, comics, and newspapers were not major sources of gender differences in reading habits.

Influence of the use of reading medium (responses to RQ2)

In line with previous research (e.g., Delgado et al., 2018), we discovered that students who read more often in paper format, regardless of their gender, tended to perform better in the reading assessment. Printed paper provides physical dimensions to the text and tactile stimuli (e.g., Singer & Alexander, 2019). When reading via paper format, students take notes conveniently and immersively engage and reflect on the texts (Yang & Hu, 2022), which could improve their literal and inferential comprehension skills (e.g., Duncan et al., 2016) and further enhance their reading performance.

Nevertheless, the study did not refute the function of digital reading, since some digital reading activities could be of benefit to the development of digital competence (e.g., Salmerón & Delgado, 2019). For instance, information seeking in digital texts positively influences adaptive navigation skills (e.g., Naumann, 2015). Moreover, the discovered advantage of the paper format might also be associated with PISA's measure of reading performance, i.e., only 35% of tasks are based on multiple-source texts, which particularly require digital reading skills (OECD, 2019). For future studies, considering other outcomes beyond reading performance (e.g., digital competence) is advisable for comprehensively understanding the role of digital reading and for exploring the scientific use patterns of reading mediums.

Influence of time spent on leisure reading (responses to RQ3)

Extending previous research that highlighted the importance of leisure reading (e.g., Torppa et al., 2018, 2020), the present study compared the influence of different time spans spent in everyday leisure reading on students' reading performance. For female students, the findings showed that more than 2 h of leisure reading a day helped them obtain the best reading performance. To some extent, leisure reading time reflects both intrinsic motivation and reading amount. Motivated readers, who are willing to spend a considerable amount of time reading for pleasure, generally have a greater exposure to diverse reading materials (e.g., Liao et al., 2022; Troyer et al., 2019). During this process, they accumulate vocabulary and background knowledge as well as develop automated reading processes (e.g., El-Khechen et al., 2016), which could help them further comprehend texts and finish tasks competently in the PISA 2018 reading assessment. A potential ceiling effect of leisure reading time was found for male students and more than 2 h of leisure reading a day was not as effective as 1 to 2 h, which was similar to the curvilinear relationship found between subject-specific instruction time and student academic performance (Teig et al., 2018), i.e., more time does not always render better performance and an

inverted U-curve might exist between these two variables. Furthermore, it is worth noting that the research sample in the present study was limited to secondary school students and that the discovered positive influence of leisure reading time corresponded to the finding of Locher and Pfof (2020) in their studied adolescent group, whereas this influence might decrease in later adult stages (Locher & Pfof, 2020). Future studies are encouraged to track this dynamic relationship over the life course to find the optimal time spent on leisure reading among different age cohorts.

Influence of frequency of school-related reading (responses to RQ4)

To the best of our knowledge, the frequency of school-related reading, was first investigated based on the PISA 2018 database and our findings indicated that the school-related reading of texts with different features exerted mixed influences on students' reading performance.

A positive relationship was discovered between school-related reading of fiction and both female and male students' reading performance, extending previous research that highlighted the importance of the leisure reading of fiction (e.g., Jerrim & Moss, 2019). Characterized as extended narrative texts covering abundant vocabulary, various syntactic structures, complex lexicosemantic networks (e.g., Jerrim & Moss, 2019) and attractive event plots, fiction might benefit students' reading performance in two ways: One is the promotion of literacy skills, i.e., fiction reading is closely associated with intrinsic reading motivation (e.g., Martin-Chang et al., 2020) and positively influences students' verbal abilities including their level of knowledge about word meanings and forms, analogy, sentence completion skills, etc. (e.g., Mar & Rain, 2015; Martin-Chang et al., 2020; Mol & Bus, 2011; Spear-Swerling et al., 2010), and further enhances their reading fluency, comprehension and summarization skills, etc. (e.g., Boerma et al., 2017; McGeown et al., 2015; Pfof et al., 2013). The other is the development of the theory of mind, i.e., through fiction reading, students develop perspective-taking skills (e.g., Kidd & Castano, 2013) which are essential for narrative processing and reading comprehension (e.g., Dore et al., 2018).

With regard to the school-related reading of the other three text types, i.e., texts with diagrams or maps, texts with tables or graphs, and digital texts with links, we discovered that only the frequent reading of texts with tables or graphs seemed to exert a significant positive influence on female and male students' reading performances. Reading and interpreting tables or graphs is essential for statistical literacy (Pallauta et al., 2021), and relevant school-related experience might enhance students' familiarity with the text format and practice their skills of integrating multiple representations of information, which lays a foundation for handling noncontinuous texts in PISA. In terms of diagrams or maps, these elements often appear in scientific texts (e.g., Jian, 2022) and students read these texts mainly in response to instructional requests (e.g., Guthrie et al., 2012). As found in previous research, unlike reading for enjoyment, reading to learn exerted a negative influence on verbal abilities (e.g., Marti-Chang et al., 2021), which might be a possible reason for the discovered nonsignificant or even negative effect of frequent school-related

reading of texts with diagrams or maps. Additionally, extending previous studies (e.g., McGeown et al., 2015; Torppa et al., 2020), the findings demonstrate that the school-related reading of digital texts with links negatively influenced students' reading performance. However, as mentioned in the preceding section, the present study does not intend to deny digital reading at school and the current measure of reading performance might influence the present findings. Since school-related reading experience has not been well investigated so far (e.g., Vinterek et al., 2022), the present study could be seen as an innovative attempt to unveil the relationship between the school-related reading of different types of texts and student reading performance, whereas the negative influence found for some text types, i.e., texts with diagrams or maps and digital texts with links, needs to be further examined.

