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School-Based Early Childhood Education and Age-28 Well-Being: Effects by Timing, Dosage, and Subgroups

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Advances in understanding the effects of early education have benefited public policy and developmental science. Although preschool has demonstrated positive effects on life-course outcomes, limitations in knowledge on program scale, subgroup differences, and dosage levels have hindered progress. We report the effects of the Child-Parent Center Education Program on indicators of well-being up to 25 years later for more than 1400 participants. This established, publicly funded intervention begins in preschool and provides up to 6 years of service in inner-city Chicago schools. Relative to the comparison group receiving the usual services, program participation was independently linked to higher educational attainment, income, socioeconomic status (SES), and health insurance coverage, as well as lower rates of justice-system involvement and substance abuse. Evidence of enduring effects was strongest for preschool, especially for males and children of high school dropouts. The positive influence of 4 years or more of service was limited primarily to education and SES. Dosage within program components was mostly unrelated to outcomes. Findings demonstrate support for the enduring effects of sustained school-based early education to the end of the third decade of life.

The effects of educational enrichment in the early years of life are a central focus of developmental science and are increasingly used to prioritize social programs and policies. In the past two decades, evidence has grown that preschool or "prekindergarten" programs enhance well-being in many domains, and can promote economic benefits to society (*1*–*3*). Although the most enduring effects on school success and crime prevention are found among economically disadvantaged children (*4*), preschool programs can promote well-being across the entire socioeconomic spectrum (*5*, *6*).

The magnitude, breadth, and duration of impacts for preschool have been found to be more consistent and stronger than many prevention strategies (*7*). This pattern is likely due to the greater dosage, intensity, and scope of services. Preschools typically provide 500 hours per year. These enrichment experiences appear to initiate a pattern of cumulative advantages (*7*–*9*) that can translate to enduring life-course effects (*10*). Recent evidence on Head Start (*11*), however, suggests that enduring effects are not inevitable, and may depend on later social contexts (*12*).

Although evidence is strong that programs of relatively high quality can promote well-being, four major weaknesses reduce the strength and generalizability of evidence (*13*). The most widely documented limitation is that evidence on long-term effects is primarily from small-sample efficacy trials rather than effectiveness trials or studies of large-scale sustained programs (*2*, *4*). Studies of sustained and routinely implemented programs are essential to translational research yet long-term evidence is meager (*1*, *7*) and none have continued past age 25, which is most predictive of later development (*14*).

Three other less recognized limitations also have hindered progress. One is inadequate attention to program dosage, a prominent and modifiable characteristic. Although some studies show that the length of participation is positively associated with short-term outcomes (*7*, *15*), longer-term effects have been rarely investigated as have the added or synergistic benefits of later intervention. The second limitation is that variations in effects by child, family, and social context are under-investigated. Their identification provides valuable information for tailoring or strengthening services. Differences by gender vary by study and outcome, and long-term effects on high-risk samples warrant greater investigation. Finally, attrition is rarely taken into account in estimating effects. Studies frequently lose up to 50% of their original samples in follow-up (*16*, *17*). The power and precision of subgroup effects can be especially compromised. Bias reduction methods to account for attrition and other selection processes have become more integrated in estimation (*18*).

To assess the effects of a large-scale sustained early education program in public schools, the Chicago Longitudinal Study (CLS) (*19*) has prospectively documented the life-course development of 1,539 families (93% African American), the majority of whom participated in the Child-Parent Center (CPC) Education Program. CPC is the second oldest (after Head Start) federally funded preschool, and has been implemented in the Chicago Public Schools since 1967 (*20*). In addition to providing comprehensive services to economically disadvantaged families, the program has preschool and school-age components that enable assessments of the timing and length of participation.

