Longitudinal evidence of the role of executive functions deficits in early childhood

PAUL L. MORGAN, PH.D.[1] & GEORGE FARKAS, PH.D.[2]

[1]HARRY & MARION EBERLY FELLOW, PROFESSOR OF EDUCATION AND DEMOGRAPHY, DEPARTMENT OF EDUCATION POLICY STUDIES, DIRECTOR, CENTER FOR EDUCATIONAL DISPARITIES RESEARCH, PENN STATE

[2]PROFESSOR OF EDUCATION, SCHOOL OF EDUCATION, UNIVERSITY OF CALIFORNIA, IRVINE

Acknowledgement

- Analyses made possible by
  - Division of Research on Learning (1644355), EHR, NSF
  - National Center for Special Education Research (R324A070270 ; R324A150126), IES
  - Infrastructure support through Population Research Institute (R24HD041025), NICHD of NIH
  - No official endorsement should be inferred
- Additional colleagues include:
  - Marianne Hillemeier, Department of Health Policy and Administration, Penn State
  - Steve Maczuga, Population Research Institute, Penn State
  - Yangyang Wang, Department of Education Policy Studies, Penn State

Presentation's questions

- How well are U.S. children with or at risk for disabilities progressing in mathematics & science?

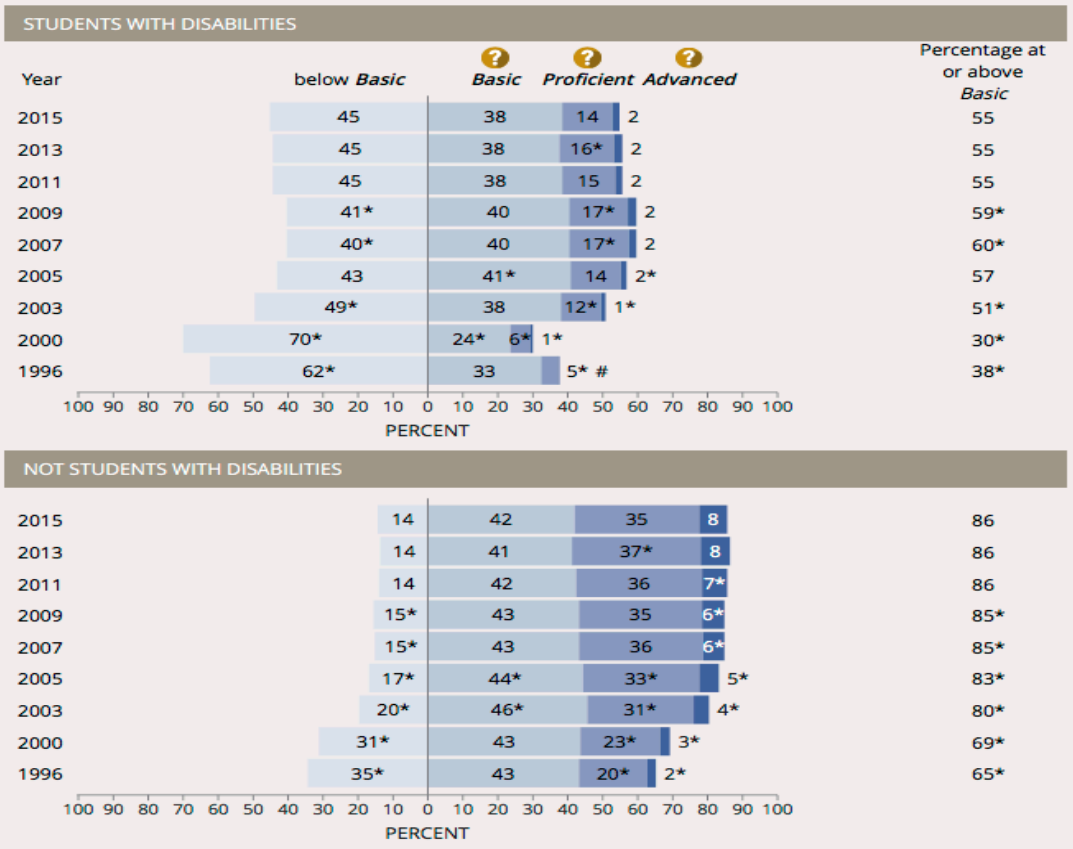
- What factors increase the risk of experiencing repeated STEM difficulties during the elementary grades?

- Are executive functions (EF) related to the early onset and over time stability of STEM difficulties?
  - Are predictive relations evident in multi-year longitudinal data from a nationally representative sample?
  - Are predictive relations evident with statistical control for potential confounds?

2015 NAEP Results: 4th Grade Mathematics

- Some progress over 20 years in the basic math proficiency of SWD
- Yet many SWD continue to display below basic levels of proficiency
  - 50% vs 15% of SW/OD

Trend in fourth-grade NAEP mathematics achievement-level results, by status as students with disabilities (SD)

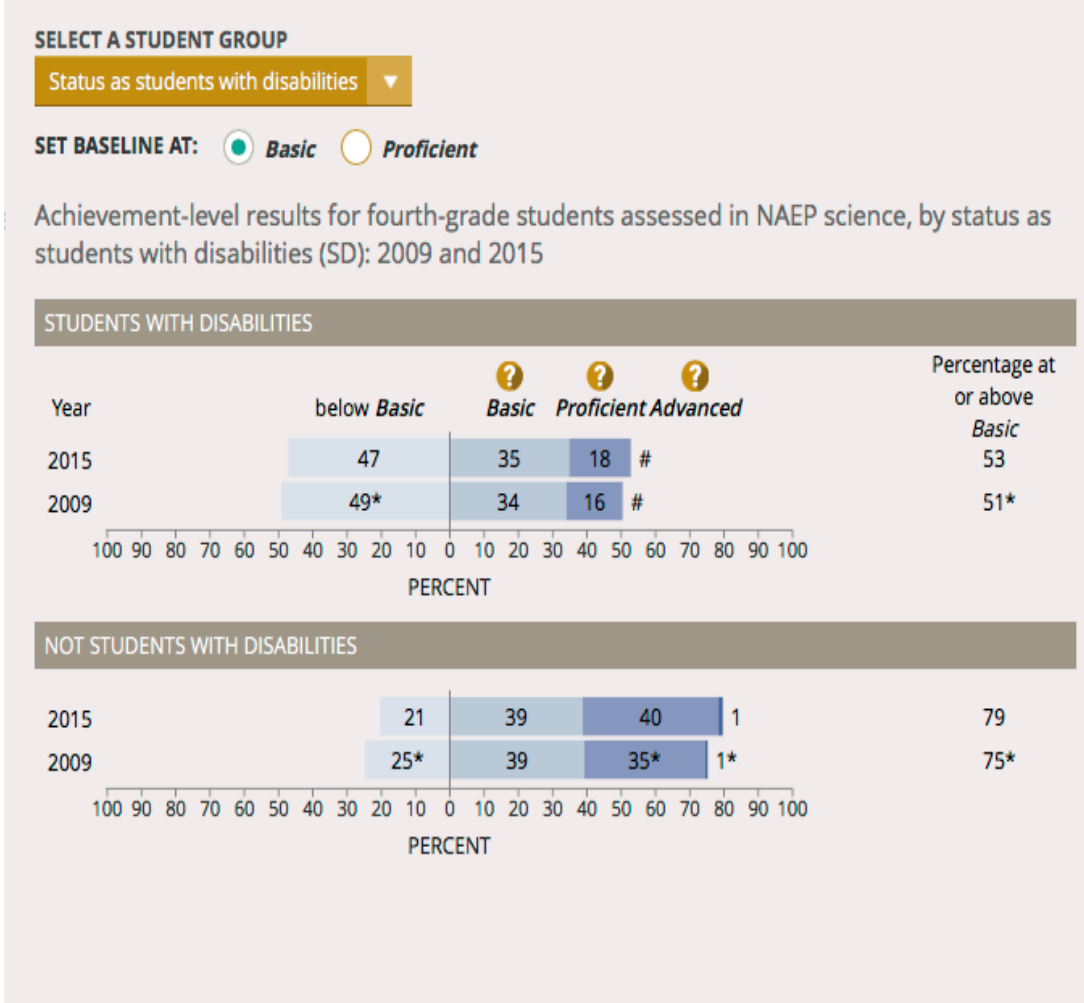


Rounds to zero.

