Proc. Natl. Acad. Sci. USA
Vol. 96, pp. 8790–8794, July 1999
Psychology

How can we boost IQs of "dull children"?: A late adoption study

MICHEL DUYME*†, ANNICK-CAMILLE DUMARET‡, AND STANISLAW TOMKIEWICZ§

*Institut National de la Santé et de la Recherche Médicale U.155, Epidémiologie Génétique, Université Paris VII, 75251 Paris, France; ‡Centre de Recherche, Médecine, Sciences, Santé et Société/Institut National de la Santé et de la Recherche Médicale U.502, 75019 Paris, France; and §Centre de Thérapie familiale Monceau, 75009 Paris, France

Edited by Eleanor E. Maccoby, Stanford University, Stanford, CA, and approved May 26, 1999 (received for review January 11, 1999)

ABSTRACT **From 5,003 files of adopted children, 65 deprived children, defined as abused and/or neglected during infancy, were strictly selected with particular reference to two criteria: (*i*) They were adopted between 4 and 6 years of age, and (*ii*) they had an IQ <86 (mean = 77, SD = 6.3) before adoption. The average IQs of adopted children in lower and higher socioeconomic status (SES) families were 85 (SD = 17) and 98 (SD = 14.6), respectively, at adolescence (mean age = 13.5 years). The results show (*i*) a significant gain in IQ dependent on the SES of the adoptive families (mean = 7.7 and mean = 19.5 IQ points in low and high SES, respectively), (*ii*) IQs after adoption are significantly correlated with IQs before adoption, and (*iii*) during adolescence, verbal IQs are significantly lower than performance IQs.**

In 1994, 52 experts in intelligence stated, "Although the environment is important in creating IQ differences, we do not know yet how to manipulate it to raise low IQs permanently" (1). Numerous studies conducted in several countries have shown that, for children living in disadvantaged families, adverse experiences during infancy can lead to intellectual impairment and, more specifically, to verbal deficiency (2, 3). However, several questions remain. First, is educational intervention effective in changing the IQs of children living in low socioeconomic status (SES) families? The answer to this question remains a matter of debate. Some authors have claimed that educational programs are effective means of boosting IQs (4–6) while others have found them ineffective for long term IQ gains (5, 7–9). Second, assuming that there is a sensitive period for learning during early childhood, to what extent can adverse experiences during the first years of life lead to irreversible intellectual impairment, even when experiences during middle and later childhood are positive? Third, although adoption studies have shown an increase in IQ for children born to low SES parents and adopted early by middle or upper SES families (10–14), no study has demonstrated that adoption after early childhood by middle or upper SES families leads to IQ gains dependent on SES for children with borderline IQs (<86).

Our study contributes in a direct manner to the question of the extent to which environment, defined by the SES of adoptive parents, can alter the cognitive development of disadvantaged children after early childhood. Late adoption represents the only human situation that provides a scientific opportunity to conduct a methodological evaluation of the impact of a total change from a deprived environment to an enriched one (ref. 15; ref. 16, p. 351).

All previous studies of late adoption have shown an improvement in cognitive performance (17) but have not provided decisive answers to the questions previously raised. Some studies are based on case analyses and do not allow for generalization (18, 19). Others focus on children adopted before the age of 3 (20–22), but the Mental Developmental Index or IQ observed at these early ages are hardly indicative of the IQ observed at adolescence. There are some studies involving subjects adopted after 4 years of age, but they include very few subjects who had borderline IQs before adoption (23, 24). Moreover, in these studies, the variation in IQ gains in relation to the SES of the adoptive families was not examined. This latter variable is important given the fact that a previous adoption study has shown that the IQs of early adopted children vary significantly according to the SES of the adoptive parents, independently of the SES of the adopted children's biological parents (25).