In this study, we investigate links between CPC participation and well-being by age 28. While previous studies of publicly-funded programs (*21*) including CPC (*22*) have showed positive evidence, due to the age of assessment in early adulthood, a full range of economic, health, and family outcomes has not been assessed. Moreover, unlike previously, we examine differential effects by timing and length of intervention as well as child and family attributes. We also take into account through propensity score analysis the potential biasing effects of attrition and selection bias. Our major questions are: (1) Is CPC participation beginning in preschool and continuing into school-age associated with multiple domains of well-being? (2) Do estimated effects vary by child and family characteristics as well as dosage levels? (3) Are effects consistent across models for reducing bias in estimates?

Born in 1979–1980, the CLS sample is the entire cohort of 989 children who completed preschool and kindergarten (half- or full-day) in all 20 CPCs and 550 low-income children who did not attend the program in preschool but participated in a full-day kindergarten intervention in five randomly selected schools. 15% attended Head Start with most others in home care. That the comparison group participated in an enrichment program minimizes bias in group selection. First- to third-grade program services are offered to all students. Table 1 shows the patterns of participation and for inclusion in the adult follow-up study (*13*).

In this alternative-intervention, quasi-experimental design, groups matched on age, eligibility for intervention, and family poverty. In support of the interpretability of estimates, group comparisons at the beginning of the study and at follow-up show similarity on preprogram characteristics (Table 1 and table S2). Sample characteristics have been consistent over time.

Located in or close to elementary schools, the CPC program provides educational and family-support services between the ages of 3 and 9. The key goal stated by founder Lorraine Sullivan is that the centers "are designed to reach the child and parent early, develop language skills and self-confidence, and to demonstrate that these children, if given a chance, can meet successfully all the demands of today's technological, urban society" (*23*). The program emphasizes basic skills in language arts and math through relatively structured but diverse learning experiences that include whole-class instruction, small-group and individualized activities, and frequent field trips. All teachers have bachelor's degrees and are certified in early childhood education. Classes are small (17 in preschool; 25 in kindergarten to third grade) and are staffed by teacher aides. In addition to the head teacher in each site, the parent resource teacher and outreach representative direct multi-faceted and intensive services in the parent resource room. The scope of services helped ensure high participation. Heavy outreach by staff also led to participation by families most in need (*13*). Preschool and kindergarten were funded by Title I of the Elementary and Secondary Education Act of 1965 (P.L. 89-10; 79 Stat. 27) while school-age services were funded by the State of Illinois and Chicago Boards of Education. In 2011 dollars, the average costs per child were as follows: preschool ($9,233), school-age over and above regular instruction ($4,113), and preschool plus school-age relative to lesser program services ($5,600).

As shown in Table 1, 90.1% of the original sample had follow-up data on educational attainment or socioeconomic status (mean age 28.3 years). Recovery rates for the groups were nearly identical. They ranged, in the overall sample, from 80% to 96% for other outcomes (table S1). Well-being was assessed in five domains: educational attainment, socioeconomic status (SES), health status and behavior, crime and justice system involvement, and family outcomes (tables S3–S5). High school completion, for example, was a high school diploma or equivalent. One indicator of SES was a composite index of education and income. Measures were a combination of administrative and survey data from many sources (e.g., education, crime, and income records) and are theoretically related to the ultimate goal of economic independence.

We estimated effects using probit, linear, and negative binomial regression analysis adjusted for 15 preprogram attributes and weighted by attrition propensities through Inverse Probability Weighting (IPW) (*24*). IPW has been shown to yield the most efficient estimates (*25*). The weight was $1/p_1$, where p_1 is the predicted probability of being in the recovery sample ($R_i = 1$; otherwise 0) for each outcome (i) as a function of 26 predictors known to influence attrition (table S6 and fig. S6). Standard errors were corrected for site clustering. Robustness of estimates was fully assessed (table S7).