* Significantly different ($p < .05$) from 2015.
NOTE: Percentage-point differences are calculated based on the differences between unrounded percentages.

2015 NAEP Results: 4th Grade Science

- Suggestive evidence of increasing proficiency in science
- Yet many SWD continue to struggle
- Why these gaps exist is unclear
  - The NAEP data are not longitudinal & only "pick up" in 4th grade



Limited knowledge about which children are likely to experience STEM difficulties

- Relatively few population-based longitudinal studies currently available including of elementary school-aged populations (e.g., Morgan et al., 2016)

- Risk factors that may increase the risk for STEM difficulties are poorly understood (e.g., Byrne & Miller, 2007)

- Yet understanding which children are at risk for STEM difficulties has major implications for policy, research, & practice
  - May help guide the timing & targets of early screening, monitoring, & intervention efforts

Multi-year, longitudinal, & nationally representative datasets analyzed

- Early Childhood Longitudinal Study-Kindergarten Cohort, 1998-1999 (ECLS-K: 1998)
  - Prospective cohort of 20,000 children entering U.S. kindergarten classrooms in 1998-1999 who were followed until end of 8th grade
- Early Childhood Longitudinal Study-Birth Cohort of 2001 (ECLS-B)
  - Prospective cohort of 14,000 children born in U.S. in 2001 who were followed until kindergarten entry
- Early Childhood Longitudinal Study-Kindergarten Cohort of 2011 (ECLS-K: 2011)
  - Prospective cohort of 14,000 children entering U.S. kindergarten classrooms in 2010-2011 being followed until end of 5th grade
- Include individually administered achievement assessments, extensive data collection on characteristics of children, families, & schools, over multi-year timeframes, & include multiple survey waves

Who Is At Risk for Persistent Mathematics Difficulties in the United States?

Journal of Learning Disabilities
2016, Vol. 49(3) 305–319

DOI: 10.1177/0022219414553849
journaloflearningdisabilities.sagepub.com
SAGE

Paul L. Morgan, PhD[1], George Farkas, PhD[2], Marianne M. Hillemeier, PhD, MPH[1], and Steve Maczuga, MS[1]

Abstract

We analyzed two nationally representative, longitudinal data sets of U.S. children to identify risk factors for persistent mathematics difficulties (PMD). Results indicated that children from low socioeconomic households are at elevated risk of PMD at 48 and 60 months of age, as are children with cognitive delays, identified developmental delays or disabilities, and vocabulary difficulties. In contrast, children attending preschool either in Head Start or non–Head Start classrooms are at initially lower risk of PMD. Kindergarten-aged children experiencing either low socioeconomic status or mathematics difficulties are at greatest risk for PMD across third, fifth, and eighth grades. Also at risk for PMD between third and eighth grades are children displaying reading difficulties or inattention and other learning-related behaviors problems, children with identified disabilities, and those who are retained. Educationally relevant and potentially malleable factors for decreasing young children's risk for PMD may include increasing children's access to preschool, decreasing their risk of experiencing vocabulary or reading difficulties, and avoiding use of grade retention.

Table 2. Multiple Logistic Regression Models of 48- to 60-Month Repeated Mathematics Difficulty Using 24-Month Predictors, ECLS-B Data.

Predictor	Model 1	Model 2	Model 3	Model 4
Cognitive delay, 24 months	3.64***	2.76***	2.68***	1.94***
Child's age, 60-month assessment		0.79***	0.79***	0.80***
Male		1.22	1.25*	1.15
Lowest SES quintile, 48 months		12.59***	12.44***	10.08***
Second lowest SES quintile, 48 months		6.87***	6.79***	5.55***
Middle SES quintile, 48 months		4.79***	4.79***	4.29***
Second highest SES quintile, 48 months		2.90**	2.90***	2.75**
Mother's age at birth > 35 years		0.99	0.96	0.95
Mother's age at birth < 18 years		1.41	1.39	1.42
Mother not married at child birth		1.17	1.16	1.19
Black		1.12	1.10	1.23
Hispanic		1.27	1.28	1.32
Other race/ethnicity		1.09	1.09	1.12
Child's birth weight < 1,500 g			2.26***	1.94***
Child's birth weight 1,500 to 2,500 g			1.64***	1.64***
Labor complications			0.85	0.85
Medical risk factors			0.99	0.96
Behavioral risk factors			1.07	1.05
Obstetric procedures			1.01	1.02
Congenital anomalies			0.81	0.77
Low word score, 24 months				1.50**
Low approaches to learning, 24 months				1.31
Delay or disability, 48 months				2.32**
Head Start, 48 months				0.60**
Center-based care, 48 months				0.49***

Note. N = 5,950. Values are odds ratios. Population rounded in accordance with Institute of Education Sciences security restrictions. 25.9% lowest = low word score; 22% lowest = low approaches to learning; 25% lowest = low *Bayley*. Multiple imputation used, regression weighted, and complex sample design used. Persistent mathematics difficulties = 15.6%.
*p < .05. **p < .01. ***p < .001.

Coefficients are Odds Ratios

Table 4. Multiple Logistic Regression Models of Kindergarten Predictors of PMD for Third, Fifth, and Eighth Grade, ECLS-K Data.

Predictor	Model 1	Model 2	Model 3
Low *Mathematics Test* score, spring kindergarten	16.84***	13.19***	7.60***
Child age, spring first grade		1.04*	1.04
Male		0.68*	0.48***
Lowest SES quintile, first grade		8.19***	6.43***
Second lowest SES quintile, first grade		4.86***	4.23***
Middle SES quintile, first grade		3.67***	3.43***
Second highest SES quintile, first grade		2.25**	2.17**
Mother's age at birth > 35 years		1.35	1.32
Mother's age at birth < 18 years		1.50	1.37
Mother not married, spring first grade		1.12	1.03
Black		1.87***	1.87**
Hispanic		0.65**	0.73
Other race/ethnicity		1.04	1.10
Child's birth weight < 1,500 g		0.73	0.48
Child's birth weight 1,500 to 2,500 g		1.35	1.44
Low *Reading Test* score, spring kindergarten			1.84***
Low approaches to learning, spring kindergarten			2.54***
Disabled spring first grade			2.16***
Ever in Head Start			1.28
Ever in center-based care			0.93
Child retained, third grade			2.26*

Note. $N = 8,411$. Values are odds ratios. Low spring kindergarten mathematics score < 24%, weighted; low spring kindergarten *Reading Test* score < 25%, weighted; low spring kindergarten approaches to learning < 24%. Multiple imputation done, regression weighted, and complex sample design used. Persistent mathematics difficulties = 16.1%.
*$p < .05$. **$p < .01$. ***$p < .001$.

Coefficients are Odds Ratios

Science Achievement Gaps Begin Very Early, Persist, and Are Largely Explained by Modifiable Factors

Paul L. Morgan[1], George Farkas[2], Marianne M. Hillemeier[1], and Steve Maczuga[1]

We examined the age of onset, over-time dynamics, and mechanisms underlying science achievement gaps in U.S. elementary and middle schools. To do so, we estimated multilevel growth models that included as predictors children's own general knowledge, reading and mathematics achievement, behavioral self-regulation, sociodemographics, other child- and family-level characteristics (e.g., parenting quality), and school-level characteristics (e.g., racial, ethnic, and economic composition; school academic climate). Analyses of a longitudinal sample of 7,757 children indicated large gaps in general knowledge already evident at kindergarten entry. Kindergarten general knowledge was the strongest predictor of first-grade general knowledge, which in turn was the strongest predictor of children's science achievement from third to eighth grade. Large science achievement gaps were evident when science achievement measures first became available in third grade. These gaps persisted until at least the end of eighth grade. Most or all of the observed science achievement gaps were explained by the study's many predictors. Efforts to address science achievement gaps in the United States likely require intensified early intervention efforts, particularly those delivered before the primary grades. If unaddressed, science achievement gaps emerge by kindergarten and continue until at least the end of eighth grade.

