

How Early Experience Matters in Intellectual Development in the Case of Poverty¹

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Experiments with rodents indicate that severe early psychological and social deprivation has lasting detrimental effects on learning ability that are not remedied by exposure to enriching experiences in adulthood. Findings indicate that environmental adversity early in life works to limit the development of intelligence with consequences for later functioning. Animal experiments are best viewed as supplying a rationale for early intervention in disadvantaged infants and children who would otherwise be likely to evince low intellectual capabilities later in life. Animal experiments conducted to date do not support an interpretation that early enrichment necessarily boosts later intellectual performance beyond the normal or species-typical range. They indicate that early intervention promotes normative development by preventing adverse early rearing conditions from leading to negative consequences for cognitive ability and self-regulation. The Abecedarian Project, an early enrichment intervention with infants from economically deprived backgrounds, is presented as an example of how early experience matters in terms of human intellectual development in disadvantaged populations. The results of that program reflect what one would expect from the rodent studies mentioned above.

KEY WORDS: early intervention; intelligence; animal models.

The evidence to be reviewed in the first section of the paper indicates that rodents reared in “enriched” psychological environments show better learning ability than animals reared under psychologically and socially impoverished circumstances. However, there is no evidence that animals reared in so-called enriched laboratory environments show learning abilities beyond the normal or species-typical range. Rather, the rodent research indicates that the enriched early experience averts the deterioration of learning ability that is seen when animals are reared

under impoverished conditions early in life. Exposure to enriched conditions later in life is without effect in rodents that have been severely deprived early in life. These findings suggest that interventions with impoverished human populations should be instigated as early as possible with a view to preventing intellectual deterioration in such populations.

The earliest systematic study of the role of early experience in influencing the later learning abilities of rodents was done by Bernard Hymovitch (1952), a doctoral student of Donald Hebb. Hymovitch reared young rats under four conditions and then later tested them in the very challenging Hebb-Williams maze. The maze test consists of a series of twelve problems in which the path between the start and finish (food) boxes is altered from problem to problem by rearranging the internal walls of the maze. This maze is considerably more difficult than a Y- or T-maze, so it taxes the animal’s learning ability to a much greater degree than usual maze tasks.

Hymovitch’s animals were housed individually in (1) a stovepipe cage (which permitted little motor or

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Table 1. Mean Errors in Hebb–Williams Maze of Rats Reared Under Four Different Conditions

Stovepipe	Running wheel	Mesh cage	Free environment
223	235	140	137

Note. Data from Hymovitch (1952). The Stovepipe and Running wheel groups made significantly more errors than the Mesh cage and Free-environment groups ($p < .001$).

visual experience), (2) an enclosed running or activity wheel (which permitted a lot of motor activity but little variation in visual experience), (3) a mesh cage that restricted motor activity but allowed considerable variation in visual experience as it was moved daily to different locations in the laboratory. (4) The fourth group of animals contained twenty animals that were reared socially in a so-called free environment box that was very large (6' × 4') compared to the other conditions, and was fitted with a number of blind alleys, inclined runways, small enclosed areas, apertures, etc., that offered the rats a wide variety of opportunities for motor and visual exploration and learning in a complex physical environment. The animals lived in these four environments from about 27 days of age to 100 days of age, at which time the testing in the Hebb–Williams maze was completed. The results of testing are shown in Table 1.

As shown in Table 1, rearing in the stovepipe and the enclosed running wheel led to the same level of poor performance, whereas rearing in the mesh cage and the free environment led to the same level of good performance over 21 days of testing in the Hebb–Williams maze. All the groups showed the same level of improvement over the 3 weeks of testing, so the animals reared in the mesh cages and free environment began functioning at a superior level early in testing.

Next, in order to determine whether it was the early experience in each environment that made for the differences between the groups, Hymovitch repeated the experiment with four groups of animals that differed in *when* they had the free-environment or stovepipe experience: One group had the free-

environment experience from 30 to 75 days of age and then were placed in the stovepipe for 45 days; a second group had the stovepipe experience from 30 to 75 days and then had the free-environment experience for 45 days; a third group remained in the free environment throughout the experiment; and a fourth group remained in their normal laboratory cages throughout the experiment (these would be the most thoroughly or consistently deprived from the standpoint of motor and visual experience).

