The acquisition of academic and executive functioning skills during early elementary school: Contrasting the role of constrained and unconstrained prekindergarten skills

Tiffany Jamie Foster[a]

Kylie Garber Bezdek[a]

Margaret Burchinal[b]

[a] Department of Psychology & Neuroscience, University of North Carolina at Chapel Hill
235 E Cameron Ave
Chapel Hill, NC 27514
United States

[b] Frank Porter Graham Child Development Institute, University of North Carolina at Chapel Hill
CB 8180
Chapel Hill, NC 27599-8180
United States

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Growing concern about the fade-out of prekindergarten (pre-k) impacts has raised questions about whether the skills typically promoted in pre-k programs predict the acquisition of the skills needed for school success (Farran & Lipsey, 2017; Yoshikawa, Weiland, & Brooks-Gunn, 2016). Further systematic research is needed to guide decisions about which skills to prioritize. The present study aims to contribute to this goal by considering how children's skills at the end of pre-k relate to their academic, language, and executive function (EF) trajectories from the beginning of kindergarten to the end of first grade.

The skills children learn in school can be grouped into two categories: constrained and unconstrained. Constrained skills, such as identifying letters, are finite and children tend to learn them relatively quickly and easily. On the other hand, unconstrained skills, such as vocabulary, are large domains acquired thorough experiences over time (Snow & Matthews, 2016). There is concern that early education focuses too much on constrained skills (Bailey, Watts, Littlefield, & Geary, 2014; Snow & Matthews, 2016). Unconstrained skills are typically more difficult to teach but may better prepare children to handle the increasingly complex demands of school. For example, strong vocabulary and executive functioning skills may help children better comprehend and flexibly think about more complicated topics in areas such as math and reading (Snow & Matthews, 2016).

To date, research examining children's early skills as predictors of school outcomes has often been limited to the examination of one or a small subset of skills or outcomes at a single timepoint. However, school-related skills tend to be moderately to highly correlated (e.g. Pace et al., 2019), which may lead to the overestimation of associations when only one skill is considered as a predictor. Furthermore, looking at outcomes at a single timepoint does not consider how early skills relate to gains in skills over time. Research looking at longitudinal outcomes and a larger group of early skills appears to suggest that unconstrained skills are particularly important for predicting gains in skills over time and should be promoted more in pre-k (Burchinal et al., 2019; Pace et al., 2019).

Purpose of the Study

The present study explored the end of pre-k skills that are important for predicting the level of skills children have upon entering kindergarten and gains in skills over time. Based on previous research, the present study examined two hypotheses. First, a skill within a given domain will be the best predictor of that outcome. Second, unconstrained skills (i.e., vocabulary and EF) will be the best predictors of gains in skills over time.

Participants and Procedures

The present study used a sample of 455 children who attended a state-funded pre-k program (see Table 1). Classrooms were randomly selected from six rural counties in the state, and children were randomly selected from each classroom. About half of the children were male and half were female. Considering race/ethnicity, about 24% of the children were white, 30%

were black, 42% were Hispanic, and 4% fell into another category. Spanish-speaking dual language learners (DLLs) made up about 43% of the sample. Each fall and spring, children's math, literacy (i.e., decoding), and vocabulary skills were assessed using the Woodcock-Johnson Tests of Achievement III, EF (i.e., cognitive flexibility and inhibitory control) was tested using the NIH Toolbox, and learning behaviors were examined through teacher ratings on the Learning Behaviors Scale.

