5. A. F. Dixson, *Primate Sexuality: Comparative Studies of the Prosimians, Monkeys, Apes and Human Beings* (Oxford Univ. Press, New York, 1998).
6. D. L. Cheney *et al*., in *Reproduction and Fitness in Baboons: Behavioral, Ecological, and Life History Perspectives*, Springer Series Developments in Primatology: Progress and Prospects, L. Swedell, S. R. Leigh, Eds. (Springer, New York, 2006), pp. 147–176.
7. S. E. Johnson, in *Reproduction and Fitness in Baboons: Behavioral, Ecological, and Life History Perspectives*, Springer Series Developments in Primatology: Progress and Prospects, L. Swedell, S. R. Leigh, Eds. (Springer, New York, 2006), pp. 177–198.
8. J. M. Rodriguez-Llanes, G. Verbeke, C. Finlayson, *Anim. Behav.* **78**, 643 (2009).
9. R. M. Sapolsky, *Science* **308**, 648 (2005).
10. M. N. Muller, R. W. Wrangham, *Behav. Ecol. Sociobiol.* **55**, 332 (2004).
11. S. Creel, *Trends Ecol. Evol.* **16**, 491 (2001).
12. D. H. Abbott *et al*., *Horm. Behav.* **43**, 67 (2003).
13. R. M. Sapolsky, *Am. J. Primatol.* **5**, 365 (1983).
14. R. M. Sapolsky, *Psychoneuroendocrinology* **17**, 701 (1992).
15. J. M. Setchell, T. Smith, E. J. Wickings, L. A. Knapp, *Horm. Behav.* **58**, 720 (2010).
16. T. J. Bergman, J. C. Beehner, D. L. Cheney, R. M. Seyfarth, P. L. Whitten, *Anim. Behav.* **70**, 703 (2005).
17. R. J. Nelson, *An Introduction to Behavioral Endocrinology* (Sinauer, Sunderland, MA, ed. 3, 2005), chap. 11.
18. M. L. Roberts, K. L. Buchanan, M. R. Evans, *Anim. Behav.* **68**, 227 (2004).
19. J. C. Wingfield, R. E. Hegner, A. M. Dufty Jr., G. F. Ball, *Am. Nat.* **136**, 829 (1990).
20. R. P. Michael, D. Zumpe, *Am. J. Primatol.* **30**, 213 (1993).
21. J. C. Wingfield, R. M. Sapolsky, *J. Neuroendocrinol.* **15**, 711 (2003).
22. F. B. Bercovitch, T. E. Ziegler, *Annu. Rev. Anthropol.* **31**, 45 (2002).
23. Information on methods is available on *Science* Online.
24. L. R. Gesquiere, P. O. Onyango, S. C. Alberts, J. Altmann, *Am. J. Phys. Anthropol.* **144**, 169 (2010).
25. D. L. Cheney, R. M. Seyfarth, *Adv. Stud. Behav.* **39**, 1 (2009).
26. K. L. R. Rasmussen, *Behav. Ecol. Sociobiol.* **17**, 161 (1985).
27. S. C. Alberts, J. Altmann, M. L. Wilson, *Anim. Behav.* **51**, 1269 (1996).
28. S. C. Alberts, H. E. Watts, J. Altmann, *Anim. Behav.* **65**, 821 (2003).
29. S. C. Alberts, J. C. Buchan, J. Altmann, *Anim. Behav.* **72**, 1177 (2006).
30. S. C. Mills *et al*., *Am. Nat.* **173**, 475 (2009).
31. M. P. Muehlenbein, *Am. J. Phys. Anthropol.* **130**, 546 (2006).
32. G. Hausfater, D. F. Watson, *Nature* **262**, 688 (1976).

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References

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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 understanding. 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 four or more years 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 most other 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 no previous studies have continued past age 25, which is most predictive of later development (*14*).

Three other less well 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; studies of the added or synergistic benefits of continuing school-age intervention are also few. The second limitation is that variations in effects by child, family, and social context are underinvestigated. 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 into estimation (*18*).

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