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Reciprocal Effects of Self-Regulation, Semantic Knowledge, and Reading Comprehension in Early Elementary School

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Abstract

Many assume that cognitive and linguistic processes, such as semantic knowledge (SK) and self-regulation (SR) subserve learned skills like reading. However, complex models of interacting and bootstrapping effects of SK, SR, instruction, and reading hypothesize reciprocal effects. Testing this "lattice" model with children (*n* = 852) followed from 1^{st}–2^{nd} grade (5.9–10.4 years-of-age), revealed reciprocal effects for reading and SR, and reading and SK, but not SR and SK. More effective literacy instruction reduced reading stability over time. Findings elucidate the synergistic and reciprocal effects of learning to read on other important linguistic, self-regulatory, and cognitive processes, the value of using complex models of development to inform intervention design, and how learned skills may influence development during middle childhood.

Children who are unable to read well by the end of second grade are unlikely to achieve adequate reading skills (Spira, Bracken, & Fischel, 2005), with serious consequences for academic and life success (Morrison, Bachman, & Connor, 2005). Learning to read calls on social, cognitive, linguistic, and text-specific processes, and we are beginning to understand how these processes work together and interact with literacy instruction to support the development of proficient literacy skills. Whereas it is largely assumed, for example, that cognitive and linguistic processes, such as working memory and vocabulary, underpin learned skills, such as reading comprehension (e.g., Swanson & O'Connor, 2009), it is possible that there are reciprocal effects; learning to read may improve cognitive and linguistic skills, which may, in turn further support developing text-specific processes, such as reading comprehension (RC). These interacting processes may combine with the literacy instruction children receive to further impact RC outcomes (Connor et al., 2013; Verhoeven, van Leeuwe, & Vermeer, 2011). The purpose of this study is to test this model of interacting and reciprocal effects of cognitive, linguistic, and text-specific processes, which Connor and colleagues have called the lattice model (Connor et al., 2014), using longitudinal data collected from the beginning of first grade through the end of second grade.

RC, a learned skill, has been defined as the active extraction and construction of meaning from text and is influenced by the students' purpose for reading, the type and difficulty of the text, and the circumstances under which reading occurs (Snow, 2001). In contrast to spoken language, which has a long history in our species and likely evolved to fit the existing constraints of our brains and auditory system (Elman et al., 1996), reading and writing are

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comparatively recent add-on inventions, and thus their development is easily derailed. For example, there are languages that have no written form, cultures where a large proportion of the members are illiterate, and by some estimates, writing (and hence reading) was only invented about 5200 years ago (Daniels & Bright, 1996). Across the US, more than 30% of children fail to learn proficient reading skills (NAEP, 2013), which is much higher than the estimated 7% of children who struggle to develop typical language (Tomblin et al., 1997). Thus, RC might be best considered a skill that is much more likely to develop fully when children receive formal and effective instruction (Taylor, Roehrig, Connor, & Schatschneider, 2010).

It has been argued that in first grade, RC and decoding are conflated constructs, with much of the variance in RC explained by children's decoding skills (Keenan, Betjemann, & Olson, 2008). Certainly decoding can present a bottleneck to reading. If second graders have failed to learn to decode proficiently, they are unlikely to become highly proficient readers (Spira et al., 2005). However, accumulating evidence suggests that by second grade, RC is increasing in complexity and is not well represented by word reading tasks alone (Foorman, Herrera, Petscher, Mitchell, & Truckenmiller, 2015). Hence, for this study, we use age-appropriate latent variables to represent more code-based reading skills at the beginning of first grade moving to more complex conceptualizations of RC as children's reading skills improve through the end of second grade.

The nature of children's prior exposure to language is an important predictor of linguistic performance (e.g., Tomasello, 2003), and it has been shown that ongoing linguistic experience can shape both language comprehension (e.g., Fine & Jaeger, 2013; Kaschak & Glenberg, 2004) and language production (e.g., Kaschak, Kutta, & Jones, 2011). The nature of children's semantic knowledge structures is also crucial for successful language comprehension. Kintsch's (1988) Construction-Integration model places background knowledge at the center of the comprehension process, where it is proposed that comprehension results from the combination of information gleaned from the linguistic input with information about the world that is retrieved from long-term memory. Lack of relevant knowledge leads to a decrement in comprehension performance (Glenberg & Robertson, 1999; Kintsch, 1998). The triangle theory of reading (Seidenberg, 2005) proposes that reading skill hinges on the reciprocal relations among three components: phonological knowledge, orthographic knowledge, and semantic knowledge. The process of learning to read involves learning the relation between orthographic and phonological knowledge, and ultimately developing the ability to link orthographic knowledge and semantic knowledge. The lattice model expands on this model to include instruction and cognitive and linguistic processes, as well as social-emotional aspects of learning (e.g., motivation, etc.) that are beyond the scope of the present study.

