Contributions of Growth Rates in Phonological and Spatial Skills to Chinese Reading and Mathematical Competencies: A Longitudinal Study of Hong Kong Kindergarteners

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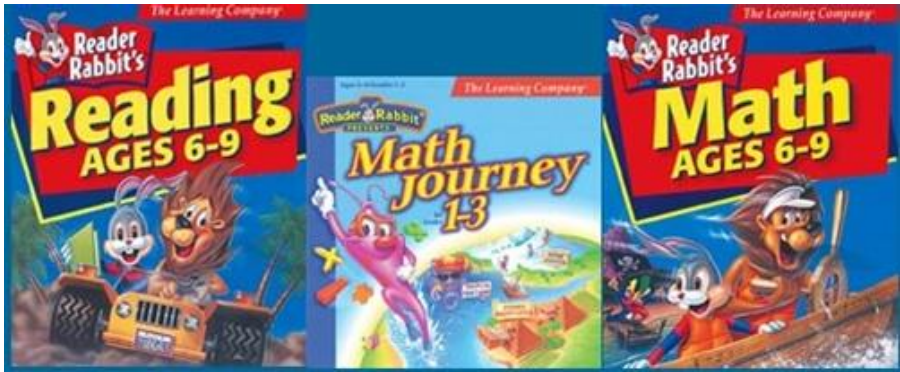
Why Study Early Reading and Mathematics?

- Early reading and mathematical competencies are predictive of

(1) school academic achievement (Duncan et al., 2007: *Ns* = 21,260; 17,196; 12,686; 1,928; 1,364; 985; *Developmental Psychology*);

(2) adult socioeconomic status, including *income*, *housing*, *education*, and *occupation* (Ritchie & Bates, 2013: *N* = 18,558; *Psychological Science*).



Domains of Reading and Mathematics

- Domains of reading: reading accuracy, reading fluency, reading comprehension etc
- The present study: Reading accuracy/Chinese character recognition (e.g., read aloud 朋友 鼻子)

- Domains of mathematics: arithmetic (number and operations), algebra, geometry, measurement etc
- The present study: Arithmetic word problems (算術應用題; e.g., Ivy has four pens. Her brother gives her three more pens. How many pens does Ivy have now?)

How Hong Kong Kindergarteners Learn to Read and Calculate?

- Drill children in reading, writing, and calculating?
- Children: low motivation to learn?

- Engage children in playful learning to develop their generic skills that can help them read, write, and calculate later on?
- Children: high motivation?

What Generic Skills Might Be Helpful?

- Language skills (developed through social communication etc): vocabulary, phonological skills, morphological skills etc.

- Spatial skills (developed through spatial talk and playing spatial manipulation toys etc): spatial perception, spatial visualization etc.

- Executive functions (developed through pretend play etc): inhibitory/attention control, cognitive flexibility, working memory etc.

Generic Skills in This Study

- Language skills: phonological awareness
- Overall level predicted both Chinese reading and mathematical competencies (Siok, & Fletcher, 2001; Zhang & Lin, 2015)

- Spatial skills: spatial perception
- Overall level predicted both Chinese reading and mathematical competencies (Lin, Sun, & Zhang, 2016; Zhang, 2016; Zhang et al., 2014)

Why Phonological Awareness?

- Definition: the ability to detect and manipulate units of oral language, such as syllables, onsets and rimes, and phonemes.

- Importance for reading: double deficit hypothesis

- Importance for arithmetic (word problems):

- Help understand linguistic information and build a linguistic representation of the problem;
- Facilitate processing of verbal codes for number words.

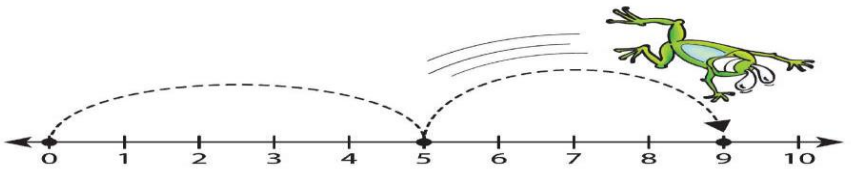
Why Spatial Perception?

- Definition: the most basic spatial function that involves identifying spatial relations among task components in sprite of distracting information.

- Importance for Chinese reading:

- Facilitate processing of the rich visual-spatial features of Chinese characters. E.g., 烏龜

- Importance for arithmetic:



- Help build a spatial representation of numbers, i.e., mental number line

Research Gap

- Prior work is limited to assessing phonological and spatial skills at a single point in time and examine the relations from overall level of these skills to Chinese reading and mathematical competencies.

- Little work has been done to explore whether the rates of growth in phonological and spatial skills are predictive of subsequent Chinese reading and mathematical competencies.

Why is Rate of Growth so Important?