A summary of findings for select outcomes in four domains is shown in Table 2, including preschool, school-age, and extended intervention. For brevity, our measure of

extended intervention here is for 4 to 6 years versus fewer. Findings for an alternative measure of extended intervention (extended-2) and for other outcomes including family status are shown in table S9. Unadjusted group differences are also reported (table S8). We emphasize domains in which two or more indicators shows significance at the 0.05 level.

Relative to the comparison group, the preschool group had significantly higher levels of educational attainment for 3 of 4 select outcomes in Table 2 and 4 of 6 attainment outcomes overall (table S9). This included highest grade completed (12.15 vs. 11.88; $p = 0.03$), attendance in a 4-year college (14.7% vs. 11.2%; $p = 0.04$), high school completion (81.5% vs. 75.1%; $p = 0.007$), and on-time high school graduation (44.3% vs. 36.6%; $p = 0.018$). These educational advantages translated to higher economic status, including occupational prestige (2.8 vs. 2.5; $p = 0.03$), SES composite score (education and income) of 4 or higher (34.4% vs. 28.6%; $p = 0.03$; scale of 0–8), and average annual income in 2007 dollars ($11,582 vs. $10,796; $p = 0.001$). Moreover, a higher percentage had an occupational prestige level of 4 or higher (28.2% vs. 21.4%; $p = 0.01$), synonymous with postsecondary training. No differences were detected for degree completion, employment, or a combined measure (table S9).

School-age participation was associated with a higher rate of on-time high school graduation (44.4% vs. 35.3%; $p = 0.011$) while extended intervention was linked to highest grade completed (12.21 vs. 11.95, $p = 0.02$), high school completion (82.7% vs. 77.2%; $p = 0.01$), on-time graduation (48.6% vs. 31.3%; $p = 0.001$) as well as the SES composite score of 4 or higher (35.9% vs. 30.3%; $p = 0.036$), and the occupational prestige index (3.1 vs. 2.7, $p = 0.017$; table S9). Based on the alternative extended-intervention contrast, only on-time high school graduation differed between groups (table S9). This conservative test minimizes any possible synergistic effect of intervention, however, because kindergarten achievement was included in the model.

The preschool group had a higher rate of health insurance coverage (75.9% vs. 63.9%; $p < 0.01$), including private insurance (49.1% vs. 39.5%; $p = 0.01$). They also had significantly lower rates of substance abuse (13.7% vs. 18.9%; $p = 0.01$) and drug and alcohol abuse (16.5% vs. 23.0%; $p = 0.004$; table S9). The extended program group had a higher rate of private health insurance coverage (51.8% vs. 42.2%; $p = 0.001$) but this difference was not found for the alternative contrast.

The preschool group also had lower rates of crime and justice system involvement for 2 of 3 select outcomes including any arrest (47.9% vs. 54.3%; $p = 0.03$) and felony arrest (19.3% vs. 24.6%; $p = 0.02$) as well as any incarceration or jail history (15.2% vs. 21.1%; $p = 0.04$) (table S9). Because the latter two outcomes were measured from official records, they are more severe and have higher costs. No differences were detected for the number of arrests, arrests for violence, or convictions. School-age and extended intervention were unrelated to justice involvement. For public aid and family outcomes, no meaningful differences were found (table S9).

Although subgroup differences were detected, they were limited to specific outcomes and intervention components (table S11). The most consistent evidence was for gender and parent education. Figure 1 shows the primary findings. Male preschool participants showed substantially greater well-being than the male comparison group for high school completion (77.5% vs. 63.5%; $p = 0.002$) and substance abuse (33.7% vs. 42.9%; $p = 0.002$) whereas female program groups had similar rates. In contrast, females showed comparatively greater effects of school-age intervention than males. Because this latter finding was not found for another outcome, cautious interpretation is warranted.