As can be seen in Table 2, the animals that experienced the free environment early and the stovepipe later in life performed just as well as the animals that remained in the free environment throughout the experiment. The crucial finding is that the animals who experienced the stovepipe environment early and the free environment later in life performed as poorly as the animals that remained in their normal cages throughout the experiment (the most deprived group). It is important to note that these differences in problem-solving ability were not in evidence when Hymovitch challenged the rats with a simpler alley maze and more like the ones that were in wide use in most animal learning laboratories at the time. It is only when they were challenged by the much more difficult Hebb–Williams series of problems that the differences in problem-solving ability were in evidence.

Forgays and Forgays (1952), other students of Donald Hebb's, undertook to replicate Hymovitch's important findings and also to determine (1) whether the "playthings" in the free environment were crucial and (2) why the mesh-cage-reared animals did so well without direct experience of interacting with the multifarious objects in the free environment. They found indeed that presence of the "playthings" (inclined planes, blind alleys, etc.) were essential to the superior performance of the free-environment animals and that the mesh-cage-reared animals only do as well when their cages are moved about frequently so that they visually encounter a considerable degree of varied environmental input, including the opportunity

Table 2. Mean Errors in Hebb–Williams Maze of Rats With Different Early and Late Environmental Experiences

Free environment/ stovepipe	Stovepipe/ free environment	Free environment/ free environment	Normal cage/ normal cage
161	248	152	221

Note. Data from Hymovitch (1952). The Stovepipe/Free Environment and Normal Cage groups made significantly more errors than the other two groups ($p < .001$).

to watch the animals in the free environment with the playthings.

It was not long before these early experience studies were extended to other animals, including nonhuman primates, where social isolation and otherwise highly restricted, deprived rearing conditions were employed. Indeed, even in primates with relatively large brains, the normal or usual variety of experiences early in life was critical for the appearance of normal exploratory and learning abilities later in life. Deprived infants showed severe deficiencies in their later behavior (Harlow *et al.*, 1965). Just having a large brain is insufficient for the development and manifestation of the superior problem-solving skills characteristic of primates (Mason, 1968; Sackett, 1968).

The “environmental enrichment” rearing paradigm has provided a quite useful procedure for delineating the role of experience in the development of learning and brain anatomy, physiology, and chemistry in rodents (review in Black & Greenough, 1998) as well as humans (review in Curtis & Nelson, 2003). No one claims that the enrichment provided in laboratory studies raises learning ability above the norm. It is in contrast to severe deprivation that enrichment shows its statistically significant effects, as in the Hymovitch study described above. In fact, Rosenzweig *et al.* (1972) mention in passing, in their article on “Brain changes in response to experience,” that rearing rats in a semi-naturalistic enclosure outside the laboratory produced even more striking improvements than the enriched rearing procedure in the laboratory. Clearly, then, the laboratory enrichment model is most appropriately seen in the light of sparing or decreasing the damage done by severe early experiential deprivation and, thus, makes the rodent model of enriched early experience a suggestive paradigm for instigating very early interventions in human populations at risk for poor intellectual and cerebral outcomes; namely, those living at, or below, the poverty line. One such study is the Abecedarian Project.