Keywords: achievement gaps; at-risk students; early childhood; growth trajectories; hierarchical linear modeling; longitudinal; minorities; poverty; racial/ethnic minorities; regression analyses; science achievement; science education; secondary data analysis; socioeconomic status; survey research

Source: Morgan, P. L., Farkas, G., Hillemeier, M. M., & Maczuga, S. (2016). Science achievement gaps begin early, persist, and are largely explained by modifiable factors. *Educational Researcher, 45,* 18-35.

The Consequences of Poor Science Education in Kindergarten

A majority of low-income and minority kindergarteners come in with poor general science knowledge—and closing that gap may be crucial for ensuring academic success later on.

LYDIA LUM | FEB 27, 2016 | EDUCATION

Science Achievement Gaps, Present in Early Years, Persist Over Time

By Jackie Zubrzycki on February 23, 2016 12:07 PM

Tweet Share 88

EDUCATION 02/24/2016 01:48 pm ET

Study Explains The Sad Reason Behind The Achievement Gap In Science

If this gap continues, the consequences could be dire.

By Rebecca Klein

The Biggest Hole in STEM Pipeline Starts Before Kindergarten

Kindergartners' knowledge predicts science achievement through 8th grade.

Education | Education Lab | Local News

Knowledge about the natural world in kindergarten predicts later success on science tests

Originally published March 1, 2016 at 6:00 am | *Updated February 29, 2016 at 6:15 pm*

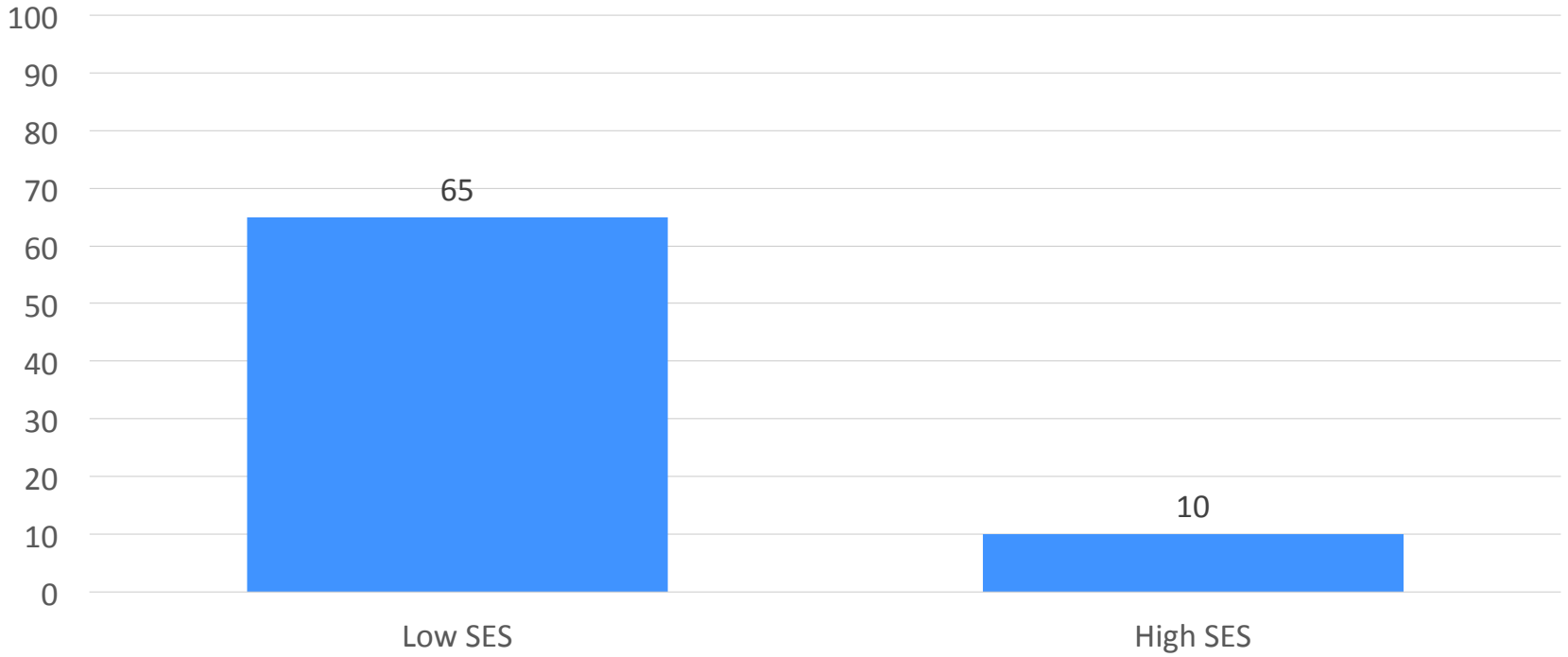
New study shows that gaps in what kids know about the natural and social world in kindergarten persist through middle school.

By John Higgins

Seattle Times education reporter

Kids start falling behind in science in kindergarten. Here's how we can change that.

Figure 1: Children at risk often arrive at kindergarten already behind in general knowledge



Percentage of Group in Lowest 25% on General Knowledge Test, Fall of Kindergarten (ECLS-K Data, *N*=7,757)

Table 2
Standardized Parameter Estimates Predicting General Knowledge Test Scores, Weighted (n = 7,210)

Variable	Fall Kindergarten General Knowledge Score	Spring First-Grade General Knowledge Score	
		Model 1	Model 2
Intercept	.13***	.19***	.09***
Child is Black	–.62***	–.65***	–.28***
Child is Hispanic	–.29***	–.29***	–.06**
Child is Asian	–.41***	–.32***	–.11*
Child is American Indian	–.52***	–.55***	–.20***
Child is other race/ethnicity	–.06	–.06	–.05
Family SES at kindergarten	.39***	.36***	.06***
Child age in months at fall kindergarten	.28	.21***	.00
Child is male	–.01***	.07***	.12***
Child's mother is not married at fall kindergarten	–.12***	–.10***	–.00
Family speaks non-English at home at kindergarten	–.34***	–.61***	–.03
General Knowledge Test at fall kindergarten			.58***
Reading Test at fall kindergarten			.08***
Mathematics Test at fall kindergarten			.03***
Approaches to Learning, fall kindergarten			.05***
R^2	.38	.38	.64

Note. SES = socioeconomic status.
*p < .05. **p < .01. ***p < .001.

85% decrease

Figure 2: Large and persistent science achievement gaps from 3rd-8th grade, by family SES

