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CHAPTER 4

LIMITED REARING EFFECTS ON INTELLIGENCE (IQ)

In *Nature's Gambit* (Feldman, 1986), we can read case histories of extraordinary intellectual achievement. Adam Konantovich could speak in grammatical sentences at 3 months of age and read simple books at 1 year. At the age of 5 years, when attending a puppet show for preschoolers at the Boston Museum of Science, Adam answered a rhetorical question about what whales eat as follows: "Krill, they're small shrimp, but they're not microscopic." Billy Delvin was reading about particle physics at age 7 and scored better on the mathematics Scholastic Aptitude Test (SAT) than many junior high school students. Yet another story of precocity was told to me by a friend who is a professor at Harvard. His young daughter, then only about 18 months old, was greeted in the supermarket by a women who smiled and said, "Coochie, coochie, coo." His daughter then turned to her mother and asked, "Is she trying to talk to me?" These stories tell us that some children are born with unusually great aptitude for intellectual achievement. We recognize intuitively that no amount of "intellectual stimulation" (even the 3,000 books in the home of Adam Konantovich) could produce such talent in a child lacking special "gifts," but these unusual cases cannot tell us how important rearing environment is for intellectual development more generally—the issue broached in this chapter.

General Intelligence: Definitions and Controversies

Most social scientists recognize that "academic intelligence" refers to the ability to acquire the kinds of information taught in schools. Indeed, the first IQ tests were developed in France by Alfred Binet for the express purpose of early identification of children having difficulty with academic subjects. Beyond this common-sense statement, there is less agreement about a definition of "intelligence" because the kernel of skills needed for schooling is difficult to summarize in a short statement. Consensus definitions of intelligence among psychologists and educational specialists with expertise on intelligence included "abstract reasoning and thinking," "the capacity to acquire knowledge," and "problem solving ability" (Snyderman & Rothman, 1987). *Webster's Third International Dictionary* (1968) gives as one definition of intelligence "the faculty of understanding: capacity to know or apprehend." Another definition, clearly influenced by the development of psychometrics (i.e., the scientific study of individual differences in intelligence), is as follows: "the available ability as measured by intelligence tests or by other social criteria to use one's existing knowledge to meet problems, to use symbols or relationships, to create new relationships, to think abstractly" (p. 1174).

Although intelligence is a fuzzy concept, it provides enough narrowing criteria to exclude many rankable areas of human performance. In an unfortunate choice of terminology, Gardner (1983) discusses multiple human "intelligences," including such diverse types as musical ability, personal intelligence, and bodily/kinesthetic ability. As in math and English, individual differences in each of these other domains would cover a huge range, be relatively stable, and be rankable. However, these are not areas of "intelligence" according to our definition, because individual differences in abstract reasoning and problem solving are not strongly associated with individual differences in these other performance domains. For instance, professional tennis players, although sharing an inordinate degree of athletic talent, have IQ scores ranging from borderline retarded to brilliant, and so on for the other areas of performance. There would be less to quibble about had Gardner chosen the phrase "multiple talents" rather than "multiple intelligences," which confuses these other areas of ability with IQ.

Even if we restrict our consideration to the verbal and mathematical problem-solving skills of academic intelligence, questions about generality versus specificity remain. It is clear that in rare cases, specificity is so extreme that masterful performance in one domain of human accomplishment accompanies great retardation in nearly all others. Consider the case of Leslie Lemke, who was born profoundly retarded and suffering from cerebral palsy (Feldman, 1986). He was blind, his eyes having been surgically removed after birth for unexplained medical reasons. When he was about 18 years old, Leslie's mother added music to his daily routine, but she was unprepared for what came next: Leslie sat down at the piano and played (despite a total absence of musical training) Tchaikovsky's Piano Concerto No. 1 with a certain touch. His musical gifts were those of an "idiot savant"—a specialized brilliance in someone who is otherwise far below average (indeed, at the time, Leslie could not speak).

