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Learning strategies and reading literacy among Chinese and Finnish adolescents: evidence of suppression

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ABSTRACT
Many arguments have been advanced in the context of the predictive correlation between learning strategies and reading achievement. There is insufficient understanding, however, of the subtle ways in which different types of learning strategies (i.e. memorisation, elaboration and control strategies) function in facilitating students' reading achievement. A *post hoc* analysis was performed to examine this issue among Chinese and Finnish adolescents who participated in the PISA 2009 reading programme. A multigroup structural equation modelling found the suppression pattern among the three strategies: control strategy is positively related to reading literacy and this association increases substantially once memorisation and elaboration strategies are accounted for. There is evidence that Chinese adolescents outperformed their Finnish counterparts due to larger suppression effect from elaboration. Implications for models of learning strategies and intervention are discussed.

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Introduction

Schools and educational researchers on the global scale are grappling with the problem of finding ways to help students learn more and better (McCombs & Miller, 2008). One way of inspiring students to learn is to equip them with a toolbox of learning strategies (Fredricks, Blumenfeld, & Paris, 2004; Weinstein, Acee, & Jung, 2011; Zimmerman, Bembenutty, Cleary, & Kitsantas, 2013; Zusho, Pintrich, & Coppola, 2003). Learning strategies refer to 'behaviours and thoughts that a learner engages during learning and that are intended to influence the learners' encoding process' (Weinstein & Mayer, 1986, p. 316). Based on a diversity of theories, different taxonomies of learning strategies have been introduced, but all of them distinguish between three categories: *control strategies* to manage and control cognitive effort when accomplishing tasks (Pintrich & de Groot, 1990; Zimmerman, 1990), *rehearsal or memorisation strategies* to rehearse or memorise facts (Biggs, 1984; Corno & Mandinach, 1983; Marton & Säljö, 1976a, 1976b) and *elaboration strategies* to connect new information to previously acquired knowledge.

It is generally believed that control and elaboration are deep strategies as they foster more mental engagement in learning and lead to greater achievement (Weinstein & Mayer, 1986; Weinstein et al., 2011). Memorisation, on the other hand, is labelled as surface strategies as it mostly leads to restricted learning (Marton & Säljö, 1976a, 1976b). Several empirical studies have provided evidence supporting the dichotomous effects of the deep and surface learning strategies on reading literacy, for example, the positive effect of control strategy (de Boer, Donker, Dignath van Ewijk, & van der Werf, 2014; Lee, 2014; Leopold & Leutner, 2015; Pintrich & de Groot, 1990) and elaboration (Hamilton, 1999), and the

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negative effect of memorisation (Areepattamannil, 2014; Chiu, Chow, & Mcbride-Chang, 2007; Lee, 2014; Pintrich & de Groot, 1990). However, some counter evidence has also emerged showing the positive effect of memorisation (Hargett, Bolen, & Hall, 1994; Marton, Wen, & Wong, 2005; Purdie & Hattie, 1996) and non-sigificant or negative effect of elaboration (Areepattamannil, 2014; Chiu et al., 2007; de Boer et al., 2014; Lee, 2014; Leopold & Leutner, 2015; Pintrich & de Groot, 1990).

Previous studies can help understand the reasons underlying the confusion. First, the majority of empirical findings are from classroom intervention enquiries. While these studies have the merits of yielding contextualised results, the results are difficult to generalise. Second, to enhance generalisability, many other studies have used data from large-scale assessment programmes, for example, data from the Programme for International Student Achievement (PISA) (to be addressed later). However, they faced limitations in terms of the analytical methods applied (i.e. correlation and regression). This entails the risk that the reported effects of learning strategies on reading reflect only the direct effects (using simultaneous regression) or total effects (using stepwise regression) on reading (Keith, 2014). The subtle interplays among different learning strategies such as mediation, moderation and suppression remain unexplained (Dewe, 2003).

Finally and most importantly, in the majority of previous studies, the relationship between learning strategies and reading literacy achievement has been seen as the addition of the effects of individual learning strategies on reading. This accumulative view of learning strategies might not depict its actual role in real learning situations. As Weinstein et al. (2011) caution, 'Much like a gestalt, the whole is greater than the sum of the parts' (p. 46). A study that adapts this Gestalt view should then be merited to unveil the mysterious 'whole' of the learning strategies in predicting reading literacy. This study was designed to explore the essential phenomenon of suppression that is implied by previous learning strategies research.

