Preschool Influences on Mathematics Achievement

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Universal preschool is being considered as a policy option in many parts of the world, but the most influential evidence relates to disadvantaged groups. Preschool improves disadvantaged children’s school readiness, educational achievements, and social adjustment (1). It is not the only influence—parental support also benefits children’s development, particularly if combined with center-based programs (2). Additionally, the longer-term effects of preschool for disadvantaged children are mediated by the schools subsequently attended (3, 4).

Studies with disadvantaged children may have little relevance for the general population. Nonetheless, such evidence has fueled an increasing interest in the universal provision of preschool education (pre-kindergarten) as a means of advancing children’s school readiness and later attainment (5). Some argue that preschool experience is critical for children’s future competence, coping skills, health, and later employment (6). Furthermore, it is argued that the benefits outweigh the costs (7).

England has high levels of preschool use from age 3 onward, which produces benefits over no preschool in the early school years (8). Our study concerns longer-term effects in the general population in England. This study considered the influence of home environment on children’s development [often a stronger factor than socio-demographic characteristics (9)], and preschool and school effectiveness (10).

Preschool centers (141) were randomly chosen in six areas demographically similar to England overall. The preschool stage of the study involved children from nursery classes, playgroups, private day nurseries, centers run by a local authority, nursery schools, and integrated children’s centers and, thus, included all types of preschool centers in England at the time of the study. Children’s cognitive ability at ages 3 to 4 and 5 and mathematical attainment at age 10 were assessed and family data obtained by interview (11). The parental interview when children were age 3 to 4 covered learning activities enabling the creation of a home learning environment (HLE) index (11). The typical child attended preschool for 18 months part-time, and primary school for more than 5 years full-time by age 10.

Children’s numeracy at the start of primary school (age 5) was analyzed, with controls for background influences and prior attainment at age 3 to 4 years (start of preschool). Multilevel models are a standard form of regression analysis, particularly suited to data exhibiting a hierarchical structure (12), and they provide a method of analyzing mathematics achievement at age 5, with 30 child, family, area, and preschool variables as covariates (11). Residual effects associated with individual preschools after these variables were accounted for provided a measure of a preschool’s effectiveness in promoting numeracy. Preschools where children performed better than expected on the basis of prior attainment and background were deemed more effective; preschools where children performed worse than expected were deemed less effective (11).

Children in English state primary schools take national assessments at 7 and 11 years. Analyses of data from 540,000 pupils attending 15,000 schools produced school effectiveness measures standardized for all English state primary schools. We controlled for prior ability, eligibility for free school meals (poverty marker), gender, age, ethnicity, English as second language, school composition, and area characteristics.

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The advantages of home learning environment and preschool are apparent years later in children’s math achievement.
Findings
Variables in the data set typically had less than 5% missing data. Multiple imputation was used to produce estimates for missing data and to avoid any possible bias. Results for complete and imputed data were equivalent, and imputed data results are reported. The HLE, preschool effectiveness, and primary school effectiveness all showed significant effects on children’s mathematics achievement at age 10 ($P < 0.001$). Total variance accounted for was 22%. Effect sizes (ESs) are from the final model, after we allowed for all other variables (supporting online material text).

Low birth weight; girls (versus boys); and lower parental occupational, educational, or income status were significantly and independently linked with lower mathematics scores (table S2). Ethnic group differences were regarded as unreliable owing to small group size. Cognitive ability of the average preschool child and the percent of children in the primary school with special educational needs (SEN) had weak, significant relations with mathematics achievement at age 10. Other factors were not statistically significant after allowing for the above. After controlling for other child, parental, preschool, and school variables, the HLE, preschool effectiveness, and primary school effectiveness all showed separate significant effects on mathematics achievement at age 10 ($P < 0.001$).

We examined the effects on mathematical attainment at age 10 of having high (1 SD or more above mean), low (1 SD or more below mean), and medium (within 1 SD of the mean) scores in HLE and preschool and school effectiveness. The HLE had significant, positive effects at both high and medium levels, compared with low (ES = 0.40 and 0.21, respectively). Preschool effectiveness was significant only for high compared with low (ES = 0.26), whereas primary school effectiveness had significant effects for both high and medium levels (ES = 0.33, and 0.39, respectively) compared with low levels.

The sample was divided into families with low annual incomes (<£17,000, or ~U.S. $32,000), 52.5% or higher incomes (>£17,000, 47.5%). The final multilevel model was run separately for each income group. Results were similar for the two groups, which indicated that the effects apply across the income spectrum with minor differences (table S2).

Discussion
The effects observed for background variables were similar to other studies (13, 14). However, HLE effects were substantial and occurred across the whole population. The HLE had low correlations with parents’ socioeconomic status or education ($r = 0.28$ to 0.32) and showed independent effects slightly less than mother’s education but greater than father’s education and family income. This indicates that what parents do is as important as who parents are.

Previous work with this sample had shown that the effect of 1 year of part-time preschool was equivalent to increasing family income by more than £10,000 (U.S. $19,000) a year (8). We show that the effect of primary school was even more important than preschool (0.39 versus 0.26 SD), but both were sufficiently large to be important for any government wishing to maximize educational achievement. They are greater than the effect for father’s education and similar to that for family income but less than that for mother’s education (see figure, page 1161). Analyses for low and higher income groups reveal that the effects for the HLE and preschool and school effectiveness are remarkably similar for both income groups, which indicates their importance across the income spectrum. These effects are predictive, but we cannot assume causality. Observational studies, such as this study, do not have random assignment, so it is always possible that results may reflect selection bias and/or the operation of unmeasured variables (11).

Countries vary in preschool provision. Some deliver preschool services universally (United Kingdom, Scandinavia, and France), whereas other countries provide services to some children only (United States) and some are moving rapidly to increase provision (China) (15). However, there is international support for our findings. The PISA project indicates that enhanced mathematics achievement is associated with preschool experience internationally (16). In the United States, prekindergarten improved mathematics and reading at kindergarten (17), with greatest gains if preschool started between 2 and 3 years as found in England (18). Preschool boosted primary school achievement in Bangladesh (19), with similar results reported for 10 countries (20). During preschool expansion in Uruguay, comparisons of (i) siblings with and without preschool and (ii) regional variations revealed clear preschool benefits in secondary school (21). Similar Argentinian data revealed that 1 year of preschool was associated with primary school attainment increases of 0.23 SD (22), analogous to the effect of high versus low effective preschools reported here.

We study demonstrates the relative magnitude of home, preschool, and school effects likely to occur with universal preschool education, which is common in many advanced societies and is increasingly sought by others. The HLE before school exerted a powerful effect. Although any preschool has benefits (18), effective or higher-quality preschools have the greatest effect. Preschool learning environments can be improved through programs that target cognitive functioning (23) and staff training (24).

References and Notes
11. Materials and methods and additional discussion are available as supporting material on Science Online.
25. We thank A. Leyland for technical advice. Supported by the U.K. Department for Children, Schools and Families. Our data will be publicly available as an anonymized data set subject to government approval. Further information is available from the authors on request.

Supporting Online Material
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