We suggest that there is a logical path of reciprocal development between semantic knowledge and the development of literacy skills. Semantic knowledge provides some of the scaffolding needed for children to successfully comprehend printed text—children with better existing semantic knowledge will likely be more successful readers. As literacy skills develop, the comprehension of printed text allows children to acquire more semantic knowledge. Thus, the semantic knowledge may be both a driver of, and a result of, increasing reading skill (Anderson & Freebody, 1981; Cain, Oakhill, & Bryant, 2004; Hoover & Gough, 1990; Kintsch, 1988). Reciprocal effects, with reading predicting language, appear to emerge around second grade, which is between the ages of 7 and 8 years (Storch & Whitehurst, 2002; Verhoeven et al., 2011). Hence, in this study, we follow children from the beginning of first (about age 6 years) through the end of second grade (about age 8 years) and use a construct, semantic knowledge (SK), that includes both vocabulary and academic knowledge (Snow, 2010).

Executive functioning is a multidimensional construct, which includes attention, working memory, task-switching, behavioral-self-regulation, and other processes that support purposeful and flexible adaptation to the environment, particularly on tasks such as reading, that require focused attention (Blair & Raver, 2012; Connor et al., 2010; Fuhs, Nesbitt, Farran, & Dong, 2014; Grammer, Carrasco, Gehring, & Morrison, 2014; McClelland et al., 2007). In this study we focus on specific self-regulatory skills (SR) considered by many to represent the coordination of components of executive functioning including attention, working memory, task switching, and effortful control (e.g., Allan, Hume, Allan, Farrington, & Lonigan, 2014; Cameron et al., 2012). Constructs considered to be, or having strong associations with SR have demonstrated relations with language and literacy (e.g., Arrington, Kulesz, Francis, Fletcher, & Barnes, 2014; Blair, 2002; Kuhn et al., 2014; Lin, Coburn, & Eisenberg, in press; McClelland et al., 2007; Stipek & Valentino, 2014; Swanson & O'Connor, 2009; Trueswell, Sekerina, Hill, & Logrip, 1999) with some evidence that SR has reciproal effects (e.g., Fuhs et al., 2014). However, in younger students there are mixed findings regarding the bidirectionality of relations between SR, language and literacy skills (e.g., Weiland, Barata, & Yoshikawa, 2014) increasing the need for new studies that explore these relations and in particular address questions of reciprocity for both language and RC.

Several plausible mechanisms have been proposed to account for the possible reciprocal relations between SR and academic skills. These include the linguistic component to many tasks, particularly working memory (Booth, Boyle, & Kelly, 2010; MacDonald & Christiansen, 2002), the role that self-directed, inner speech (a linguistic process) may play in cognitive regulation (Barkley, 1997; Cragg & Nation, 2010). Some conjecture that students with stronger behavioral and attentional self-regulatory skills are better able to engage with instruction within classrooms and thus precipitate both improved academic skills and improved SR because of the opportunity to practice self-regulation during instructional episodes (e.g., to stay focused and attentive during small-group instruction, Blair & Diamond, 2008; Lonigan et al., 2015). One possibility, raised by Fuhs et al. (2014) is that executive functioning and SR may be particularly important for skills that require substantial attention, cognitive processing including metacognition (Efklides & Misailidi, 2010), and RC; more so than for already mastered skills (such as naming alphabet letters would be for most first and second grade students). By tracking relations across a time period where RC remains a challenging skill for students, we are able to explore this possibility.

In sum, extant research suggests the plausibility of reciprocal relations among SR, SK, and RC in the context of instruction. To date, however, there has not been a study that simultaneously examines all of these relations longitudinally from the beginning of first grade through the end of second grade (from about 6 to 8 years of age, at the beginning of middle childhood). A finding of reciprocal effects would have implications for theory and practice.