- Suppose you've got two job offers:

Offer	Starting Salary (Overall Level)	Rate of Growth per Year	Your Decision
1	HK$10,000	HK$10,000	?
2	HK$20,000	HK$1,000	

Why is Rate of Growth so Important?

- Suppose you have two students in your class:

Student	K1 Phonological Skills (Overall Level)	Rate of Growth per Year	K3 Chinese Reading and Math Ability
1	40 Points	20 Points	?
2	50 Points	5 Points	

Why is Rate of Growth so Important?

- Rate of growth may contain more information about children's developmental and learning potential than overall level measured at a single time point.

- Zone of proximal development (Vygotsky, 1934/1962; ZPD): the gap between current capability and potential capability after learning (i.e., growth)
  - ZPD is a better predictor of academic success than traditional IQ, which assesses only current capability.

Research Question

- Do (1) overall levels of phonological and spatial skills at the start of kindergarten and (2) their rates of growth over time contribute to Chinese reading and mathematical competencies as measured at the end of kindergarten?

Method

- **Participants**

  106 Chinese children (57 girls; age at the first time point: *M* = 45.1 ± 3.4 months) from two kindergartens in Hong Kong.

Children were tested individually a total of 5 times by trained testers from K1 to K3: in the spring (May, Time 1 [T1]; *N* = 106) of K1, the fall (November, Time 2 [T2]; *N* = 88) and spring (May, Time 3 [T3]; *N* = 80) of K2, and the fall (November, Time 4 [T4]; *N* = 75) and spring (May, Time 5 [T5]; *N* = 71) of K3.

Method

- **Measures**

  Seven tests were used across the different time points. Spatial perception and phonological skills were tested at each point from T1 to T4. Chinese reading and mathematical competencies were tested at T5. Three control measures, i.e., spatial visualization, spatial analogic reasoning, and mental rotation, were tested at T4 or T5.

The reliabilities of the tests were all very good ($\geq .71$). The raw sum scores were calculated for all variables and used in all analyses.

Method

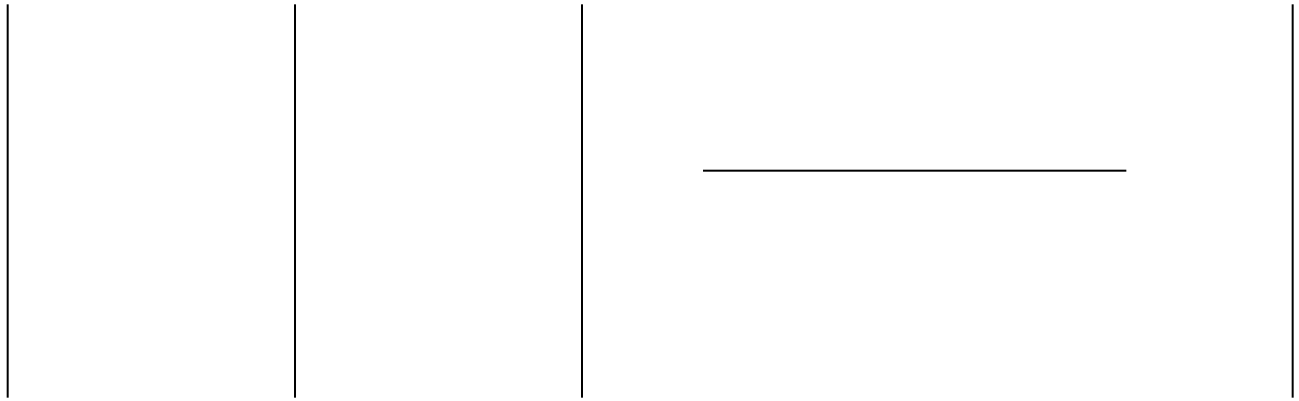
Measures

1. **Phonological awareness.** This was assessed using a test of syllable awareness (16 items), which represents phonological awareness involving the detection and manipulation of sounds at the syllable level (McBride-Chang, 2004). Children were read each three-syllable phrase (e.g., 大門口/daai6 mun4 hau2/) and asked to isolate and say aloud one of the syllables (e.g., the first syllable,大/daai6/).

