

Metacognition Explains the Gender Differences in Digital Reading Performance: A Multilevel Mediation Analysis

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ABSTRACT

Gender differences in reading have become a heated topic, and a reoccurring pattern of results is that girls outperform boys significantly. As digital reading prevails, the discrepancies in digital reading between girls and boys are also prominent. For the purpose of exploring the reason why boys lag behind in terms of digital reading performance and therefore unveil the underlying mechanism in improving students' digital reading literacy, this study used multilevel mediation analysis to investigate whether students' metacognition, i.e., metacognition of understanding, remembering, summarizing and assessing credibility, explain the gender differences in digital reading performance. This study adopted Programme for International Student Assessment (PISA), launched by Organization for Economic Co-operation and Development (OECD) as the data source. Results of 12,058 samples from 361 schools in China showed that their better achievement in metacognition significantly mediated girls' excelling performance in digital reading. Pedagogical implementations focusing on metacognition were given to render help for both genders in digital reading performance.

1. Introduction

Gender differences in achievement in reading, a traditionally considered female-stereotyped subject, have long been a concern for educators worldwide. Several studies found that girls outperform boys significantly in traditional print reading (Stroud & Lindquist, 1942). As we step into the digital reading era, the changes in reading literacy reflect new characteristics. Reading materials are not limited to traditional paper texts but involve all readable, visible and audible texts (Yu, Song, & Wang, 2017). As paper-based reading turns to the computer-mediated one, the gender gap in digital reading performance favouring girls is still non-negligible (Cheung, Mak, & Sit, 2013; OECD, 2019). Researchers attempted to investigate the underlying reasons why boys' digital reading performance is inferior to girls'. Plausible reasons for these discrepancies lie in different perspectives, such as children's attitudes, reading behaviours, etc. (Huang, Liang, & Chiu, 2013). Despite the above-mentioned literature, limited attention has been paid to the plausible effect of metacognition on gender differences in digital reading performance.

Metacognition is defined as the competence to think over and control the comprehension strategies for reading (OECD, 2019). Amid complex information of digital reading, students need to assess the quality and credibility of reading information (Lang, Kammerer, Stürmer, & Gerjets, 2021) with a clear mind based on understanding the text content (Maier & Richter, 2013) and summarizing and integrating the information (Reid, Morrison, & Bol, 2017). Therefore, to cultivate students' digital reading literacy, the metacognitive ability to understand, memorize, summarize, and evaluate information quality and credibility becomes particularly important (Li & Yao, 2021). Artelt and Schneider (2015) found that there were significant correlations between students' metacognition and their reading competence based on the evidence from 34 OECD countries. Furthermore, metacognition has also been proved of its facilitating role when students read both in paper-based (e.g., Lau & Ho, 2016) as well as in computer-based forms (e.g., Lee & Wu, 2013; Lim & Jung, 2019).

As reviewed in the literature, there are two clear-cut lines of research exploring (1) the reasons for gender difference in digital reading and (2) the influence of metacognition on students' digital reading performance. Scarce attention, however, has been focused on the plausible mediating effect of metacognition on the gender differences in digital reading. This study attempted to explore whether metacognition could explain the gender gap in digital reading performance based on this research gap.

2. Methods

2.1 Data Source and Variables

Publicly accessible data from the Program for International Student Assessment (PISA) were used as data sources in this study. PISA is an international assessment of the learning performance of 15-year-olds and is highly recognized for its importance in providing pedagogical advice to participating economies (Grek, 2009). Reading is the major domain in PISA 2018, which assesses both print and digital reading scores for different economies.

