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Psychological Science 2012 23: 310 originally published online 24 February 2012
DOI: 10.1177/0956797611426728

Research Article

ASSOCIATION FOR PSYCHOLOGICAL SCIENCE

Psychological Science
23(3) 310–319

DOI: 10.1177/0956797611426728
http://pss.sagepub.com
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Preschools Reduce Early Academic-Achievement Gaps: A Longitudinal Twin Approach

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Abstract

Preschools may reduce inequalities in early academic achievement by providing children from disadvantaged families with higher-quality learning environments than they would otherwise receive. In this study, longitudinal data from a nationally representative sample of more than 600 twin pairs were used to estimate the contributions of genes, the shared environment, and the nonshared environment to cognition and achievement scores in children enrolled versus not enrolled in preschool. Attending preschool at age 4 was associated with reductions in shared environmental influences on reading and math skills at age 5, but was not associated with the magnitude of shared environmental influences on cognition at age 2. These prospective effects were mediated by reductions in achievement gaps associated with minority status, socioeconomic status, and ratings of parental stimulation of cognitive development. Lower socioeconomic status was associated with lower rates of preschool enrollment, which suggests that the very children who would benefit most from preschools are the least likely to be enrolled in them.

Keywords

preschool, socioeconomic status, academic achievement, cognitive development, school readiness, behavioral genetics, individual differences, schools

Received 7/6/11; Revision accepted 9/21/11

Children's academic skills at kindergarten entry predict their continued academic success throughout their school years (Duncan, Dowsett, et al., 2007). Social inequalities in family-level, school-level, and community-level environments have all been implicated as contributing to disparities in early achievement (Duncan, Brooks-Gunn, & Klebanov, 1994; Huston & Bentley, 2010). It is well established that children from low-income families attend lower quality schools than those attended by children from higher-income families (Huston, 2004; Meyers, Rosenbaum, Ruhm, & Waldfogel, 2004). Yet despite the robust associations between socioeconomic privilege and school quality, some researchers have characterized schools as "equalizers" of social disparities in achievement. Supporting this seemingly paradoxical perspective, Downey, von Hippel, and Broh (2004) reasoned that "some children may have relatively poor school experiences, but the disadvantages in their non-school environments may be even more severe . . . In this way schools can favor advantaged students, yet still serve as equalizers" (pp. 613–614).

This same rationale suggests that early organized child care prior to kindergarten entry (i.e., preschool) may be particularly effective in reducing social disparities in skills at kindergarten entry, specifically by benefiting children being raised in poorer homes. As Barnett (1995) commented, "the best predictor of the size of [preschool] program effects may be the size of the gap between the program and home as learning environments . . . Thus, effects might be expected to be largest for the most disadvantaged" (p. 43). Indeed, the findings of previous studies (e.g., Bassok, 2010; Geoffroy et al., 2007, 2010; Magnuson, Meyers, Ruhm, & Waldfogel, 2004) indicate that the immediate benefits of center-based care are larger for racial minorities and socioeconomically disadvantaged groups than for nonminorities and nondisadvantaged groups. For example, using data from more than 12,000 American children, Magnuson and colleagues (2004) reported that the positive associations between enrollment in center-based day care during the year prior to kindergarten and achievement-test scores during kindergarten were stronger for children from impoverished families and children with poorly educated mothers.

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Previous studies, however, have been limited in three respects. First, they have not examined whether the relation between preschool enrollment and the magnitude of achievement gaps emerges prospectively or exists in full prior to the preschool years. In order to infer causation rather than selection as the basis for the relation between preschool enrollment and the magnitude of achievement gaps, the relation would have to exist only after the beginning of the preschool years. Second, because previous researchers have used data from only one child per family, they have been unable to estimate the effects of preschool on the total extent of between-family variation. Third, the specific characteristics of families examined have typically been macro-level characteristics, such as socioeconomic status (SES) and race, but not more proximal indices of the home environment, such as cognitive stimulation by parents. On the basis of previous work implicating more proximal learning environments, particularly parenting behaviors, as critical mediators of racial and socioeconomic disparities in achievement (Duncan et al., 1994; Guo & Harris, 2000; Lugo-Gil & Tamis-LeMonda, 2008), one might expect preschool enrollment to diminish the influences of minority status and SES on child development, in part by reducing the influences of more proximal parenting behaviors.

To address these outstanding issues, the current project used longitudinal data from a nationally representative sample of monozygotic and dizygotic twins nested within families. The twin design was used to separate disparities in achievement associated with the between-family environment from disparities in achievement associated with the unique (within-family) environment and with genes. In addition to estimating the relation between preschool attendance and the total amounts of between-family environmental variation, I also estimated the associations between preschool attendance and the sizes of achievement gaps related to minority status, SES, and parental stimulation of cognitive development. Thus, this project examined the extent to which total between-family variation in achievement was reduced by preschool attendance and the extent to which these reductions could be accounted for by reductions in the associations between both macro-level characteristics of families and a proximal index of parenting. Moreover, by measuring children at ages 2, 4, and 5, I was able to estimate the extent to which the patterns observed were evident prior to preschool enrollment (which would be consistent with a selection but not causation account) or only after preschool enrollment (which would be consistent with a causal account of preschool enrollment in attenuating achievement gaps).

Method

Participants

Participant data were drawn from the Early Childhood Longitudinal Study, Birth Cohort (ECLS-B) twin sample (Snow et al., 2009), which was representative of twins born in the United States in 2001. The sample was 61% White; 16% African American; 16% Hispanic; 3% Asian; 1% Pacific Islander, American Indian, or Alaska Native; and 4% multiracial. Fifty-one percent of the twins were male, and 49% were female; 25% were at or below the poverty line at study entry. The analyses reported here were conducted using data from three waves: age 2 years in 2003 and 2004, age 4 years (preschool age) in 2005 and 2006, and age 5 years (kindergarten age) in 2006. Zygosity diagnoses and preschool information were available for 1,200 twins from 600 families.[1]

Measures

Zygosity (2 years). Using the procedure described in Tucker-Drob, Rhemtulla, Harden, Turkheimer, & Fask (2011), I classified zygosity on the basis of physical similarity ratings that had been made by trained observers. Zygosity classifications from physical similarity ratings such as these have been consistently shown to be more than 90% accurate when cross-validated using twins of known zygosity (Forget-Dubois et al., 2003; Goldsmith, 1991; Price et al., 2000). Same-sex pairs who received a dizygotic classification were eliminated from analyses if their parents indicated that there was a medical reason for their dissimilarity. Thirty percent of twins in the final sample were diagnosed as monozygotic, 30% were diagnosed as same-sex dizygotic, and 40% were opposite-sex dizygotic.