In addition, preschool participants whose parents were high school dropouts showed significantly larger effects than participants of graduates for high school completion, felony arrest, and substance abuse. For example, preschool participants of high school dropouts had a rate of felony arrest (13.9%) that was nearly half the rate for the comparison group of school dropouts (25.2%). A similar risk indicator—4 or more family risks—also moderated preschool impacts on felony arrest and substance abuse. While these findings support the compensatory value of intervention, we found no differences by race/ethnicity, early home environment, and other factors. A similar pattern was found for extended intervention.

For program dosage within components, length of preschool was unrelated to nearly all measures of well-being (table S12). School-age participation for 2 or 3 years was linked to higher rates of on-time high school graduation (41.5% vs. 28.5%; $p = 0.025$). Relative to 4 years, extended intervention for 5 or 6 years was linked to a lower rate of arrest for violence (13.4% vs. 20.8%; $p = 0.002$), and this was also found for the alternative contrast (14.1% vs. 19.3%; $p = 0.019$).

To assess the robustness of estimates, we tested five additional model specifications for each intervention contrast, ranging from no adjustment on preprogram attributes to inclusion of covariates, and IPW-attrition and IPW-selection adjusted models. For the latter, the inverse of the estimated propensity score for program participation (17 predictors; table S6) was multiplied by IPW-attrition and this product (double correction) was the model weight. Other propensity methods such as matching yielded similar findings (table S7, fig. S4).

We found evidence of consistency across model specifications. The predominant pattern is shown in Figure 2 for moderate or higher SES and felony arrest. This

generalized to subgroup estimates reported above. Among the four specifications shown, the unadjusted group differences for SES (7.1 points) and felony arrest (6.4 points) are slightly higher than the adjusted rates but the type of adjustment, including the double correction, did not affect estimates in any meaningful way. The reduction over the comparison group in felony arrest was 27% whereas for SES it was an increase of 20%. These findings strengthen confidence in the beneficial effects of intervention.

The interpretation of findings as the impact of intervention is further supported by corroboration that five sets of mediators can account for effects. In this model, participation impacts well-being through the accumulation of cognitive skills, social adjustment, motivation, and family and school support behaviors from school entry up to early adulthood (*26*). We found that these mediators explained 60% or more of the observed effects of preschool and nearly 40% or more for extended intervention (tables S13 and S14). The mediators completely accounted for effects on SES, education, and felony arrest. The process of influence is initiated by the impact on cognitive skills at age 5 and parent involvement and continues through socio-emotional adjustment, school quality, and reductions in problem behavior. These paths have been found for outcomes at younger ages (*20*, *27*).

Overall, we found that the most consistent and enduring effects were for preschool participation, which started at ages 3 or 4. Its impact was broad, including education, SES, health behavior, and crime outcomes. Since the program affected multiple indicators within these domains, impacts are unlikely to be artifacts of measurement. Findings for later intervention were limited primarily to education while those for extended intervention were exclusive to education and economic well-being. Because of the high avoidable costs of school dropout and related problems (*28*, *29*), our findings strengthen evidence that sustained, publicly-funded early education can be a cost-effective strategy for promoting well-being.

The enduring effects of the program were observed within a social context characterized by high levels of risk that substantially counteract the positive influences of early experience (*30*, *31*). In addition to residing in neighborhoods of persistent poverty where the majority of students fail to complete high school, over half of participants changed schools frequently and only 25% of participants attended schools of relatively high quality. That the program, especially in preschool, showed such broad and practically significant effects on well-being despite these environmental challenges is encouraging for prevention programming.

That male participants and those from higher risk families showed the largest preschool effects is consistent with prior studies (*3*, *4*, *7*), and given our estimation, cannot be due to differential attrition. The advantage for males was found even with no initial group differences (table S2). These findings suggest that early interventions can reduce health disparities, especially if they impact educational attainment, a key path to later health and SES (*10*, *32*). One implication is that national goals of increasing quality and years of healthy life can be achieved in part through access to quality educational programs.