Method

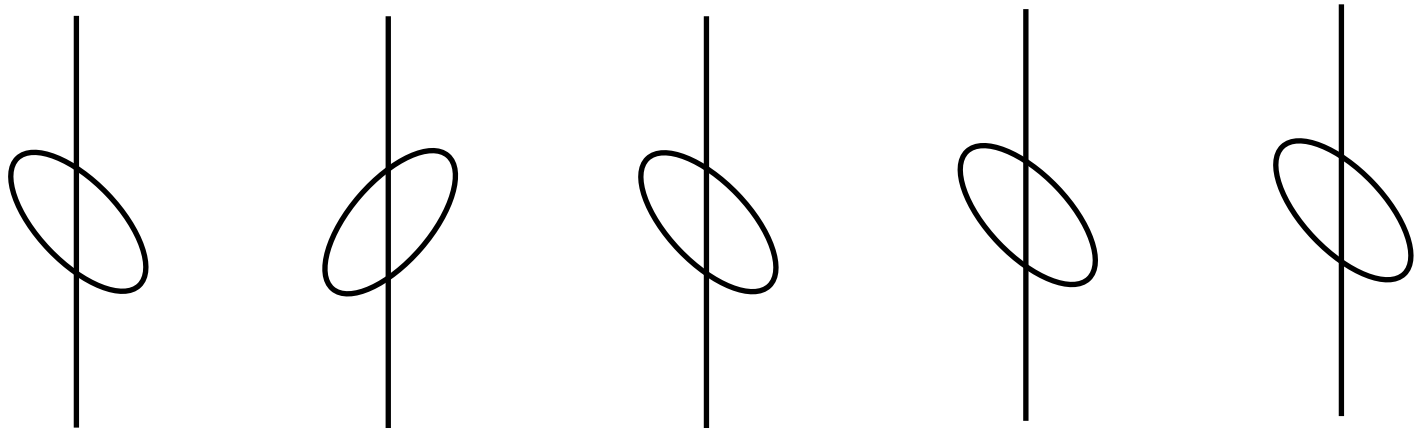
2. Spatial perception. This was assessed using the visual-spatial relationship subtest (16 items) from the Test of Visual-Perceptual Skills Revised (Gardner, 1996). Children were asked to select a target figure presented partly or wholly in a different orientation from four other simultaneously presented figures.

E.g.,



Item 1

Method



Item 4

Item 16

Method

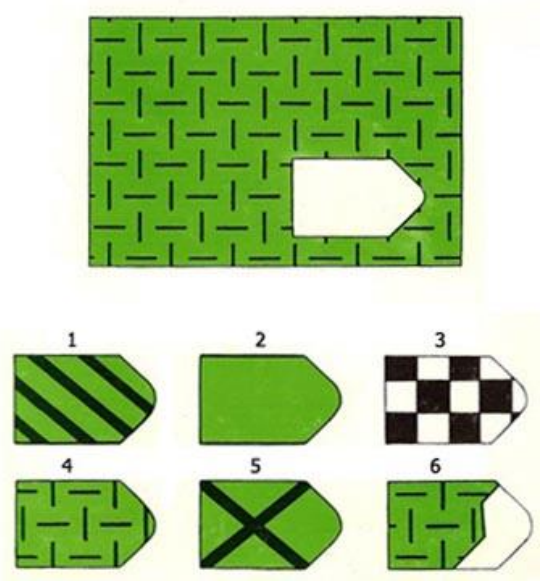
3. Chinese reading. This was assessed using a word reading test (60 double-character Chinese words; for a similar test see Lin et al., 2010). All the words were based on Hong Kong preschool and primary school textbooks. Children were asked to read the words, which were arranged with increasing difficulty, from beginning to the end. The test was stopped when the child had failed to read 10 consecutive words. The answer was considered correct only when both of the two characters in a word had been read accurately.

Method

4. **Mathematics competence.** This was assessed using an arithmetic word problems test (10 items) adapted from the Story Problems subtest of the Number Competency Core Battery (Jordan, Kaplan, Ramineni, & Locuniak, 2009). The test contains five addition and five subtraction items (sample item: “Ah Ming has four pens. His elder brother gives him three more pens. How many pens does Ah Ming have now?”). Children were read each item and asked to respond with a verbal answer of a number word.

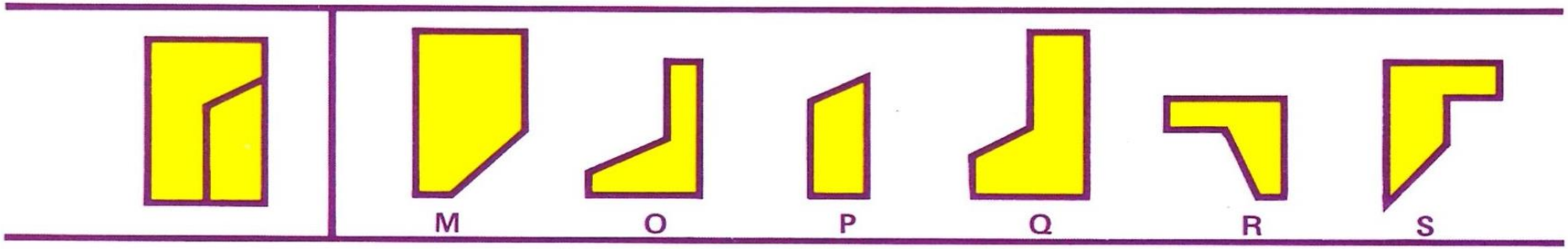
Method

5. Spatial analogic reasoning. This was assessed using sets A and B of Raven's Colored Progressive Matrices (Raven, 1958). Each set consists of 12 items. Given a matrix with a missing part, the child was asked to select a figure from six options to complete the matrix.



