Eight-Year Growth in Math Skills and Its Relationship to Nonsymbolic and Symbolic Number Processing

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Introduction

• A growing body of research seeks to understand the relation between numerical magnitude processing skills, as indexed by nonsymbolic (e.g. groups of objects) and symbolic (e.g. Arabic digits) magnitude comparison tasks, and math performance.[1, 2]

• Nonsymbolic comparison tasks are thought to index the precision of representation within neural systems supporting the perception of numerical magnitude.[3] However, the mechanisms indexed by the symbolic comparison task are more opaque, ranging from efficiency of the mapping of symbolic numerals onto their nonsymbolic counterpart to efficiency of a completely independent number system.[4, 5]

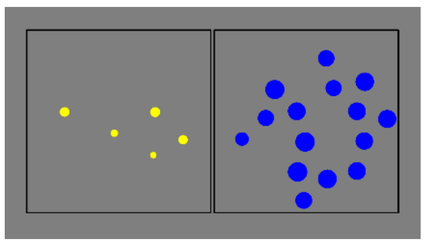
• A number of studies have shown an independent relation between nonsymbolic processing and math competence, and at least an equal number have shown an independent relation between symbolic processing and math, with no clear explanation for the varied results.[6]

• To our knowledge, no studies have investigated the relation between concomitant symbolic and nonsymbolic performance and math development. Specifically, do individuals with low performance on both the symbolic and nonsymbolic comparison task display different behavioral profiles than those performing poorly on just one of the tasks?

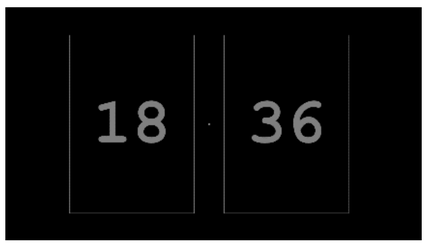
• To answer this question, we related symbolic and nonsymbolic number comparison performance in a longitudinal sample of 408 students to gain in math performance from Pre-K to 6th grade, 6th grade math skills, working memory, and inhibitory control.

Tasks for Performance Groups

Nonsymbolic Comparison

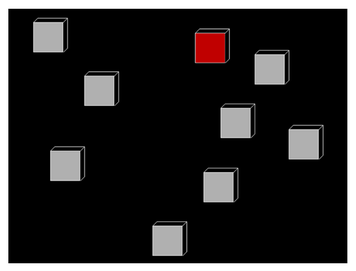


Symbolic Comparison

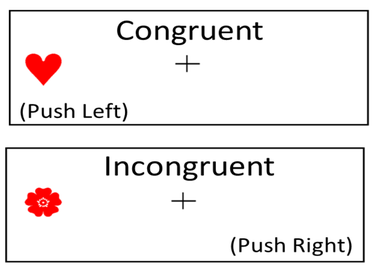


Cognitive Tasks

Corsi Block Tapping



Hearts & Flowers



Descriptive Statistics

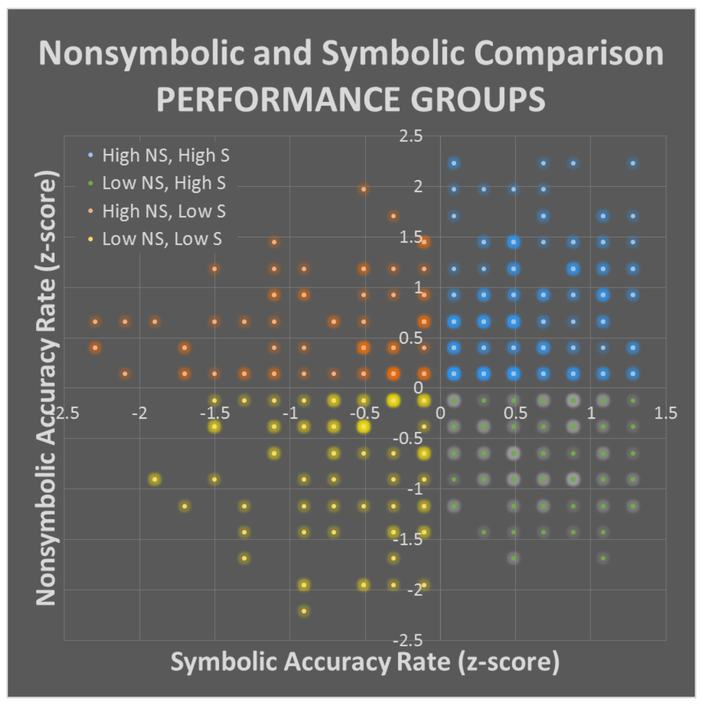
N = 408 (238 females)	Mean	SD	Range
Age at WCJ III – QC (Pre-K, years)	4.44	0.31	3.92 – 5.83
Age at WCJ III – QC (6th grade, years)	12.05	0.32	11.40 – 13.42
Nonsymbolic (NS) accuracy rate (%)	.754	.049	.629-.871
Symbolic (S) accuracy rate (%)	.918	.057	.74-1.00
Backward Corsi (max span)	4.99	1.16	2 - 8
Hearts and Flowers accuracy (%)	.750	.138	.35 – 1.00
Key Math-3: Numeration (age-scaled)	10.28	2.2	6-16
Key Math-3: Algebra (age-scaled)	10.37	2.3	6-16
Key Math-3: Geometry (age-scaled)	9.72	2.1	5-16
Key Math-3: Composite (age-scaled)	10.12	2.0	6.00-15.67
WCJ III – QC (Pre-K, raw score)	4.53	3.16	0-19
WCJ III – QC (6th grade, raw score)	35.97	3.68	23-46
TCAP Math percentile rank	37.9	26.17	1-99
TCAP Reading percentile rank	33.4	25.47	1-98