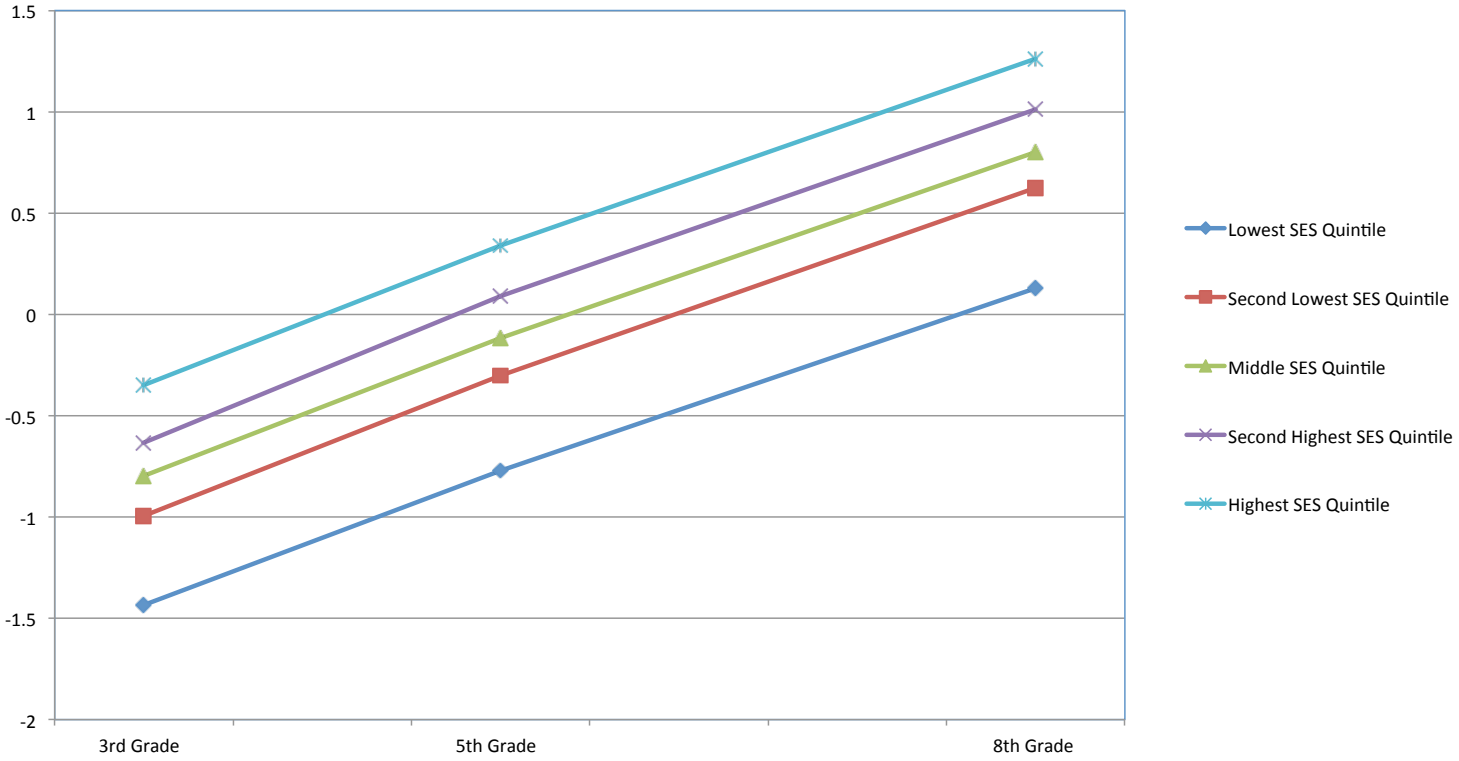


Table 4
Weighted Parameter Estimates of Three-Level Growth Models Predicting Science Achievement (n = 7,731–7,757)

Variable	Model 1	Model 2	Model 3	% Reduction
Intercept	–.72 ***	–.80 ***	–.53 ***	26.39
Time	.03 ***	.03 ***	.01 ***	66.67
Time × Time	–.0001 ***	–.0001 ***	.0001 ***	200.00
Time-varying Reading Test			.24 ***	
Time-varying Mathematics Test			.26 ***	
Time-varying Approaches to Learning rating			.014	
Time-varying percentage minority in school			–.02 ***	
Time-varying percentage of free lunch in school			–.005	
Time-varying school academic climate			.001	
Effects on intercept				
Child is Black	–.52 ***	–.19 ***	–.13 ***	75.00
Child is Hispanic	–.23 ***	–.06 ***	–.04 **	81.30
Child is Asian	–.08 *	.01	.002	102.50
Child is American Indian	–.45 ***	–.14 ***	–.03	93.33
Child is other race/ethnicity	–.13 **	–.05 *	–.04	69.23
Family SES at first grade	.30 ***	.05 ***	.01	96.67
Child age in months at spring first grade	.08 ***	–.02 ***	.001	98.75
Child is male	.16 ***	.15 ***	.12 ***	25.00
Child's mother is not married at spring first grade	–.06 ***	–.02	–.01	83.33
Family speaks non-English at home at fall kindergarten	–.24 ***	.10 ***	–.06 ***	75.00
General Knowledge Test at spring first grade		.42 ***	.31 ***	
Reading Test at spring first grade		.09 ***	–.01	
Mathematics Test at spring first grade		.09 ***	–.06 ***	
Approaches to Learning, spring first grade		.02 ***	–.03 ***	
Parenting quality, third grade			.001 ***	

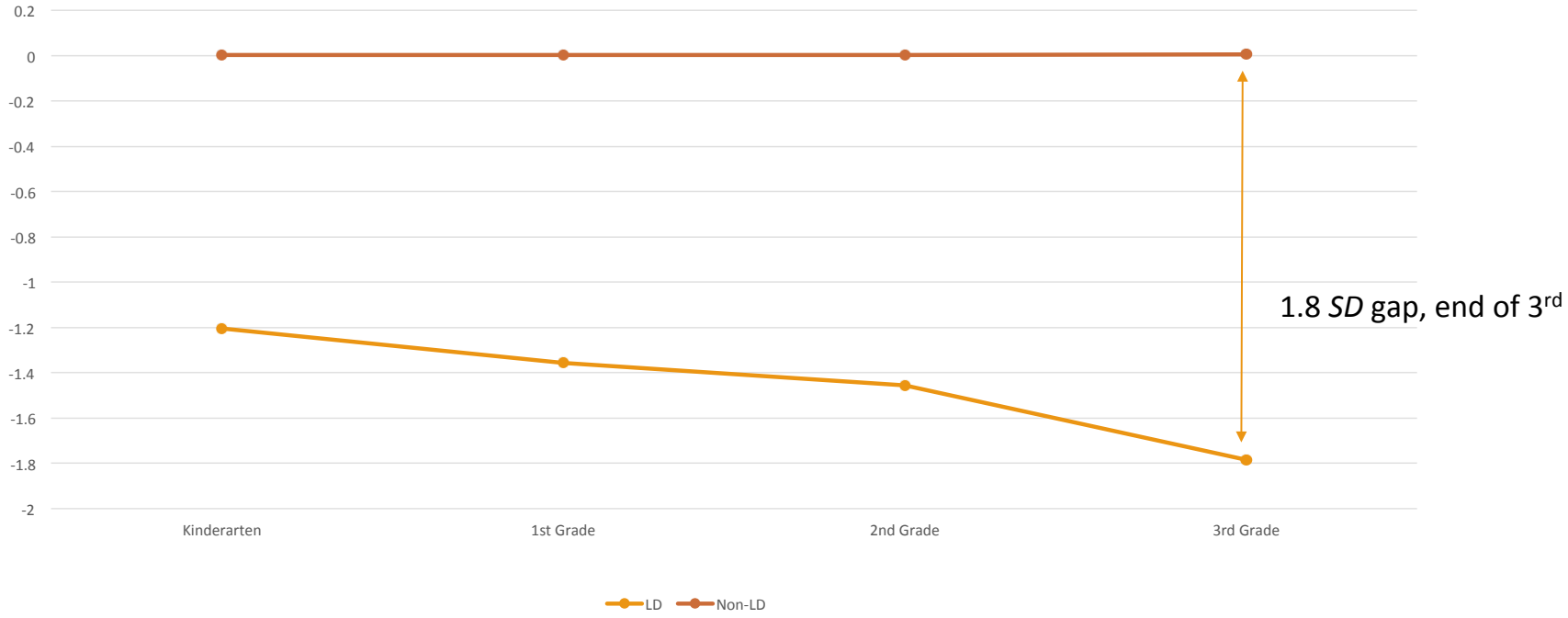
How are children with LD doing in STEM in the primary grades?

- Prior analyses based on older samples initially assessed in 1998-1999, & 2001, what about more recently?

- Do STEM difficulties begin to occur by the primary grades for children with LD, including using a direct measure of science achievement?