The present research was carried out on a sample of deprived children with borderline IQs at the end of early childhood. All of the subjects had experienced a radical environmental change through adoption between the ages of 4 and 6 years. The purpose was twofold: (*i*) to study whether there was a quantitative discontinuity in IQ scores: i.e., whether the mean IQ gain increased significantly according to the adoptive parents' SES; and (*ii*) to study whether the IQs were stable: i.e., whether the child's rank remains the same or changes on the IQ assessments before and after adoption. Indeed, the notion of discontinuity differs from that of instability. For example, longitudinal studies of children reared by their biological parents have shown that, although some children show quantitative changes in IQ between childhood and adolescence, IQs generally remain stable between the first test in middle childhood and the last test in adolescence (26). A study of children with delays has shown that the mean IQ for the group as a whole decreased over time but found a stability of IQs across this time (27). Given these findings, we examined the effect of environmental change through adoption by studying both means and correlations for IQ scores. This approach offers two advantages. First, comparisons between the IQ means before and after adoption enable us to estimate IQ gains (i.e., the discontinuity of IQ). Second, correlations between these two IQ assessments indicate the stability or instability of IQs from childhood to adolescence.

We assessed IQs to examine (*i*) whether there is a significant increase in mean IQs between the assessment before adoption and that observed >5 years later; (*ii*) whether a link exists between the later IQ means [full (FIQ), verbal (VIQ) and performance (PIQ)] and the levels of the adoptive parents' SES—the higher the SES, the higher the gain in mean IQ—and, (*iii*) whether the two IQ assessments are significantly positively correlated.

Given the fact that studies of maternal deprivation during infancy have shown the negative impact of this variable on VIQ (ref. 2, p.223), mean VIQs after adoption may be lower than mean PIQs. Another subject of concern was whether, on average, the IQs of mildly retarded children (IQs <71) tested before adoption would increase more or less than those of

The publication costs of this article were defrayed in part by page charge payment. This article must therefore be hereby marked "*advertisement*" in accordance with 18 U.S.C. §1734 solely to indicate this fact.

PNAS is available online at www.pnas.org.

This paper was submitted directly (Track II) to the *Proceedings* office.
Abbreviation: SES, socioeconomic status; FIQ, full IQ; VIQ, verbal IQ; PIQ, performance IQ; EA, early adoption; LA, late adoption.
†To whom reprint requests should be addressed. e-mail: duyme@ccr.jussieu.fr.

upper borderline children (from 81 to 85) tested before adoption (28).

METHODS

The sample was drawn from a population of children who had been admitted to seven public adoption agencies between 1970 and 1978 (29). Subjects included in the sample of the present study met five criteria. They had all been (*i*) neglected and/or abused during infancy, having been definitively removed from their biological family by court order after judicial procedures; (*ii*) placed in many foster families and/or institutions before adoptive placement; and (*iii*) assessed by a psychometric test that provided an IQ <86 and >60 in the year preceding adoptive placement. In addition, they were (*iv*) aged 4–6 at the time of the adoptive placement; and (*v*) aged 11–18 and being raised by the two adoptive parents at the time of the second psychometric test.

The procedure followed was identical to that used in previous French studies (12, 14, 22). It was approved by the French Ministry of Health, French Ministry of Education, and the National Association of Adoptive Homes. The adopted children were located and tested by using the following method: (*i*) a survey in several adoption agencies of all adopted children; (*ii*) collection of data from files with information regarding the child, the biological families, and the adoptive families; and (*iii*) location of the school currently attended by the child. In the schools, all of the children in a given class were group-tested by a psychologist. Two children, one of whom was the adopted child, were then individually assessed by using the Weschler Intelligence Scale for Children (WISC-R) ($n = 58$) or the Weschler Adult Intelligence Scale (WAIS) ($n = 7$) (30, 31). Psychologists, teachers, and children involved in the study were blind to the fact that this was a study of adopted children. This procedure was followed to avoid the singling out of the adopted children.