Preschool enrollment (4 years). When the twins were 4 years old, parents were asked whether each of the twins was enrolled in center-based child care on a regular basis. Parents reported that 15% of twins were enrolled in the federally funded Head Start program, 61% of twins were enrolled in other forms of center-based care, and 26% were not enrolled in any center-based care. A twin was considered enrolled in preschool if he or she was enrolled in any form of center-based care (including Head Start). There were six pairs in which only one of the twins was enrolled in preschool; these pairs were eliminated from analyses. Eliminating children attending Head Start from analyses produced similar results to those reported here.

Early mental ability (2 years). At 2 years, ECLS staff individually administered to each twin the Bayley Short Form–Research Edition (BSF-R; Andreassen & Fletcher, 2007), a shortened form of the Bayley Scales of Infant Development, Second Edition (Bayley, 1993). Item response theory was used to create a mental-ability score, which was based on items tapping the quality of exploration of objects, early problem solving, the production of simple sound and gestures, and receptive and expressive communication with words. The reliability estimate for this score was .88 (Andreassen & Fletcher, 2007).

Early academic achievement (4 years and 5 years). During the preschool wave, children's early math skills (including number sense, counting, operations, patterns, and spatial sense) and reading skills (including letter recognition, letter sounds, phonological awareness, matching words, and receptive vocabulary) were assessed. Separate math and reading scores were derived for each child using item response theory. Reliability estimates for both scores were .92 (Najarian, Snow, Lennon, & Kinsey, 2010).

Minority status. Minority status was dummy-coded as 1 for White and 0 for non-White. Racial minorities were coded together because there were not enough twin pairs from the different minority groups to confidently estimate effects for each race and ethnicity separately.

SES. SES was indexed from parental reports of paternal and maternal education, paternal and maternal occupation, and family income at the 4-year wave. Each of these five variables was standardized to a mean of 0 and a standard deviation of 1 in the complete ECLS-B sample, and then averaged to create the SES composite score.

Parental stimulation of cognitive development (4 years). At the preschool wave, each twin separately participated in a 10-min semistructured activity with his or her parent. These interactions were video-recorded, and trained coders rated the interactions on a number of different dimensions using 7-point Likert-type scales. This project focused on ratings of parental stimulation of cognitive development, which is the extent to which the parent taught the child in an effortful, developmentally appropriate manner to enhance cognitive, language, and perceptual development. Interrater reliability of this rating was estimated at greater than 90% for both waves of data collection (Andreassen & Fletcher, 2007; Najarian et al., 2010). Scores for each twin pair were averaged and then centered at the mean (by subtracting 4.276) to obtain the most reliable index of parental stimulation at the family level.

Analyses

Full-information-maximum-likelihood estimation in Mplus statistical software (Muthén & Muthén, 2010) was used to fit structural equation models (SEMs).[2] The standard SEM for twins raised together partitions variation in a given phenotype (Y) into variation attributable to additive genetic influences (A), shared environmental influences (C) that operate at the family level and serve to make twins within a pair more similar to one another, and nonshared environmental influences (E) that operate on each twin individually and serve to make twins within a pair dissimilar from one another.[3] Note that aspects of the family environment that are either differentially experienced by twins or have differential effects on twins do not contribute to the shared environment. According to genetic theory, additive genetic variation is correlated at 1.0 for monozygotic twins and at .50 for dizygotic twins. By definition, shared environmental variation is correlated at 1.0 across all twin pairs, and nonshared environmental variation is uncorrelated across all twin pairs. For the current study, this standard SEM was expanded in order to examine whether the amounts of variation attributable to A, C, and E differ for children who attend preschool (preschool = 1) versus children who do not attend preschool (preschool = 0), as follows (cf. Purcell, 2002):

$$Y_{t,p} = \mu + b_{\text{preschool}} \times \text{preschool}_p + (a + a' \times \text{preschool}_p) \times A_{t,p} + (c + c' \times \text{preschool}_p) \times C_{t,p} + (e + e' \times \text{preschool}_p) \times E_{t,p}, \quad (1)$$

where μ is the mean of the phenotype; $b_{\text{preschool}}$, a, c, and e are the main effects of preschool enrollment, A, C, and E, respectively; and a', c', and e' represent the interactions of preschool enrollment with A, C, and E, respectively. The subscript t indicates that a term was allowed to vary across twins within a pair, and the subscript p indicates that a term was allowed to vary across twin pairs.

Measured family-level covariates were added to the model and allowed to interact with preschool enrollment. The following is a model that includes a single measured family-level covariate (X):

$$Y_{t,p} = \mu + b_{\text{preschool}} \times \text{preschool}_p + (b_F + b'_F \times \text{preschool}_p) \times X_p + (a + a' \times \text{preschool}_p) \times A_{t,p} + (c + c' \times \text{preschool}_p) \times C_{t,p} + (e + e' \times \text{preschool}_p) \times E_{t,p}, \quad (2)$$

where b_F is the main effect of the covariate, and b'_F is the interaction effect of the covariate with preschool enrollment. If, in Model 2, b'_F was significantly different from 0, and c' was attenuated relative to its value in Model 1, the interaction between preschool and the measured covariate mediated some of the Shared Environment × Preschool interaction effect.