The study also shows the potential limits of the long-term effects of dosage within program components. Although extended intervention linked to well-being, the number of years of preschool and extended services was unrelated to most outcomes. Consistent with other studies (*2*, *33*), greater dosage of school-age intervention was linked to high school graduation. These results suggest that among high quality programs there may be a threshold beyond which effects diminish. In previous studies (*34*, *35*), however, preschool and extended-intervention dosage was associated with improved child and adolescent well-being including school readiness, remedial education, child maltreatment, and delinquency.

In conclusion, early education programs can impact life-course outcomes necessary for economic success and good health. The findings of this study indicate that while there are limits to the effects of the CPC program for particular outcomes and groups, impacts which endured provide a strong foundation for the investment in and promotion of early childhood learning.

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Supporting Online Material

www.sciencemag.org/cgi/content/full/science.1203618/DC1

Materials and Methods
SOM Text
Figs S1 to S6
Tables S1 to S14
References

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Fig. 1. Well-being for selected outcomes by maternal education, gender, and program groups. Error bars represent ±1 SE. Means and rates on the outcome are adjusted for 15 preprogram characteristics (table S2) and attrition by IPW. Extended intervention is 4 or more years of CPC participation from preschool to third grade versus participation for 3 years of less. Outcomes were measured by age 28 from multiple source including administrative data and adult surveys. Mothers education was measured by age 3 of the study participant.

Fig. 2. Robustness estimates for SES and felony arrest by model specification. Error bars represent ±1 SE. The *y* axis represents marginal effects in percentage points. Models are adjusted for 15 preprogram characteristics (table S2) except Model 1. Models 1 is unadjusted. Model 2 is adjusted with covariates. Model 3 is adjusted for attrition by IPW. Model 4 is adjusted for attrition and program selection by IPW. Base rates of unadjusted comparison group are (A) 29.3%. (B) 32.4%, (C) 31.4%, (D) 25.6%, (E) 21.5%, and (F) 22.7%.