Suppression and learning strategies during reading

Statistical research on suppression dates back to the 1940s. Horst (1941) identified that the inclusion of an apparently invalid predictor variable (i.e. having a minimal or zero zero-order correlation with the dependent variable) to a regression equation can contribute an enhanced proportion of explained variance. He called this phenomenon *suppression* and a predictor of this type a *suppressor variable* (or simply *suppressor*). Darlington (1968) used 'negative suppressor' to describe the situations where the initial zero-order correlation between a predictor variable and an outcome variable is non-negative, whereas its partial correlation with (or regression coefficient to) the dependent variable turns negative when used concurrently with another predictor variable that is positively correlated with the outcome variable.

Conger (1974) revised the work of Horst (1941) and Darlington (1968) and defined suppressor variable as one that 'increases the predictive validity of another variable (or set of variables) by its inclusion in a regression equation. This variable is a suppressor only for those variables whose regression weights are increased' (p. 36). In this definition, three suppressor conditions are differentiated: (1) Horst's (1941) *classic suppression*; (2) Darlington's *negative suppression*; and (3) *reciprocal suppression*. This third category by Conger (1974) refers to the situation where two good predictors share information irrelevant to the outcome variable. The Conger definition clearly emphasises what is essential is a shift in zero-order correlation between the initial predictive variable and the outcome variable to an enhanced regression coefficient. This definition can be applied to situations with more than two predictor variables (Tzelgov & Henik, 1991). The current study applies the Conger definition.

In learning strategies research, the concept of suppression is not new. Pintrich and de Groot (1990) examined the relationship between cognitive strategy use (i.e. rehearsing, elaboration and organisation) and self-regulation (i.e. metacognitive strategies such as planning, skimming and comprehension monitoring) to classroom achievement in science and English (consisting of three categories of tasks: seatwork, exams/quizzes and essays/reports). They found the zero-order correlations between cognitive strategy use and seatwork as non-significant. Nevertheless, once the metacognitive strategies predictor was added (which was positively correlated with the dependent variable: $r = .18$, $p < .02$), the regression weight for cognitive strategies as the predictor of the seatwork performance indicator shifted from non-significant to negative (partial $r = -.18$, $p < .02$). The researchers concluded that cognitive strategy use acted as a negative suppressor variable and interpreted this phenomenon as the outcome of their use of self-reported instrument. Nevertheless, the justification of this interpretation has never been tested in other studies.

Another study deserving our space was conducted in the field of educational psychology. In their project, Leopold and Leutner (2015) investigated the effect of Grade-10 students' combined use of self-regulation (or metacognitive strategies including monitoring and control) with some particular cognitive strategies such as text highlighting (a specific rehearsal strategy) and visualising (a particular elaboration strategy). The results of the study showed that highlighting alone produced a large negative effect on reading ($d = -1.25$), but when self-regulation joined in, the negative effect declined significantly ($d = -.21$) (for an introduction to the d index, see the Results section). The study also showed that visualising intervention alone produced medium significant positive effect ($d = .72$) as much as when self-regulation was added ($d = .78$). The shifts of cognitive predictors' effects on the reading outcome apparently point to the phenomenon of suppression effects, though it is not clear which type of suppression emerged in that study, given the absence of a self-regulation only group. Although this type of empirical studies is still few, the information carried is strong: it is highly possible that there is a suppression mechanism hidden under the learning strategies system that affects reading literacy.

To fill in the gap, this study aimed to examine the hypothetical suppression effects of memorisation and elaboration strategies on the predictive relationship of control strategy to reading literacy. Given the recent global enthusiasm for comparing learning of international participants of large-scale assessment programmes, this investigation was designed to use PISA 2009 survey and assessment data from two top-performing nations: China-Shanghai (shortened as China hereafter) and *Finland***.**

The study

Research questions

Three particular questions are addressed:

(1) Is there any difference in the nature (measurement invariance) of learning strategy use (i.e. memorisation, elaboration and control) as measured by the scale, between Chinese and Finnish adolescents?
(2) Do memorisation and elaboration suppress the predictive relation of control strategy use to reading literacy? If so, what is the difference between suppression among Chinese and Finnish adolescents?
(3) How does each suppressor function across Chinese and Finnish adolescents?

Data source

The study used data from PISA data administered in 2009 (or PISA 2009) available from (http://pisa2009.acer.edu.au). PISA assesses adolescent students' (15-year old) performance in reading, mathematics and science. It is administered every three years in participating countries and economies, with a rolling focus on reading, science or mathematics each year. The 2009 data were selected as they were the latest version focusing on reading literacy at the time of this study. More than 46,000 adolescents representing the population of about 1.4 million participated in PISA 2009. Given our additional interest in comparing adolescents from top-performing nations, the study used the China data (the top ranking among all participating nations; $N = 4967$; male = 2445, female = 2522) and Finland data (ranking third among all participating nations and top among participating Western nations; $N = 4180$; male = 2061, female = 2119).