Results

Descriptive statistics

Means, standard deviations, and intercorrelations among the study variables are presented in Table 1. The family-level variables (age, SES, minority status, and parental stimulation of cognitive development) were all moderately interrelated, the cognition and achievement variables (BSF-R, reading, and math scores) were moderately to strongly interrelated, and the family-level variables were moderately correlated with the cognition and achievement variables.

Likelihood of preschool enrollment

Table 2 presents the results of a multiple logistic regression predicting the log odds of preschool enrollment at the 4-year wave. Results of the analysis indicated that older children and children from higher SES families were more likely to attend preschool.

Table 1. Descriptive Statistics and Correlations Among All Variables

Variable	*M* (*SD*)	Correlations 1	2	3	4	5	6	7	8
1. BSF-R score at 2-year wave	122.72 (10.74)	—							
2. Reading score at 4-year wave	−0.56 (0.72)	.41	—						
3. Reading score at 5-year wave	0.26 (0.87)	.34	.69	—					
4. Math score at 4-year wave	−0.58 (0.78)	.42	.76	.68	—				
5. Math score at 5-year wave	0.27 (0.79)	.41	.69	.85	.74	—			
6. Age (in months) at 4-year wave	52.89 (4.10)	.02	.28	.31	.33	.27	—		
7. Socioeconomic status at 4-year wave	0.13 (0.85)	.32	.50	.40	.47	.47	.02	—	
8. Minority status (non-White = 0, White = 1)	.62 (—)	.24	.36	.27	.29	.33	−.02	.42	—
9. Parental stimulation of cognitive development	0.00 (0.86)	.22	.28	.28	.25	.27	−.08	.49	.32

Note: Statistics are given for only one twin per pair to avoid dependencies. Parental stimulation was mean-centered. BSF-R = Bayley Short Form–Research Edition (Andreassen & Fletcher, 2007).

Shared Environment × Preschool interactions

Table 3 presents parameter estimates from the application of Model 1 to mental-ability scores at age 2 and to reading and math scores at ages 4 and 5. First, although the logistic regression analyses reported in Table 2 indicate that there are, in fact, family and child characteristics that systematically predict the likelihood of preschool attendance, the magnitudes of genetic and environmental influences on mental ability at age 2 did not significantly differ by subsequent preschool enrollment status (i.e., the a', c', and e' coefficients were not significantly different from zero). The shared environment accounted for 58% of the variance in BSF-R scores among 2-year-olds who were not enrolled in preschool at age 4, as compared with 60% among twins who were enrolled in preschool at the same age.

Table 2. Results From a Multiple Logistic Regression Predicting the Log Odds of Preschool Enrollment at the 4-Year Wave

Predictor	Estimate	*SE*	*p*
BSF-R score at 2-year wave	−0.003	0.010	.791
Age (in months) at 4-year wave	0.065	0.023	.004
Socioeconomic status at 4-year wave	0.521	0.140	.001
Minority status (non-White = 0, White = 1)	−0.008	0.210	.969
Parental stimulation	0.080	0.135	.554

Note: The results given come from a model that included only one twin per pair to avoid dependencies. BSF-R = Bayley Short Form–Research Edition (Andreassen & Fletcher, 2007).

That a Shared Environment × Preschool interaction does not occur when cognition is measured prior to the preschool years suggests that later Shared Environment × Preschool interactions are not simply manifestations of preexisting interactions.

Second, at 4 years, shared environmental influences on math and reading scores began to differ by preschool attendance, although these differences were not statistically significant for reading and only marginally significant for math. For math scores, the shared environment accounted for 74% of the variance among children who did not attend preschool at age 4 and 55% of the variance among children who attended preschool at age 4. For reading scores, these proportions were 82% and 63%, respectively.

Finally, by 5 years, shared environmental influences on math and reading scores differed sharply between children who attended preschool at age 4 and those who did not. The shared environment accounted for 72% of the variance in math scores at age 5 among children who were not enrolled in preschool versus 47% of the variance among those who were enrolled the previous year. For reading scores, these proportions were 73% and 43%, respectively. Figure 1 illustrates this pattern by showing the unstandardized variance in math and reading scores accounted for by the shared environment at ages 4 and 5 by preschool enrollment. The magnitude of shared environmental influence on these two outcomes began to differ at age 4, with the difference growing substantially over the 1-year interval. By age 5, family-level influences on achievement were substantially lower for children who had attended preschool during the previous year.

Table 3. Parameter Estimates of Mental Ability and Academic Achievement From Shared Environment × Preschool Models

	BSF-R score (2 years)		Math score (4 years)		Reading score (4 years)		Math score (5 years)		Reading score (5 years)	
Parameter	Estimate	*SE*	Estimate	*SE*	Estimate	*SE*	Estimate	*SE*	Estimate	*SE*
$b_{preschool}$	1.877*	0.863	0.481*	0.068	0.440*	0.063	0.401*	0.084	0.481*	0.091
a	4.122*	1.547	0.256*	0.107	0.000	0.468	0.384*	0.074	0.435*	0.063
a'	0.130	1.893	0.116	0.119	0.282	0.472	0.048	0.089	0.099	0.078
c	7.474*	0.881	0.668*	0.055	0.643*	0.042	0.760*	0.067	0.816*	0.071
c'	0.928	1.033	−0.120†††	0.067	−0.085	0.054	−0.256*	0.080	−0.278*	0.087
e	4.857*	0.472	−0.307*	0.033	0.303*	0.018	−0.272*	0.031	−0.244*	0.028
e'	0.465	0.581	−0.014	0.039	0.014	0.028	−0.048	0.038	−0.065††	0.035
μ	121.401*	0.721	−0.921*	0.060	−0.868*	0.055	0.005	0.077	−0.095	0.083

Note: The table lists parameter estimates for the main effects of preschool enrollment ($b_{preschool}$), additive genetic influences (a), shared environmental influences (c), and nonshared environmental influences (e), as well as the interactions of the last three variables with preschool enrollment (a', c', and e'). For the 4-year wave, preschool was coded as 0 for no preschool enrollment and 1 for preschool enrollment. BSF-R = Bayley Short Form–Research Edition (Andreassen & Fletcher, 2007).
$^{††}p = .07$. $^{†††}p = .06$. $^{*}p < .05$.