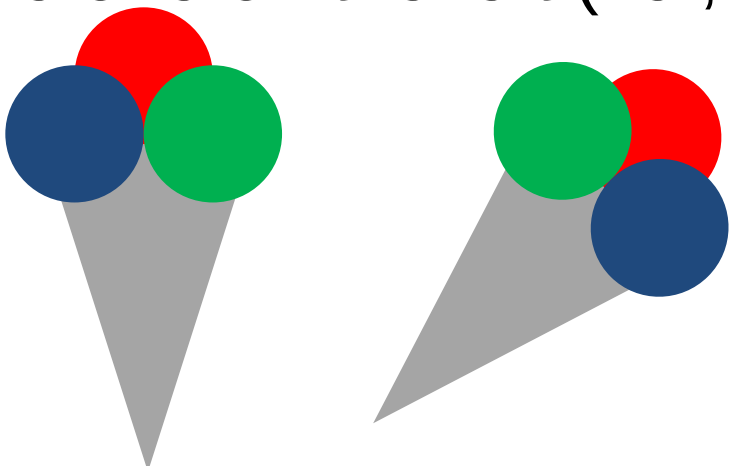
Method

6. Spatial visualization. This was assessed using a subtest of Spatial Relations (31 items attempted within a three-minute time limit) from the Woodcock-Johnson (1977) test battery. The child was asked to identify the subset of pieces needed to form a complete shape with multiple-point scored items.



Method

8. Mental rotation. This was assessed using a mental rotation test modeled from the ice cone task in Perrucci, Agnoli, and Albiero (2008). The stimuli are 36 pairs of printed ice cones with three scoops in different color (red, green, and blue). In each pair, the child was asked to judge whether the ice cone on the right (i.e., the test stimulus) is the same as the one on the left (i.e., the comparison stimulus).



Method

- Data analysis: latent growth curve modeling

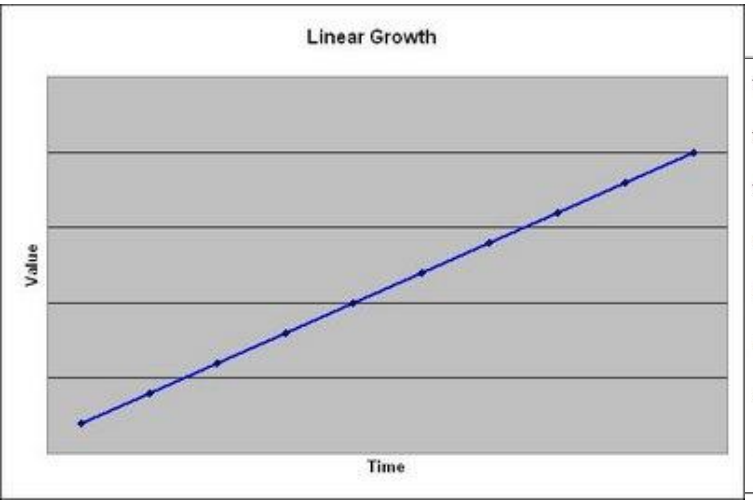
- Growth modeling has been used in the field of behavioral science, education, and social sciences to distinguish between the growth rate and overall level parameters of a developmental phenomenon.

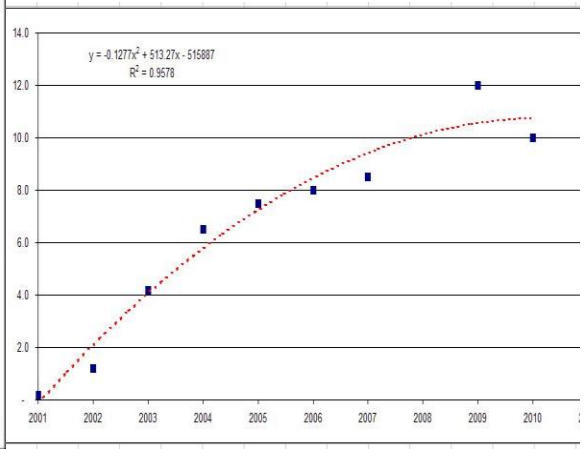
- Growth modeling attempts to model intra-individual change over time and examine predictors and consequences of inter-individual variability in such change.