The adopted children were selected from the files of seven public agencies from various French regions. Of the 5,003 files of adopted children, 633 were adopted after age 4, 132 had an IQ of <90 in the year preceding adoption (29), and 67 had an IQ >60 and <86. These 67 children met all of the qualifying criteria mentioned above and were reported in institutional files to be without physical defect, chronic illness, or genetic disease. The follow-up sample loss was extremely slight: IQ scores were obtained for 65 subjects. The mean age for adoptive placement was 57.7 months (SD = 7.5). The mean age for IQ testing before adoption was 52.6 months (SD = 7.2). The mean age was 162.6 months (SD = 22.8) for testing after adoption. Age quotient tests were used for IQ evaluation before adoption: 79% of the subjects were administered the French standardized version of the American Terman Merrill, 15% were given the Bayley, and 6% were administered other French tests of intelligence (32, 33). All of the children had histories of abuse and/or neglect by their parents or foster families (see above selection criterion *i*). Some social data concerning the biological mothers was found in the adoption agency files. It must be kept in mind, however, that information regarding social characteristics of the biological mothers was not systematically recorded in the case files. Our information, though comprehensive, is therefore not exhaustive. Of the 65 mothers, 54 were single parents, 44 had other children under the Child Welfare Authorities, 39 were followed by social workers, 23 were housed by others or were homeless, and 27 were unemployed. However, because information was not always available in the files, it is likely that the number of the social disadvantages of the mothers was actually higher than what we found. Fifty-eight biological mothers had their occupation noted: They all had no professional qualifications. The seven remaining mothers had other foster children in care and/or were persons of no fixed abode. No information was available regarding the parents of one of the children. The children in care experienced multiple changes: They moved between working class foster families or institutions an average of four times before adoption [mean = 4.03, SD = 1.84, median = 4, Shapiro-Wilk's W test for normality: $P < 0.01$]. Children in institutions or living with foster families did not systematically receive intervention services. Moreover, France has not yet developed educational or special assistance support programs for adoptive families.

Following the same classification procedure as that used in a previous French adoption study (22), the 65 subjects were divided into three SES groups, by a psychologist who was blind to the children's IQs, on the basis of the adoptive father's occupation. The high SES group included high-level managers or professionals; the middle SES group consisted of middle or lower level managers, tradesmen, or craftsmen; in the low SES group were unskilled workers. Test scoring, using a blind procedure, was performed by another psychologist. There was no statistically significant selective placement based on the number of shifts from foster homes and the adoptive father's SES [Spearman R ($n = 65$) = −0.05, not significant]. Based on the adoptive parents' SES, the mean IQ before adoption varied from 76.5 to 78.5 (see Table 1), and the differences between them were not statistically significant. There was no statistically significant selective placement based on these IQs (Shapiro-Wilk's W test for normality: $P < 0.01$) and the adoptive SES, [Spearman R ($n = 65$) = −0.002, not significant]. Moreover, the adoptive parents had no knowledge of the previous IQs of the children.

Two comparison groups also were analyzed. To hold constant the adoption variable and to have subjects without noticeable adverse experiences during infancy, these groups, extracted from another French study conducted by our research team, consisted of the whole sample of children born to the lowest SES families and adopted before 7 months by families with low ($n = 10$) or the highest SES ($n = 10$) (25). These early adoption (EA) groups were tested by using the same procedure as the late adoption (LA) groups. IQ tests were administered to the EA children, from 1 to 3 after the assessments of the LA children, at age 14 (172 and 168.5 months; SD = 4.6 and 2.9 in high SES and low SES, respectively).

RESULTS

As shown in Table 1, all three LA groups have higher IQ means after adoption. The full mean IQ gain for the whole sample was 13.9 points (i.e., from 77.6 to 91.4 mean IQ). Moreover, mean IQ increased significantly as adoptive parents' SES group increased. From low to high SES, mean IQ gains were 7.7, 15.8, and 19.5 (from 85.5 to 98 mean IQ), respectively. A significant effect of adoptive fathers' SES on IQ gain was thus shown [$F(2, 62) = 4.5$, $P < 0.02$]. This latter result clearly indicates that mean IQ gains varied according to the adoptive fathers' SES: Mean IQs after adoption were lower for children adopted into lower SES families and higher for children adopted into higher SES families. Similarly, there was a significant correlation between IQs after adoption and SES [r ($n = 65$) = 0.33, $P < 0.01$].