* Pre-K measures are in orange. 6th grade measures are in blue.

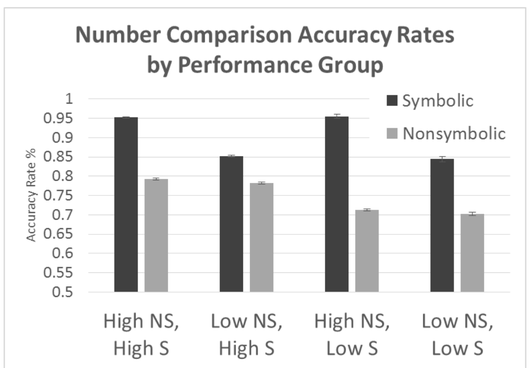
Participants

- Participants were drawn from a longitudinal study of early math skills.[7]
- Students were located in 76 schools during their 6th grade year.
- Sample includes only students with complete measures (study n = 521).
- Children performing 2.5 SD's outside the group mean in either comparison task were removed from the sample.
- Students were recruited from a large Southeastern city at Pre-K.
- Students were generally low performing. Mean scores for state-level achievement testing in 6th grade were in the mid 30th percentile.

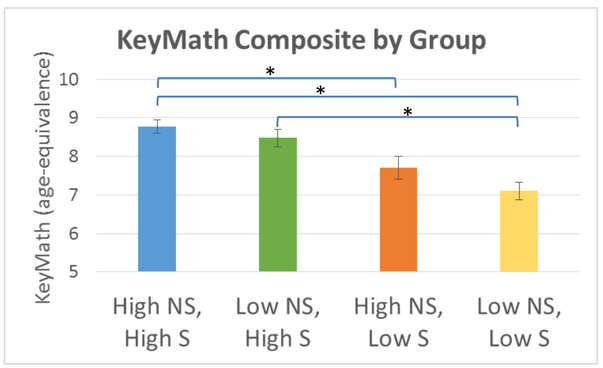
Methods

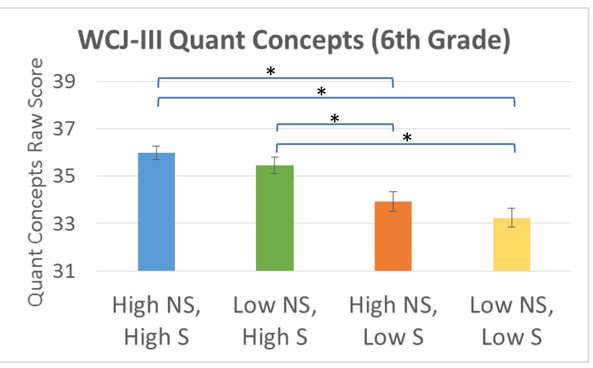


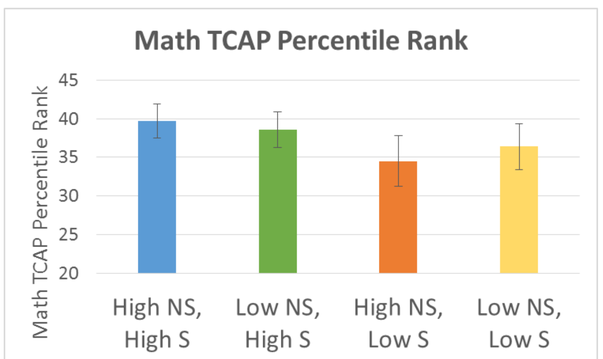
- Participants were separated into 4 groups according to performance on symbolic (S) and nonsymbolic (NS) number comparison tasks (mean split).
- High NS, High S (n=152), Low NS, High S(n=108), High NS, Low S (n=71), Low NS, Low S (n=77).
- ANOVA's and Tukey's HSD tests were performed to compare performance groups on each measure.