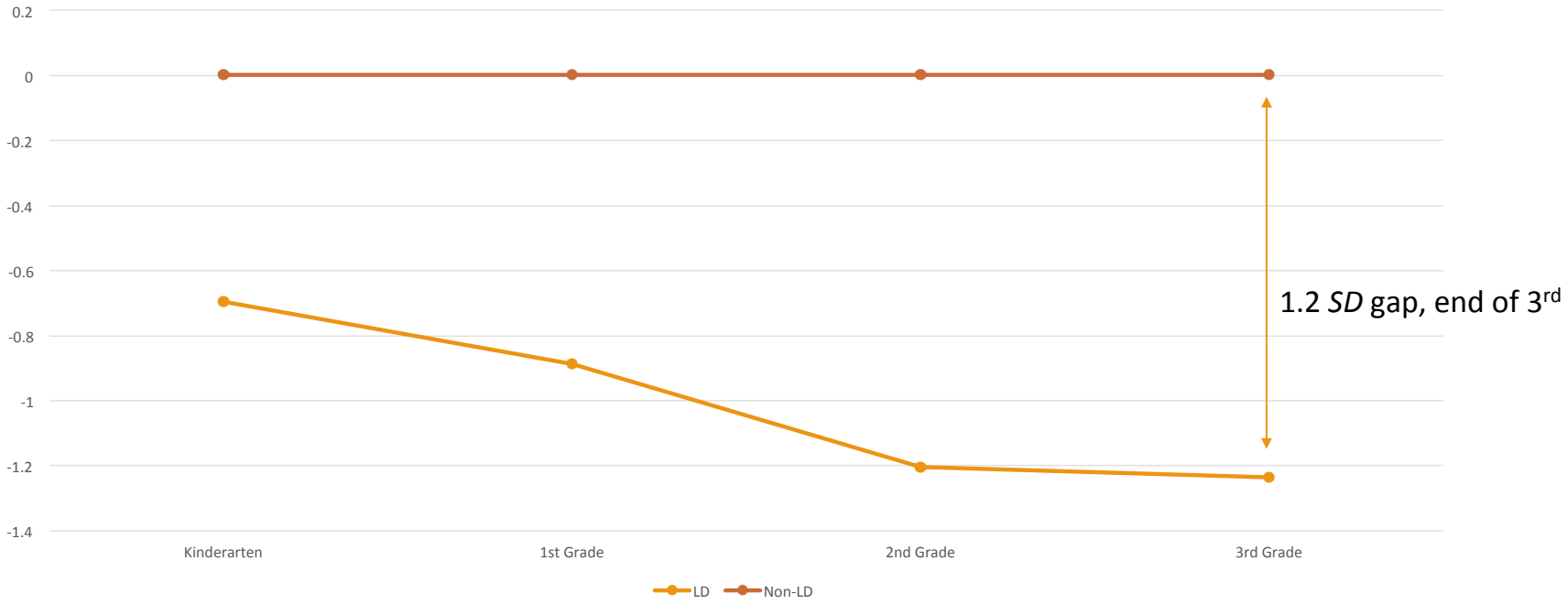
- Do EF help explain why children with or at risk for LD are experiencing STEM difficulties?

Figure 3: K-3rd grade mathematics achievement gaps between children with and without LD



Note: Author's calculations, LD as identified by spring of 1st grade, ECLS-K: 2011 Data, *n*s = 60 LD; 8,270 non-LD

Figure 4: K-3rd grade science achievement gaps between children with and without LD



Note: Author's calculations, LD as identified by spring of 1st grade, ECLS-K: 2011 Data, *n*s = 60 LD; 8,270 non-LD

What are EF?

- Cognitive processes hypothesized to contribute to academic achievement and classroom behavior
  - Help children control and coordinate planning, reasoning, organization, regulation, & information integration (e.g., Best, Miller, & Naglieri, 2011; Blair & Raver, 2014, 2015)

- The mind's "air traffic controllers"
  - *Working memory (WM)* helps children manage information maintenance and processing demands as well as problem solve while avoiding information loss due to distraction (Jarrold & Towse, 2006)
  - *Cognitive flexibility (CF)* helps in attending to changing meaning in texts, incorporate new knowledge, & simultaneously disregard or update previously used knowledge (Yeniad, Malda, Mesman, van IJzendoorn, & Pieper, 2013)
  - *Inhibitory control (IC)* helps children ignore impulsive responses and remain engaged during classroom instruction and activities (Allan et al., 2014; Berry, 2012)

- Especially useful when completing novel or cognitively demanding tasks (Banich, 2009)

Are general relations between EF & achievement & behavior evident between kindergarten into 2nd grade

- Examined whether EF during kindergarten uniquely predictive of children's reading, math, & science achievement in 2nd grade, as well as their classroom behaviors

- These types of analyses helps establish the potential "bang for the buck" of targeting EF

- Extensive statistical control for potential confounds, including for achievement & behavioral domain-specific & -general autoregressors, socio-demographics (e.g., family SES, race/ethnicity, gender), & other types of EF

Source: Morgan, P. L., Farkas, G., Hillemeier, M. M., Pun, W., & Maczuga, S. (conditionally accepted). Kindergarten children's executive functions predict their 2nd grade academic achievement and behavior. *Child Development.*

Panel Regression Model Estimates (OLS) of 2nd Grade Children's Academic Achievement, ECLS-K: 2011 Data, N = 8,920).	Reading Achievement, Spring 2nd Grade	Math Achievement, Spring 2nd Grade	Science Achievement, Spring 2nd Grade
Intercept	-0.41 ***	-0.29 **	-1.03 ***
Working memory, spring kindergarten	**0.09 *** **	**0.12 *** **	**0.08 *** **
Cognitive flexibility, spring kindergarten	**0.05 *** **	**0.06 *** **	**0.10 *** **
Inhibitory control, spring kindergarten	**0.05 ***	0.03	0.01
Black	-0.02	-0.30 ***	-0.26 ***
Hispanic	0.01	-0.09 **	-0.09 **
Other race/ethnicity	0.01	0.03	0.01
Female	0.09 ***	-0.23 ***	-0.15 ***
Lowest SES quintile, kindergarten	-0.34 ***	-0.23 ***	-0.22 ***
Second lowest SES quintile, kindergarten	-0.20 ***	-0.13 ***	-0.14 ***
Middle SES quintile, kindergarten	-0.11 ***	-0.10 ***	-0.07 **
Second highest SES quintile, kindergarten	-0.07 ***	-0.09 **	-0.06 *
Child uses non-English at home, spring kindergarten	0.06	0.15 ***	0.05
IEP, spring 2nd grade	**-0.42 *** **	**-0.35 *** **	**-0.22 *** **
Age (in months), spring 2nd grade	-0.04 **	-0.05 ***	-0.01
Reading achievement, spring kindergarten	**0.33 *** **	**0.05 *** **	**0.09 *** **
Math achievement, spring kindergarten	**0.15 *** **	**0.42 *** **	**0.18 *** **
Science achievement, spring kindergarten	**0.11 *** **	**0.09 *** **	**0.27 *** **
Externalizing problem behaviors, spring kindergarten	0.03 *	0.03 **	0.02
Internalizing problem behaviors, spring kindergarten	-0.01	-0.002	0.02
Behavioral self-regulation, spring kindergarten	**0.07 *** **	**0.11 *** **	**0.07 *** **
Vocabulary score 12-15	**0.32 ** **	**0.38 *** **	**0.67 *** **
Vocabulary score 16-19	**0.52 *** **	**0.52 *** **	**1.16 *** **
Vocabulary score 20	**0.56 *** **	**0.60 *** **	**1.36 *** **
R^2	.59	.61	.57

Panel Regression Model Estimates (OLS) of Second Grade Children's Classroom Behavior, ECLS-K: 2011 Data, N = 8,920).	Externalizing Problem Behaviors	Internalizing Problem Behaviors	Behavioral Self-Regulation
Intercept	-0.02	0.01	-0.13
Working memory, spring kindergarten	-0.01	**-0.03 ***	**0.04 ****
Cognitive flexibility, spring kindergarten	0.01	0.01	-0.02
Inhibitory control, spring kindergarten	**-0.14 *****	**-0.06 ****	**0.11 *****
Black	0.17 ***	-0.09 *	0.01
Hispanic	-0.10 *	-0.10 *	0.12 ***
Other race/ethnicity	-0.05	-0.03	0.10 **
Female	-0.20 ***	-0.0001	0.29 ***
Lowest SES quintile, kindergarten	0.17 **	0.12 *	-0.22 ***
Second lowest SES quintile, kindergarten	0.19 ***	0.12 **	-0.18 ***
Middle SES quintile, kindergarten	0.11 ***	0.08 *	-0.14 ***
Second highest SES quintile, kindergarten	0.07 **	-0.001	-0.07 **
Child uses non-English at home, spring kindergarten	-0.11 ***	-0.16 ***	0.17 ***
IEP, spring 2nd grade	**0.13 ****	**0.24 *****	**-0.23 *****
Age (in months), spring 2nd grade	0.02	0.04 **	-0.02
Reading achievement, spring kindergarten	-0.01	-0.01	0.04 **
Math achievement, spring kindergarten	-0.02	-0.08 ***	0.15 ***
Science achievement, spring kindergarten	0.02	0.004	0.004
Externalizing problem behaviors, spring kindergarten	0.41 ***	0.02	-0.12 ***
Internalizing problem behaviors, spring kindergarten	-0.06 ***	0.18 ***	0.01
Behavioral self-regulation, spring kindergarten	-0.02	**-0.08 *****	**0.22 *****
Vocabulary score 12-15	0.004	-0.02	-0.01
Vocabulary score 16-19	0.004	0.01	0.06
Vocabulary score 20	0.03	-0.05	0.09
R^2	.35	.13	.37

Are deficits in executive functions promising targets to address STEM achievement gaps?