Analysis

Hierarchical linear modeling (HLM) examined children's skill trajectories across four time points from the beginning of kindergarten to the end of first grade while accounting for repeated measures on children and nesting of children in schools. The model estimated individual quadratic growth curves for the outcomes and regressed the individual intercepts and slopes onto the child's pre-k skills. The model included level 1 residuals and random variances for individual intercepts and slopes. Covariates included child race, DLL status, and sex, household income, and maternal education as well as classroom quality as a time-varying covariate (see Table 1 for descriptive information). Multiple imputation was used to handle missing data. The reduced-form equation is:

$$Y_{ij} = (B_0+B_1 Grade_{ij}+B_2\ Grade^2_{ij}+B_3<Pre\text{-}k\ Skills>_j+B_4<Covariates>_j+ B_5<Pre\text{-}k\ Skills>_j*Grade_{ij}+B_6<Pre\text{-}k\ Skills>_j*Grade^2_{ij}+B_7 Quality_{ij})+ (u_{0j}+u_{1j}Grade_{ij}+u_{2j}Grade^2_{ij}) + r_{ij}$$

Results

As shown in Table 2, while pre-k skills within a given area tended to be the best predictors of outcomes within that same area at the start kindergarten, more limited evidence emerged to support the prediction of outcomes across skill areas. Looking at cross-domain predictions in the fall of kindergarten, math skills were positively predicted by all skills except cognitive flexibility and decoding, decoding was positively predicted by vocabulary and inhibitory control, vocabulary was positively predicted by math, cognitive flexibility was positively predicted by vocabulary, and inhibitory control was positively predicted by learning behaviors. Considering gains over time (see Figures 1 and 2), higher pre-k math skills, inhibitory control, and learning behaviors were related to greater gains in decoding with larger gains being made earlier. For vocabulary, higher pre-k inhibitory control was related to greater gains over time. For the remaining significant predictors of gains, starting with a higher level of pre-k skill was related to smaller gains. For example, higher decoding in pre-k was related to smaller gains in decoding over time with greater gains being made later.

Conclusion

Overall, the findings of the present study support the expectations that early skills within a given domain will predict school-age outcomes in that same domain and that starting with higher skills in a given area will often relate to slower gains in that area over time. However, unlike previous research that found evidence to suggest that early unconstrained skills predict larger gains in various skill areas (Burchinal et al., 2019; Pace et al., 2019), the present study did

not find a consistent pattern of evidence to indicate that a specific type of skill predicts larger gains across skill domains. Overall, both constrained and unconstrained skills appear to play a role in child outcomes, suggesting the need for future work to take a more balanced approach toward considering the role of both types of skills in children's school success.

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Table 1

Descriptive Statistics for Sample Characteristics and Main Predictors and Outcomes by Grade

	N	Proportion	-
Demographics			
Child Sex			
Male	230	0.51	-
Female	225	0.49	-
Race/Ethnicity			
White	109	0.24	-
Black	134	0.30	-
Hispanic/Latino	192	0.42	-
Other	19	0.04	-
Language			
English Only	260	0.57	-
Dual Language Learner	195	0.53	-
Household Income (< $30,000)	198	0.54	-
Household Income (> $30,000)	170	0.46	-
	N	Mean	Std. Deviation
Maternal Education	452	12.25	2.44
Classroom Quality			
CLASS Pre-K	451	4.35	0.59
CLASS K	346	4.60	0.60
CLASS Grade 1	242	4.36	0.62
Pre-K Assessments			
WJ AP - Math	438	406.87	22.11
WJ LW - Decoding	439	339.39	23.58
WJ PV - Vocabulary	433	459.50	17.31
Cognitive Flexibility	417	19.64	13.13
Inhibitory Control	428	26.66	11.81
Learning Behaviors	424	1.71	0.34
Fall K Assessments			
WJ AP - Math	384	418.66	18.07
WJ LW - Decoding	385	360.81	26.95
WJ PV - Vocabulary	385	464.26	14.32
Cognitive Flexibility	347	24.32	13.83
Inhibitory Control	363	31.75	10.48
Spring K Assessments			
WJ AP - Math	356	437.44	15.63
WJ LW - Decoding	357	409.89	28.26
WJ PV - Vocabulary	357	469.60	11.89
Cognitive Flexibility	338	30.07	12.44
Inhibitory Control	341	35.72	7.69
Fall G1 Assessments			
WJ AP - Math	378	444.22	14.21
WJ LW - Decoding	378	423.01	30.13
WJ PV - Vocabulary	378	473.83	11.45
Cognitive Flexibility	329	32.41	11.45
Inhibitory Control	330	36.98	6.99
Spring G1 Assessments			
WJ AP - Math	374	457.77	14.40
WJ LW - Decoding	374	450.27	29.60