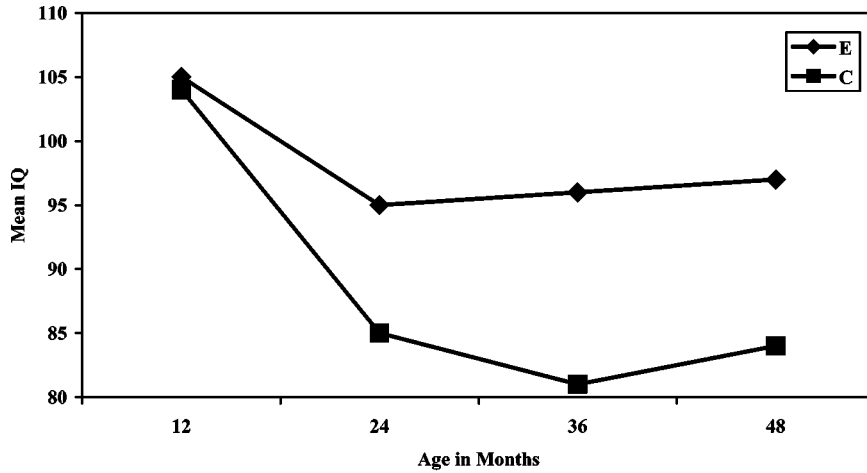
The Abecedarian Project (Ramey & Campbell, 1991; Ramey *et al.*, 1998) was an early compensatory education intervention beginning at birth for children at high risk for poor intellectual development because of multiple factors present in low SES environments. Participants were selected for the study using a high-risk index that included parental education level, income, father absence, work history, evidence of low IQ in mother, father or siblings, history of social service contacts, and family history of school failure and psychopathology (see Ramey & Campbell, 1984). Utilizing a randomized design, children were

initially assigned to one of two conditions, receipt of a comprehensive educational daycare intervention from birth through age 5 years or a no-treatment control. The educational daycare component of the intervention utilized a variety of developmentally appropriate curricula designed to facilitate children’s language, motor, social, and cognitive growth. The center in which the educational daycare was delivered, provided full-day care, 50-weeks per year. Study participants entered care as early as 3-weeks of age with 93% of participants enrolled by 3 months of age.

At the end of the educational daycare intervention at age 5 years, children were again randomly assigned to either a school age follow through condition or a no treatment control. The school age intervention was delivered through home visitors who served as liaisons between home and school. The intervention was designed to increase parent involvement in the educational process and provided parents with activities and strategies to support children’s academic progress.

Assignment to groups at birth and again at age 5 years resulted in a total of four intervention conditions; a group receiving the early daycare intervention from birth through age 5 years plus school age follow through services to age 8 years, a group receiving only the educational daycare intervention, a group receiving only the school age follow through services, and an untreated control group.

In numerous publications, the Abecedarian intervention has demonstrated long-term effects on intelligence and on several aspects of developmental competence from early childhood through young adulthood (Campbell *et al.*, 2001; Campbell & Ramey, 1994, 1995; Ramey & Campbell, 1984). As seen in Fig. 1, the treatment and control groups in the Abecedarian study were equivalent at the end of the first year. At subsequent time points during the intervention, however, a treatment related difference in intelligence was noted in favor of the intervention recipients. In particular, while both groups exhibited a decline in intelligence following age 12 months, the drop was greater for the control group, resulting in an average treatment related difference during the educational daycare phase of the intervention of 11 IQ points with a pooled sample effect size of 1.75 (Campbell *et al.*, 2001). This finding suggests that the daycare intervention was effective in attenuating a decline in intelligence associated with adverse rearing conditions among children living in poverty.

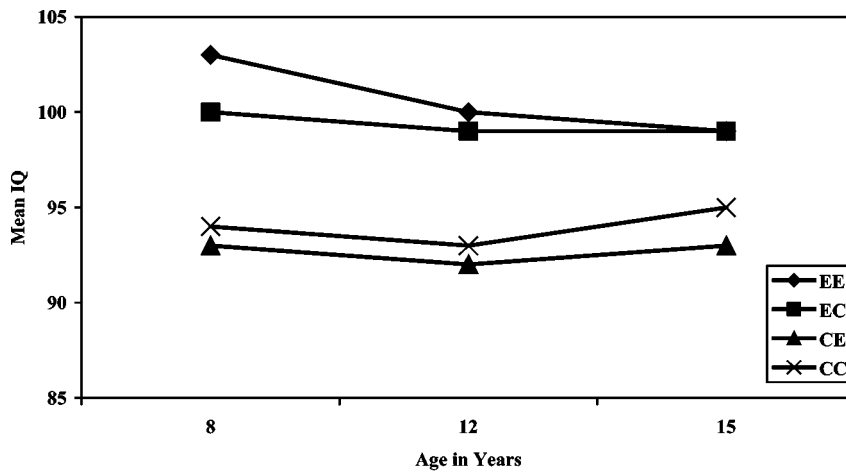


E = experimental C = control
 Effect for treatment at 24, 36, and 48 months significant at $p < .001$