For the purpose of this study to explore the mediating effect of metacognition on different gender groups' digital reading performance, six variables were selected. Students' gender information (ST004D01T) was retrieved from the PISA 2018 student questionnaire for the dependent variable. Regarding the dependent variable, scores of students' digital reading performance (PV1READ) were selected. In terms of metacognition, PISA assessed students' metacognition from three dimensions, including students' metacognition of understanding and remembering (UNDREM), summarizing (METASUM), and assessing credibility (METASPAM). Among all the countries/regions that participated, 12,058 samples from 361 schools in China were selected because their digital reading scores ranked highest, the lessons of which might give enlightenment to other economies. For purposes of controlling the effects of students' background condition, the index of students' economic, social, and cultural status (ESCS) was selected as the control variable. In terms of the variable feature, the independent variable of student gender is a dichotomous parameter showing that 52.11% of the total population are girls, the rest of five variables are all continuous variables, and their respective descriptive information are UNDREM (Mean=0.20, SD=0.99), METASUM (Mean=-0.12, SD=0.96), METASPAM (Mean=0.08, SD=0.96), ESCS (Mean=-0.36, SD=1.09), and PV1READ (M=561.03, SD=90.34).

2.2 Multilevel Mediation Model

A prominent feature of PISA lies in its hierarchical data. Specifically, PISA data at the student level are nested at the school level. Multilevel analysis is necessary when the intraclass correlation coefficient (ICC) is greater than 0.1 (Snijders & Bosker, 2012). The ICC result of the current study is 0.4718, indicating that 0.4718 of the total variances lie in the school level. Therefore, multilevel analysis is imperative. The mediation model is necessary to explore the mediating effects of three kinds of metacognitions on the gender differences in digital reading. Based on the hierarchical character of PISA data and the effects of different mediators, a multilevel mediation model was used in the current study (see Fig. 1). Fig. 1 manifests the three-mediator model in the current study, where X affects Y through three parallel mediators in four pathways, i.e., three indirect pathways and one direct pathway. Indirect pathways start from X to Y through M_1 (UNDREM), M_2 (METASUM), and M_3 (METASPAM), while the direct pathway of X influencing Y does not run through any mediator. According to Hayes (2013), this model follows the following equations:

$$M_1 = i_{M_1} + a_1X + e_{M_1} \quad (1)$$

$$M_2 = i_{M_2} + a_2X + e_{M_2} \quad (2)$$

$$M_3 = i_{M_3} + a_3X + e_{M_3} \quad (3)$$

$$Y = i_Y + c'_X + b_1M_1 + b_2M_2 + b_3M_3 + e_Y \quad (4)$$

where

i_{M_1} , i_{M_2} , i_{M_3} , and i_Y are the constants of each regression;

e_{M_1} , e_{M_2} , e_{M_3} , and e_Y are the errors in the calculation of M_1 , M_2 , M_3 and Y ;

a_1 , a_2 and a_3 quantify the effects of X on M_1 and M_2 , respectively;

c' quantifies the direct effect of X on Y when mediators are controlled; and

b_1 , b_2 and b_3 quantify the effects of M_1 , M_2 and M_3 on Y .

According to Hayes (2013), the total effect of X on Y in the mediation analysis is the sum of direct and indirect effects; therefore, the total effect (c) of could be calculated by the following equation:

$$c = c' + a_1b_1 + a_2b_2 + a_3b_3 \tag{5}$$

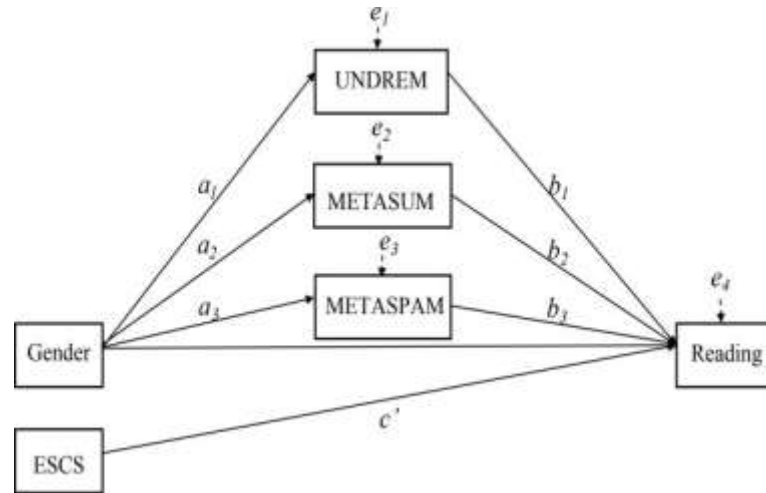


Fig. 1 Conceptual diagram of the multilevel mediation model.