The Shared Environment × Preschool interaction is further illustrated in Figure 2, which plots math and reading scores at age 5 as a function of latent shared-environment factor scores and preschool enrollment. The relation between scores on the latent shared-environment factor and achievement scores is steeper for children who had not attended preschool than for those who had. For very low scores on the shared environment (1.5 standard deviations below the mean), children who had been enrolled in preschool scored approximately 0.8 points better in math and 0.9 points better in reading than those who had not been enrolled in preschool. For very high scores on the shared environment (1.5 standard deviations above the mean), there was no appreciable achievement disparity between children who had attended preschool and those who had not. In the next set of analyses, I sought to clarify these results by examining measured rather than latent characteristics of families.

Interactions between measured covariates and preschool

Parameter estimates for applications of Model 2 are presented in Table 4 for math skills at age 5 and in Table 5 for reading skills at age 5. Three parameters from each model are of particular interest: b_F, b'_F, and c'. The b_F parameter represents the main effect of the measured covariate for children who had not attended preschool at age 4; this parameter was significantly positive in all cases: For children who had not attended preschool at age 4, being White, being from a higher-SES family, and receiving more parental stimulation predicted greater math and reading scores at age 5. The b'_F parameter (the interaction between the measured covariate and preschool) represents the difference in the effect of the measured covariate for children who had been enrolled in preschool at age 4. This

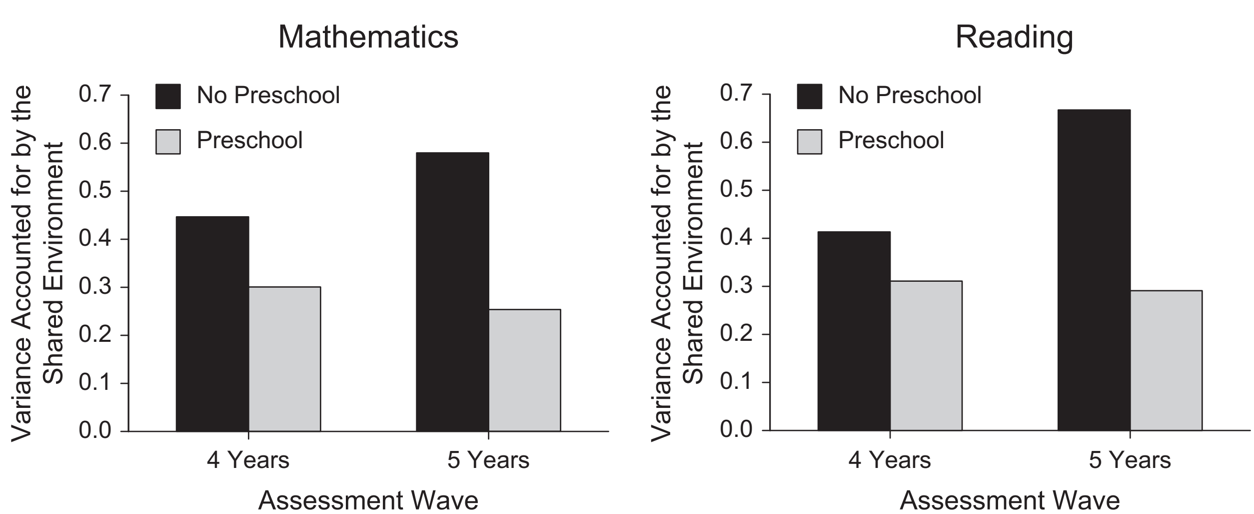

Fig. 1. Unstandardized variance in achievement scores accounted for by the shared environment as a function of assessment wave and whether or not participants were enrolled in preschool at the age-4 wave. Results are shown separately for math scores (left graph) and reading scores (right graph).

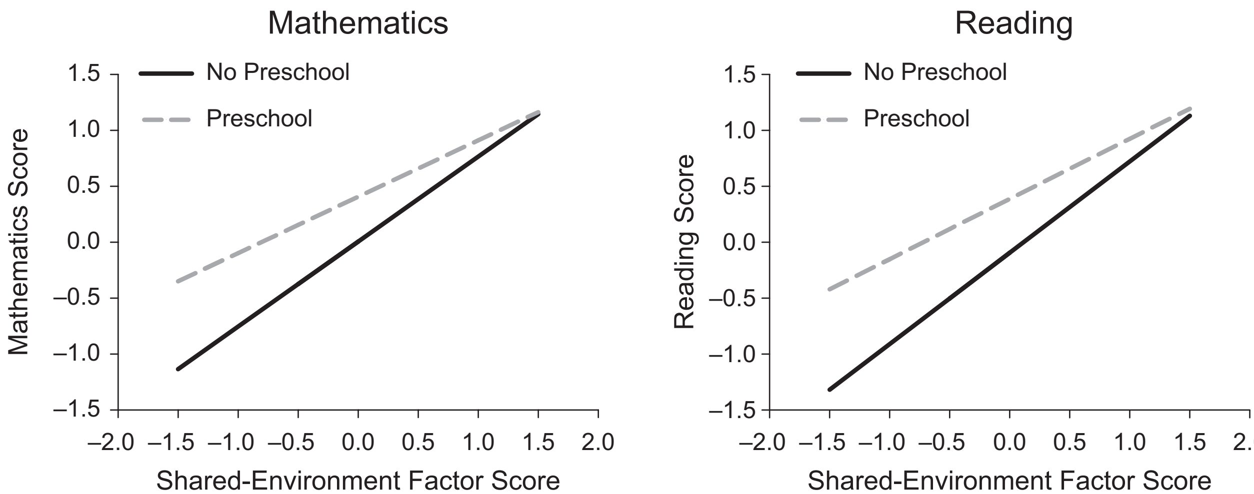

Fig. 2. Math scores (left graph) and reading scores (right graph) at age 5 as a function of score on the latent shared-environment factor and whether or not participants had been enrolled in preschool the previous year. The mean math score at age 5 was 0.27 (SD = 0.79). The mean reading score at age 5 was 0.26 (SD = 0.87). Shared-environment factor scores are on a Z metric (M = 0, SD = 1).

parameter was significantly negative in all cases: The associations between ethnic minority status, SES, and parental stimulation, on the one hand, and math and reading scores at age 5, on the other hand, were substantially reduced for children who had been enrolled in preschool at age 4.