Method

Sample

These data were collected as part of a longitudinal study, completed in 2012, examining the impact of individualized student instruction (ISI) based on students' decoding, vocabulary, and comprehension skills from first through third grade where teachers were randomly assigned to receive professional development in either ISI-Reading or ISI-Math (Connor et al., 2013). In the ISI-Reading condition, teachers used technology that recommended amounts of code- and meaning-focused instruction for each student based on his or her vocabulary, decoding, and RC skills. Students who were in the ISI-Reading classrooms generally had stronger end of first and second grade reading scores (letter-word identification, passage comprehension, and reading comprehension) compared to children in the ISI-Math classrooms. There were no significant differences between groups for language or SR outcomes (see Supplementary Online Materials, SOM, Table S1).

Approximately 47% of the students across the entire sample qualified for free or reduced priced lunch (FRL, an indicator of family poverty). Six percent of the students were Black, 81% were White, and the remaining students belonged to other ethnic and racial groups. Student ages ranged between 5.9 and 8.6 years at the beginning of first grade with a mean age of 6.7 years. They were between 7.6 and 10.4 years old at the end of second grade (mean = 8.5 years). Students who were retained in first grade were not included in this study. All teachers were certified and all used the same core literacy curriculum: Houghton-Mifflin *Storytown* for first through second grades. Schools (n = 5) were located in a North Florida district along the Gulf coast and were economically diverse, with school-wide rates of FRL enrollment ranging from 39% and 59%.

In 2008–2009, 468 first-graders and their teachers were recruited for the study. We then followed the students into second grade and recruited their new teachers and classmates (n = 636 students). Of the original first grade students, second grade data were available for all but 10%. These students were lost to follow-up because they left the district and moved too far away to follow. Data for all of the children who had data in first and or second grade (n = 852) were included in this study.

Measures

Students were assessed in the fall (August-September), early spring (February-March) and spring (April-May) of each school year on a battery of language, literacy, and cognitive assessments in a quiet place in their school. Trained research assistants conducted the assessments. For this study, we selected fall and spring assessments that represented our constructs—RC, SK, and SR.

We used three measures to assess RC: two subtests from the *Woodcock-Johnson Tests of Achievement-III* (WJ-III, Woodcock, McGrew, & Mather, 2001); the *Letter-word*

Identification Test (LW) and *the Passage Comprehension test (PC)*, and the *Gates-MacGinitie Reading Tests* 4th edition (GMRT, MacGinitie & MacGinitie, 2006). *The Letter-word Identification* test starts with letter and letter-sound identification and then asks children to read lists of increasingly difficult words. During the *Passage Comprehension* assessment students are asked to read a sentence or passage and provide a missing word to complete the sentence or story. Both assessments provide reliable measures of reading, even with young students (alpha = .94 for RC and .88 for PC). W scores, which are a variation of the Rasch score (Rasch, 2001) and provide an equal interval metric across grades, were used in the analyses. A W score of 500 represents the expected score of a 10-year-old student.

The GMRT is a group administered assessment that requires students to answer questions after viewing a series of pictures or reading passages that are designed to tap decoding and comprehension. This test was administered in spring of first grade and in fall and spring of second grade. Extended scale scores (ESS), which are similar to W scores and provide an equal interval metric centered at 500, were used in the analyses. Means and standard deviations are provided in Table 1 and Table S2. These tests have shown high reliability at alpha = .91 for the vocabulary subtest and .92 for the comprehension subtest.

To assess SK we used two assessments from the WJ-III, the *Picture Vocabulary* (PV) and the *Academic Knowledge* (AK) assessments. The PV test (alpha = .81), which was administered individually, asks students to name a series of increasingly unfamiliar pictures. The AK task (alpha = .90) is administered individually and all items are presented and answered orally (e.g., *Why do people put money in the bank?)* and, according to the test developers, assesses "acquired content or curricular knowledge, an aspect of crystallized intelligence, in various areas of science (biological and physical sciences), social studies (history, geography, government, and economics), and humanities (art, music and literature)" (Mather & Woodcock, 2001, p. 87). Additionally, it requires children to listen to orally presented questions and respond appropriately. Again, W scores were used in the analyses.