- To date, EF deficits reported to increase the risk for to lower STEM achievement (e.g., Peng et al., 2012)
  - May constitute potentially useful targets of early STEM interventions (Morgan et al., 2016; Viterbori et., 2015) for reducing math and science achievement gaps (Blair & Raver, 2014; Gropen et al., 2011)
  - This includes for students with disabilities (Geary et al., 2009; Morgan et al., 2016; Toll et al., 2011; Vugs et al., 2014)
- Yet knowledge about multi-year risk for school-aged students is very limited.
  - Most available studies have used preschool- or kindergarten-aged convenience samples (Best et al., 2009)
  - The few studies analyzing school-aged samples have mostly used cross-sectional (Monette et al., 2015) or short-term (e.g., single year) longitudinal designs (Fuhs, Nesbitt, Farran, & Dong, 2014; Lefevre et al., 2013)
  - Many have examined only a single type of EF rather than multiple types simultaneously (Fitzpatrick & Pagani, 2012)
- Few studies have analyzed EF growth trajectories using nationally representative data, thereby limiting the generalizability of their findings (Morgan et al., 2016)

Contents lists available at ScienceDirect

Contemporary Educational Psychology

journal homepage: www.elsevier.com/locate/cedpsych

Executive functioning deficits increase kindergarten children's risk for reading and mathematics difficulties in first grade

Paul L. Morgan [a,*], Hui Li [a], George Farkas [b], Michael Cook [a], Wik Hung Pun [a], Marianne M. Hillemeier [a]

[a] The Pennsylvania State University, University Park, Pennsylvania, USA
[b] University of California, Irvine, California, USA

ARTICLE INFO

Article history:
Available online

Keywords:
Executive functioning
Working memory
Cognitive flexibility
Learning difficulties
Longitudinal

ABSTRACT

Whether executive functioning deficits result in children experiencing learning difficulties is presently unclear. Yet evidence for these hypothesized causal relations has many implications for early intervention design and delivery. We used a multi-year panel design, multiple criterion and predictor variable measures, extensive statistical control for potential confounds including autoregressive prior histories of both reading and mathematics difficulties, and additional epidemiological methods to preliminarily examine these hypothesized relations. Results from multivariate logistic regression analyses of a nationally representative and longitudinal sample of 18,080 children (i.e., the Early Childhood Longitudinal Study – Kindergarten Cohort of 2011, or ECLS-K: 2011) indicated that working memory and, separately, cognitive flexibility deficits uniquely increased kindergarten children's risk of experiencing reading as well as mathematics difficulties in first grade. The risks associated with working memory deficits were particularly strong. Experimentally-evaluated, multi-component interventions designed to help young children with reading or mathematics difficulties may also need to remediate early deficits in executive function, particularly in working memory.

Table 2
Logistic regression models (odds ratio coefficients) predicting reading or mathematics difficulties (lowest 10%), spring first grade, ECLS-K: 2011 data.

	Reading difficulties		Mathematics difficulties	
	Model 1	Model 2	Model 1	Model 2
Executive Functioning Deficits (Spring Kindergarten)				
Working memory deficits	2.66 *	2.17 *	3.38 *	2.87 *
Cognitive flexibility deficits	1.35 *	1.27 *	1.79 *	1.71 *
Prior Learning Difficulties (Spring Kindergarten)				
Reading difficulties	11.15 *	8.77 *	3.37 *	2.77 *
Mathematics difficulties	4.62 *	3.71 *	11.67 *	9.30 *
Socio-demographics				
Male		1.32 *		0.96
Black		0.90		1.13
Hispanic		1.18		0.96
Asian		0.79		0.54 *
Other race		1.08		1.02
Family SES		0.78 *		0.83 *
Poverty		1.16		1.10
Age		1.07		1.02
Prior Behavioral Functioning (Spring Kindergarten)				
Behavioral self-regulation		0.62 *		0.61 *
Externalizing problem behaviors		0.96		0.95
Internalizing problem behaviors		1.05		1.03
Governmental Assistance, Childcare				
Food stamps (12 months)		1.18		0.99
WIC when pregnant		1.14		1.05
WIC as an infant or toddler		1.00		1.08
Regular center care program		0.98		1.00
Temporary assistance		1.03		1.09

Note: Executive functioning deficits, prior learning difficulties defined as scoring in the lowest 10% of the respective measure's distribution; WIC = Special Supplemental Nutrition Assistance Program for Women, Infants, and Children; SES = socioeconomic status. All continuous variables have been standardized with $M = 0$, $SD = 1$.

* $p \leq .05$, ** $p \leq .01$, *** $p \leq .001$.

- WM & CF deficits increase kindergarten children's risk for reading and math difficulties in 1st grade
- WM deficits are an especially strong risk factor
- These increased risks are evident despite statistical control for many potential confounds including prior histories of reading or math difficulties in kindergarten

Coefficients are Odds Ratios

Are EF deficits predictive of STEM difficulties over time?

- Analytical subsample of 8,330 children participating in the ECLS-K: 2011
- Children's math & science achievement individually assessed, as were their EF
- Use of growth mixture modeling using standardized scores to identify homogenous classes of achievement trajectory, with particular focus on repeatedly low achievement
  - Groups identified using BIC, minimum size of 5% of sample, & posterior probabilities above .70
- Multinomial logistic regression to estimate the risk of deficits in WM, CF, IC of experiencing repeated academic difficulties in mathematics, reading, and science
  - EF deficits using lowest 10% cut off, averaged across fall & spring of kindergarten
  - Robustness checks using other deficit identification criteria

Source: Morgan, P. L., Farkas, G., Hillemeier, M. M., Oh, Y., Wang, Y., & Maczuga, S. (in revision). Executive function deficits in kindergarten predict repeated academic achievement difficulties across elementary school.

Figure 5. Trajectories of Mathematics Test Scores (Standardized at each time point) for Grade 1, 2, and 3, ECLS-K: 2011 Data (N = 8, 330).