Pearson product–moment correlations between IQs before and after adoption (Table 1) were statistically significant for the whole sample [r ($n = 65$) = 0.39, $P < 0.01$]. Within each SES group, the correlation varied from 0.31 to 0.45. The difference in correlations according to the adoptive parents' SES was not significant [χ^2 (2, $n = 65$) = 0.31, P not significant]. Therefore, IQs after adoption tend to vary according to IQs before adoption. The restricted range of IQs before adoption calls for the reassessment of this correlation

Table 1. Mean IQ (SD) and correlations before and after adoption

SES		Late adoptees: Mean IQ Before adoption	Late adoptees: Mean IQ After adoption	Late adoptees: Mean IQ Difference*	Late adoptees: IQ correlation r	Late adoptees: IQ correlation r_c	Early adoptees
							$n = 10$
Low	FIQ	77.83 (6.8)	85.54 (17.0)	7.71 (15.2)‡	0.45†	0.71§	92.4 (15.4)
$n = 24$	VIQ		84.54 (15.5)				92.1 (17.2)
	PIQ		89.71 (18.2)				94.0 (12.2)
Middle	FIQ	76.45 (6.5)	92.23 (11.3)	15.77 (10.2)§	0.45†	0.72§	
$n = 22$	VIQ		91.55 (12.1)				
	PIQ		94.73 (13.5)				$n = 10$
High	FIQ	78.53 (5.7)	98.00 (14.6)	19.47 (13.9)§	0.31	0.61§	103.6 (12.2)
$n = 19$	VIQ		93.26 (16.7)				105.1 (12.4)
	PIQ		103.84 (12.5)				101.1 (12.0)
Total	FIQ	77.57 (6.3)	91.45 (15.2)	13.88 (14.0)§	0.39	0.67§	
$n = 65$	VIQ		89.46 (15.1)				
	PIQ		95.54 (16.0)				

r_c, Correlation estimated for restriction[34] range where SD for an unrestricted range of IQ before adoption is 13.4[29]. *Difference between IQ mean before and after adoption; P levels are computed from t for dependent sample; †$P < 0.05$; ‡$P < 0.02$; §$P < 0.001$. Summary of all effects for the design: SES, Early vs. Late adoptees (EL) on FIQ: SES [F (1,59) = 7.98, $P = 0.006$)], EL [F (1,59) = 2.21, $P = 0.14$], SES × EL [F (1,59) = 0.2, $P = 0.88$)]. Summary of all effects for the design: SES on Verbal vs. Performance (VP) IQs as repeated measures. SES [F (2,62) = 4.02, $P = 0.02$)], VP [F (1, 62) = 12.65, $P = 0.0007$], SES × VP: [F (1,62) = 1.45, $P = 0.24$]. Summary of all effects for the design: SES, EL on VP as repeated measures: SES (F = 8.1, $P = 0.006$), EL (F = 1.92, $P = 0.17$), VP (F = 3.89, $P = 0.05$), SES × EL (F = 0.03, $P = 0.85$), SES × VP (F = 0.005, $P = 0.94$), EL × VP (F = 6.65, $P = 0.01$), SES × EL × VP: (F = 2.68, $P = 0.11$). The df effect and df error are 1 and 59.

using a correction for restriction of range (34, p.163). The new value for the whole group is 0.67 (Table 1).

Comparisons between the IQ gains of children found to be mildly mentally retarded and those rated upper borderline before adoption are shown in Table 2. There was a significant IQ gain for mildly mentally retarded children (14.5), which, however, was not significantly higher than that of upper borderline children (12.1).

Results for VIQs and PIQs of adolescent adoptees are shown in Table 1. An ANOVA using the adoptive parents' SES and IQ test subscales as dependent repeated measures showed a main effect for SES ($P = 0.02$): The higher the adoptive family's SES, the higher the mean score for VIQ and PIQ. There was a significant effect for subscale factor ($P < 0.001$): The VIQ mean was lower than the PIQ mean. There was no significant interaction between SES and IQ test subscales.