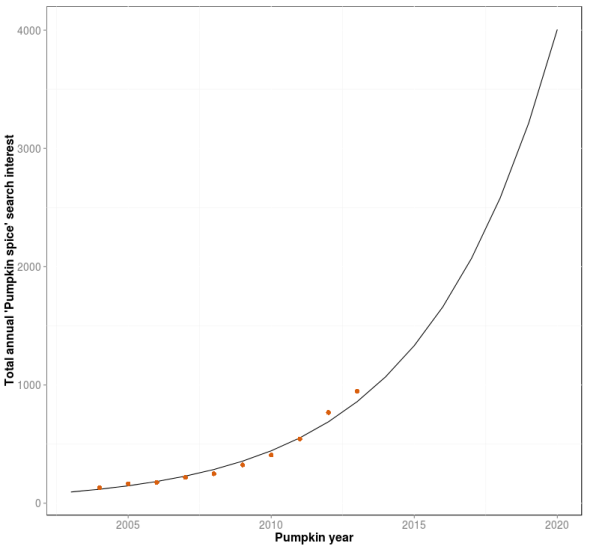
- The analyses were performed using Mplus 7, which allows missing data without list- or pair-wise deletion of

Method

- Data analysis: two phases
- Estimate the overall levels and rates of growth in phonological and spatial skills separately using unconditional latent growth curve modeling (linear or quadratic growth?);







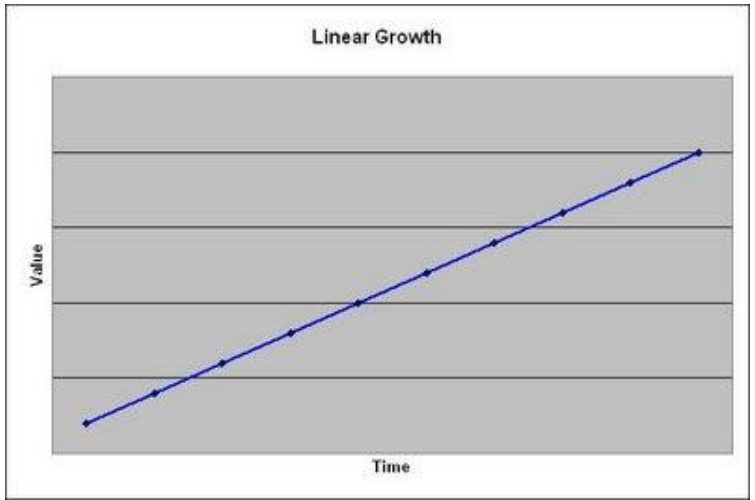
Method

- Data analysis: two phases

- Investigate whether Chinese reading and mathematical competencies were predicted from the earlier levels and rates of growth in phonological and spatial skills after accounting for the influences of spatial visualization, spatial analogic reasoning, and mental rotation using parallel growth curve modeling.

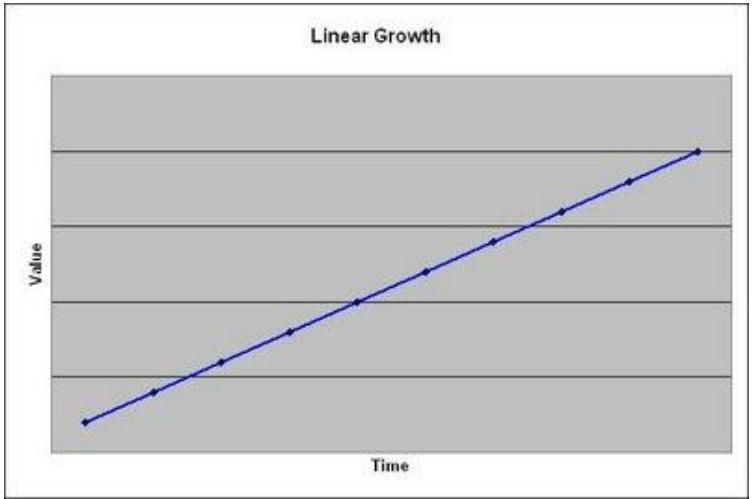
Results

- The growth in phonological awareness was represented by a linear growth model: χ^2 (5, N = 106) = 6.890, p = .229, CFI = .957, TLI = .948, RMSEA = .060, SRMR = .080.
- The initial level of phonological awareness was relatively low at T1 (M = 4.054, SE = .345, p < .001), followed by a positive rate of growth every half year (M = 3.416, SE = .151, p < .001) from T1 to T4



