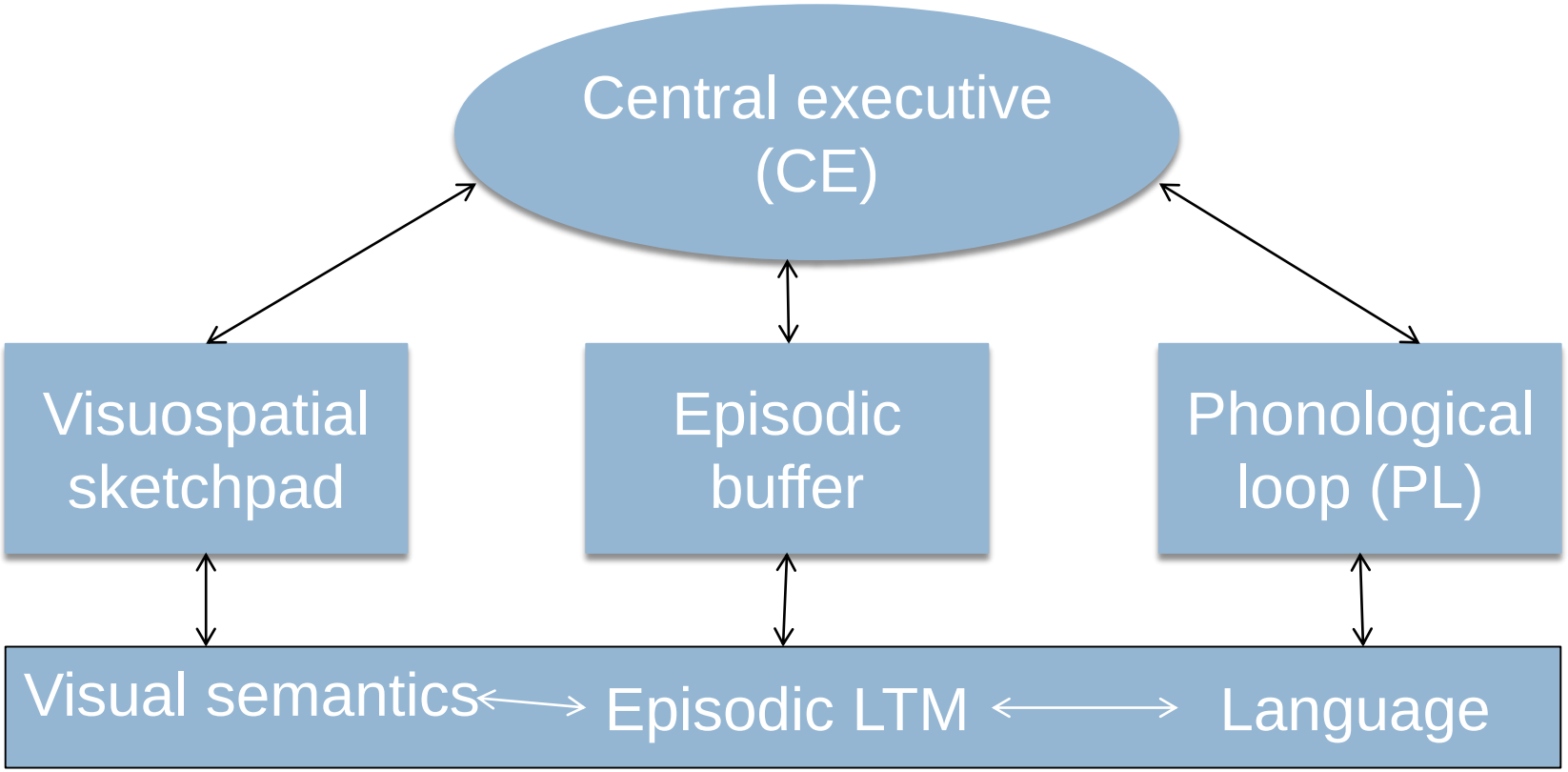
DOES WORKING MEMORY PREDICT MATHEMATICS ACHIEVEMENT OF CHILDREN IN THE PRIMARY GRADES?

Irina Tzoneva, Douglas College

Multi-Component Model of Working Memory



Baddeley & Hitch, 1974; Baddeley, 1986, 1996, 2000

Background

1. The Central Executive:
    - supports the learning of novel tasks
        - computing calculations (Fuchs et al., 2010, 2014)
        - mathematics word problem solving (Swanson, 2011).