The LA group was compared with the EA sample (14) on full IQ using a two-by-two factorial design. Two independent variables, each split into two contrasted levels, were used: early vs. late adoptees and high vs. low SES adoptive families. Results showed a main effect for the SES of adoptive families and no significant difference between LA and EA children on the full IQ scale. Another analysis was performed by using VIQ and PIQ as the dependent repeated measures factor. A main effect was found for SES, but the significant interaction between the EA vs. LA factor and the VIQ vs. PIQ factor indicated that VIQ was significantly lower than PIQ in the LA groups but not in the EA groups (see Table 1).

Table 2. IQ gains for mildly retarded and upper borderline adopted children

	Mean IQ Before adoption	Mean IQ After adoption	IQ gains
MR ($n = 10$)	65.7 (3.7)	80.2 (11.9)	14.5 (12.7)
UB ($n = 27$)	83.0 (1.6)	95.1 (15.4)	12.1 (15.2)

To test the significant difference between before-after adoption IQs, t test for dependence samples were used. For MR: $t = 3.6$, $P = 0.006$; for UB: $t = 4.12$, $P = 0.0003$. The Spearman R correlation between IQs before adoption and adoptive SES is 0.08, $P = 0.64$; therefore, there is no selective placement between these IQs and adoptive SES. MR, mildly retarded; UB, upper borderline.

DISCUSSION

Our results show that the adoptive environment for children adopted after 4 years of age is effective in boosting low IQs. Children who had low pre-adoption IQs and were adopted between the ages of 4 and 6 had much higher scores at adolescence. They had an average IQ gain of 13.9 points, 19.5 points when they were adopted by high SES families. These results support those of McKay *et al.* (35), who studied two groups of deprived children from 3.5 to 7 years of age living with their biological parents. One group participated in a treatment program integrating health, nutritional, and educational activities and showed an average IQ increase of 13 points. They scored an average of 92.4 at 8 years of age whereas a control group who did not receive these services scored 79.4. There are also numerous longitudinal studies showing that mentally deficient and environmentally deprived children who receive no treatment decline in IQ until early to middle adolescence (ref. 7, p. 51; ref. 35, p. 276; ref. 36; and ref. 37, p. 258).

It must be stated that the mean IQ gains found in this study are limited, however. Indeed, in higher SES adoptive families, the mean IQ is 98 points and remains slightly below the general population average of 100 (SD = 15). In the French standardization sample for the WISC-R (38), the mean IQs for upper and lower SES families are 111.8 (SD = 14.1) and 96.5 (SD = 14), respectively. These mean scores are significantly different from those of the adopted children (98 and 85.5). However, the results of these LA children are not significantly different from those of EA children born to the lowest SES parents. Therefore, when the background of the biological parents of the adopted children is taken into account, these gains do not seem as limited.

It also must be pointed out that, although, for LA children, VIQ scores are lower than PIQ scores regardless of adoptive family SES, this is not true for early adoptees. In this study, both VIQ and PIQ were shown to be malleable, but VIQ was upgraded more substantially for early than late adoptees. It seems that there is a modest sensitive period effect here: A supportive environment will be especially valuable for VIQ at the time when language develops most rapidly, between age 1.5 and 4 years. PIQ may not have any such special window of time when environmental inputs make the most difference.

The effect of the adoptive parent's SES on children's IQ has been shown in the present study. Although a previous study has shown the effect of adoptive family SES on the IQ of children adopted before the age of 1 (14), this study highlights the effects of SES on LA children with low IQs before adoption.

From a methodological point of view, the IQ gain cannot be solely due to regression to the mean. Indeed, if the mean difference between IQs before and after adoption by low SES families may be attributed in part to this regression, the difference of 11.8 points [Least-Significant-Difference (LSD) test $P = 0.005$] between children adopted into low SES families and those adopted into upper middle SES families can only be attributed to the effects of the adoptive parents' SES. Moreover, if there were a regression effect, one would expect to find that very low IQs increase more than higher ones. This result was not observed (Table 2). An increase in IQ scores because of a test–retest effect is unlikely because an average of 9 years separated the two assessment periods. Other longitudinal studies of disadvantaged children with subnormal or borderline IQs who were reared by their parents and received no special intervention have not found this practice effect over a similar time span. On the contrary, a mean continuity or decline in IQs was observed (27, 39, 40).