Finally, the c' parameter represents the extent to which the remaining shared environmental influences (i.e., unmeasured family-level variation unaccounted for by the measured covariates) are lower for children who had attended preschool at age 4. In all cases, this parameter was attenuated relative to its corresponding estimate in Table 3, which indicates that the interactions between the measured covariates and preschool accounted for some of the Shared Environment × Preschool interactions. When measured covariates were not included in the model, the c' coefficient was −0.256 for math scores at age 5 and −0.278 for reading scores at age 5. For models that included minority status, SES, and parental stimulation, these estimates were −0.142, −0.152, and −0.203, respectively, for math scores at age 5, and −0.189, −0.152, and −0.224, respectively, for reading scores at age 5.

The interactions between preschool and minority status, SES, and parental stimulation of cognitive development are illustrated in Figure 3. Each panel in the figure plots the model-implied average achievement-test scores at age 5 for children

Table 4. Parameter Estimates for Models of Math Skills at Age 5 (Kindergarten Age)

	Preschool × Minority Status model		Preschool × Socioeconomic Status model		Preschool × Parental Stimulation model	
Parameter	Estimate	*SE*	Estimate	*SE*	Estimate	*SE*
$b_{preschool}$	0.674*	0.115	0.238*	0.070	0.338*	0.079
b_F	0.886*	0.133	0.570*	0.068	0.430*	0.082
b'_F	−0.551*	0.151	−0.216*	0.079	−0.274*	0.094
a	0.382*	0.074	0.379*	0.074	0.381*	0.074
a'	0.049	0.089	0.057	0.089	0.050	0.089
c	0.622*	0.064	0.563*	0.064	0.678*	0.065
c'	−0.142†††	0.078	−0.152††	0.080	−0.203	0.079
e	0.272*	0.031	0.273*	0.032	0.272*	0.031
e'	0.048	0.039	0.046	0.038	0.048	0.039
μ	−0.489*	0.100	−0.216*	0.079	0.055	0.072

Note: The table lists parameter estimates for the main effects of preschool enrollment ($b_{preschool}$), additive genetic influences (a), shared environmental influences (c), and nonshared environmental influences (e), as well as the interactions of the last three variables with preschool enrollment (a', c', and e'). The b_F parameter represents the main effect of the measured covariate for children who had not attended preschool at age 4, and the b'_F parameter represents the difference in the effect of the measured covariate for children who had been enrolled in preschool at age 4. Minority status was coded as 0 for non-White and 1 for White. At the 4-year wave, preschool was coded 0 for no preschool enrollment and 1 for preschool enrollment.
††p = .07. †††p = .06. *p < .05.

Table 5. Parameter Estimates for Models of Reading Skills at Age 5 (Kindergarten Age)

	Preschool × Minority Status model		Preschool × Socioeconomic Status model		Preschool × Parental Stimulation model	
Parameter	Estimate	*SE*	Estimate	*SE*	Estimate	*SE*
$b_{preschool}$	0.750*	0.130	0.325*	0.078	0.415*	0.086
b_F	0.813*	0.151	0.588*	0.075	0.443*	0.089
b'_F	−0.533*	0.170	−0.274*	0.088	−0.277*	0.102
a	0.433*	0.063	0.433*	0.063	0.434*	0.063
a'	0.100	0.078	0.105	0.078	0.099	0.078
c	0.711*	0.068	0.622*	0.067	0.733*	0.069
c'	−0.189*	0.085	−0.152†††	0.087	−0.224*	0.087
e	0.244*	0.028	0.244*	0.028	0.244*	0.028
e'	0.065†	0.035	0.064††	0.035	0.065†	0.035
μ	−0.549*	0.113	−0.018	0.069	−0.043	0.077

Note: The table lists parameter estimates for the main effects of preschool enrollment ($b_{preschool}$), additive genetic influences (a), shared environmental influences (c), and nonshared environmental influences (e), as well as the interactions of the last three variables with preschool enrollment (a', c', and e'). The b_F parameter represents the main effect of the measured covariate for children who had not attended preschool at age 4, and the b'_F parameter represents the difference in the effect of the measured covariate for children who had been enrolled in preschool at age 4. Minority status was coded as 0 for non-White and 1 for White. At the 4-year wave, preschool was coded as 0 for no preschool enrollment and 1 for preschool enrollment.
†p = .08. ††p = .07. †††p = .06. *p < .05.

who had been enrolled in preschool at age 4 and those who had not, stratified by different levels of the measured covariate. For both math and reading scores, preschool provided greater benefits for children who were non-White, from a lower-SES family, and raised by a parent rated as less cognitively stimulating. In other words, differences in early math and reading scores associated with race, SES, and parental stimulation are reduced among children who attended preschool.

Stepwise analyses

A stepwise approach was used in the final set of analyses to sequentially add minority status, SES, and parental stimulation to the models of reading and math at 5 years. Details on these analyses and their results are described in the Supplemental Material available online. In summary, when all three interactions were included in a simultaneous model, none of the interactions was individually significant. This indicates that the interaction effects largely represent an overlapping set of family-level influences that are together attenuated by preschool enrollment.

Discussion

The major finding reported in this article is that preschool enrollment at age 4 was prospectively associated with substantially reduced family-level influences on early reading and math skills at age 5. Among children who attended preschool at age 4, shared environmental influences accounted for 47% of the variance in math scores and 43% of the variance in reading scores at age 5. In contrast, among children who did not attend preschool at age 4, shared environmental influences accounted for 72% of the variance in math scores and 73% of the variance in reading scores at age 5. The magnitude of shared environmental influences on cognitive test scores at age 2 did not differ by subsequent preschool enrollment, which suggests that the interaction effects observed at age 5 were not simply manifestations of preexisting interactions.