More typically, however, abilities in the academic domain show much closer integration. Subtest scores on an IQ test intercorrelate positively with one another in the .40 to .60 range—a positive relationship meaning that someone who scores below average on one IQ subtest is also likely to score below average on the others. This positive relationship occurs despite disparate test content. IQ subtests on the Wechsler Adult Intelligence Scale (WAIS) and the Wechsler Intelligence Scale for Children (WISC) include a General Information test, in which general "cultural literacy" is tested (e.g., number of weeks in a year, distances between major cities); a Comprehension subtest; a Vocabulary subtest; a Block Design subtest, in which a presented design must be reproduced quickly with red and white blocks; a Digit Span subtest, in which numbers heard must be repeated back; and several other subtests. The subtests either require previously acquired knowledge, or require quick reasoning but place fewer demands on accumulated past knowledge. When subtest scores are combined to form a total score, this score is said to represent "g," or general intelligence—the commonality of performance across different intellectual domains.

In his book *The Mismeasure of Man*, Stephen Jay Gould (1981) has stridently attacked the concept of a *g* underlying the domain of academic intelligence. His historical review covers debates among factor analysts over the number of dimensions underlying performance on IQ tests containing substantively diverse subtests. Spearman defended the concept of *g*, focusing on the commonality among subtests; at the other extreme, Guilford identified 120 separable ability dimensions within IQ tests. More commonly, the tests are seen as factoring into just a few dimensions, such as Thurstone's primary mental abilities of verbal comprehension and spatial visualization.

The two views of IQ tests, however, are really compatible. When the general population is broadly sampled to include people of diverse ability levels, *g* stands out in the positive intercorrelation of subtests, and one dimension may be used profitably to rank people. At the same time, further factor analysis of the subtests should identify specific factors that are themselves intercorrelated. Thus, separating factors provides a more exact ranking of individuals in particular subdomains of intellectual ability—allowing one, for instance, to identify more exactly the most and least mathematically skilled individuals, rather than using the more general ranking provided by a total test score that includes verbal as well as mathematical components. On the other hand, because of the correlation of the factors, the total score is just a more general ranking, not a dishonest or useless one, and for many purposes may serve as well as or better than a subtest score. After all, the civil service does not want to identify future mathematicians, but merely wants to find the people who are brighter (in a broad sense) than others.

Gould admits many of these facts, but puts a different emphasis on them. Although he acknowledges that Spearman's *g* factor extracted from a group of tests can encompass over half the variation in them (p. 314), he treats the factor-analytic solutions as purely arbitrary. He argues that *g* is a chimerical statistical artifact, just one mathematical solution among many equivalents. He calls it the "rotten core" (p. 320) of the hereditarian view of intelligence.

As a consumer of SAT scores, however, Gould must be aware that even in the restricted population of students ambitious enough to seek a college education, mathematical and verbal subtests correlate about .70, sharing about half their variance. The rank order of test takers on the total SAT score does not deviate greatly from their rank order on the basis of either the verbal or mathematical portion alone. This practical phenomenon, observed across many intellectual tests when administered to diverse populations, is enough alone to justify the use of the total score *g* rather than a component score in many applied and theoretical contexts. In sum, *g* is neither chimerical nor rotten, because the general population includes few people with skills as disjunctive as Leslie Lemke's. The "idiot savant" view of intelligence promoted by Gould is neither endorsed by modern factor analysts nor influential in the practical uses of IQ tests (Snyderman & Rothman, 1987).

The crux of IQ testing—or any measurement of intellectual achievement in academic work—is its relationship to socially valued outcomes (Barrett & Depinet, 1991). Parents care about IQ ability because of its power to forecast academic success. But the IQ test is embedded in a richer set of correlates than merely years of schooling, and these additional correlates, if anything, intensify the emotions surrounding the interpretation of IQ scores. IQ is particularly important for entry into and success in high-prestige occupations, such as medicine, law, and university teaching. It is unlikely that one would find a natural scientist, lawyer, or doctor with an IQ below 110, but this cutoff would exclude 75% of the white population or 95% of the black population in the United States from eligibility, according to current score distributions.