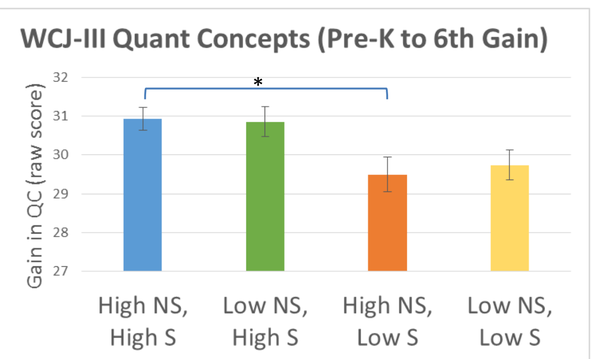


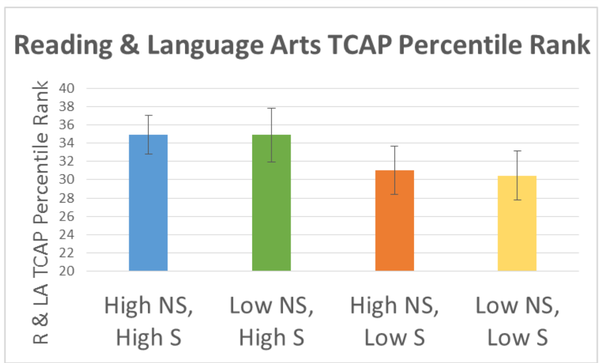
Results

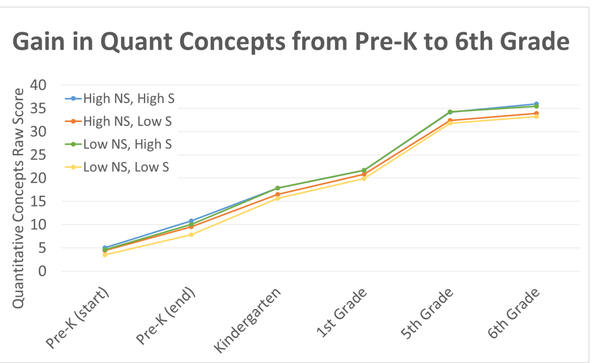


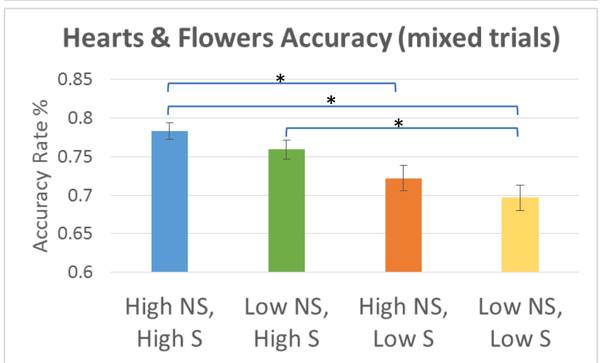


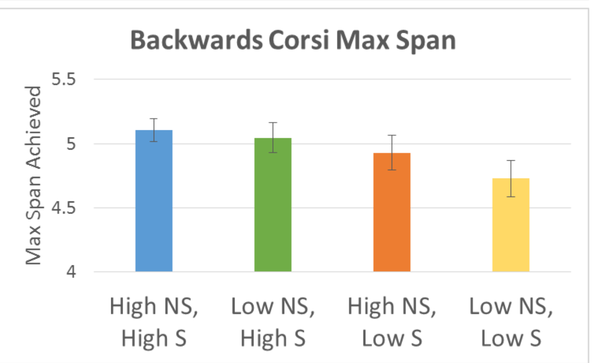












Discussion

- Performance groups differed in KeyMath 3 and Quantitative Concepts in 6th grade, and differed in growth of Quantitative Concepts from Pre-K to 6th grade. No group differences were observed in grade-level Math or Language Arts achievement tests.
- Individuals with low performance on the symbolic task alone did not differ from individuals with low performance on both symbolic and nonsymbolic tasks. In general, their math achievement scores were lower than groups with higher symbolic performance.
- In contrast, individuals with low nonsymbolic performance alone did not differ in any regard from the group with high performance on both tasks. In general, they performed better in math achievement measures than individuals with low symbolic performance.
- No differences in working memory were found according to performance group, but significant differences were found in inhibitory control. Specifically, groups with low performance on the symbolic comparison task performed more poorly.
- These results suggest **that low performance in both tasks may not represent a unique profile**, but instead, provide further evidence[8] that performance on symbolic comparison tasks has a stronger relationship with math achievement.

Measure Bivariate Correlations

Measure (N = 408)	1	2	3	4	5	6	7	8
1. KeyMath 3 Composite (6th grade, age-equivalence)								
2. WCJ-III Quantitative Concepts (6th grade, raw score)	.735**							
3. Math TCAP (6th grade, percentile rank)	.306**	.249**						
4. WCJ-III gain in Quant Concepts (Pre-K to 6th, raw score gains)	.364**	.640**	.105*					
5. Reading & Language Arts TCAP (6th grade, percentile rank)	.327**	.249**	.684**	.092				
6. Hearts & Flowers (accuracy rate %, mixed trials)	.327**	.294**	.159**	.099*	.105*			
7. Backwards Corsi (max span achieved)	.340**	.262**	.153	.119*	.092	.188**		
8. Nonsymbolic Comparison (accuracy rate %)	.116*	.086	.006	.013	.003	.142**	.057	
9. Symbolic Comparison (accuracy rate %)	.278**	.311**	.031	.178**	.066	.262**	.117*	.116*

* p < .05, ** p < .01

References & Acknowledgements

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