To assess SR, we used two measures: the *Head Toes Knees Shoulders* task (HTKS, Cameron & Connor, 2004; McClelland et al., 2007) in fall and spring of first grade, and the *Conners Rating Scale* (Conners, 2001), which was completed by the students' teachers in the spring of first grade. The HTKS is designed to tap the coordination of SR skills including attention, working memory, task switching, and behavioral inhibition. The more difficult version of the HTKS, which is appropriate for children through first grade (about 7 years of age), includes 20 items that utilize four behavioral commands: "touch your head", "touch your toes", "touch your knees" and "touch your shoulders." Children are asked to do the opposite of what the tester says. For example, if the tester says "touch your head" the child should touch his or her toes. The HTKS has been shown to be significantly related to direct measures of cognitive flexibility, working memory, and inhibitory control in prekindergarten and kindergarten in multilevel regressions (β's .15–.42; McClelland et al., 2014; Ponitz et al., 2008). The HTKS has also been found to be significantly related to parent-reported attention and inhibitory control (r's .20–.25); to direct assessments of working memory, inhibitory control, and cognitive flexibility (Lan, Legare, Cameron Ponitz, Li, & Morrison, 2011; McClelland & Cameron, 2012); and to teacher ratings of self-regulation in the classroom using multilevel models (β's .20–.40) (Gestsdottir et al., in press; McClelland et al., 2007;

Ponitz, McClelland, Matthews, & Morrison, 2009; Wanless et al., 2011). In addition, previous studies have demonstrated that the HTKS is significantly related to growth in literacy in preschool and in first grade (Connor et al., 2010; McClelland et al., 2007).

The *Conners* was designed to assess symptoms of Attention Deficit Hyperactivity Disorder (ADHD) and the scales were designed to align with the *Diagnostic and Statistical Manual of Mental Disorders-IV.* The teacher report version is considered appropriate for children from ages 3 to 17 years. We used the short form, which includes 28 items on a four-point Likert scale from 0 = not true at all to 4 = very much true. Example items include: “Inattentive, easily distractible; short attention span” (p. 25). We used two subtests of the *Conners*, one that assesses attention and the other that assesses hyperactivity. Attention (Attn) raw scores range from 0 to 15 with higher scores indicating weaker attention skills. Hyperactivity (Hyp) raw scores ranged from 0 to 20 with higher scores indicating greater indications of hyperactivity. For all our models, we reverse coded the two scales so that higher scores represented greater SR. The scales demonstrate high internal reliability (.873–.917) for this age range across subscales) and predictive validity.

Results

Although there was a wide range of scores, overall, children in the sample demonstrated typically developing SK, RC, and SR skills with expected levels of development on all skills over time for those measures (see Tables 1 and S.2). For example, W scores on the PC increased from 441 in fall of first grade to 487 by the end of second grade with mean standard scores (M = 100, SD = 15) from 98 to 101. Similar gains were seen for the other measures. We also observed high levels of stability for SK and RC underscoring the importance of considering children's general development.

To test reciprocal effects of RC, SR and SK, we used Structural Equation Modeling (SEM) to create latent variables and conduct path analyses (Kline, 1998) using the IBM SPSS AMOS software (version 22.0). Estimated marginal means were used to accommodate missing data. Zero-order correlations revealed most of the variables to be significantly related (see Table 1). Confirmatory factor analysis was used to develop latent variables from the data. Latent variables have the advantage of reducing measurement error (Hoyle, 1995).

We used AK and PV to represent a more complex construct that captured the semantic system, semantic knowledge (SK). This construct is closely related to the construct of academic language (Snow, 2010) and is more likely to predict and be predicted by SR and RC.

PC and LW in the fall of first grade and LW, PC, and Comp in the spring of first and second grade represented RC. Again, because the GMRT is group administered, we judged it not acceptably reliable for first graders at the beginning of the school year so it was used in the spring of first grade and spring of second grade RC variables. Moreover, we have to assume that the construct of RC is changing from fall to spring in first grade as children's word reading skills become more automatic. Hence the addition of the GMRT captures increasing skills and the complexity of the construct.

For fall SR, we used the fall HTKS as an observed variable. For spring SR we used HTKS, as well as Hyp, and Attn from the *Conners* to create a latent variable.