2.3 Data Processing

Before the data processing stage, the data were preprocessed first. A small proportion of missing data in PISA needs to be imputed. The K-nearest neighbor (KNNs) imputation was realized by the knnImputation function in the DMwR package in R (Torgo, 2017). Given that gender is a binary variable, women were dummy coded to 0 and men to 1. Since the sampling distribution of PISA is not balanced, in order to ensure that the sample can represent the population and obtain unbiased parameters, students weight was calculated in R (R Core Team, 2019). The correlations among variables were calculated (shown in Fig. 2), which were all within the acceptable range. In R (R Core Team, 2019), the structural equation model (SEM) method was used for multilevel mediation analysis in lavaan package (Rosseel, 2012). SEM can not only quantify the total, direct and indirect impact of X on Y (Hayes, 2009), which is the basis of mediation analysis (Baron & Kenny, 1986), but also be applicable to hierarchical data (Hayes & Preacher, 2014).

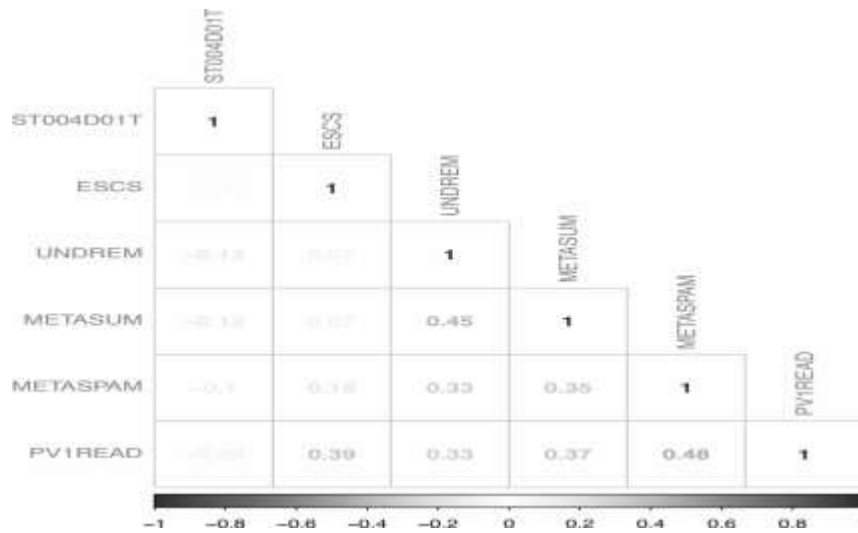


Fig. 2 Correlation matrix of variables.

3. Results and Discussion

To answer the research question concerning the mediating effects of three kinds of metacognition on the gender differences in digital reading, a statistical diagram of the model with coefficients of different paths is demonstrated in Fig. 3. The pathways of X to Y through M1, M2, and M3 were calculated and presented in the statistical diagram. The coefficient of the total effect of X on Y (c) showed a negative relationship between gender and students' digital reading performance ($\beta = -0.0666$, $CI = [-0.1050, -0.0286]$, $p = 0.0006$, $SE = 0.0194$), indicating girls outperform boys by 0.0666 unit, which is consistent with several previous studies (Cheung, Mak, & Sit, 2013; OECD, 2019). The coefficients of the pathways from three kinds of metacognition to students' digital reading performance were all positive, i.e., 0.0726 for UNDREM ($CI = [0.0432, 0.1020]$, $p = 0.0000$, $SE = 0.0150$), 0.1150 for METASUM ($CI = [0.0839, 0.1460]$, $p = 0.0000$, $SE = 0.0158$), and 0.4060 for METASPAM ($CI = [0.3860, 0.4270]$, $p = 0.0000$, $SE = 0.0105$). The positive