Influence of frequency of leisure reading (responses to RQ5)

Concerning the habits of leisure reading, the findings revealed that the reading experience of different genres exerted mixed effects on reading performance. Specifically, in line with previous studies (e.g., Jerrim & Moss, 2019; Scholes, 2021; Spear-Swerling et al., 2010), a positive relationship was found between the frequent leisure reading of fiction and students' reading performance across the gender. As mentioned in the preceding section, the role of the leisure reading of fiction in the development of literacy skills and theory of mind might explain this positive correlation. Meanwhile, in contrast to previous research (e.g., Mar & Rain, 2015), we discovered that the frequent leisure reading of nonfiction books (e.g., informational, documentary), was also associated with high reading performance, especially among the male students. There might be two potential reasons for the different findings between Mar and Rain's research (2015) and the present study: the first is the different outcome measures. The former focused on the verbal ability measured from four aspects: synonym recognition, analogical reasoning, sentence completion, and discourse comprehension. However, the latter stressed reading fluency and the cognitive processes of scanning and locating, understanding, evaluating and reflecting in various types of texts (e.g., narrations, expositions, and instructions, etc.). Since nonfiction books have become increasingly popular among students for gaining new knowledge and interacting with friends (e.g., Alexander & Jarman, 2018), the reading and sharing experience of nonfiction books might help students establish their reader identity, accumulate background knowledge, promote reading fluency and comprehension processes, and enhance the performance within the context of PISA reading assessment. The second reason is the difference in the cohorts studied. While Mar and Rain (2015) took undergraduate students as the research sample, the present study focused on the adolescent cohort. The fluctuation of reading activities and literacy skills over time (e.g., Reiter, 2022; van Bergen et al., 2021) might influence the effect of nonfiction reading on reading performance in cohorts of adolescents and undergraduates.

In contrast to the reading of fiction and nonfiction books, although the less-frequent leisure reading of magazines and newspapers, i.e., several times a year, was found to demonstrate a slight but significant positive influence among female

students, the frequent leisure reading of these two genres and of comics seemed to negatively impact the reading performance of both female and male students. This discovered negative influence resonates with previous findings (e.g., Jerrim et al., 2020; Torppa et al., 2020), which could be due to three aspects. First, given the short length of these genres, students may dip in and out of the texts quite superficially and fail to become deeply engaged in reading (e.g., Jerrim et al., 2020). Second, the frequent consumption of magazines or comic books might occupy the time that students might otherwise spend on reading fiction or nonfiction books. Third, some specific subtypes used as an alternative to these general genres might promote students' reading literacy. For example, in the consumption of newspapers, reading broadsheets helps to enrich an individual's vocabulary, while reading tabloids has a negative influence in that domain (Sullivan & Brown, 2015).

Due to the design of the PISA 2018 questionnaires, the items measuring leisure reading frequency are somewhat general, and these items are based on students' self-reports. Collecting students' reading habits from a more specific perspective and from multiple agents or conducting other measures, such as the Author Recognition Test (ART) for print exposure, to render more comprehensive and objective results would be worthwhile.

Conclusion

Based on the data of 439,847 secondary school students obtained from PISA 2018, the study examined the gender differences regarding their reading habits and further explored the influences exerted by different reading habits on students' reading performance. Through descriptive statistics, we discovered that female students chose printed books or multiple formats more often, and spent more time on leisure reading; this includes the more-frequent reading of fiction books and magazines for enjoyment. By constructing a three-level HLM for each gender group, the mixed influences of these reading habits on the reading performance were revealed: in addition to the previous emphasis placed on the positive effects of paper-format reading and the leisure reading of fiction, school-related reading of fiction and of texts with tables or graphs as well as leisure reading of nonfiction books were also positively correlated with both female and male students' reading performance. More than 2 h of leisure reading a day for female students and 1–2 h for male students resulted in greater benefits to their reading performance. Furthermore, the leisure reading of magazines and newspapers several times a year exerted a significant albeit small positive influence, while the frequent leisure reading of these two genres and of comic books as well as the frequent school-related reading of texts with diagrams or maps and of digital texts with links seemed to have nonsignificant or even negative influences.

The examination of both well-researched and less-studied reading habits and the more generalizable results resulting from a large-scale international survey offer several practical implications. It is advisable for secondary school students to appreciate paper-format reading, develop a leisure reading habit involving both fiction and nonfiction books, appreciate school-related reading experience

of texts with tables or graphs and of fiction, and scientifically allocate daily time for reading. Meanwhile, for educators and policy-makers, paying attention to the gender differences in reading habits, especially the differences in leisure reading, is justifiable. To help improve students' reading performance, appropriate interventions or reading programs are encouraged to motivate students, especially male students, to engage more frequently in reading for pleasure. In addition to highlighting the role of the reading of fiction, it is also advisable to promote the school-related assignment of popular nonfiction and texts with tables or graphs.

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1007/s11145-023-10446-y>.

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Author contributions JH and YW were in charge of research design and methodology. Data collection and analysis were mainly performed by GY and YW. YW was in charge of administration. All authors, i.e., JH, GY, XW, and YW, wrote and revised the manuscript, and they all approved the final version of the manuscript.

Data availability The research data were extracted from the databases of Programme for International Student Assessment 2018 (URL: <https://www.oecd.org/pisa/data/2018database/>) and World Bank (URL: <https://databank.worldbank.org/source/world-development-indicators>), and they were also available upon request from the authors.

Declarations

Conflict of interest The authors declare no conflicts of interest.

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