2. Phonological representations in LTM → rate of access to phonological codes → performance on early numeracy tasks (Simmons & Singleton, 2008).

3. Central executive + phonological loop components of Baddeley's model of WM are strong predictors of early numeracy and mathematics word-problem solving (e.g., de Smedt et al., 2009; Meyer et al., 2010).

Questions

1. Can these findings be extended to children in Kindergarten?
2. Do articulation speed and phonological awareness in the phonological loop independently or together contribute to children's mathematics achievement?
3. Does processing in the phonological loop influence children's mathematics achievement independently of the contribution of the central executive?
4. Need for studies considering longer developmental periods

Hypotheses

- Performance on measures of the central executive component of the working memory system in Kindergarten children is expected to predict:
  - Early numeracy in first and second grade
  - Mathematics word problem solving in second grade
  - Mathematical concepts in second grade.

Hypotheses

- Performance on measures of the phonological loop of the working memory system in Kindergarten children is expected to predict:
  - Early numeracy in first and second grade
  - Mathematics word problem solving in second grade.

Sample

- Drawn from a longitudinal study investigating working memory and writing in children
- N = 92
- 55 boys and 37 girls
- Age range: 4 years, 4 months - 6 years, 5 months (mean age = 5 years, 7 months)
- 53 schools within six school districts of the Lower Mainland in British Columbia

Sample

School District	EDI Physical Vulnerability %	EDI Social Vulnerability %	EDI Emotional Vulnerability %	EDI Language Vulnerability %	EDI Communication Vulnerability %
SD 39	14	16	14	10	23
SD 40	9	14	13	10	16
SD 41	10	14	11	15	21
SD 43	7	8	8	7	13
SD 44	8	11	12	8	10
SD 45	6	6	7	2	5
BC	12	13.3	11.9	11.3	14.2

Note. SD 39 = Vancouver School District; SD 40 = New Westminster School District; SD 41 = Burnaby School District; SD 43 = Coquitlam School District; SD 44 = North Vancouver School District; SD 45 = West Vancouver School District.

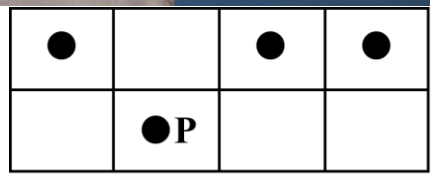
Sample

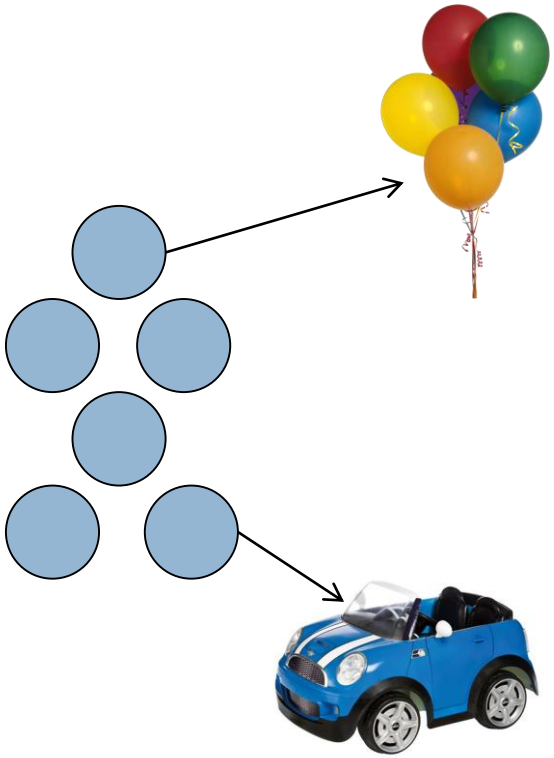
Characteristic	n	%
Children's English Language Proficiency		
Speaks English as 1st language	90	97.8
Speaks English as additional language	2	2.17
Children's Second Language Proficiency		
Speaks second language	16	17.39
Does not speak second language	76	82.61
Parental English Language Proficiency		
Speaks English as 1st language	79	86
Speaks English as additional language	13	14.13