Decades of research in organizational psychology reveal that IQ determines job performance in a variety of occupations, and although validity coefficients are slightly higher for intellectually demanding occupations than for intellectually undemanding ones, they are important in occupations from the executive suite to the janitorial staff. Because of this connection with job performance levels, the use of ability test scores to match people to occupational niches can contribute to national productivity by making the best use of the national talent pool:

> . . . the use of the Programmer Aptitude Test in place of an invalid selection method to hire 618 entry-level computer programmers leads to an estimated productivity improvement of $54.7 million ($68 million in 1981 dollars) over a 10-year period if the top 30% of applicants are hired. . . . the gross national product would be increased by $80 to $100 billion per year if improved selection methods were introduced throughout the economy. (Schmidt & Hunter, 1981, p. 1129)

The basis for these striking conclusions is simple: observing people of low versus high IQ perform in a variety of occupations. Higher IQ test scores predict the acquisition of more job-relevant knowledge, both during training and later on the job (Hunter, 1986). Greater knowledge and better problem-solving skills together explain the association of IQ scores with superior job performance, whether rated by supervisory personnel or assessed by direct observation. As Hunter notes, "learning on the job goes on at a high rate for at least five years and continues at a slower rate out to 20 years, which is as far as the data goes [*sic*] . . . even simple jobs require far more learning than is evident to outsiders" (1986, p. 360).

Explanations for Intellectual Growth

The intuitive explanation of intellectual development is that it depends on various kinds of exposures to intellectually stimulating environments. How can this intuition be contradicted? The knowledge that Darwin wrote *The Origin of Species* or that $2x + 5 = 11$ solves for $x = 3$ cannot be encoded directly in the human genome; although the latter relationship might be discovered by a very gifted child without much formal training in algebra, the former must be directly taught or learned incidentally on exposure to this piece of information. The self-evident importance of exposure leads naturally to an emphasis in socialization science on rearing, because families own different numbers of books, use different vocabulary levels, and discuss topics of different intellectual complexity around the dinner table (or more commonly today, around the TV set).

But, of course, the home is not the only source of exposure to intellectual subjects. The "lighthouses of knowledge" envisioned in the 19th century—the U.S. system of universal education—may not live up to the ideal of providing the highest-quality education to every American child, but America's schools, good and poor, reach most children and offer a source of "intellectual stimulation" separate from the family of origin. Indeed, the importance of schooling has led the Cornell psychologist Steven Ceci (1990a) to the conclusion that schooling *is* the cause of IQ test performance:

> The processes associated with schooling influence performance on IQ tests through a combination of *direct* instruction (e.g., it is in school that most children learn the answers to many IQ questions such as "In what continent is Egypt?" "Who wrote Hamlet?" and "What is the boiling point of water?") and *indirect* modes or styles of thinking and reasoning (e.g., schools encourage taxonomic/paradigmatic sorting and responding, rather than thematic/functioning responding, and this happens to be the valued form of responding on IQ tests). (pp. 71–72, emphasis in the original)

Following Ceci's line of argument, we could replace variation in family environments with variation in school environments as the source of individual differences in intelligence. And Ceci marshals several arguments to illustrate the importance of schooling. For example, intellectual growth is slower in the summer, when children are out of school, than during the school year; unschooled children are not as bright as children who attend school; and the children who are in school the longest have the highest IQ scores. The last point was illustrated by substantial correlations between years of completed schooling and IQ. Ceci (1990a) remarks, ". . . it has been known for many decades that a child's experience of schooling exerts a strong influence on intelligence test performance. Overall, there is an adjusted correlation of .68 between the number of years of school completed and IQ" (p. 73).

Ceci is definitely onto something, but I cannot accept his conclusion that schooling alone is responsible for the individual differences in IQ that we see. Ceci ignores temporal order when, for whatever reason, he fails to mention while making this argument that IQ scores obtained much *earlier* in the academic career—even at the point of school entry in preschool and first grade—also predict the number of years of completed schooling. Unless we are willing to accept time travel as a premise, the accumulated exposure to indirect and direct benefits of instruction cannot cause these early differences in IQ scores. Rather, given this temporal order in the absence of time travel, we are forced to conclude that IQ, or some third factor associated with IQ and years of schooling, directly causes the number of years of schooling completed.