Fig. 1. Intelligence measured at ages 12, 24, 36, and 48 months for children in the Abecedarian study. Reprinted from Ramey *et al.*, 1998.

As seen in Fig. 2, following the end of the preschool intervention at age 5 years, both treated and control groups evidenced highly similar trajectories for intelligence. The average treatment related

difference during this follow-up phase of the study was approximately 6 IQ points with a pooled sample effect size of .87 (Campbell *et al.*, 2001). However, although the treatment related benefit associated



Group means for preschool E and C groups were not significantly different at each time point.

EE = experimental preschool/experimental school age
 EC = experimental preschool/school age control
 CE = preschool control/experimental school age
 CC = preschool control/school age control

Fig. 2. Intelligence measured at ages 8, 12, and 15 years for children in the Abecedarian study. Reprinted from Ramey *et al.*, 1998.

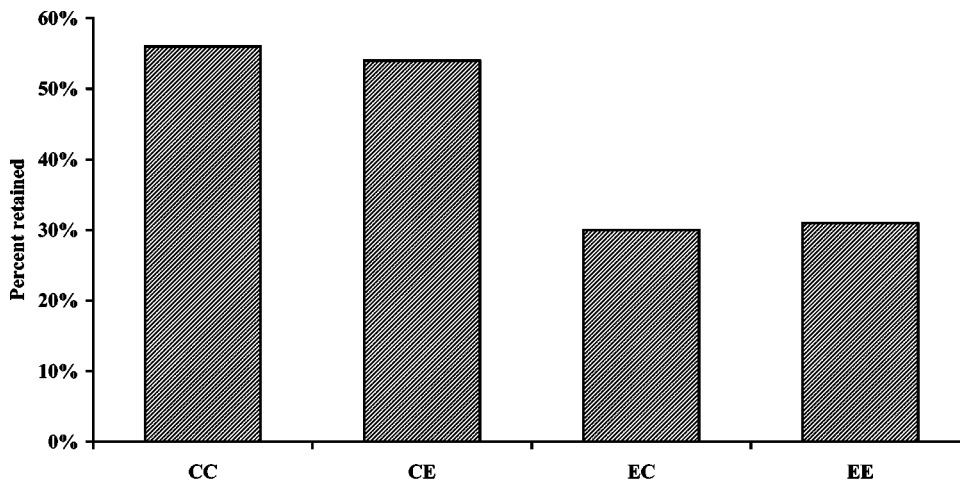
with educational daycare was maintained during the follow-up period, no effect was seen for the combination of educational daycare and school age follow through in comparison with educational daycare on its own. The effect of the intervention on intelligence was attributable to the educational daycare aspect of the program. There was no effect on intelligence associated with the school age follow through program either on its own or in combination with the educational daycare intervention. Furthermore, IQ was seen to decline linearly for all participants following the cessation of the preschool phase of the intervention.

Similar to the findings for intelligence, intervention effects on grade retention were attributable to the early educational daycare and were not associated with the school age follow through. As seen in Fig. 3, over 50% of study participants in the control only and control plus school age follow through groups were retained in grade. Among children receiving the educational daycare, however, approximately 30% were retained in grade.

In contrast to the findings for intelligence and grade retention, treatment related benefits to academic achievement were associated with the combination of the educational daycare plus school age fol-

low through for both reading and math. As shown in Figs. 4 and 5, duration of treatment was significantly related to achievement in both math and reading. Individuals receiving the early intervention plus school age follow through scored higher in both reading and math than did individuals receiving only the educational daycare. In turn, those receiving only the educational daycare scored higher than did individuals receiving only the school age follow through. Those receiving only the school age follow through, however, scored higher than did the untreated controls (Campbell & Ramey, 1995). Furthermore, relative to national norms, reading scores were stable over time while math scores were seen to decline for both groups.