Results

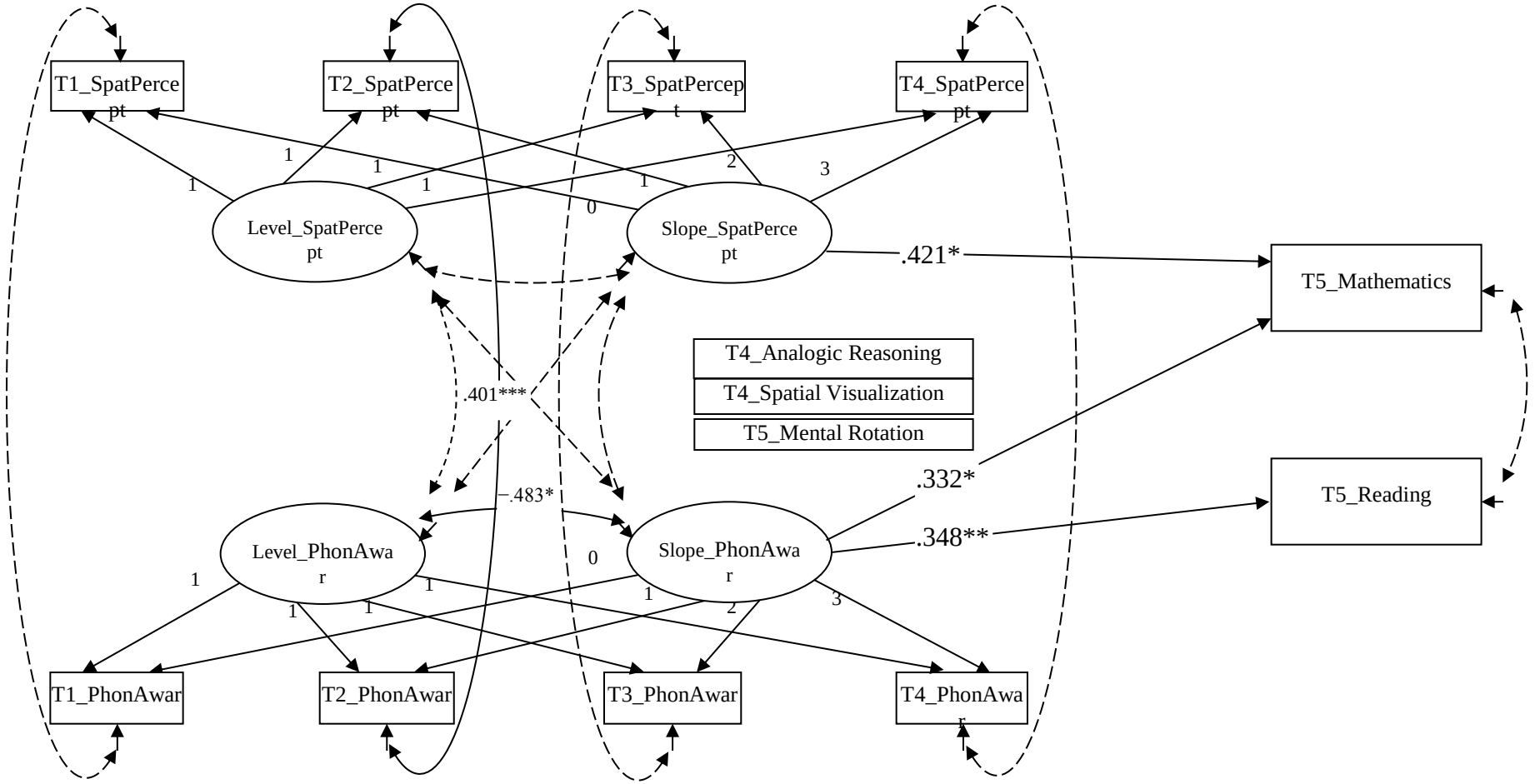
- The growth in spatial ability was represented by a linear growth model: χ^2 (5, *N* = 106) = 5.980, *p* = .308, CFI = .980, TLI = .977, RMSEA = .043, SRMR = .057.
- The initial level (intercept) of spatial ability was relatively low at T1 (*M* = 3.983, *SE* = .272, *p* < .001), followed by a positive growth rate (slope) every half year (*M* = 2.521, *SE* = .124, *p* < .001) from T1 to T4.



Results

- We then conducted parallel growth curve modeling to investigate whether Chinese reading and mathematical competencies were predicted from the earlier levels and rates of growth in phonological and spatial skills after accounting for the influences of spatial visualization, spatial analogic reasoning, and mental rotation.

Results


T1_SpatPercept
T2_SpatPercept
T3_SpatPercept
T4_SpatPercept
Level_SpatPercept
Slope_SpatPercept
.421*
T5_Mathematics
T4_Analogic Reasoning
T4_Spatial Visualization
T5_Mental Rotation
.401***
-.483*
.332*
.348**
T5_Reading
Level_PhonAwar
Slope_PhonAwar
T1_PhonAwar
T2_PhonAwar
T3_PhonAwar
T4_PhonAwar

Results

- The model-data fit was good: χ^2 (38, N = 106) = 48.949, p = .110, CFI = .953, TLI = .903, RMSEA = .052, SRMR = .072.