The correlation of 0.67 between IQs before and after adoption is moderate and indicates a degree of stability close to the stability found in longitudinal studies of biological children who have not undergone an environmental change ($r = 0.60$ between 4 and 5 or 14 and 15 years of age) (41, 42). Thus, on the basis of IQ at the end of the preschool period, the results show that there is a moderate stability for rank (43). This is a near-universal finding.

The results of comparisons before and after adoption cannot be attributed to bias stemming from the heterogeneity of the tests, which are different in the two assessments. In the absence of this test heterogeneity, the correlation would be even higher than that observed. IQ tests administered after adoption were based on more recent standardized norms than some of the IQ tests used before adoption. It is well known that tests using recent standardized norms yield lower IQs than those using older norms (43). Therefore, the difference in the IQ averages before and after adoption would have been higher had similar standardized norms been used.

This study shows that stability for rank can be found following a marked environmental change after 4 years of age regardless of the SES of adoptive families. The factors explaining this stability are undoubtedly different from those explaining the gains in mean IQs. However, the source of the stability cannot be known from this study. Our results are in keeping with those of other adoption studies in which mean levels change while rank orders remain stable (10). And they fit with studies of secular change in IQ (44, 45) that have demonstrated that IQ mean levels have risen over time. This rise is interpreted like the result of changes of environment over time. This also might be true of other characteristics, such as height, that are estimated to be highly heritable. Such changes in mean levels of IQ or height also have been observed in migration studies (45, 46).

Finally, we have no data to date indicating that adopted children will maintain their IQ gains in adulthood after having left their family environment. All longitudinal studies have shown very few IQ changes after adolescence. The present study has evaluated at adolescence (mean = 13.6 years) the effect of a total environmental shift that took place at the end of early childhood (between 4 and 6 years of age) for children who had low IQs at this early stage. It shows both the discontinuity and the stability of IQs. It shows that, even after early childhood, some environmental factors highly increase borderline IQs.

We thank J. Feingold, C. Capron, A. M. Clarke, and A. D. B. Clarke for their helpful comments on this manuscript and advice during the research. This study was supported by grants from Caisse Nationale d'Assurances Maladies des Travailleurs Salariés and National Institute of Health and Medical Research (INSERM).