Preschool attendance was prospectively associated with enhanced reading and math skills, particularly for racial and ethnic minorities, children from lower-SES families, and children whose parents were rated as less cognitively stimulating. It was primarily the overlapping effect of minority status, SES, and parental stimulation that was attenuated by preschool enrollment. Moreover, SES significantly predicted the likelihood of being enrolled in preschool, a fact suggesting that the very children who would benefit most from preschools are those who are least likely to be enrolled in preschools. Therefore, differences in the rate of preschool enrollment across families may actually serve to perpetuate achievement disparities at the population level.

Previous research on the role of early child care in equalizing between-family disparities in academic achievement has used designs with only one child per family. As a result, these studies were able to examine only whether preschool enrollment attenuates the impact of specific, measured family characteristics. In contrast, the current study used twin data, which allowed estimates of the total effect of family-level influences on achievement to be made. The method applied relies on the standard assumptions of the twin approach. However, Loehlin, Harden, and Turkheimer (2009) have demonstrated that interaction-effect estimates in twin models are far

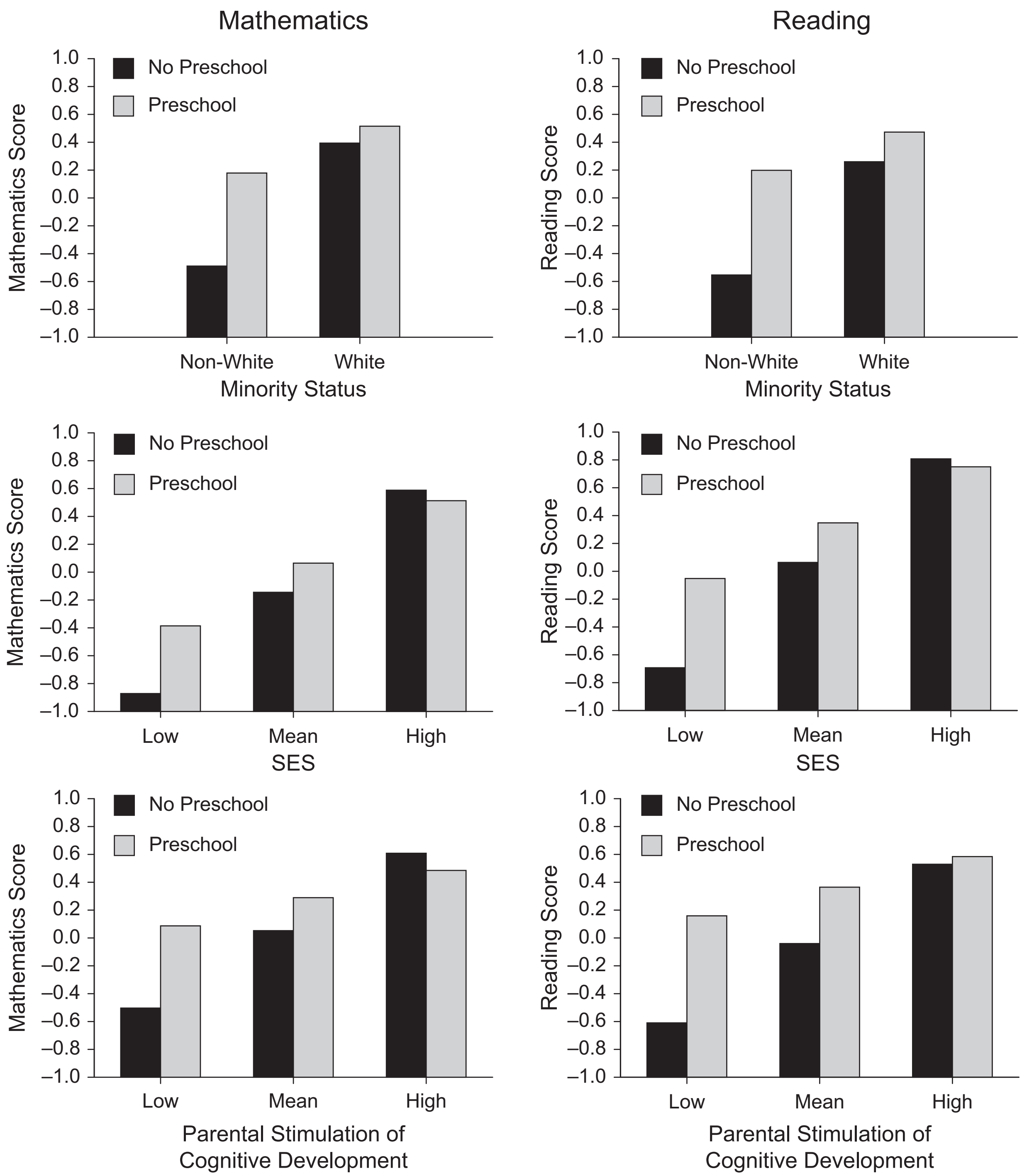

Fig. 3. Model-implied average math scores (left column) and reading scores (right column) at age 5 for children who had been enrolled in preschool at age 4 and those who had not. Results are shown as a function of minority status (top row), socioeconomic status (SES; middle row), and ratings of parental stimulation of cognitive development from a video-recorded dyadic task between parent and child (bottom row). For SES and parental stimulation, *low* is equal to 1.5 standard deviations below the mean, and *high* is equal to 1.5 standard deviations above the mean.

less influenced by violations of standard assumptions than are main-effect estimates. Because the current study was primarily concerned with interaction effects (specifically, the Shared Environment × Preschool interaction), the current findings can be considered robust.