Measures

Learning strategies

The PISA 2009 student survey (Organization of Economic Co-operation & Development, 2009) used 13 items to ask for students' use of metacognitive and cognitive learning strategies during reading (see the Appendix). The cognitive strategies items fell into two categories, namely, memorisation (4 items) and elaboration (4 items). The metacognitive strategies' items had one underlying factor – control strategies (5 items). The survey was a four-point scale, with values of 1 to 4 representing *Almost never*, *Sometimes*, *Often* and *Almost always*, respectively.

Reading literacy

PISA 2009 used items paper-and-pencil tests. The reading test used 131 items (including both multiple choice and self-constructed items) to assess adolescents' reading literacy. Responses to multiple choice items were dichotomously coded and those to self-constructed items were coded using partial credits (Organization of Economic Co-operation & Development, 2010). Rasch modelling was then performed with these raw scores to derive Rasch-based scores (for an overview of different Rasch models, please see Wright & Mok, 2004). The final measure of the reading performance was then represented by a set of five plausible values, which was obtained by accounting for the variation in the Rasch-based scores due to random sampling. The details of this calculation can be found in the PISA 2009 Technical Report (Organization of Economic Co-operation & Development, 2012).

Analyses

This study used multigroup confirmatory factor analysis (MGCFA) and multigroup structural equation model (MGSEM) to examine the proposed models. These analyses were performed on AMOS Version 20.0 (Arbuckle , 2011) using the maximum likelihood methods. The purpose of using MGCFA was to examine (1) whether a three-factor structure of the learning strategies scale represented by the memorisation, elaboration and control strategies items held across groups (configural invariance); (2) whether factor loadings were equivalent (or partially equivalent) across groups (measurement invariance). These two standards are the minimum conditions for across groups' comparison to be meaningful (Raju, Laffitte, & Byrne, 2002).

Building on MGCFA results, the reading literacy variable was added and then multigroup structural equation modelling (MGSEM) was used to examine the tenability of the hypothesised suppression effects across groups. This test followed four steps, in a hierarchical order. Step 1 tested the full measurement model that encompassed the three learning strategies variables together with the reading literacy variable across groups. This was to examine the zero-order relationships between different learning strategies and reading literacy. Step 2 tested the structural model with control strategies as predictor variable and reading literacy as criterion variable across subsamples (the baseline model for suppression hypothesis test). Step 3 added memorisation and elaboration strategies, one at a time, to test the hypothesised suppression effects on the relationship between control strategies and reading literacy across subsamples. Step 4 added memorisation and elaboration together to the baseline suppression model to test their pooled suppression effect on the relationship between control strategies and reading literacy across groups. Finally, all structural paths were first constrained to be equal across the two groups and were compared with the unconstrained model; based on model comparison results, the assumption for causal paths was successively relaxed. The suppression hypothesis would be found to be supported if, after the memorisation or/and elaboration strategies were included in a structural equation predicting reading literacy with control strategies, the initial predictive relationship of control strategies to reading literacy increased (Maassen & Bakker, 2001).

The overall fit of the MGCFA and MGSEM models was assessed using the comparative fit index (CFI), root mean square error approximation (RMSEA) and SRMR as suggested by SEM scholars (Byrne, 2013; Hu & Bentler, 1999). A value of .95 and above for CFI and a value of .05 or below for RMSEA and SRMR

Table 1. Mean scale scores (standard deviations) of Chinese and Finnish adolescents on the learning strategies scale and reading scores.

Variable	China (n = 4967)	Finland (n = 4180)	Cohen's d
Memorisation	2.40 (0.56)	2.26 (0.59)	0.24
Elaboration	2.39 (0.61)	2.18 (0.66)	0.33
Control	2.61 (0.56)	2.57 (0.64)	0.07
Reading literacy	552.12 (94.98)	537.60 (96.91)	0.15

are considered a good fit. The unconstrained models were compared to the constrained model based on the chi-square difference test applying the criteria of $p < .01$.

Results

Descriptive statistics

Prior to MGCFA and MGSEM analyses, we examined the mean differences between sampled Chinese and Finnish adolescents in terms of their self-reported frequency of learning strategy use and reading literacy (Table 1). As shown, Chinese adolescents scored higher than their Finnish counterparts on all three learning strategy use variables and on the reading literacy variable. The magnitude of these differences is reflected in effect size, or Cohen's d, to which Cohen (1969) refers to as the standardised mean difference. Drawing on his suggestion that sizes of .2, .5 and .8 as benchmarks of small, medium and large effects, respectively, the differences in memorisation ($d = .24$) and elaboration ($d = .33$) were small; the difference in control was negligible ($d = .07$); and the difference in reading literacy was small ($d = .15$). Thus, the learning strategies variables and reading literacy displayed country differences only to some small extents.