WJ PV - Vocabulary	374	477.22	12.36
Cognitive Flexibility	369	35.21	8.80
Inhibitory Control	370	38.33	4.95

Note: CLASS = Classroom Assessment Scoring System, K = kindergarten, G1 = grade 1, WJ = Woodcock Johnson, AP = Applied Problems, LW = Letter Word, PV = Picture Vocabulary

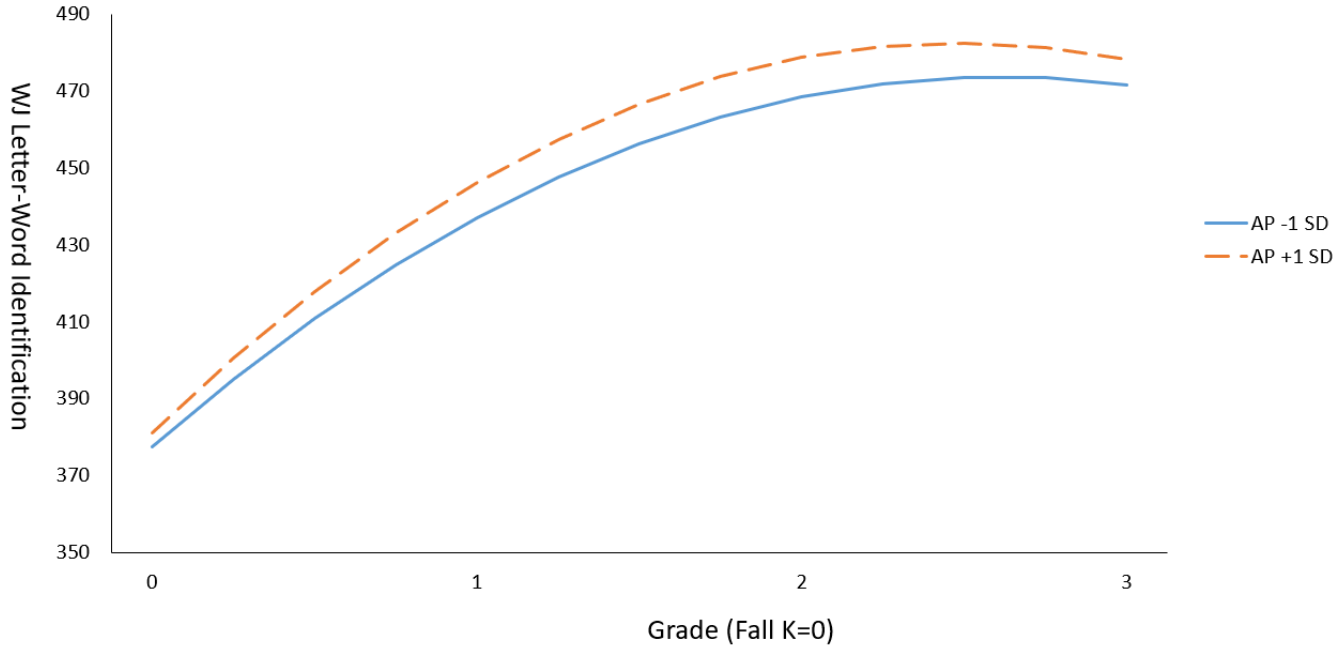
Table 2

Pre-Kindergarten Skills Predicting Child Outcomes at the Beginning of Kindergarten and Change Over Time