Because data were available from multiple waves, including a wave preceding preschool enrollment, the current study was able to test whether there were preexisting differences in the magnitude of shared environmental influences associated with later preschool status. The absence of such preexisting differences strengthens the inference that the observed interaction effects were indeed caused by preschool attendance. In theory, an even stronger causal inference could be made using a randomized experiment, such as a lottery for preschool vouchers, combined with methods to examine treatment-effect heterogeneity (e.g., Tucker-Drob, 2011).

Although this study was unique in examining multiple measured family-level covariates as modifiers of preschool effects, a limitation is that specific characteristics of preschools were not examined. One might expect that the greatest preschool boost would occur for the few disadvantaged children who are fortunate enough to attend high-quality preschools. Previous work has shown that several indices of child-care quality, including live observer ratings of preschool teachers' sensitivity, responsivity, and stimulation of cognitive development (Dearing, McCartney, & Taylor, 2009), are specifically associated with reduced achievement gaps. Other factors associated with reduced achievement gaps at school entry include earlier age of enrollment in child care (Caughy, DiPietro, & Strobino, 1994), being in a full-time rather than a part-time program (Geoffroy et al., 2007), being in a formal center-based program rather than an informal program (Geoffroy et al., 2010), and being exposed to more school-transition practices, such as preschoolers spending time in the kindergarten classroom and teachers visiting the home at the beginning of the kindergarten school year (Schulting, Malone, & Dodge, 2005). Future longitudinal studies should chart the achievement gap prior to and following preschool enrollment. Although empirical research on school and home quality (Dowsett, Huston, Imes, & Gennetian, 2008) has found that preschools "offer more opportunities for cognitive and intellectual development than do the home-based settings . . . that are typically used by low-income parents" (p. 90), it is possible that the preschool-associated gap reductions found in the study reported here were primarily driven by those preschools meeting a minimum threshold of quality.

Finally, although this study examined (and detected) effects of preschool on achievement gaps in academic achievement in kindergarten, it is unknown whether gap reductions would be maintained into later childhood, adolescence, or adulthood. The vast majority of previous experimental and quasiexperimental studies have reported large immediate benefits of preschools on impoverished children's achievement, but only a select subset (e.g., Campbell, Ramey, Pungello, Sparling, & Miller-Johnson, 2002; Schweinhart et al., 2005) have found the effects to persist in the long term. Many other studies have found that the effects fade out over time (e.g., Currie & Thomas, 1995; see Leak et al., 2010 for a meta-analysis). Barnett (1995) speculated that differences in quality and funding across programs may help to account for differences in long-term effects. It is also likely that inequalities in children's experiences following preschool serve to wash out early gains and that maintenance of gains among low-income children would generally require amelioration of inequalities that exist during the elementary school, middle school, and high school years. Notwithstanding this latter issue, economic analyses have indicated that there are long-term monetary benefits of investing in preschool programs for impoverished children (Barnett, 1995; Duncan, Ludwig, & Magnusson, 2007; Heckman, 2006).

In conclusion, the results reported here suggest that preschool attendance may help to reduce achievement gaps associated with multiple measured and unmeasured family-level variables. However, because lower-SES families are less likely to send their children to preschool, the equalizing effects of preschools at the population level may not be fully realized. It remains unclear what specific aspects of preschools are responsible for these effects or whether the immediate benefits of preschools for reducing achievement gaps would persist in the long term.

Declaration of Conflicting Interests

The author declared that he had no conflicts of interest with respect to his authorship or the publication of this article.

Funding

Preparation of this article was supported by National Institutes of Health (NIH) Grant R21 HD069772. The Population Research Center at the University of Texas at Austin is supported by NIH Center Grant R24 HD042849.

Supplemental Material

Additional supporting information may be found at http://pss.sagepub.com/content/by/supplemental-data

Notes

1. All sample sizes are rounded to the nearest 50 in accordance with ECLS-B data-security regulations.
2. The assumption underlying full-information maximum likelihood is that any patterns of missingness in the dependent variables that systematically relate to the missing values can be accounted for by the independent variables in the model. In the study reported here, there were only modest proportions of missing data, ranging from 4% to 18%, depending on the variable.
3. The shared environment may partially reflect children's genotypes as a result of being the direct or indirect outcome of their biological parents' genotypes (Scarr & McCartney, 1983).

References

Andreassen, C., & Fletcher, P. (2007). *Early Childhood Longitudinal Study, Birth Cohort (ECLS–B) psychometric report for the 2-year data collection (NCES 2007–084)*. Washington, DC: U.S. Department of Education, National Center for Education Statistics, Institute of Education Sciences.

Barnett, W. S. (1995). Long-term effects of early childhood programs on cognitive and school outcomes. *The Future of Children*, *5*, 25–50.

Bassok, D. (2010). Do black and Hispanic children benefit more from preschool? Understanding differences in preschool effects across racial groups. *Child Development*, *81*, 1828–1845.

Bayley, N. (1993). *Bayley Scales of Infant Development* (2nd ed.). San Antonio, TX: Psychological Corp.

Campbell, F. A., Ramey, C. T., Pungello, E., Sparling, J., & Miller-Johnson, S. M. (2002). Early childhood education: Young adult outcomes from the Abecedarian Project. *Applied Developmental Science*, *6*, 42–57.

Caughy, M. O., DiPietro, J. A., & Strobino, D. M. (1994). Day-care participation as a protective factor in the cognitive development of low-income children. *Child Development*, *65*, 457–471.

Currie, J., & Thomas, D. (1995). Does Head Start make a difference? *The American Economic Review*, *85*, 341–364.

Dearing, E., McCartney, K., & Taylor, B. A. (2009). Does higher quality early child care promote low-income children's math and reading achievement in middle childhood? *Child Development*, *80*, 1329–1349.

Downey, D. B., von Hippel, P. T., & Broh, B. A. (2004). Are schools the great equalizer? School and non-school sources of inequality in cognitive skills. *American Sociological Review*, *69*, 613–635.

Dowsett, C. J., Huston, A. C., Imes, A. E., & Gennetian, L. (2008). Structural and process features in three types of child care for children from high and low income families. *Early Childhood Research Quarterly*, *23*, 69–93.