role that metacognition plays in students' digital reading performance aligns with a bulk of previous studies (e.g., Artelt and Schneider, 2015; Lau & Ho, 2016; Lee & Wu, 2013; Lim & Jung, 2019). Three pathways were presented to quantify the mediating effects of the three kinds of metacognition between X and Y, i.e., from X to Y through M_1 , M_2 and M_3 . Mediating effects were calculated by multiplying a by b . The mediating effect of UNDREM showed that girls had a higher level of metacognition of understanding and remembering ($\beta=-0.2170$, $CI=[-0.2510, -0.1830]$, $p=0.0000$, $SE=0.0174$), which led to their increased value of -0.0157 in digital reading ($CI=[-0.0225, -0.0090]$, $p=0.0000$, $SE=0.0034$), and the mediating effect of UNDREM explained 23.57% of the total gender differences in digital reading. The mediating effect of METASUM showed that girls had a higher level of metacognition of summarizing ($\beta=-0.2130$, $CI=[-0.2470, -0.1800]$, $p=0.0000$, $SE=0.0172$), which led to their increased value of -0.0245 in digital reading ($CI=[-0.0320, -0.0170]$, $p=0.0000$, $SE=0.0038$), and the mediating effect of METASUM explained 36.79% of the total gender differences in digital reading. The mediating effect of METASPAM showed that girls had a higher level of metacognition of assessing credibility ($\beta=-0.1420$, $CI=[-0.1770, -0.1070]$, $p=0.0000$, $SE=0.0179$), which led to their increased value of -0.0575 in digital reading ($CI=[-0.0719, -0.0431]$, $p=0.0000$, $SE=0.0073$), and the mediating effect of METASPAM explained 86.34% of the total gender differences in digital reading. A tentative explanation for these results might be that girls' have better digital reading performance is due to their higher level of metacognition of understanding and remembering, summarizing and assessing credibility.

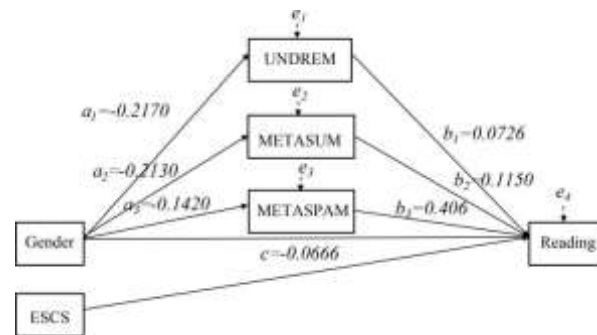


Fig. 3 Statistical diagram of the multilevel serial two-mediator model.

4. Conclusion and Implication

This study aimed to explore whether metacognition of understanding and remembering, summarizing and assessing credibility mediate the gender differences in digital reading. Results of 12,058 samples from 361 schools in China showed that their better achievement in metacognition significantly mediated girls' excelling performance in digital reading. This result reveals why boys' digital reading ability lags behind and the internal mechanism of improving students' digital reading ability. Therefore, pedagogical implementations focusing on metacognition might render help in mending the gender gap in digital reading performance. The limitation of this study lies in the second-hand data that this study used, i.e., PISA data. Using the data of PISA 2018, researchers have to do the data mining based on the existing framework, so there is limited room for this study to explore other kinds of metacognition except for the three metacognition listed above. Therefore, future studies could investigate the role of other kinds of metacognition in mediating the gender difference in digital reading performance.

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