	Child Outcomes				
	WJ AP – Math	WJ LW – Decoding	WJ PV - Vocabulary	Cognitive Flexibility	Inhibitory Control
	B(se)	*B(se)*	*B(se)*	*B(se)*	*B(se)*
Intercept	420.05*** (0.65)	363.68*** (1.04)	464.80*** (0.39)	3.35*** (0.10)	4.54*** (0.08)
Covariates					
Maternal education	0.39(0.24)	-0.27(0.48)	-0.15(0.15)	0.01(0.03)	0.01(0.03)
Household income	0.12(0.36)	1.28+(0.70)	0.39+(0.22)	0.02(0.05)	0.02(0.04)
Race (Black = 1)	-2.44+(1.26)	2.93(2.39)	-0.36(0.76)	-0.27+(0.16)	-0.20(0.14)
Sex (Male = 1)	2.41*(0.94)	3.68+(1.91)	2.11***(0.59)	-0.28*(0.12)	0.03(0.11)
Dual language (DLL = 1)	1.13(0.42)	4.66+(2.73)	-2.96***(0.85)	0.18(0.18)	0.15(0.15)
CLASS	0.11(0.71)	2.34+(1.25)	-0.67+(0.40)	0.07(0.09)	-0.08(0.08)
Pre-K Skills					
WJ AP – Math	0.59***(0.08)	0.16(0.14)	0.10*(0.05)	0.01(0.01)	0.02+(0.01)
WJ LW – Decoding	0.09(0.07)	1.18***(0.11)	-0.00(0.04)	-0.00(0.01)	-0.01(0.01)
WJ PV – Vocabulary	0.21***(0.06)	0.21*(0.10)	0.71***(0.04)	0.02**(0.01)	0.00(0.01)
Cognitive Flexibility	0.56(0.38)	0.41(0.57)	0.29(0.22)	0.25***(0.05)	-0.01(0.04)
Inhibitory Control	1.68***(0.36)	1.52**(0.57)	-0.07(0.22)	0.11*(0.05)	0.29***(0.04)
Learning behaviors	6.57**(2.24)	5.71(3.49)	0.64(1.30)	0.61+(0.32)	1.17***(0.26)
Grade	16.54***(0.78)	44.53***(1.22)	5.74***(0.49)	0.85***(0.13)	0.74***(0.12)
Pre-K Skills					
WJ AP*grade	-0.10(0.10)	0.34*(0.15)	-0.01(0.06)	0.03+(0.02)	0.00(0.01)
WJ LW*grade	-0.06(0.09)	-0.41***(0.12)	-0.04(0.05)	-0.00(0.01)	0.01(0.01)
WJ PV*grade	-0.16*(0.07)	-0.12(0.10)	-0.21***(0.04)	-0.03*(0.01)	-0.02(0.01)
CF*grade	-0.06(0.42)	0.17(0.68)	-0.08(0.26)	-0.16+(0.08)	-0.02(0.06)
IC*grade	-0.20(0.42)	1.44*(0.66)	0.45*(0.26)	-0.12(0.08)	-0.14*(0.06)
Learning*grade	0.75(2.68)	9.78*(3.84)	-1.01(1.52)	0.51(0.45)	-0.15(0.37)
$Grade^2$	-1.44***(0.25)	-5.51***(0.37)	-0.53***(0.15)	-0.05(0.04)	-0.05(0.04)
Pre-K Skills					
WJ AP*$grade^2$	0.02(0.03)	-0.10*(0.05)	0.00(.02)	-0.01*(.01)	-0.00(0.00)
WJ LW*$grade^2$	0.01(0.03)	0.10**(0.04)	0.02(0.02)	0.00(0.00)	-0.00(0.00)
WJ PV*$grade^2$	0.03(0.02)	0.05+(0.03)	0.05***(0.01)	0.01*(0.00)	0.01(0.00)
CS*$grade^2$	0.01(0.13)	-0.06(0.20)	0.02(0.08)	0.03(0.03)	0.02(0.02)
IC*$grade^2$	-0.01(0.13)	-0.40*(0.20)	-0.11(0.08)	0.04(0.02)	0.03(0.02)
Learning*$grade^2$	-0.54(0.85)	-2.62*(1.19)	0.27(0.48)	-0.25(0.15)	-0.04(0.12)