The multigroup measurement model

To determine the baseline models for the learning strategies scale, we estimated a three-factor learning strategies model that entails memorisation, elaboration and control within each group. The indicator ST27Q02 (figure out what to learn) was found to have low discrimination (i.e. having significant loadings on all three factors). A closer check reveals this item was the only one unrelated to direct comprehension and hence it was dropped for further analysis. As a result, two identical baseline models were identified (labelled as Model 1a for the China group and as Model 1b for the Finland group). This structure had three factors (memorisation, elaboration and control) with the same pattern of four error covariances (i.e. ST27Q05 with ST27Q07, ST27Q03 with ST27Q06, ST27Q09 with ST27Q12 and ST27Q13) and four cross loadings (ST27Q04 on memorisation, ST27Q09 and ST27Q13 on elaboration and ST27Q07 on control).

The two identical models fit both subdata-sets well (Table 2). Although the chi-squares are significant, the other fit indices also indicate good fit. The factor loadings of the indicators on the latent variables are all greater than .40 (except for cross-loadings) and significantly different from zero ($p < .001$), supporting the convergent validity of the measures. Memorisation, elaboration and control strategies emerge as related but distinct factors in both countries. Correlations between these learning strategies factors were .45 (between memorisation and elaboration), .76 (between memorisation and control strategies) and .75 (between elaboration and control strategies) for China. Corresponding values for the Finnish counterparts were .34, .46 and .68, respectively.

As a further test of discriminant validity, we fixed each of the three correlations within each group at 1.00 and examined the resultant increase in chi-square. The increase was significant in each of the six constraints. The smallest chi-square increase in the China group was related to the correlation between control and elaboration ($\Delta\chi^2 = 1585.48$, $p < .001$) and the smallest chi-square increase in the Finland group was related to the correlation between control and memorisation ($\Delta\chi^2 = 1986.578$, $p < .001$). This indicates that making a distinction between the three learning strategies variables provides a better fit

Table 2. Goodness-of-fit statistics for the models tested.

Model	χ^2	df	CFI	SRMR	RMSEA (CI)	Comparison	$\Delta\chi^2$	Δdf	*p*
Part 1: Measurement invariance test									
Model 1a. Baseline – China	487.59	43	.967	.026	.046 (.028, .049)	–	–	–	–
Model 1b. Baseline – Finland	421.54	43	.976	.027	.046 (.042, .050)	–	–	–	–
Model 2. Configural invariance	909.13	86	.972	.026	.032 (.030, .034)	–	–	–	–
Model 3. Full metric invariance	1005.36	99	.969	.030	.032 (.030, .033)	M3 vs. M2	96.23	13	.000
Model 4. Partial metric invariance	924.98	94	.971	.027	.031 (.029, .033)	M4 vs. M2	15.85	8	.045
Part 2: Suppression effect test									
Model 5. Full measurement	1492.34	112	.955	.032	.037 (.035, .038)	–	–	–	–
Model 6. One predictor (control)	156.43	10	.984	.020	.040 (.035, .046)	–	–	–	–
Model 7a. Two predictors (control and memorisation)	874.20	48	.955	.034	.043 (.041, .046)	–	–	–	–
Model 7b. Two predictors (control and elaboration)	726.08	46	.967	.036	.040 (.038, .043)	–	–	–	–
Model 8. Three predictors (no constraint)	1492.34	112	.955	.032	.037 (.035, .038)	–	–	–	–
Model 9. Three predictors (partial constraint)	1493.51	113	.955	.032	.037 (.035, .038)	M7 vs. M6	1.17	1	.280

to the data than treating them as a single learning strategies variable or merging any two. These results show that the learning strategies scale measured the constructs very well for both groups under study.

The two baseline models were then combined to form a configural model (Model 2) that was estimated simultaneously across groups (see Panel 1 in Figure 1). As shown in the upper part of Table 2, the model fit the data very well. The chi-square value with degrees of freedom provided the baseline value against which subsequent tests for invariance could be compared. Subsequently, we followed Byrne (2008) to test the measurement invariance across groups. First, a fully constrained MGCFA model was tested with factor loadings constrained to be equal across groups, which resulted in a good model fit (see indices for Model 3 in Table 2). However, the significance of the chi-square difference due to the full constraints suggested non-equivalence (χ^2 (df) = 96.23 (13), $p < .001$; see the right side of Table 2).

After testing series of modified models, a model (Model 5) with five constraints released was found to produce additional chi-square value non-significant at the .01 level (χ^2 (8) = 15.85; $p = .045$). Chi-square is sensitive to sample size. Given the large sample size in this study, the $p < .01$ rather than $p < .05$ criteria was applied in this study. As this model met the minimum requirement for metric invariance of at least one equal loading for each measure (Meredith & Horn, 2001), we concluded that the partial factorial invariance was established and that cross-national comparisons of the structural parameters would be meaningful (Byrne, Shavelson, & Muthén, 1989).