We started with a first grade model and tested all of the hypothesized relations among SR, SK, and RC. Model fit was determined using three widely used indicators of fit: Incremental Fit Index (IFI) and Comparative Fit Index (CFI) where adequate fit includes values above .90 and RMSEA, where good fit includes values below .06 and adequate fit includes values below .09 (Hoyle, 1995). Fit was adequate (IFI = .925; CFI = .924; RMSEA = .073). We found significant reciprocal relations between SK and RC and between RC and SR. However, we found no significant relations between SR and SK so these paths were trimmed for the final model (see Figure 1). The models were not significantly different (change in $X^2(2) = 1.56$, $p > .05$).

We then expanded the model through the end of second grade to examine whether reciprocal effects persisted. We again tested reciprocal effects between SR and SK and they were not significant and so were trimmed from the model, which improved fit. The results are provided in Figure 2. Again, model fit was adequate (IFI = .918; CFI = .918; RSMEA = .065, see Table S3 for path coefficient estimates). We replicated the first grade findings and found consistent reciprocal effects between RC and SK through the end of second grade; SR in spring of first grade predicted end of first grade RC but not end of second grade RC. Stability in SK was high from first through the end of second grade with the model explaining virtually all of the variance in children's SK scores (squared multiple correlation = 1.0, see Figure 2). RC and SR demonstrated less stability in first grade. However, stability in RC increased by the end of second grade and, again, the model explained virtually all of the variability in children's end of second grade RC scores (squared multiple correlation = .93, see Figure 2).

Because students in the ISI-Reading classrooms had significantly higher reading scores than did students in the ISI-Math classrooms, we compared the model in Figure 2 by treatment group (see SOM Table S4 and Figures S.1 & S.2). Results were essentially the same for each group, with a chi-square test revealing no significant difference between group models [$X^2(22) = 25.71$, $p = .260$]. However, as might be expected, RC for students in the ISI-Reading classrooms was less stable from first through second grade than for students in the ISI-Math classrooms (i.e., path coefficients were significantly smaller, see SOM Table S4). There were also differences in first grade reciprocal effects between RC and SK.

Discussion

The aim of this study was to begin to test the lattice model by examining reciprocal relations among self-regulation, semantic knowledge, and reading comprehension, considering instruction, in a longitudinal sample of students from the beginning of first through the end of second grade. The hypotheses generated by the model were supported but not completely. Reading comprehension demonstrated reciprocal effects with both self-regulation and semantic knowledge. However, self-regulation and semantic knowledge were, surprisingly, not related. We also examined the impact of instruction by taking advantage of the randomized controlled trial for which these data were collected. According to the lattice model, instruction is an integral part of the model as a key source of influence on children's development. The literacy instruction a child received in this study predicted their reading comprehension outcomes. Overall, models for children who received more effective versus less effective literacy instruction in first grade were similar. However, reading comprehension was less stable over time in the context of more effective instruction. That is, children's abilities early in first grade were less likely to predict their reading skills at the end of second grade because, we assume, they received generally more effective instruction compared to the children in the control group. Changing the associations between fall and spring reading comprehension also slightly changed associations between reading comprehension and semantic knowledge, with fall semantic knowledge more predictive of spring reading comprehension (path coefficient = .26) and fall reading comprehension less predictive of spring semantic knowledge (path coefficient = .02) for students in the ISI-Reading group compared to the control, where the reciprocal associations remained fairly even (.14 and .12 respectively). While we can only conjecture as to why this might be, it is possible that as students were gaining stronger reading comprehension skills in the ISI reading classrooms, they were better able to use established vocabulary and academic knowledge to bootstrap reading comprehension gains compared to the control group. Such bootstrapping effects are hypothesized in the lattice model.

In general, many researchers have assumed that the processes of self-regulation and semantic knowledge provide the foundation for learned skills, such as reading comprehension, and have not considered that there might be something about learning to read that improves self-regulation—although there is accumulating evidence that reading comprehension predicts vocabulary starting around second grade (Verhoeven et al., 2011). Our results suggest this synergistic effect may start as early as first grade, likely because we used a more complex construct, semantic knowledge.