Duncan, G. J., Brooks-Gunn, J., & Klebanov, P. K. (1994). Economic deprivation and early childhood development. *Child Development*, *65*, 296–318.

Duncan, G. J., Dowsett, C. J., Claessens, A., Magnuson, K., Huston, A. C., Klebanov, P., & Japel, C. (2007). School readiness and later achievement. *Developmental Psychology*, *43*, 1428–1446.

Duncan, G. J., Ludwig, J., & Magnusson, K. A. (2007). Reducing poverty through preschool interventions. *The Future of Children*, *17*, 143–160.

Forget-Dubois, N., Pérusse, D., Turecki, G., Girard, A., Billette, J. M., Rouleau, G., . . . Tremblay, R. E. (2003). Diagnosing zygosity in infant twins: Physical similarity, genotyping, and chorionicity. *Twin Research and Human Genetics*, *6*, 479–485.

Geoffroy, M.-C., Côté, S. M., Borge, A. I., Larouche, F., Seguin, J. R., & Rutter, M. (2007). Association between nonmaternal care in the first year of life and children's receptive language skills prior to school entry: The moderating role of socioeconomic status. *Journal of Child Psychology and Psychiatry*, *48*, 490–497.

Geoffroy, M.-C., Côté, S. M., Giguère, C.-É., Dionne, G., Zelazo, P. D., Tremblay, R. E., . . . Séguin, J. R. (2010). Closing the gap in academic readiness and achievement: The role of early childcare. *Journal of Child Psychology and Psychiatry*, *51*, 1359–1367.

Goldsmith, H. H. (1991). A zygosity questionnaire for young twins: A research note. *Behavior Genetics*, *21*, 257–269.

Guo, G., & Harris, H. (2000). The mechanisms mediating the effects of poverty on children's intellectual development. *Demography*, *37*, 431–447.

Heckman, J. J. (2006). Skill formation and the economics of investing in disadvantaged children. *Science*, *312*, 1900–1902.

Huston, A. C. (2004). Child care for low-income families: Problems and promises. In A. C. Crouter & A. Booth (Eds.), *Work-family challenges for low-income parents and their children* (pp. 139–164). New York, NY: Erlbaum.

Huston, A. C., & Bentley, A. C. (2010). Human development in societal context. *Annual Review of Psychology*, *61*, 411–437.

Leak, J., Duncan, G. J., Li, W., Magnusson, K., Schindler, H., & Yoshikawa, H. (2010, November). *Is timing everything? How early childhood education program impacts vary by starting age, program duration, and time since the end of the program*. Paper presented at the meeting of the Association for Policy Analysis and Management, Boston, MA. Retrieved from http://www.gse.uci.edu/docs/Leak_Duncan_Li_Timing_Paper_APPAM_102810.pdf

Loehlin, J. C., Harden, K. P., & Turkheimer, E. (2009). The effects of assumptions about parental assortative mating and genotype-income correlation on estimates of genotype-environment interaction in the National Merit Twin Study. *Behavior Genetics*, *39*, 165–169.

Lugo-Gil, J., & Tamis-LeMonda, C. S. (2008). Family resources and parenting quality: Links to children's cognitive development across the first 3 years. *Child Development*, *79*, 1065–1085.

Magnuson, K., Meyers, M., Ruhm, C., & Waldfogel, J. (2004). Inequality in preschool education and school readiness. *American Educational Research Journal*, *41*, 115–157.

Meyers, M. K., Rosenbaum, D. T., Ruhm, C., & Waldfogel, J. (2004). Inequality in early childhood education and care: What do we know? In K. M. Neckerman (Ed.), *Social inequality* (pp. 223–270). New York, NY: Sage.

Muthén, L. K., & Muthén, B. O. (2010). *MPlus user's guide* (6th ed.). Los Angeles, CA: Muthén and Muthén.

Najarian, M., Snow, K., Lennon, J., & Kinsey, S. (2010). *Early Childhood Longitudinal Study, Birth Cohort (ECLS-B), preschool–kindergarten 2007 psychometric report (NCES 2010-009)*. Washington, DC: U.S. Department of Education, National Center for Education Statistics, Institute of Education Sciences.

Price, T. S., Freeman, B., Craig, I. W., Petrill, S. A., Ebersole, L., & Plomin, R. (2000). Infant zygosity can be assigned by parental report questionnaire data. *Twin Research*, *3*, 129–133.

Purcell, S. (2002). Variance components models for gene-environment interaction in twin analysis. *Twin Research*, *5*, 554–571.

Scarr, S., & McCartney, K. (1983). How people make their own environments: A theory of genotype → environment effects. *Child Development*, *54*, 424–435.

Schulting, A. B., Malone, P. S., & Dodge, K. A. (2005). The effects of school-based kindergarten transition policies and practices on child academic outcomes. *Developmental Psychology*, *41*, 860–871.

Schweinhart, L. J., Montie, J., Xiang, Z., Barnett, W. S., Belfield, C. R., & Nores, M. (2005). *Lifetime effects: The High/Scope Perry Preschool Study through age 40*. Ypsilanti, MI: High/Scope Press.

Snow, K., Derecho, A., Wheeless, S., Lennon, J., Rosen, J., Rogers, J., . . . Einaudi, P. (2009). *Early Childhood Longitudinal Study, Birth Cohort (ECLS-B), kindergarten 2006 and 2007 data file user's manual (2010-010)*. Washington, DC: U.S. Department of Education, National Center for Education Statistics, Institute of Education Sciences.

Tucker-Drob, E. M. (2011). Individual differences methods for randomized experiments. *Psychological Methods*, *16*, 298–318.

Tucker-Drob, E. M., Rhemtulla, M., Harden, K. P., Turkheimer, E., & Fask, D. (2011). Emergence of a Gene × Socioeconomic Status interaction on infant mental ability between 10 months and 2 years. *Psychological Science*, *22*, 125–133.