Testing Battery

Construct	Measure	Administered		
		K	Grade 1	Grade 2
IQ				
Vocabulary	Stanford-Binet V Verbal Reasoning	X		
Working Memory	Working Memory			
Central Executive	Story Retelling	X		
	Visual Matrix	X		
	Spatial Organization	X		
Phonological Processing				
Phonological Deletion	CTOPP Elision	X		
Articulation Speed	Articulation Speed	X		
Mathematics Outcomes				
General Computation	Woodcock-Johnson III Calculation		X	X
Computation Fluency	Woodcock-Johnson III Calculation Fluency		X	X
Mathematical Concepts	Woodcock-Johnson III Quantitative Concepts			X
Word Problems	Woodcock-Johnson III Applied Problems			X

Working Memory
Central Executive Measures





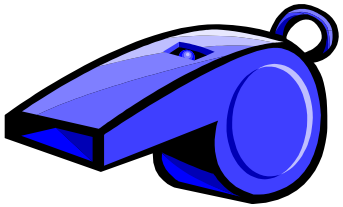
Working Memory
Phonological Loop Measures

- Elision – CTOPP
  - Say cat. Now say cat without saying /c/.

- Articulation Speed



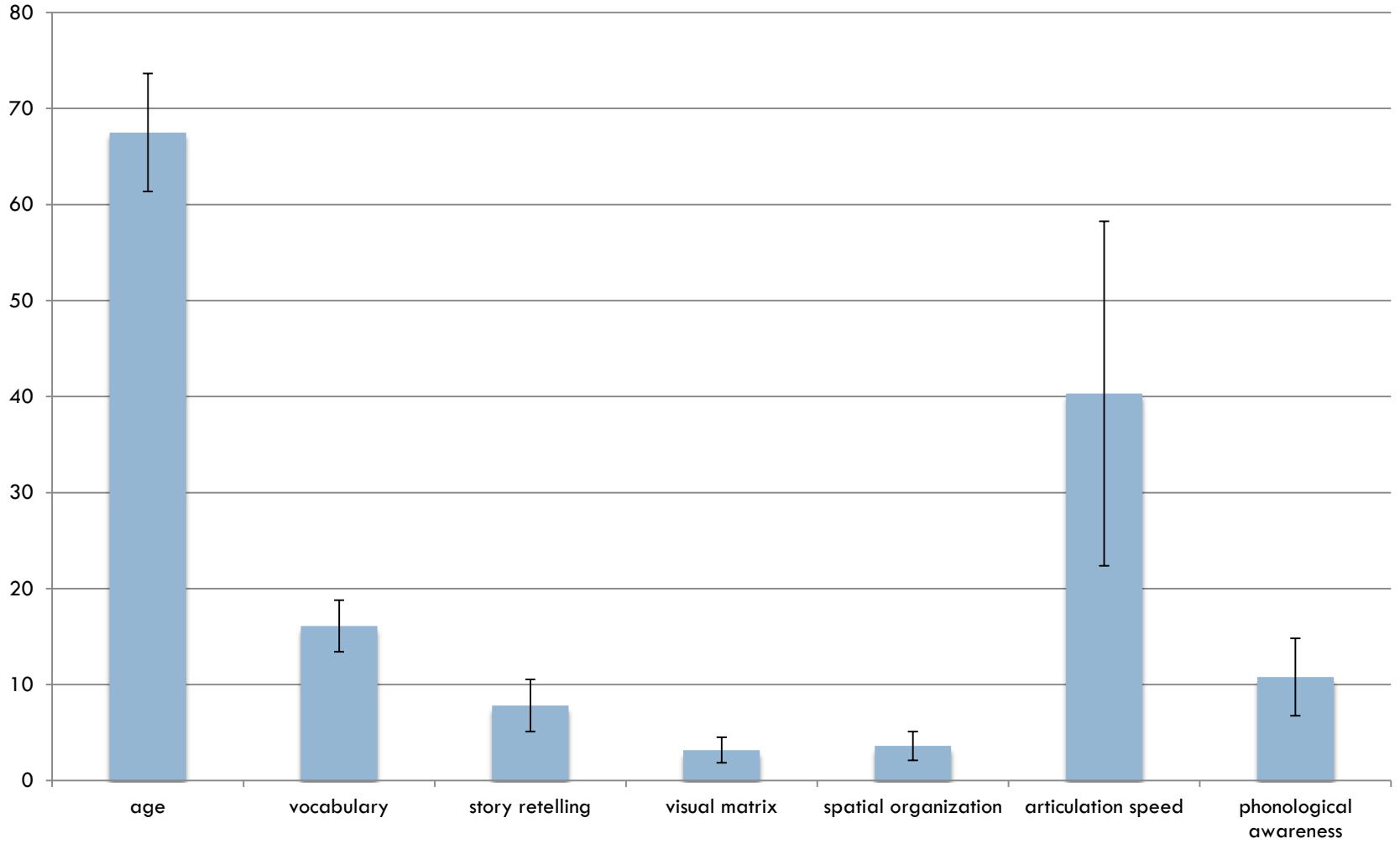




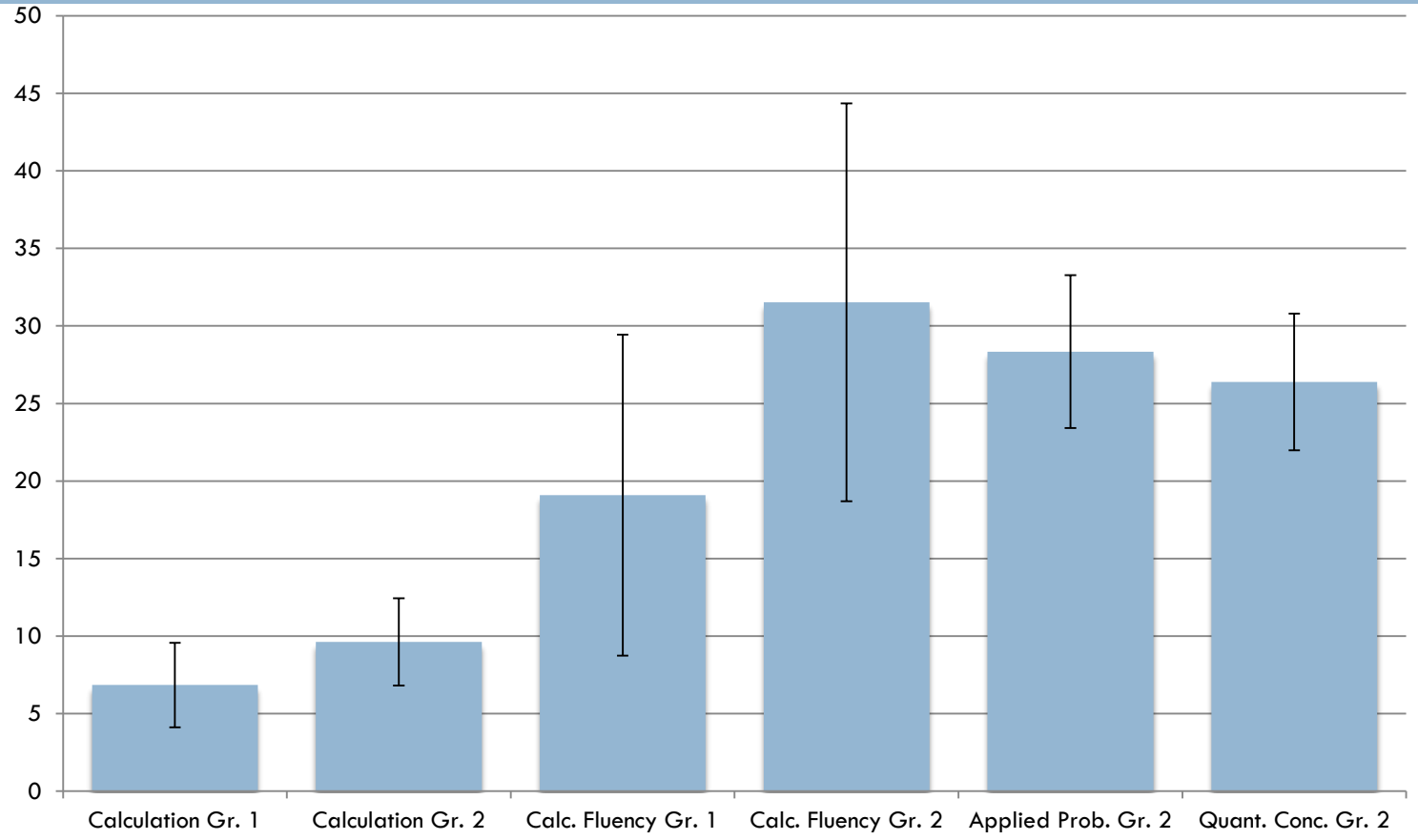
Mathematics Measures

- General computation
  - 1 + 3 =
  - 69
    - 28
- Mathematical concepts
  - 4 X 4 = 16
  - 5 3 _
- Word Problems