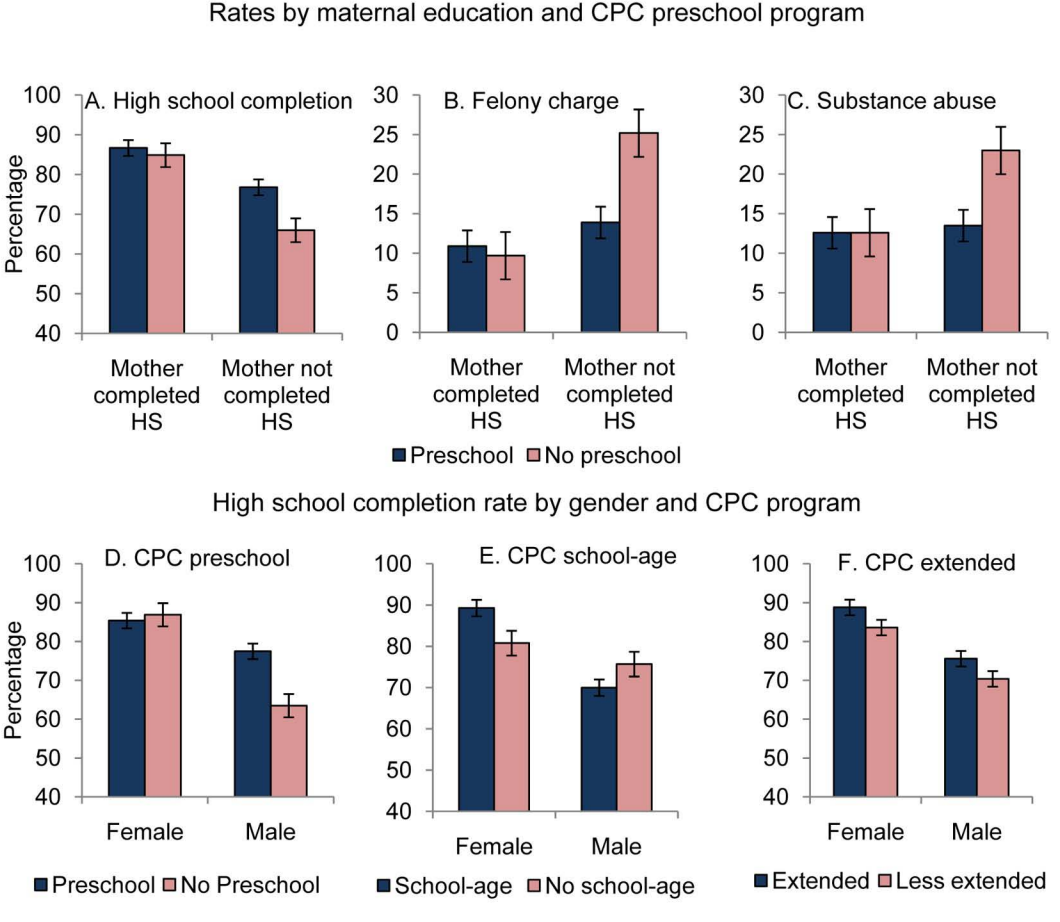
Table 1. Patterns of participation and sample recovery of Child-Parent Center (CPC) Education Program and comparison groups in the Chicago Longitudinal Study. Cases for program participation span the 6-year period (1983–1989) that defines enrollment in the CPC intervention. Among the comparison group, 389 cases were from randomly selected schools participating in an alternative kindergarten intervention. 176 cases in the comparison group were eligible to receive limited services in CPC kindergarten but enrolled in different classrooms. Some cases in the comparison group participated in the school-age program because it was open to any child enrolled in elementary school from first to third grade. Cases were lost during post-program years primarily because they moved from Chicago and could not be located, were deceased, or did not have sufficient identifying information to track. The number of equivalent covariates shown is for the preschool group (table S2a). The respective numbers for the school-age and the extended intervention groups were 18 and 15 (tables S2b and S2c). For the latter, one covariate was equivalent (adult administrative records) after adjustments for child and family preprogram characteristics. Only 15 of the 20 covariates were included in the analyses.