Why might improving reading comprehension predict improving self-regulation and semantic knowledge? Indeed, by any standard, the path coefficient from fall first grade reading comprehension to spring first grade self-regulation was large (standardized path coefficient = .60). There is emerging evidence that reading interventions may change the structure of the brain (Shaywitz et al., 2004; Simos et al., 2007). The pathways between the visual cortex, auditory cortex, and cortical areas involved in language use (e.g., Broca's and Wernicke's areas) strengthen (Pugh et al., 2001), which may provide a partial explanation for the reciprocal effects of semantic knowledge and reading comprehension and, perhaps, self-regulation as the prefrontal cortex continues to develop (Del Giudice, 2014). Learning to read may also contribute to developing metacognition (Cain, Oakhill, & Bryant, 2004), which might support developing cognitive and self-regulatory processes in general. Instruction in first grade is more formal than at home, or in preschool and kindergarten. Students are expected to sit and listen for longer stretches of time. Furthermore, learning to read is difficult, and requires attention and persistence. This change in the structure of instruction may support developing self-regulation as well as reading comprehension and semantic knowledge as children progress through school. The impact of reading comprehension on semantic knowledge has greater support in the literature, which offers several pathways (Cain, Oakhill, & Lemmon, 2004). For example, children are exposed to academic words through print and story reading that are not used in every day conversations (Dickinson & Porche, 2011).

There are limitations to this study that should be considered as the results are interpreted. First, this sample was socio-economically diverse but was relatively less ethnically and racially diverse than nationwide norms as evidenced by a high percentage of White participants relative to other ethnicities. According to the US Census Bureau, the nationwide percentage of children under 18 years of age living in poverty is about 20% (http://www.census.gov/hhes/www/poverty/about/overview/index.html); however, about 47% of the children in our sample qualified for FRL in 2009–2010 http://nces.ed.gov/programs/digest/d12/tables/dt12_046.asp) when these data were collected. Hence the children in this sample were at somewhat higher risk for underachievement than the typical population and this should be considered. The oversampling of children attending higher poverty schools was intentional as part of evaluating the ISI-Reading intervention.

Second, we were not able to use consistent self-regulation measures because the *Conners* was given only once in early spring of first grade and was not given in second grade; nor was the HTKS. This study should be replicated with consistent measures of both self-regulation and executive functioning and more measures of each. By including more measures of self-regulation and executive functioning, we would be able to better understand the association between the two constructs, whether they are actually two constructs, and their reciprocal relation with language and literacy. Further, while our academic measures captured reading comprehension, and, one might argue that our assessment of academic knowledge assessed listening comprehension, we did not explicitly assess students' intellectual ability (IQ)—although certainly semantic knowledge would be highly influenced by verbal IQ. Third, because the SEM models presented in this study do not explicitly include teacher and school variables but consider them indirectly through instruction, these and other important sources of influence, such as socioeconomic status, on children's developing reading comprehension, self-regulation, and semantic knowledge are missing.

Although interventions for executive functioning and self-regulation have been investigated, there is limited evidence that improving working memory, for example, results in improved reading comprehension (see for example, Swanson & O'Connor, 2009). In contrast, there are an ever-increasing number of effective literacy interventions. For example, the ISI-reading intervention revealed a significant effect of treatment on both reading, and on HTKS for children with low fall HTKS scores (Connor et al., 2010). The researchers conjectured that high expectations for self-regulated learning during child-managed activities might have explained the results. The present results suggest that the more effective reading instruction leading to greater reading comprehension probably contributed as well. Other interventions that integrate support for self-regulated learning with explicit writing instruction are also effective (Harris, Graham, & Mason, 2006). Based on these results, it may be the integration of support for self-regulation, semantic knowledge, and literacy that underlie the interventions' efficacy.