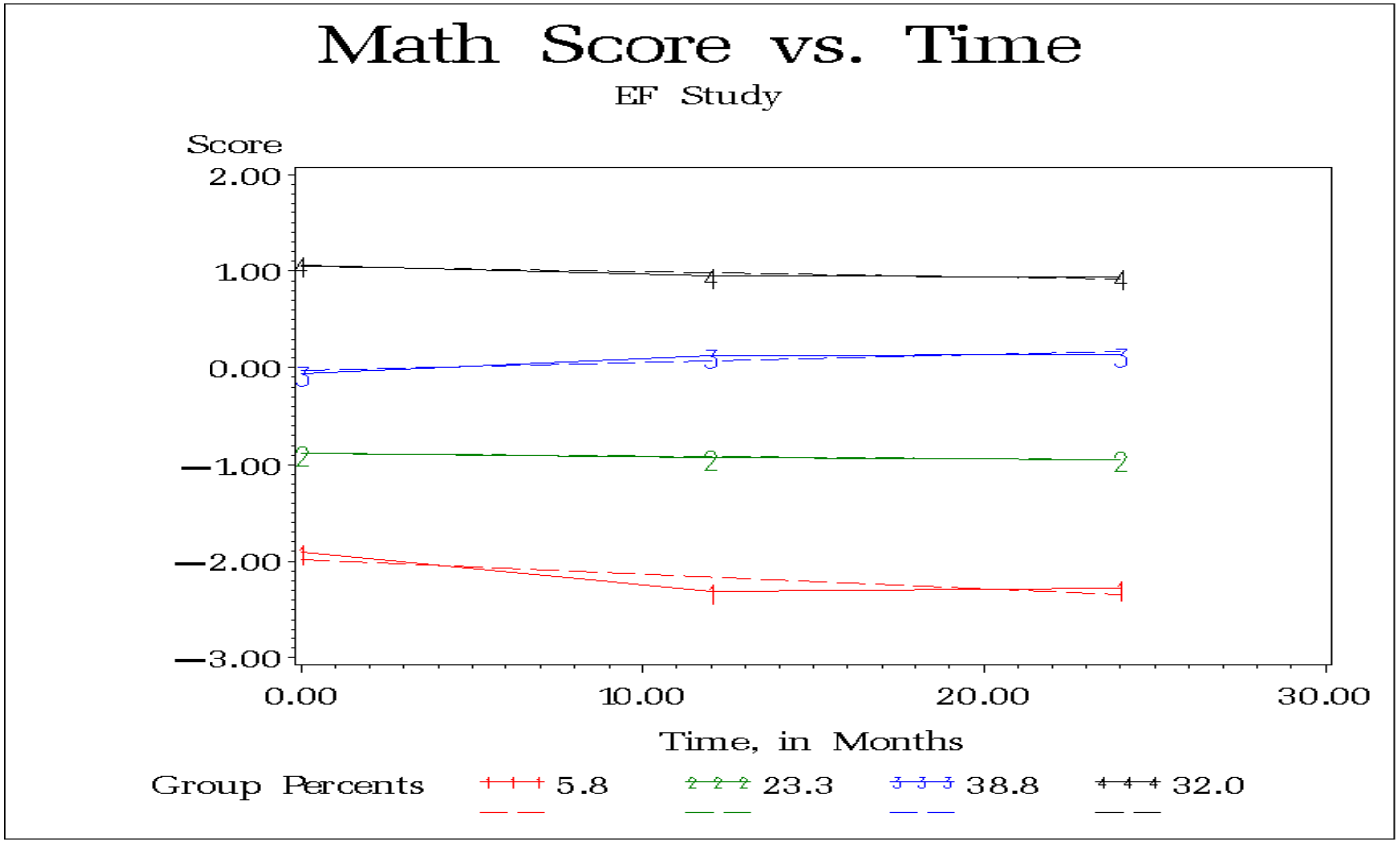
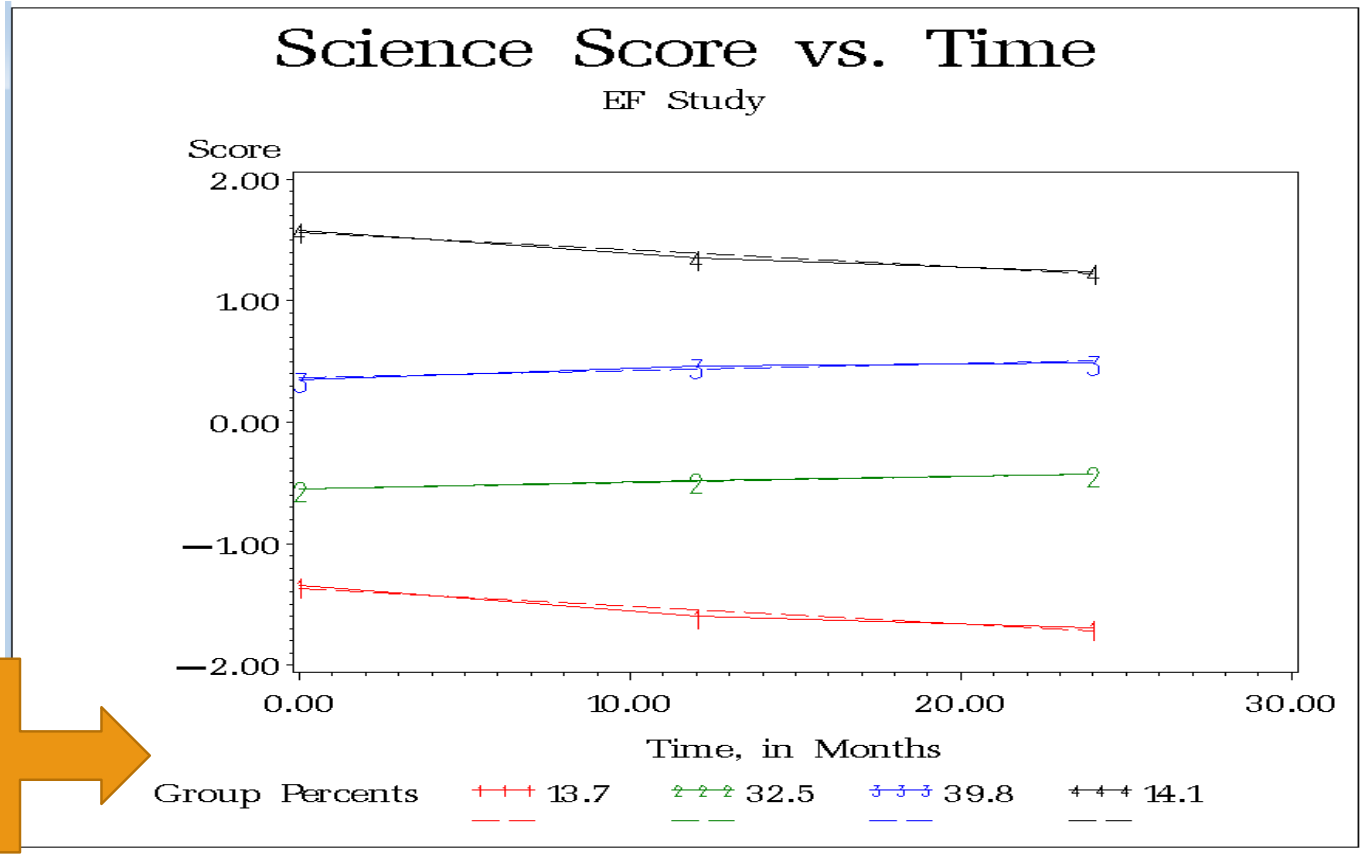


Figure 6. Trajectories of Science Test Scores (Standardized at each time point) for Grade 1, 2, and 3, ECLS-K: 2011 Data (N = 8,330).



Note Group 1 & 4 sizes here vs. Group 1 & 4 sizes of of 5.8% & 32% for math

Table 1. Predictors (Odds Ratios) of Trajectory Group Membership of Math Achievement (1st-3rd Grade, ECLS-K: 2011 Data; N = 8,330)

	Group 1 (Repeatedly Lowest Achievement, 5.8%)						Group 2 (Repeatedly Low Achievement, 23.3%)						Group 4 (Repeatedly High Achievement, 32%)					
	Model 1		***Model 2***		***Model 3***		Model 1		Model 2		Model 3		Model 1		Model 2		Model 3	
Executive Function Deficits																		
Cognitive Flexibility Deficits	**6.58**	***	**1.72**	***	**1.70**	**	2.28	***	1.16		1.15		0.42	***	0.86		0.82	
Working Memory Deficits	**14.58**	***	**5.00**	***	**5.25**	***	4.29	***	2.19	***	2.15	***	0.22	***	0.74		0.78	
Inhibitory Control Deficits	**4.81**	***	**2.24**	***	**2.25**	***	2.08	***	1.52	***	1.63	***	0.78	*	1.24		0.98	
Academic Achievement, S of K																		
Reading Achievement			1.01		1.00				1.02	**	1.01				1.00		1.00	
Math Achievement			**0.68**	***	**0.68**	***			0.83	***	0.83	***			1.23	***	1.23	***
Science Achievement			**0.92**	***	**0.92**	***			0.95	***	0.95	***			1.05	***	1.04	***
Child's Age at K Entry					0.99						1.01						0.97	***
Child's Race/ethnicity																		
Black					3.74	***					3.30	***					0.32	***
Hispanic					0.81						1.06						0.62	***
Asian					0.16	**					0.59	**					1.16	
Other Race					1.62						1.30						1.09	
Male					0.67	**					0.66	***					2.43	***
SES					0.96						0.89	*					1.17	**
LD, 1st Grade					**4.02**	*					2.58	*					0.41	