Consider the acquisition of vocabulary. Most vocabulary is learned incidentally from exposures to spoken and written language. During childhood, vocabularies grow from just a few words to thousands of words—a pace of acquisition so rapid that few parents have any idea about the origin of each new word. Schooling contributes importantly to this growth of vocabulary when words are acquired incidentally as children read texts—that is, when they infer the words' meaning from their natural context in a written passage (Nagy, Herman, & Anderson, 1985). During the middle school years, children acquire about 3,300 words each year. According to Nagy et al.'s (1985) estimates, they read about a million words per year and encounter from 15 to 55 unknown words in each 1,000 words of text. On the basis of their experimental results, a child has a 5% to 11% chance of correctly inferring a word's meaning from context on a single exposure; thus, children in the middle grades learn approximately 3,125 words from reading in a year, or nearly enough words to account for their annual vocabulary growth.

What accounts for individual differences in vocabulary acquisition? Clearly, individual differences in the amount read are part of the story, because the more reading is done, the more unknown words will be encountered and possibly acquired once their meaning is inferred from context. Another important process is the ability to extract a word's meaning from context when it is encountered in a passage. Using constructed passages, research studies have demonstrated that the ability to extract word meaning from context varies greatly by IQ level. In these studies, passages of simple vocabulary are constructed that contain one unknown word—a nonsense word, but one having a meaning in its new context. High-IQ individuals more successfully extract the meaning of the unknown word from its context in the otherwise simple passage (Sternberg, 1985, pp. 233–234). Readers may want to try the following passage:

> Two ill-dressed people—the one a tired women of middle years and the other a tense young man—sat around a fire where the common meal was almost ready. The mother, Tanith, peered at her son through the *oam* of the bubbling stew. (Sternberg, 1985, p. 233)

If this process holds, we can infer that brighter individuals will more easily acquire the meaning of unknown real words encountered in natural texts, and thus develop larger vocabularies, than less capable individuals.

Although we have a sense of why some individuals' vocabularies are larger than others, we still do not know what the crucial environments are. One view is that the rearing environment makes a large difference, because parental vocabularies differ markedly. But this view may miss the richness of the total environment to which any child who is not severely deprived is exposed. Even in the Arizona desert children can discover the meaning of the word "umbrella," because exposures are available, although perhaps not so commonplace as in London. The word "penguin" may be learned from a *National Geographic* special, from a cartoon, from reading a story about Antarctica, and from many other sources. The total number of exposures (a million words in text, millions more in spoken language) may reduce the variability in the size of vocabulary that is attributable to rearing environments, because the family environment is only a small part of the total social environment, and all aspects of this environment are rich in incidental learning opportunities.

This view that applies to vocabulary may hold for intellectual development generally. The total stimulation needed for intellectual development may be available to any child in families from the working class to the professional class; the environmental differences noticed among families may be relatively unimportant for the eventual intellectual growth attained. The critical environments may not be those *imposed* on children by virtue of accidents of birth, but those actively sought by children, and shaped by how children parse the stream of experience to which they are exposed. Even minority children do not exist in poor social environments, although their environments may be culturally *different* from the majority's. The process described in Chapter 3—the active gene–environment correlation—would then explain intellectual development, much as it does the development of character.

Behavior Genetic Studies of Rearing Environments and IQ

The behavior genetic literature on IQ is vast and is not comprehensively reviewed here. This literature unambiguously establishes the inheritance of intellectual abilities in families: Shared genes lead to resemblance in intellectual abilities, regardless of whether the pairs of relatives live together and experience similar environmental influences or live apart and experience different ones. Heritability estimates range from 40% to 70%, indicating that substantial variation in intellectual ability has substantial genetic basis.