- The rate of growth in phonological awareness explained 12.1% of the variance in Chinese reading competence and 11.0% of the variance in mathematical competence at the end of kindergarten.

- The rate of growth in spatial perception explained 17.7% of the variance in mathematical competence at the end of kindergarten.

Discussion

- The most striking finding of this study is that growth rates of phonological and spatial skills over K1 to K3 had a substantial impact on Chinese reading and mathematical competencies at the end of K3. Furthermore, the impacts of the growth rates were above and beyond the overall levels of phonological and spatial skills.

- These findings are consistent with Vygotsky's (1934/1962) proposal that learning potential (i.e., ZPD or growth) is a strong predictor of academic competence.

Discussion

- The rates of growth in phonological and spatial skills may contain important information about young children's potential in phonological and spatial acquisition, respectively.

- In turn, they further help predict young children's academic status at the end of kindergarten.

Conclusion

- This study provides strong evidence for the longitudinal relations from phonological and spatial skills to Chinese reading and mathematical competencies.

- It adds to the existing literature and underscores the critical importance of the rates of growth in phonological and spatial skills to developing early Chinese reading and mathematical competencies.

Implications

- Theoretical and methodological implications: It is essential to understand the trajectory of cognitive development, because the trajectory may carry important information about children's developmental and learning potential.

Implications

- Practical implications: Helping young children develop phonological and spatial skills may lead to improvement in their Chinese reading and mathematical competencies. Because our findings show that growth rate strongly predicts later competence, teachers and practitioners may need to monitor young children's progress in phonological and spatial learning frequently throughout the preschool years and provide appropriate learning opportunities for those whose rate of growth is slower than that of their classmates.

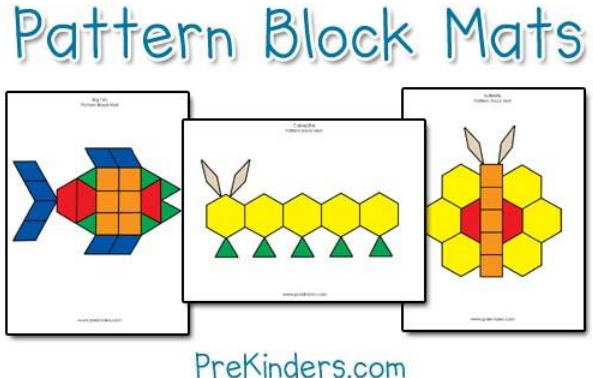
Thank you!