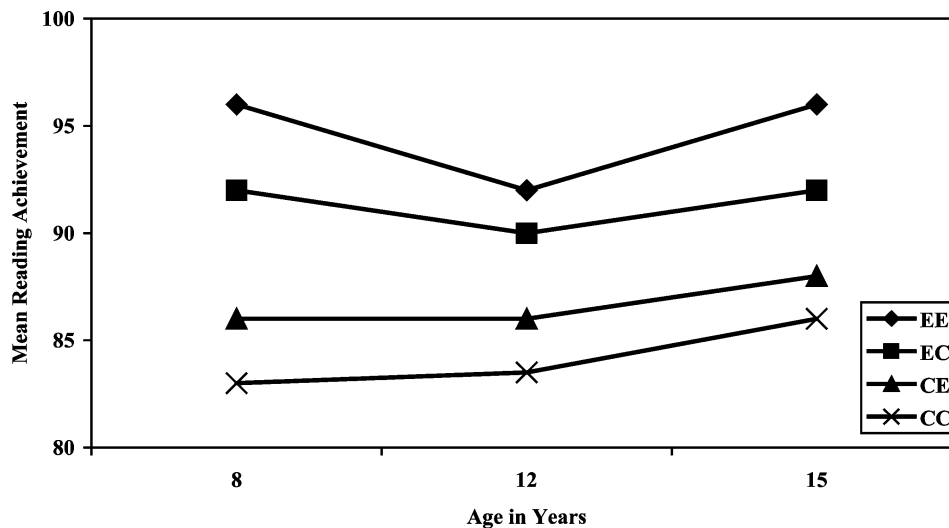
The notable aspect of the rodent work by Hy-movitch and others described earlier is the finding of an early experience effect. Later deprivation was not associated with learning impairment and later enrichment following early deprivation failed to alter the effect of adverse early experience on later learning and memory. These results in the animal model are for the most part consistent with those obtained from the provision of intervention services in the Abecedarian Project. Specifically, the school age follow through intervention failed to confer any benefit to intelligence



Comparison of preschool E and C groups, $\chi^2 (N=93) = 5.10, p < .02$.

- EE = experimental preschool/experimental school age
- EC = experimental preschool/school age control
- CE = preschool control/experimental school age
- CC = preschool control/school age control

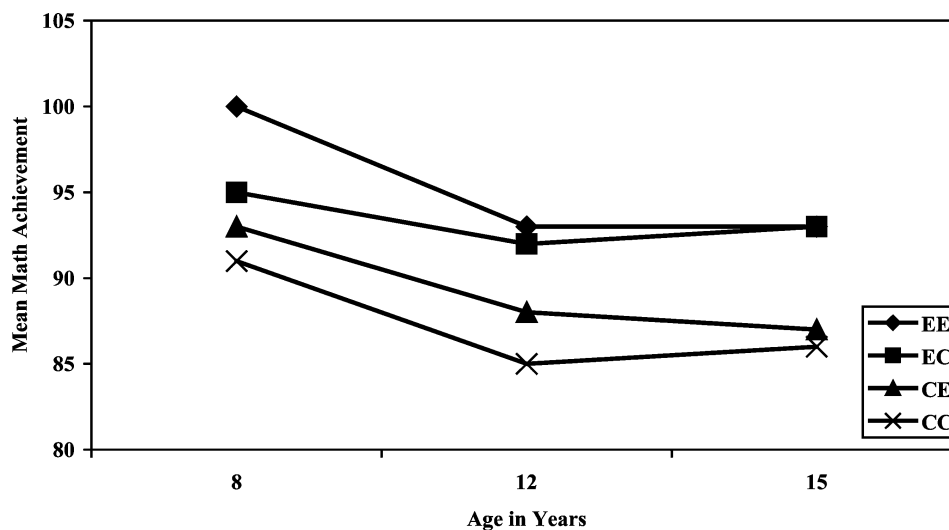
Fig. 3. Percent of Abecedarian participants retained in grade as a function of treatment condition. Reprinted from Campbell & Ramey, 1995.