An implication of this study is that effective instruction as children learn to read and comprehend may support cognitive and linguistic development reciprocally and synergistically. The findings of this study reinforce the importance of early elementary grades for many aspects of development during early and middle childhood (Del Giudice, 2014), and illustrate the usefulness of more complex models of development. In turn, such models suggest that high-quality, multi-component instructional interventions within these critical developmental periods are likely to be more effective in the long run than highly specific interventions that target just one construct. Using this information to inform interventions can bolster their potential to positively impact students' development across multiple domains and could ultimately contribute to improving the educational landscape of our nation's young students.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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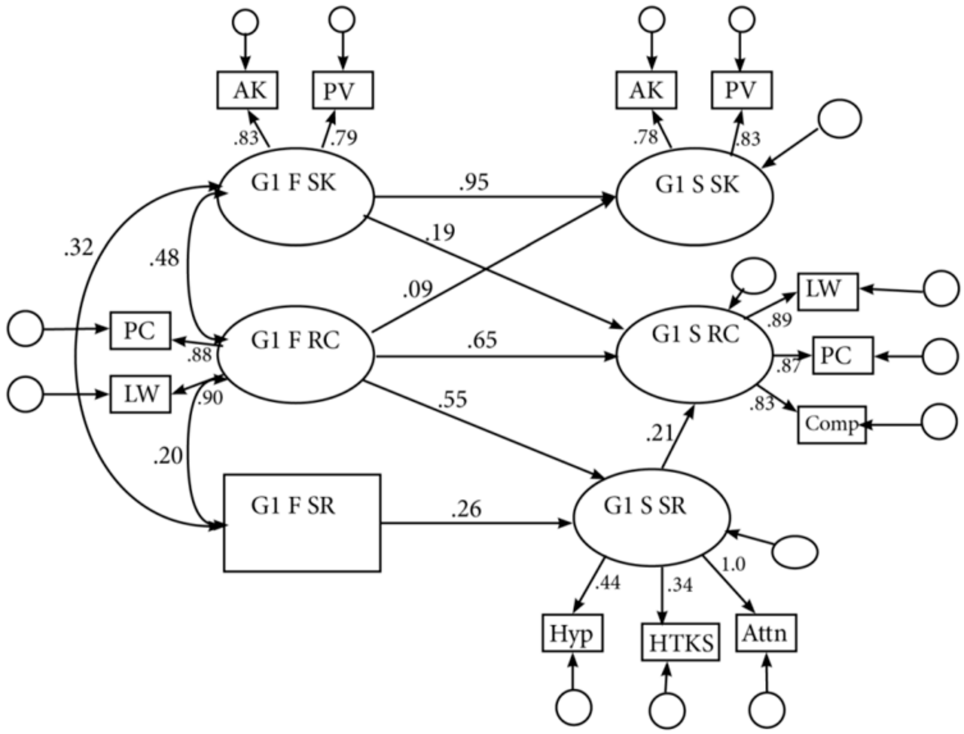

Figure 1.

First grade path diagram. All standardized path coefficients are significantly greater than 0 ($p < .05$.). First grade = G1, Fall = F, and Spring = S, Head Toes Knees Shoulders = HTKS, Passage Comprehension W score = PC, Gates MacGinitie Reading Test Extended Scale Score = Comp. Picture Vocabulary W score = PV, Academic Knowledge = AK. SK = Semantic Knowledge, RC = Reading Comprehension, SR = Self Regulation. IFI = .925; CFI = .924; RMSEA = .072. Numbers by the variables are the squared multiple correlations, which represent the variance explained by the model for that variable (e.g., The model explains 81% of the variance in RC). The path diagram from AMOS is in the SOM Figure S. 3.

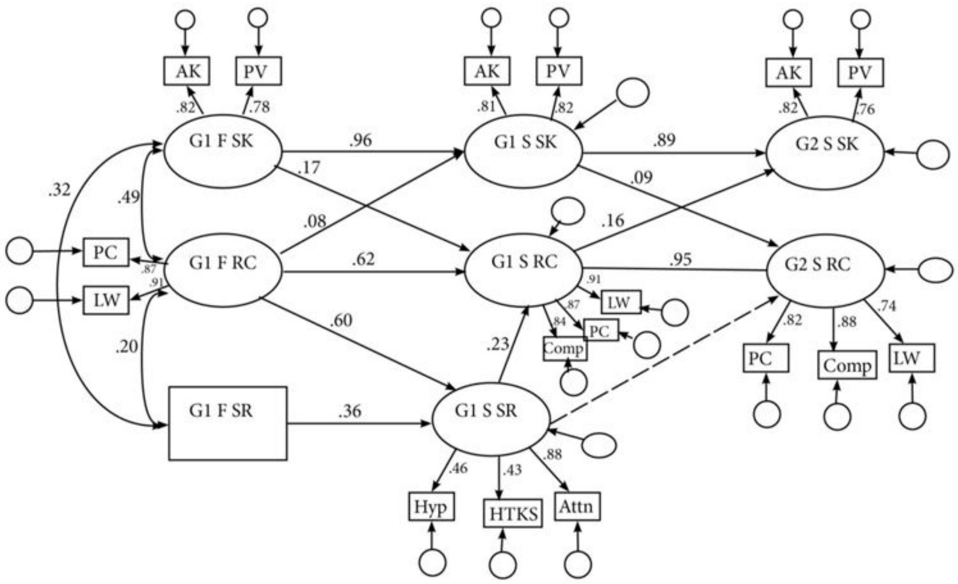

Figure 2.