Construction Toys

- Legos®, Mega Bloks®

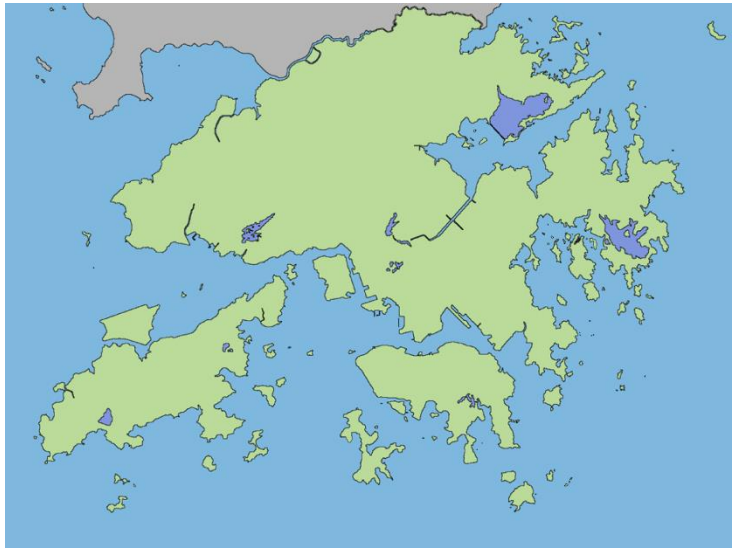
Wikki Stix®

- Pattern blocks

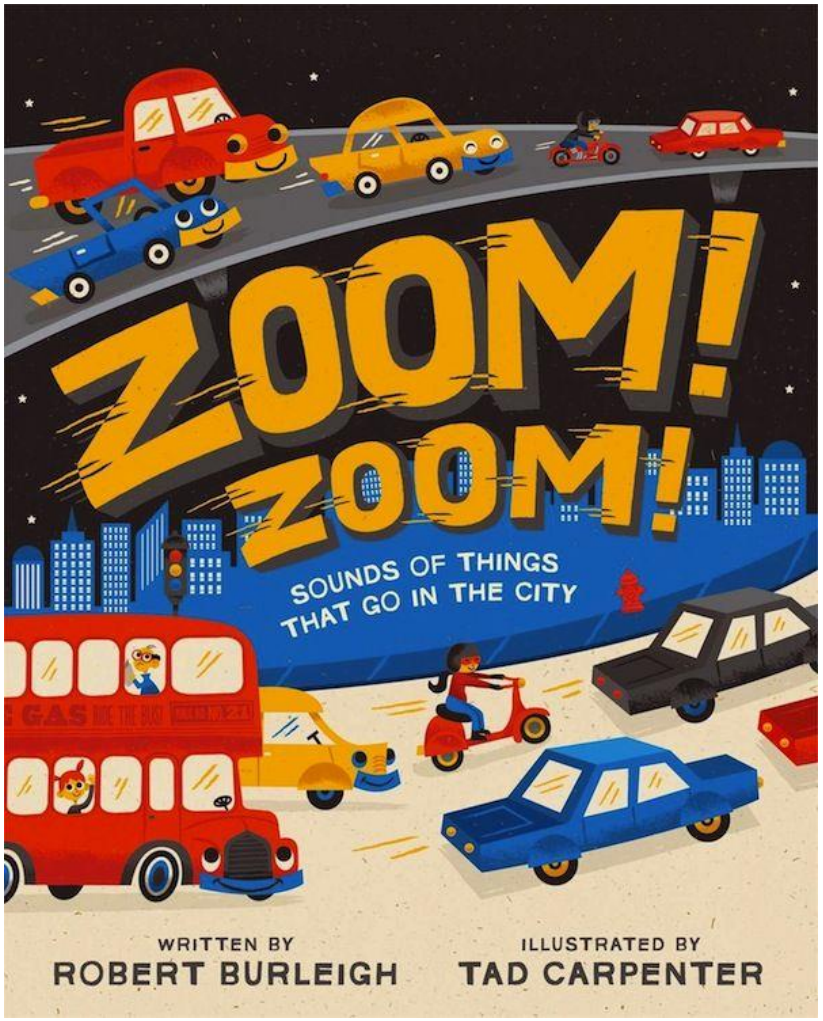


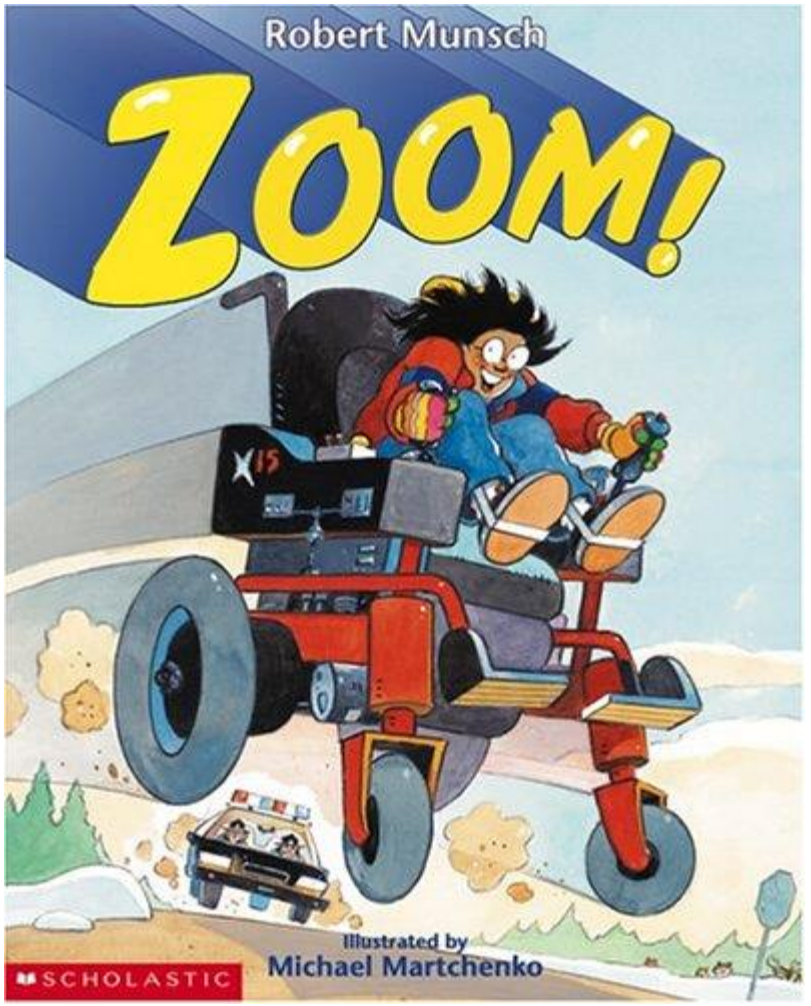
Tangrams

Puzzles, Maps, and Models



Books and Cartoons that Contain Spatial Components





Fine-motor Activities