Test for duration of treatment, $F(1,80) = 10.46, p < .002$

EE = experimental preschool/experimental school age
 EC = experimental preschool/school age control
 CE = preschool control/experimental school age
 CC = preschool control/school age control

Fig. 4. Reading achievement scores for children in the Abecedarian study as a function of treatment condition. Reprinted from Ramey *et al.*, 1998.



Test for duration of treatment, $F(1,81) = 5.07, p < .03$

EE = experimental preschool/experimental school age
 EC = experimental preschool/school age control
 CE = preschool control/experimental school age
 CC = preschool control/school age control

Fig. 5. Mathematics achievement scores for children in the Abecedarian study as a function of treatment condition. Reprinted from Ramey *et al.*, 1998.

and provided only a minimal boost to reading and math achievement. It failed to raise achievement scores to levels observed among children receiving the educational daycare component of the intervention. Although the intensity and duration of the school age treatment were far less than that of the educational daycare component, findings in the Abecedarian study are consistent with the timing effect observed in the study by Hymovitch. Early intervention is associated with improved developmental outcomes. Later intervention following a specified developmental time period is not.

Evidence for sustained benefits associated with the timing of early intervention in the Abecedarian Project are perhaps further bolstered by the fact that similar programs beginning somewhat later in life have not demonstrated ongoing benefits to intelligence such as those observed in the Abecedarian study (Campbell *et al.*, 2001; Schweinhart & Weikart, 1997). Treatment in the Abecedarian study began in infancy while that in similar programs in which treatment effects diminished over time, the Perry Preschool Program and Early Training Project, began at 3 or 4 years of age. Although the issue of the timing of early intervention in this instance is confounded with duration of treatment, the findings for timing are consistent with the animal model investigated by Hymovitch. The important manipulations to disentangle relations among timing, duration, and intensity, however, have yet to be made.

In conclusion, we suggest that findings from animal models of deprivation and enrichment and from the available human data suggest that environmental enrichment following a prolonged period of severe deprivation is not likely to be effective in establishing a level of functioning that would have been expected had that deprivation been absent. However, this is not to say that enrichment should not be provided following a period of prolonged deprivation or that such enrichment would not serve to provide some measure of improvement. On the contrary, such enrichment in humans would likely work toward the prevention of even worse developmental outcomes associated with early chronic deprivation. It is important to recognize, however, the limits of enrichment and expectations regarding developmental effects from stimulating enriching experience. As noted by the developers of the Abecedarian Project, "A sizeable boost in (intelligence) test performance seems relatively easy to accomplish in early childhood but difficult to sustain at the same level thereafter. Although rates of change (in IQ) after early childhood (in the

Abecedarian Project) were parallel in the treatment and control groups, the trend was downward in both" following the termination of the educational enrichment (Campbell *et al.*, 2001, p. 240). Overall, we suggest that environmental enrichment represents only one among a wide variety of factors that influence the development of intelligence. Available evidence suggests that rather than providing a boost or increase in intelligence beyond an expected developmental range, early intervention works by preventing an expected decline in intelligence resulting from highly adverse rearing environments.

In contrast to the null effects of exposure to enrichment in adulthood found by Hymovitch, in which the period of early deprivation was of a much longer term (75–100 days) than is usual in more recent studies of enrichment in rodents, several investigations have found positive brain and behavioral effects via exposure to enriched conditions in adulthood (e.g. Kempermann *et al.*, 1997). However, we have not found any studies of enrichment in adulthood in rodents which involved animals that had been first reared under deprived conditions for as long as 75–100 days. Thus, while we do not deny that adult rodents can benefit from enrichment, it may be that a prolonged period of earlier deprivation may severely curtail or eliminate such benefits, particularly in the area of cognitive development as shown in Hymovitch's study.

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