The multigroup structural model

To test the hypothesised suppressions, a series of measurements and structural models were fit to the data. First, a full measurement model was constructed to examine the correlations among learning strategies factors (i.e. memorisation, elaboration and control) and reading literacy (Model 5; see Panel 2 in Figure 1). Second, a baseline structural model was constructed to examine the predictive relationship of the control variable with reading literacy (Model 6). Third, memorisation and elaboration were added to the baseline model, one at a time, to test the hypothesised suppression effect of each variable on the predictive relationship between control strategies and reading literacy (Model 7a for

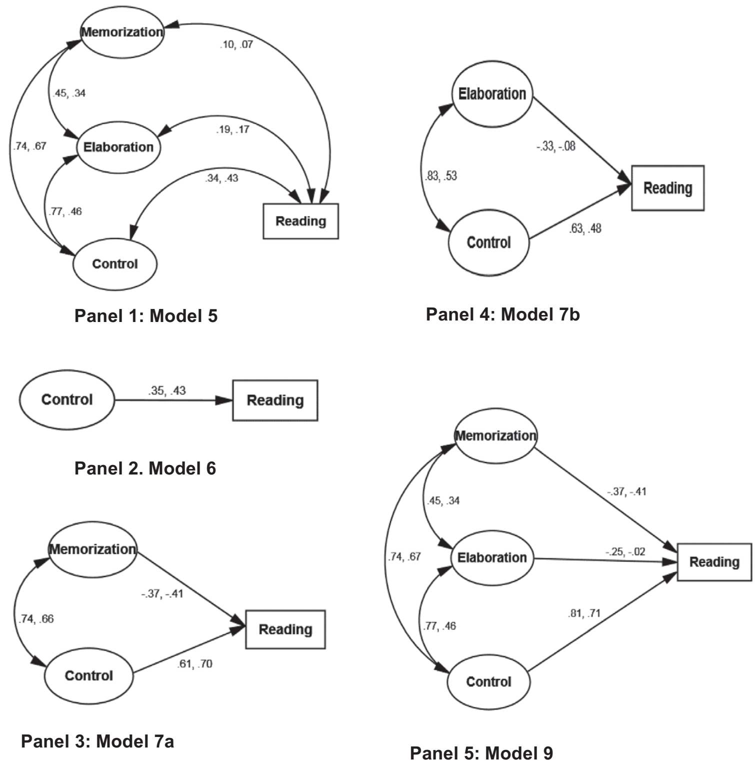

Figure 1. Models for suppression test.
Note: On the left side is the estimate for the China group and the right is the estimate for the Finland group.

memorisation and Model 7b for elaboration). Next, elaboration and memorisation were added together to the baseline model to examine the pooled suppression (Model 8). Finally, the equivalence of factor covariance and path coefficients was evaluated across the China and Finland groups until a plausible partial invariance model emerged (Model 9). The measurement models for memorisation, elaboration and control used for suppression test were based on the partial measurement invariance structure established earlier. Panels reflecting these models are presented in Figure 1 and model fit results are presented in the lower part of Table 2.

The full measurement model (Model 5) tested across the two groups fits the data well (see indices for Model 5 in the lower part of Table 2). In the case of the China group, the memorisation and elaboration variables were found to have positive but weak associations with reading literacy ($r = .10$, p < .001 and $r = .19$, $p < .001$, respectively). In addition, the control variable has a positive and medium association with reading literacy ($r = .34$, $p < .001$). The patterns of the counterpart coefficients for the Finland sample were similar: the associations of memorisation and elaboration with reading literacy were weak and positive ($r = .07$, $p < .001$ and $r = .17$, $p < .001$, respectively) while the association of control with reading literacy was medium and positive ($r = .43$, $p < .001$). The model (Model 6) constructed to test the predictive relationship of the control variable alone to reading literacy across the two groups fits the data well (see indices for Model 6 in the lower part of Table 2), indicating good fit and worthiness of the interpretation. In both groups, the control variable had a positive and medium association with reading literacy ($r = .35$, $p < .001$ for China and $r = .43$, $p < .001$ for Finland).

After including the memorisation variable as a second predictor (Model 7a) of reading literacy, the model fit indices changed slightly but still fit well (see indices for Model 7a in the lower part of Table 2). However, radical shifts in coefficients occurred in both groups. The path coefficient from memorisation

Table 3. Predictive and suppression effects on reading (China/Finland).