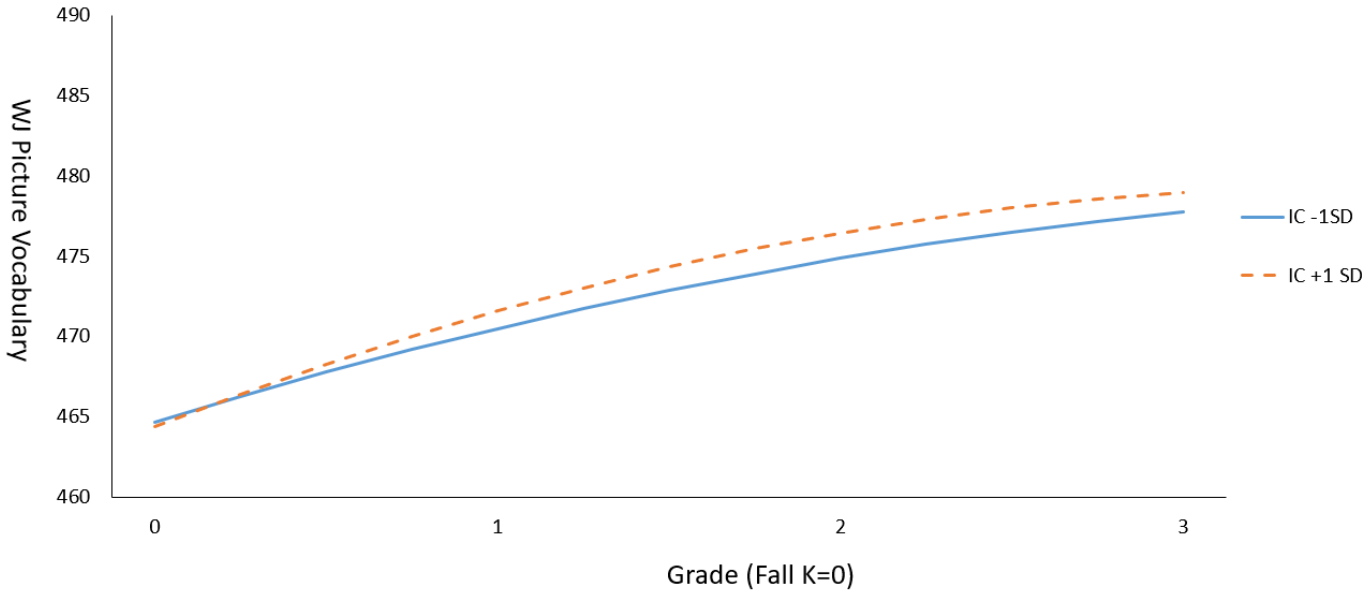
Note: + p < .10, * p < .05, ** p < .01, *** p < .001; CLASS = Classroom Assessment Scoring System, WJ = Woodcock Johnson, AP = Applied Problems, LW = Letter Word, PV = Picture Vocabulary, CF = cognitive flexibility, IC = inhibitory control, Learning = learning behaviors; grade coded as 0 for fall of kindergarten, 1 for spring of kindergarten, 2 for fall of grade 1, and 3 for spring of grade 1

Figure 1. Pre-k math skills predicting change in decoding skills through the end of first grade.



Note: WJ = Woodcock Johnson, AP = Applied Problems, 0 = fall of kindergarten, 1 = spring of kindergarten, 2 = fall of grade 1, 3 = spring of grade 1

Figure 2. Pre-k inhibitory control predicting change in vocabulary skills through the end of first grade.



Note: WJ = Woodcock Johnson, IC = inhibitory control, 0 = fall of kindergarten, 1 = spring of kindergarten, 2 = fall of grade 1, 3 = spring of grade 1