Table 1. Predictors (Odds Ratios) of Trajectory Group Membership of Science Achievement (1st-3rd Grade, ECLS-K: 2011 Data; N = 8,330)																		
	Group 1 (Repeatedly Lowest Achievement, 13.7%)						Group 2 (Repeatedly Low Achievement, 32.5%)						Group 4 (Repeatedly High Achievement, 14.1%)					
	Model 1		**Model 2**		**Model 3**		Model 1		Model 2		Model 3		Model 1		Model 2		Model 3	
Executive Function Deficits																		
Cognitive Flexibility Deficits	**6.85**	***	**1.91**	***	**1.95**	***	2.25	***	1.30	*	1.34	*	0.40	***	0.70		0.68	
Working Memory Deficits	**9.62**	***	**2.08**	***	**1.89**	***	2.97	***	1.14		1.06		0.13	***	0.55		0.57	
Inhibitory Control Deficits	**2.59**	***	**1.29**		**1.46**	*	1.51	***	1.07		1.17		0.70	*	1.05		1.01	
Academic Achievement																		
Reading Achievement			**0.96**	***	**0.94**	***			0.98	***	0.97	***			1.02	***	1.02	***
Math Achievement			**0.87**	***	**0.88**	***			0.93	***	0.94	***			1.07	***	1.06	***
Science Achievement			**0.67**	***	**0.67**	***			0.83	***	0.83	***			1.22	***	1.22	***
Child Age at K Entry					1.03	*					1.02	*					1.00	
Child Race																		
Black					4.30	***					2.27	***					0.82	
Hispanic					1.09						1.08						1.04	
Asian					0.50	**					0.74	*					0.98	
Other Race					0.79						0.91						1.39	*
Male					0.51	***					0.68	***					1.30	**
SES					0.81	**					0.88	**					1.39	***
LD, 1st Grade					**4.37**	*					3.25	*					2.25	

Limitations

- Correlational, non-experimental data
  - Strong causal inferences are not possible, experimental studies necessary to establish causality
  - Our findings help establish, co-variance, temporal precedence & account for many alternative explanatory factors

- EF measurement limitations due to logistics of 1:1 administration to a very large sample

- Glass "half full" but also "half empty"
  - Effect sizes are small but non-trivial
  - Yet EF deficits are malleable, within the constrained set of malleable factors in school-based contexts, & might be additional targets with interventions that also address academic skills deficits

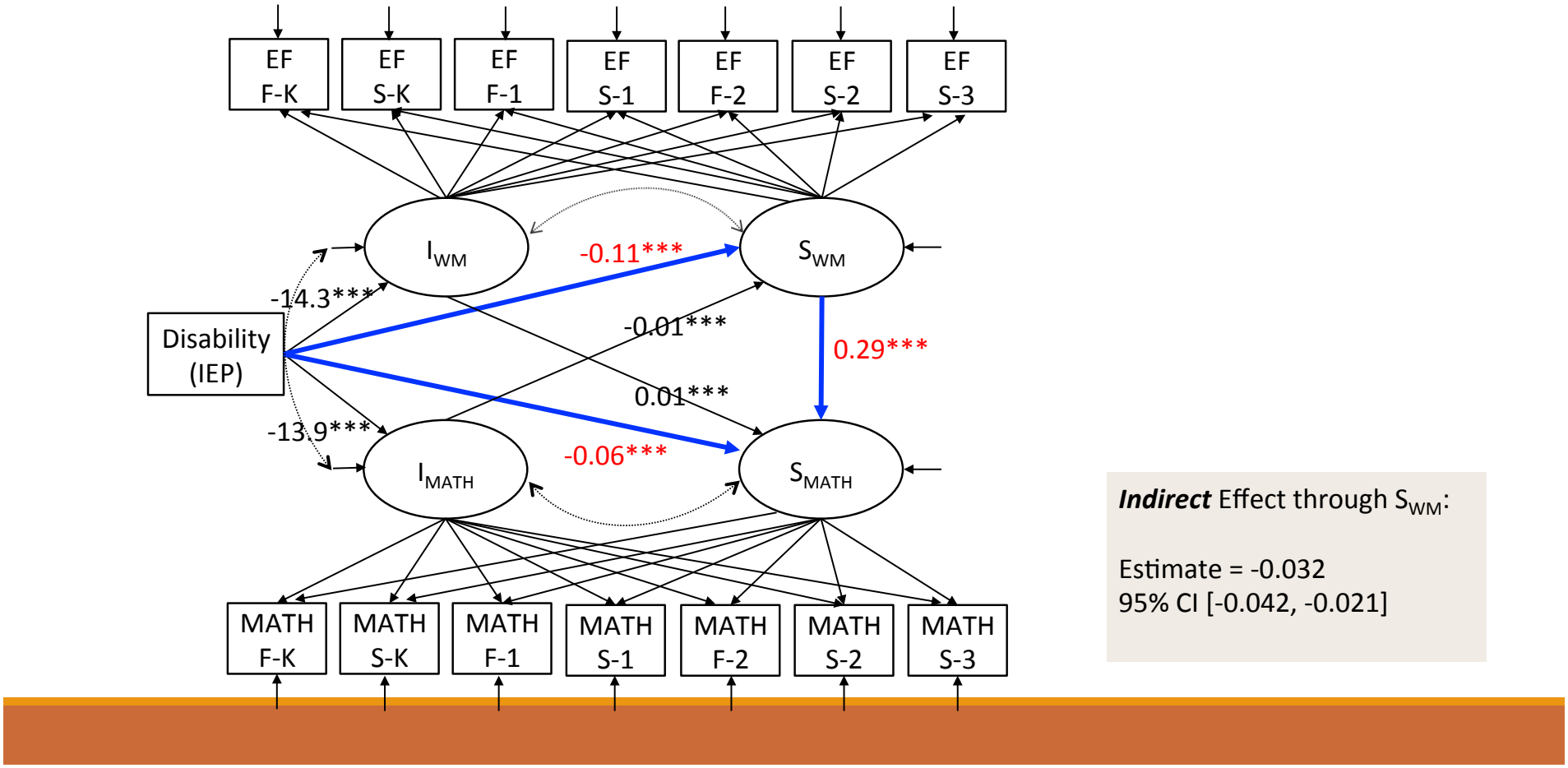
Summary

- Children with or at risk for learning disabilities begin to display repeated STEM difficulties by elementary school
  - This increased risk is consistently observed & begins very early
- These STEM difficulties persist & may worsen over time
- LD children's greater risk for repeated STEM difficulties are not explained by family SES, race/ethnicity, gender, or prior history of academic difficulties
- EF generally is related to both academic achievement & classroom behavior, & EF deficits increase the the risk for experiencing repeated STEM difficulties
  - WM may be an especially promising target of experimentally-evaluated interventions

Thank you

- Paul L. Morgan
  - paulmorgan@psu.edu
  - @PaulMorganPHD
- George Farkas
  - gfarkas@uci.edu

Effects of Disability on Mathematics Achievement: Working Memory as a Potential Mediator



Indirect Effect through S_{WM}:

Estimate = -0.032
95% CI [-0.042, -0.021]

What should parents, teachers, and policymakers be doing?

- Parents & teachers
  - Model STEM thinking and literacy, interest in STEM content
    - Making observations
    - Asking questions
    - Generating and evaluating hypotheses about the everyday world

- Policymakers
  - Increase access to informal & formal learning opportunities prior to school entry
  - Address widespread racial and economic segregation in U.S. schools
  - Increase use of early universal screening for children at risk

- https://www.youtube.com/watch?v=_LWgPh_k5DI

The STEM Superhero of *Sesame Street*

How and why the lovable, mistake-prone Grover was selected to teach children about science, technology, and math

KATE STRINGER | FEB 27, 2017 | EDUCATION

Share Tweet ... TEXT SIZE − +

Like *The Atlantic*? Subscribe to The Atlantic Daily, our free weekday email newsletter. Email SIGN UP