Statistics	Models[a]	Model 5	Model 6	Model 7a	Model 7b	Model 8
	Memorisation	.10/.07	–	−.37/−.41	–	−.37/−.41
Coefficient	Elaboration	.19/.17	–	–	−.33/ −.08	−.25/−.02
	Control	.35/.43	.35/.43	.61/.70	.63/.48	.81/.71
Variance explained (R2)	R^2 implied[b]	–	12/18%	37/49%	40/23%	66/50%
	R^2 change (vs. M6)	–	0/0%	25/31%	28/5%	54/32%
	R^2 change (vs. M8)	–	54/32%	29/1%	26/27%	0/0%

[a]On the left side is estimate for the China group and on the right is estimate for the Finland group.
[b]As the negative coefficients from suppressors are substantively meaningless, the direct effect of the major predictor variable is used to derive the total variance explained of the criterion variable.

shifted to the opposite direction ($r = -.37$, $p < .001$ in China and $r = -.41$, $p < .001$ in Finland). Meanwhile, the path coefficients from the control variable to reading literacy increased suddenly ($r = .81$, $p < .001$ in China and $r = .70$, $p < .001$ in Finland). Thus, according to Conger (1974), memorisation served as a suppressor of the relationship between control and reading literacy. For both groups, the initial relationship between memorisation and reading literacy was positive and small and that between control and reading literacy was positive and medium. However, once memorisation was properly added as a second predictor, the relationship between memorisation and reading literacy turned to the opposite direction, while the path coefficients from the control variable to reading literacy became much stronger.

The model that accounted for elaboration (Model 7b) fit the data well (see indices for Model 7b in the lower part of Table 2). Similarly, the inclusion of elaboration shifted the path coefficients from elaboration to reading literacy in both samples to the opposite direction ($r = -.33$, $p < .001$ in China and $r = -.07$, $p < .001$ in Finland). Concurrently, the path coefficient from the control variable to reading literacy became stronger in both groups ($r = .63$, $p < .001$ in China and $r = .48$, $p < .001$ in Finland). As with memorisation, elaboration served as a suppressor of the predictive relationship of the control variable to reading literacy.

A full structural model (Model 8) was then constructed by adding memorisation and elaboration concurrently to the baseline suppression model (Model 6) to examine the pooled coefficients' effects. This model fit the data as well as its measurement form (Model 5). Structural equity across groups was then examined. After placing a series of constrains on the six variance–covariances (i.e. three correlations and three paths), Model 9 that constrained the path from memorisation to reading literacy was the only one to produce a non-significant chi-square change (χ^2 (df) = 1.165 (1), $p < .280$); it is therefore regarded as a plausible representation of the data across groups.

Results of this partial structural invariance model (Model 9) were then used to interpret our findings regarding the pooled predictive and suppressing effects. Coefficients' results are reported in the upper part of Table 3. In this final model, the pooled path coefficient from memorisation to reading literacy became negative and medium ($r = -.37$, $p < .001$ for the China group and $r = -.41$, $p < .001$ for the Finland group). Compared with their counterparts that excluded elaboration (Model 7b: $r = -.37$, $p < .001$ for China and $r = -.41$, $p < .001$ for Finland), these two values remained almost unchanged. Although these results might provide some hints on potential weak suppression effects of elaboration, they are not considered as meaningful indicators of real suppression effects. Also, in this final model, the pooled path coefficient from elaboration became negative and medium ($r = -.25$, $p < .001$ for China and $r = -.02$, $p < .001$ for Finland) versus the values in the model that excluded memorisation ($r = -.33$, $p < .001$ for China and $r = -.08$, $p < .001$ for Finland). The further shift of the path coefficient to the negative direction in the two groups could also give hints regarding the suppression effects of memorisation. Again, they were not reliable for interpreting suppression effect. Next, we turn to the coefficient shifts of the path from the control variable to the reading literacy variable.

After adding concurrently the memorisation and elaboration variables to the baseline suppression model, the coefficient of the path from the control variable to the reading literacy variable suddenly shows a larger and stronger effect ($r = .81$, $p < .001$ for China and $r = .71$, $p < .001$ for Finland), versus the values in the model that excluded memorisation ($r = .63$, $p < .001$ for China and $r = .48$, $p < .001$ for Finland) and those on the model that excluded elaboration ($r = .61$, $p < .001$ for China and $r = .70$, $p < .001$ for Finland). Examining the drop of total variance explained (R^2) of the reading literacy variable provides a more direct sense of the suppression effect (See the lower part in Table 3). Removal of the memorisation variable resulted in sudden drops in R^2 in both China and Finland subsamples ($\Delta R^2 = 26\%$ for China and $\Delta R^2 = 27\%$ for Finland), indicating stable and medium suppression effects from memorisation. However, drop in R^2 incurred by removing the elaboration variable varied across groups ($\Delta R^2 = 29\%$ for China and $\Delta R^2 = 1\%$ for Finland), suggesting that adolescents in China benefited much while their Finnish counterparts benefited little by enhanced control strategies due to more frequent use of elaboration strategies.