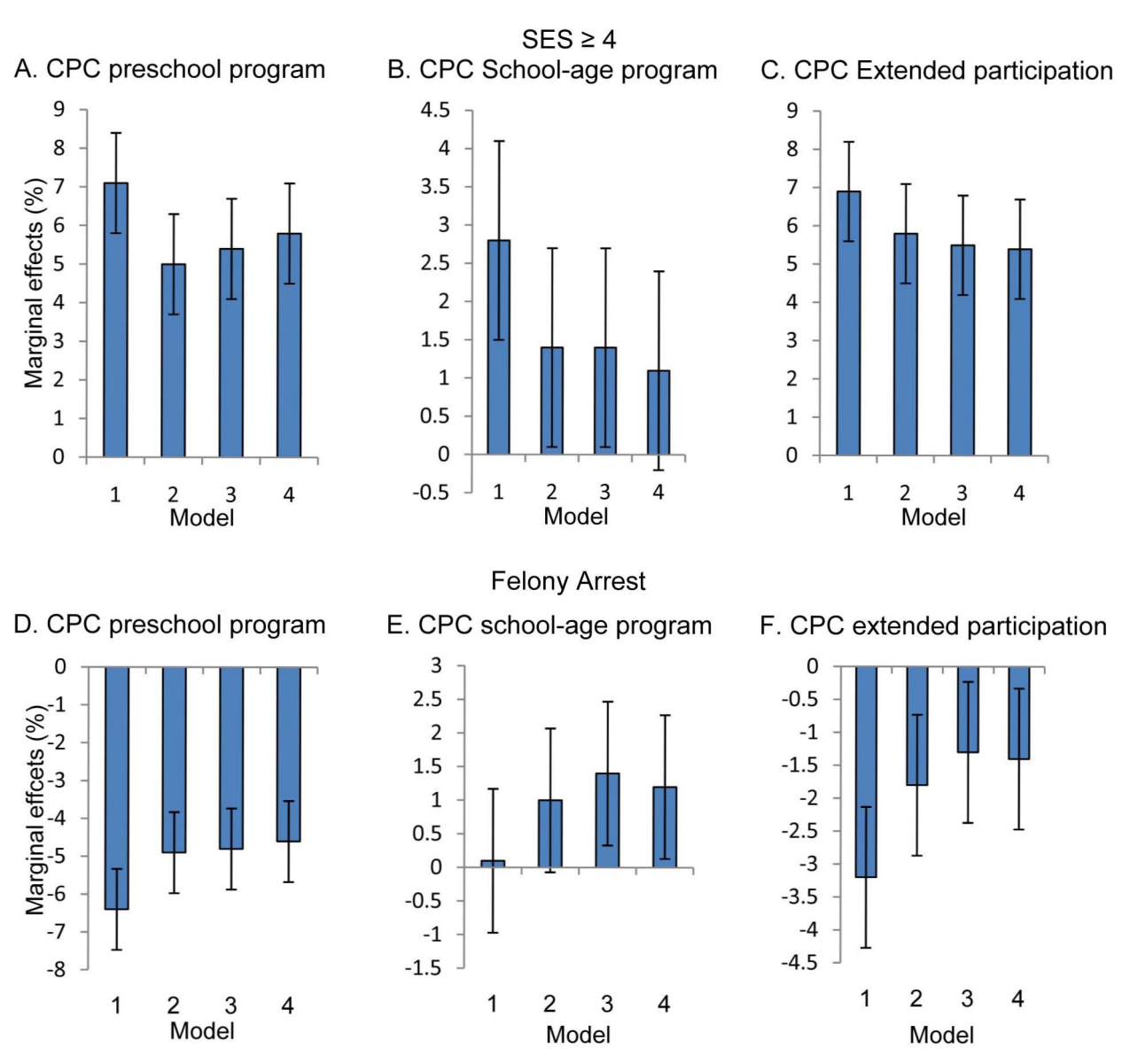
Study category	Total sample	CPC intervention group	Comparison group
Original sample	1539	989	550
Program participation			
No. in center-based preschool (Head Start)	1073	989	(84)
Full-day kindergarten (%)	74.2	59.9	100
No. with CPC school-age participation (%)	850 (55)	684 (69)	166 (30)
No. with CPC extended intervention (4–6 years) (%)	553 (36)	553 (56)	0 (0)
No. lost due to mobility, mortality, or other (%)	171 (11)	104 (11)	67 (12)
Sample recovery and characteristics by age 28			
No. with educational attainment/employment (%)	1386 (90)	900 (91)	486 (88)
No. (min, max) for family, health, and justice outcomes	1233, 1473	808, 950	425, 523
Percentage sample recovery for min, max (%)	80, 96	82, 96	77, 95
Average age on 31 August 2008 (years)	28.29	28.27	28.32
No. of covariates equivalent with comparison group (of 20)		18	

Table 2. Means and group differences for selected adult outcomes by age 28 adjusted for attrition by inverse probability weighting (IPW) and preprogram characteristics. See table S9 for all outcomes and findings for the alternative extended intervention contrast. Extended intervention-1 = Child-Parent Center (CPC) participation for 4 to 6 years (preschool to second or third grade) versus fewer years. Unadj and adj. diff. = unadjusted and adjusted group difference. All adjusted models used robust standard errors, and attrition was taken into account through IPW as a sampling weight in the model for each study outcome. Sample sizes vary by measure. Ages of assessment were are follows: educational attainment (28.3), socioeconomic status (SES; 27.6), health status and behavior (27.6), and crime and justice system involvement (26.6). SES ≥ 4 = index of education and income from 0 to 8.