1. Mainstream Science on Intelligence (1994) *The Wall Street Journal*, Dec. 13, p. A18.
2. Rutter, M. & Rutter, M. (1993) *Developing Minds* (Penguin Books, London).
3. Walsh, A. (1989) *J. Genet. Psychol.* **151,** 279–285.
4. Garber, H. L. (1988) *The Milwaukee Project: Preventing Mental Retardation in Children at Risk* (Am. Assoc. Mental Retardation, Washington, DC).
5. Schweinhart, L. J. & Weikart, D. P. (1993) *Young Children* **49,** 54–58.
6. Ramey, C. T. & Ramey, S. L. (1998) *Am. Psychol.* **53,** 1159–1160.
7. Spitz, H. H. (1986) *The Raising of Intelligence* (Erlbaum, London).
8. Herrnstein, R. J. & Murray, C. (1994) *The Bell Curve* (The Free Press, New York).
9. Detterman, D. K. & Thompson, L. A. (1997) *Am. Psychol.* **52,** 1082–1090.
10. Weinberg, R. A., Scarr, S. & Waldman I. D. (1992) *Intelligence* **16,** 117–135.
11. Skodak, M. & Skeels, H. M. (1949) *J. Genet. Psychol.* **75,** 85–125.
12. Schiff, M., Duyme, M., Dumaret, A., Stewart, J., Tomkiewicz, S. & Feingold, J. (1978) *Science* **200,** 1503–1504.
13. Teasdale, T. W. & Sorensen, T. I. A. (1983) *J. Biosoc. Sci.* **15,** 509–518.
14. Capron, C. & Duyme, M. (1989) *Nature (London)* **340,** 552–554.
15. Clarke, A. D. B. & Clarke, A. M. (1992) *Int. Rev. Res. Ment. Retard.* **18,** 137–157.
16. Rutter, M., Dunn, J., Plomin, R., Simonoff, E., Pickles, A., Maughan, B., Ormel, J., Meyer, J. & Eaves, L. (1997) *Dev. Psychopathol.* **9,** 335–364.
17. Hodges, J. & Tizard, B. (1989) *J. Child Psychol. Psychiatry* **30,** 53–75.
18. Koluchova, J. (1976) in *Early Experience: Myth and Evidence*, eds, Clarke, A. M. & Clarke, A. D. B. (Open Books, London), pp.56–66.
19. Skuse, D. (1984) *J. Child Psychol. Psychiatry* **25,** 543–572.
20. Rutter, M. (1998) *J. Child Psychol. Psychiatry* **39,** 465–476.
21. Skeels, H. M. (1966) *Monogr. Soc. Res. Child Dev.* **31,** 1–56.
22. Duyme, M. (1988) *Dev. Psychol.* **24,** 203–209.
23. Kadushin, A. (1970) *Adopting Older Children* (Columbia Univ. Press, New York).
24. Tizard, B. & Hodges, J. (1978) *J. Child Psychol. Psychiatry* **19,** 99–118.
25. Capron, C. & Duyme, M. (1996) *Intelligence* **22,** 259–275.
26. Clarke, A. D. B. & Clarke, A. M. (1984) *J. Child Psychol. Psychiatry* **25,** 191–210.
27. Keogh, B. K. Bernheimer, P. Mittler, & L. P., Guthrie, D. (1992) *Am. J. Ment. Retard.* **101,** 365–373.
28. Snow, R. E. & Yalow, E. (1982) in *Handbook of Human Intelligence*, ed. Sternberg R. J. (Cambridge Univ. Press, Cambridge, U.K.), pp. 493–559.
29. Dumaret, A. C., Duyme, M. & Tomkiewicz, S. (1997) *Early Child Dev. Care* **134,** 23–42.
30. Weschler, D. (1981) *Manuel Echelle d'Intelligence de Weschler pour Enfants, Forme Révisée* (Les Editions du Centre de Psychologie Appliquée, Paris).
31. Weschler, D. (1970) *Manuel Echelle d'Intelligence de Weschler pour Adultes* (Les Editions du Centre de Psychologie Appliquée, Paris).
32. Terman, L. M., Merrill, M. A. & Cesselin, F. (1959) *Echelle de développement mental de Terman-Merril* (Editions et Applications Psychologiques, Paris).
33. Brunet, O. & Lézine, I. (1974) *Echelle de Développement Psychomoteur de la Première Enfance* (Editions et Applications Psychologiques, Issy les Moulineaux, France).
34. MacNemar, Q. (1969) *Psychological Statistics* (Wiley, London).
35. McKay, H., Sinisterra, L., McKay, A., Gomez, H. & Lloreda, P. (1978) *Science* **200,** 270–278.
36. Jensen, A. R. (1977) *Dev. Psychol.* **13,** 184–191.
37. Deutsch, C. (1973) in *Review of Child Development Research, Vol. 3: Child Development and Social Policy*, eds. Caldwell B. M. & Ricciuti N. H. (Univ. Chicago Press, Chicago).
38. Grégoire, J. (1995) *Évaluer L'Intelligence de L'Enfant* (Mardaga, Liège, Belgium).

39. Sameroff, A. J., Seifer, R., Baldwin, A. & Baldwin C. (1993) *Child Dev.* **64,** 80–97.
40. Campbell, F. A. & Ramey C. T. (1994) *Child Dev.* **65,** 684–698.
41. Hindley, C. B. & Owen, C. F. (1978) *J. Child Psychol. Psychiatry* **19,** 329–350.
42. Wilson, R. S. (1984) *Child Dev.* **5,** 298–317.
43. Flynn, J. R. (1987) *Psychol. Bull.* **101,** 171–191.
44. Flynn, J. R. (1998) *The Rising Curve: Long Term Gains in IQ and Related Measures*, ed. Neisser U. (Am. Psychol. Assoc., Washington, DC), pp. 25–66.
45. Neisser, U. (1997) *Am. Sci.* **85,** 440–447.
46. Anderson, A. M. (1982) *Nature (London)* **297,** 180–181.