Discussion and conclusion

This study aims to enhance our understanding of the interrelation between learning strategies and reading literacy. Using data of Chinese and Finnish adolescents' responses to the PISA 2009 survey and reading assessment, we compared the quality and quantity of learning strategy use across the two subsamples. The quality aspect regarded the factorial structure of the learning strategies scale. Using MGCFA, the study examined the assumed three-dimension factorial structure based on theories and previous studies: two cognitive strategies (memorisation and elaboration) and one metacognitive strategy (control). The findings show a good fit as well as good convergence and discrimination validities of the measurement model in both groups. This suggests that the scale was invariant in nature when measuring adolescents' self-reported use of learning strategies.

The focus of the MGSEM analysis relates to the quantitative aspect of learning strategy use. Specifically, the study explored the interplay between adolescents' use of memorisation and elaboration and use of control in predicting their PISA reading literacy. We first examined the zero-order relationships among the three learning strategies factors and reading literacy in the whole sample. It was revealed that all three learning strategies factors had positive and significant relations with reading literacy, the correlations relevant to memorisation and elaboration being minimal and that relevant to control being medium. Subsequently, we performed MGSEM and compared the paths from the learning strategies predictors to the reading factor. Interestingly, the predictive effect of control on reading literacy increased suddenly and at the same time, both the predictive relations of memorisation and elaboration to reading literacy moved in opposite directions. Indeed, memorisation and elaboration were found to act as suppressors of the residual variance of control strategy use in predicting reading (MacKinnon, Krull, & Lockwood, 2000). Comparing this enhanced effect in different groups, we found that Chinese adolescents benefited more than their Finnish counterparts from the whole suppression system. A closer look reveals that this imbalance seems to have resulted from the unstable performance of elaboration across groups: while its suppression in the China group was strong, in Finland group it appeared to be trivial.

Our findings that cognitive strategies suppress the predictive relation between metacognitive strategies and reading literacy corroborate our earlier position. According to this mechanism, control strategy plays a dominant role in predicting reading literacy. But control strategy does not work alone: when memorisation and elaboration strategies join in, the predictive effect of control strategy on reading literacy increases dramatically. These findings are consistent with what was discovered or emerged in previous studies (e.g. Leopold & Leutner, 2015; Pintrich & de Groot, 1990). Although for some unknown reasons, the phenomenon of suppression has either been ascribed to unforeseeable features of instrument use (Pintrich & de Groot, 1990) or simply left unnoticed (Leopold & Leutner, 2015). However, the features of the study design and the large effect sizes emerged out of the PISA 2009 data from Chinese and Finnish adolescents should be able confirm that the suppression is a real reflection of the reality rather than an accidental presence out of some methodological problems.

One reason for the emergence of this suppression could be that metacognitive and cognitive strategies are intertwined. This explanation can be drawn from the work of Veenman and colleagues

(Veenman, 2011; Veenman, Van Hout-Wolters, & Afflerbach, 2006). The scholars assert that metacognitive activities not only overlook and govern cognitive activities but also draw heavily on them. According to this theory, in this study, control strategy was used to monitor and evaluate the use of memorisation and elaboration strategies but was also limited by them. Through this bidirectional system, control strategy clamped down information inappropriately memorised or elaborated on the one hand; more appropriately and efficiently memorised and elaborated information enhanced efficiency of control strategy use on the other. In this sense, the predictive relation of memorisation, elaboration and control strategy use to reading literacy becomes one that is more than the accumulation of each individual predictor's effect. The soundness of this interpretation can be well supported using findings emerged from Leopold and Leutner's (2015) psychological experimental study.

This cognitive account of *suppression also* fits well with theories in reading research. During the reading process, a reader needs to decode stimulus and retain this information for further processing (a representation of memorisation). To map incoming information to the information foundation, one needs to activate linguistic and prior knowledge (a representation of elaboration). During this course, both relevant and irrelevant information gets activated (Kintsch, Patel, & Ericsson, 1999). While the former is essential for intended mental representation building, the latter usually introduces confusion and distraction (Gernsbacher, 1997). At this juncture, the *suppression* system comes into play and reinforces the relevant and inhibits the irrelevant. Therefore, the volume of information activated can be understood as the mediator between cognitive strategies and comprehension. In this way, the portion of variance attributable to control of irrelevant information gets cleared out by the portion of variance attributable to inappropriate memorisation and elaboration. Put another way, the more efficient the memorisation and elaboration functions become, the less control strategy will be needed to process irrelevant information.