Adult outcome	CPC preschool[1]				CPC school-age[2]				CPC extended intervention-1[3]			
	Unadj. diff.	Interv	Comp	Adj. diff.	Unadj. diff.	Interv	Comp	Adj. diff.	Unadj. diff.	Interv	Comp	Adj. diff.
Educational attainment												
Highest grade completed in years	0.33**	12.15	11.88	0.27*	0.16*t*	12.07	12.03	0.04	0.33**	12.21	11.95	0.26*
High school completion	7.6**	81.5	75.1	6.4**	3.8*t*	80.0	78.5	1.5	6.6**	82.7	77.2	5.5**
On-time high school graduation, %	9.6**	44.3	36.6	7.7*	7.9**	44.4	35.3	9.1*	12.1**	48.6	31.3	17.3**
BA or AA degree, %	0.8	8.4	8.5	-0.1	1.4	8.8	7.4	1.4	2.1	9.5	8.3	1.2
Socioeconomic status												
SES ≥ 4, %	7.1*	34.4	28.6	5.7*	2.8	32.8	31.6	1.2	6.7*	35.9	30.3	5.6*
Average annual income (2007 dollars)	932**	11,582	10,796	786*	54	11,250	11,278	-28	1,102*t*	11,822	10,942	880
Food stamp participation, ages 24–27, %	2.5	49.1	44.8	4.3	-2.9	43.9	52.0	-8.1*	-1.8	45.0	48.9	-3.9
Health status and behavior												
Any health insurance coverage, %	10.0*	75.9	63.9	12.0**	0.3	70.5	73.7	-3.1	6.7*	75.7	69.6	6.1**
Substance abuse (excluding alcohol), %	-6.5**	13.7	18.9	-5.2*	-0.1	16.1	14.7	1.4	-3.6	14.3	16.2	-1.9
Crime and justice system involvement												
Any arrest (including self reports), %	-6.2*	47.9	54.3	-6.4*	4.9*t*	52.4	47.5	4.9[t]	-1.5	51.1	49.7	1.4
Felony arrest, %	-6.4**	19.3	24.6	-5.3*	1.2	21.6	20.4	1.2	-3.2	19.5	21.2	-1.7
Any conviction, %	-5.2*	25.1	28.8	-3.7	1.1	27.0	25.9	1.1	-4.4*t*	24.1	26.7	-2.6

[1]Adjusted for school-age participation, 8 indicators of pre-program risk status (table S2), sex of child, race/ethnicity, child welfare history by age 4, neighborhood poverty at 1980, a dummy-coded variable for missing data on risk status, and home environment problems at ages 0–5. [2]Adjusted for preschool participation, 8 indicators of pre-program risk status (table S2), sex of child, race/ethnicity, child welfare history by age 4, neighborhood poverty at 1980, a dummy-coded variable for missing data on risk status, and home environment problems at ages 0–5. [3]Adjusted for 8 indicators of pre-program risk status (table S2), sex of child, race/ethnicity, child welfare history by age 4, neighborhood poverty at 1980, a dummy-coded variable for missing data on risk status, and home environment problems at ages 0–5. ** $p < 0.01$, * $p < 0.05$, and $t < 0.10$.


Rates by maternal education and CPC preschool program
A. High school completion
B. Felony charge
C. Substance abuse
Percentage
Mother completed HS
Mother not completed HS
Preschool
No preschool
High school completion rate by gender and CPC program
D. CPC preschool
E. CPC school-age
F. CPC extended
Female
Male
Preschool
No Preschool
School-age
No school-age
Extended
Less extended


SES ≥ 4
A. CPC preschool program
B. CPC School-age program
C. CPC Extended participation
Marginal effects (%)
Model
Felony Arrest
D. CPC preschool program
E. CPC school-age program
F. CPC extended participation
Marginal effcets (%)
Model