Means (SD) - Kindergarten



Means (SD) – Grade 1 and Grade 2



Data Analysis

- Model 1 (Verbal Ability)
  - Age and Vocabulary
- Model 2 (Phonological Loop)
  - Phonological Awareness and Articulation Speed
- Model 3 (WM Executive)
  - WM Executive
- Model 4 (WM Executive)
  - Phonological Awareness and Articulation Speed; WM Executive
- Model 5 (Phonological Loop)
  - WM Executive; Phonological Awareness and Articulation Speed

Calculation – Grade 1

Model	R^2	B	*SE*	β	*t* ratio
WM Executive	.19				
Age		-.06	.11	-.06	-.52
Vocabulary		.05	.10	.05	.49
Phonological Awareness		.24	.11	.24*	2.21
Visual Matrix		-.14	.12	-.14	-1.15
Spatial Organization		.37	.12	.36**	3.10

Note. *$p < .05$. **$p < .01$.

Calculation – Grade 2

Model	R^2	B	*SE*	β	*t* ratio
WM Executive	.19				
Age		-.14	.12	-.14	-1.19
Vocabulary		.06	.10	.06	.62
Phonological Awareness		.19	.11	.18	1.68
Visual Matrix		-.07	.13	-.07	-.56
Spatial Organization		.40	.12	.38**	3.30

Note. $^{**}p < .01$.

Calculation Fluency – Grade 1

Model	R^2	B	*SE*	β	*t* ratio
WM Executive	.16				
Age		-.04	.12	-.04	-.36
Vocabulary		-.01	.10	-.01	-.09
Phonological Awareness		.23	.11	.23*	2.12
Visual Matrix		-.13	.13	-.13	-1.05
Spatial Organization		.34	.12	.33**	2.81

Note. *$p < .05$. **$p < .01$.

Calculation Fluency – Grade 2

Model	R^2	B	*SE*	β	*t* ratio
WM Executive	.19				
Age		-.19	.12	-.18	-1.58
Vocabulary		.06	.10	.06	.61
Phonological Awareness		.17	.11	.16	1.50
Visual Matrix		-.03	.13	-.03	-.21
Spatial Organization		.41	.12	.39**	3.37

Note. $^{**}p < .01$.

Applied Problems – Grade 2

Model	R^2	B	*SE*	β	*t* ratio
WM Executive	.27				
Age		.01	.10	.01	.08
Vocabulary		.18	.09	.21*	2.30
Phonological Awareness		.10	.09	.12	1.11
Articulation Speed		-1.06	.51	-.20*	-2.09
Visual Matrix		.14	.10	.16	1.37
Spatial Organization		.18	.10	.20	1.83

Note. *$p < .05$.

Quantitative Concepts – Grade 2

Model	R^2	B	*SE*	β	*t* ratio
WM Executive	.13				
Age		-.17	.10	-.20	-1.70
Vocabulary		.05	.09	.07	.62
Phonological Awareness		.10	.09	.12	1.10
Visual Matrix		-.09	.10	-.10	-.83
Spatial Organization		.27	.10	.33**	2.72

Note. $^{**}p < .01$.

Conclusions

1. Performance on measures associated with the central executive and phonological loop in Kindergarten predicted:
    - single and double-digit computations in Grade 1

2. Performance on measures associated with the central executive in Kindergarten predicted:
    - more complex computational skills in Grade 2
    - knowledge of mathematics concepts in Grade 2

3. Performance on measures associated with the phonological loop in Kindergarten predicted:
    - mathematics word problem solving in Grade 2.

Conclusions

1. Phonological awareness and articulation speed predict unique aspects of mathematics performance.

1. The relations between phonological awareness and children's computational abilities shift over time.

1. Assessment of a working memory system in Kindergarten is a reliable predictor of later mathematics achievement.

1. Exposure to a mathematics curriculum plays a more important role than age in explaining the relations between the WM system available to children in K and later mathematics achievement.

Limitations

- A substantive amount of variance remained unexplained in the models.
- Future research will benefit from additional measures of working memory.
- No information available about instructional practices used in elementary classrooms.

Future Directions

1. Can Kindergarten aged children be taught strategies to compensate for limitations in the central executive component of the working memory system?

1. Should the focus be on working memory training in relation to numeracy skills or should the focus be on direct mathematics training?

2. Creating comprehensive early interventions to improve mathematical outcomes.