With respect to the relative importance of the two suppressors across groups, the results reveal that the overall suppression effect is stronger in the China group. Looking closer, we found that the memorisation suppressor functions relatively steadily in enhancing the predictive power of control. It contributed to 26% of the total reading variance explained by control in the China group and a similar proportion (27%) in the Finland group. Recall that comparison of mean values shows more memorisation use by Chinese adolescents. However, the suppression effects of memorisation use in both groups are similar, indicating more use of learning strategy does not necessarily lead to more benefits, a conclusion in line with previous findings. But this is only part of the story about the role memorisation plays. Before continuing on this, we describe the findings about the elaboration suppressor first.

Our results with the elaboration predictor indicate that this suppressor increased the effect by 29% of total reading variance explained by the control strategy in the China group while only 1% in the Finland group, which explains why Chinese adolescents outperformed their Finnish counterparts in terms of the pooled suppression effect. This is most interesting, as it points to the current dilemma that researchers are confronted with during the past decade. For too long, Chinese learners have been labelled as rote-learners internationally due to their heavy reliance on memorisation (Rao & Chan, 2010), a type of surface-level learning strategy deemed to be of little value for academic achievement by learning researchers (Biggs, 1987). In the most recent years, however, the fact that Chinese students have continuously excelled in large-scale assessments such as PISA has stunned researchers in the East as well as the West.

Many empirical studies have been conducted, focusing upon Chinese learners. A major finding of these studies is that while it seems true that Chinese students rely heavily on memorisation for learning, the way they engage in memorisation is not necessarily rote-learning; rather, they apply a variety of higher order strategies such as association, analysing and comprehending to facilitate memorisation (Marton et al., 2005). As a result, for Chinese learners, what memorisation leads to is not necessarily static and fragmented pieces of knowledge; it might as well be chunks of information sorted out in a logical order. Knowledge stored in such a manner plays a crucial role in speeding up the retrieval process during reading comprehension, on the one hand, and ensures activation of more relevant information, on the other (Kintsch, 1998). Both of these features might have helped Chinese adolescents use elaboration and hence control strategy more efficiently. That having been said, the reason why Chinese adolescents outperformed their Finnish counterparts in the use of elaboration should be traced back to the way they use memorisation.

Limitations and implications

This study faced several limitations. As this is only a secondary analysis of large-scale assessment data, we were not able to include other cognitive strategies such as organisational strategies in our model. This exclusion weakens the conclusion that cognitive strategies suppress metacognitive strategies in predicting reading literacy. Future studies may consider the inclusion of organisational strategies in addition to those used for PISA survey. In addition, as this is only a cross-sectional study, our discussion about the contributory effects of memorisation on elaboration, which again is to control strategy, is still argumentative. Future research may consider longitudinal designs to explore the interrelationship between metacognitive and cognitive strategies in predicting reading literacy.

Regardless, our findings shed light on the understanding of learning strategies in several ways. First, we understand that it is insufficient to understand the role of learning strategies as functioning additively; rather, one relies on or even evolves from the other. Second, the fact that Chinese students make better use of elaboration strategy to enhance reading is noteworthy. Their outstanding performance indicates that their success might be attributable to the way they use memorisation. Perhaps memorisation is not necessarily surface learning by nature; its level should depend on how one uses it and for what reasons. Together, these findings suggest that before strategy instruction, it is better to diagnose the weaknesses and strengths of the students before moving forward to training. The mastery of a repertoire of learning strategies can make students surf easier when confronted with challenges during reading.

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Appendix. PISA 2009 student survey question 27

© OECD, 2010, available at http://pisa2009.acer.edu.au/downloads/PISA09_Student_questionnaire.pdf

Question: When you are studying, how often do you do the following?

(1 = Almost never, 2 = Sometimes, 3 = Often and/or 4 = Almost always)

(About memorisation strategies)
(1) Try to memorise everything that is covered in the text;
(2) Try to memorise as many details as possible;
(3) Read the text so many times that they can recite it;
(4) Read the text over and over again.

(About elaboration strategies)
(1) Try to relate new information to prior knowledge acquired in other subjects;
(2) Figure out how the information might be useful outside school;
(3) Try to understand the material better by relating it to my own experiences;
(4) Figure out how the text information fits in with what happens in real life.

(About control strategies)
(1) When I study, I start by figuring out what exactly I need to learn;
(2) When I study, I check if I understand what I have read;
(3) When I study, I try to figure out which concepts I still haven't really understood;
(4) When I study, I make sure that I remember the most important points in the text;
(5) When I study and I don't understand something, I look for additional information to clarify this.