First through second grade path diagram. All standardized path coefficients are significantly greater than 0 ($p < .05$) except for the path from G1 S SR to G2 S RC (dashed). First grade = G1, Second grade = G2, Fall = F, and Spring = S, Head Toes Knees Shoulders = HTKS, Passage Comprehension W score = PC, Gates MacGinitie Reading Test Extended Scale Score = Comp. Picture Vocabulary W score = PV, Academic Knowledge = AK. SK = Semantic Knowledge, RC = Reading Comprehension, SR = Self Regulation. IFI = .918; CFI = .918; RSMEA = .065. Path coefficients are centered on their respective path. Numbers by the variables are the squared multiple correlations. The path diagram from AMOS is in the SOM (Figure S.4).

Table 1

Zero-Order Correlations Among Variables Used in the Analyses

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1. G1 F AK	1																
2. G1 F PV	.63***	1															
3. G1 F LW	.36***	.3***	1														
4. G1 F PC	.4***	.34***	.79***	1													
5. G1 S AK	.68***	.58***	.41***	.39***	1												
6. G1 F HTKS	.31***	.23***	.17***	.2***	.31***	1											
7. G1 S PV	.67***	.72***	.39***	.39***	.61***	.2***	1										
8. G1 S LW	.37***	.28***	.77***	.68***	.41***	.2***	.38***	1									
9. G1 S PC	.52***	.41***	.61***	.62***	.46***	.24***	.51***	.77***	1								
10. G1 S Comp	.5***	.4***	.61***	.61***	.52***	.26***	.46***	.71***	.74***	1							
11. G1 Hyp	.17**	.05	.16**	.21**	.12	.22***	.08	.23***	.16**	.19**	1						
12. G1 Attn	.33***	.22**	.49***	.56***	.41***	.37***	.29***	.62***	.54***	.53***	.44***	1					
13. G1 S HTKS	.21***	.19***	.16***	.24***	.3***	.46***	.18***	.2***	.21***	.25***	.14*	.35***	1				
14. G2 S AK	.66***	.59***	.45***	.45***	.75***	.25***	.61***	.43***	.49***	.55***	.06	.43***	.24***	1			
15. G2 S PV	.58***	.6***	.43***	.39***	.62***	.18**	.63***	.46***	.46***	.48***	-.05	.32***	.11*	.59***	1		
16. G2 S LW	.33***	.3***	.62***	.49***	.4***	.14**	.39***	.81***	.68***	.64***	.05	.43***	.12*	.46***	.47***	1	

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
17. G2 S PC	.51***	.39***	.54***	.48***	.53***	.2***	.46***	.61***	.59***	.63***	.07	.39***	.17**	.57***	.51***	.72***	1
18. G2 S Comp	.45***	.41***	.44***	.45***	.48***	.24***	.45***	.51***	.6***	.64***	.13	.4***	.26***	.53***	.43***	.62***	.62***
Mean (SD)	475.09 (11.09)	481.88 (9.95)	419.43 (27.58)	441.97 (23.18)	480.63 (9.84)	33.77 (7.40)	487.22 (9.84)	462.18 (22.23)	474.90 (13.70)	415.78 (45.16)	-4.28 (5.34)	-3.42 (4.04)	37.17 (3.78)	489.54 (10.51)	494.00 (9.69)	487.01 (19.20)	487.51 (11.36)

Note. First grade = G1, Second grade = G2, Fall = F, Spring = S, Head Toes Knees Shoulders Raw Score (RS) = HTKS, Conners RS Attention = Attn, Conners Hyperactivity – Hyp, Passage Comprehension W = PC, Picture Vocabulary W = PV, Academic Knowledge W = AK.

* $p < .05$,

** $p < .01$,

*** $p < .001$