Table 4.1 presents a list of IQ correlations, admittedly from heterogeneous studies, showing the typical decline of resemblance with decreasing genetic relatedness (Loehlin, 1989). For instance, MZ twins raised apart correlated .72, whereas cousins (who possess some environmental similarity, as do imperfectly separated MZ twins) correlated only .15. There are many ways to estimate heritability. Directly, from the correlation of MZ twins raised apart, it would be 72%; indirectly, from the correlation of parent and offspring reared apart, it would be 48%; from siblings reared apart, it would also be 48%. Model-fitting the correlations shown in Table 4.1, Chipuer, Rovine, and Plomin (1990) settled

TABLE 4.1. IQ Correlations for Different Pairs of Relatives

Group	Mean correlation	No. of pairs
MZ twins reared apart	.72	65
MZ twins reared together	.86	4,672
DZ twins reared together	.60	5,533
Siblings reared together	.47	26,473
Parent and child reared together	.42	8,433
Cousins	.15	1,176
Biological siblings reared apart	.24	203
Parent and child reared apart	.24	720
Unrelated siblings reared together[a]	.29	345
Unrelated siblings reared together[b]	.34	369
Parent and adopted child	.19	1,491

Note. Correlations for unrelated family members reared together come from older studies. The children were young, and selective placement effects were present. Original source: Bouchard & McGue (1981). Adapted from Loehlin (1989). Copyright 1989 by the American Psychological Association. Adapted by permission.

[a] Biological child of adoptive parent with adopted sibling.

[b] Adopted siblings from successive adoptions.

on a broad-sense (additive plus dominance) heritability of 51%. Loehlin (1989) fitted several different statistical models to the same correlations and arrived at broad-sense heritabilities ranging from 47% to 58%.

The surprise in the table is not the evidence for IQ heritability, but rather the evidence for an influence of different rearing environments. The adopted siblings correlated .34, suggesting that rearing environment accounts for 34% of variation in IQ (the correlation is not doubled because these siblings shared the full common environmental effect, despite sharing none of their genes). The estimate from adoptive parent and offspring was weaker (19%), but perhaps a parent and child share fewer experiences relevant to intellectual development than siblings do. These data raise a possibility of an ecumenical resolution of the nature–nurture debate in regard to IQ, as they imply that rearing experiences combine additively with inherited advantage or disadvantage in intellectual development.

Yet we have already seen that caution is needed in considering the sparse evidence for rearing influence. The adoptive data summarized in Table 4.1 contain two pitfalls. The first is selective placement (i.e., an adoptee's being placed in a family of social background similar to that of the biological parent)—a problem common in adoption studies of IQ, but virtually nonexistent in adoption studies of personality traits. As noted in Chapter 2, selective placement can lead to a genetic influence's being read as an environmental one. A second problem is that many adoption studies have used as subjects young children of preschool or early gradeschool ages; the correlations in Table 4.1 represent a mix of ages, mostly young children. If the model of active gene–environment correlation is correct (Scarr & McCartney, 1983), then as environmental opportunities outside the family accumulate, children's IQ should be more greatly affected by their genetic potential and less influenced by their rearing experiences. In other words, early exposure to a large vocabulary and parental encouragement of achievement in the home should boost IQ test performance—not because the advantaged children are made any brighter, but merely because they are exposed to material that is relatively lacking in the home environments of less advantaged children. This real advantage cannot be maintained into adolescence and adulthood, however, because eventually most children (except those living in the most depriving environments) should encounter sufficient intellectual stimulation to reach their potential for intellectual growth.

One way to test this notion is to put age directly into the models of intellectual development. In a meta-analysis of 103 reports of twin studies, McCartney, Harris, and Bernieri (1990) explored the relation of twins' ages to the size of the rearing (shared) environment component inferred from the twin study design. For intelligence, the correlation of the estimate of rearing influence with twins' ages was –.37, indicating less influence of rearing environment as the twins became older. In contrast, the heritability of intelligence increased with age as rearing influences lessened ($r = .36$). In late adulthood (average age = 66 years), the heritability of IQ may be higher than that found earlier in life (about 80%; Pedersen, Plomin, Nesselroade, & McClearn, 1992).

New adoption studies completed with older children also give less credence to a lasting influence of rearing. Sandra Scarr and Richard Weinberg (1978) completed a study of children between 16 and 22 years of age in adoptive and biological families. Although none of the families in either the adoptive or the matched biological family groups were extremely deprived, they did represent a broad range of socioeconomic statuses, from the working to the professional social classes; incomes ranged from under $10,000 to more than $40,000 (1978 dollars). Scarr and Weinberg reported:

> Occupations of the fathers in the two samples varied from janitor, auto mechanic, small farmer (income < $10,000), telephone installer, and sheet metal worker at the low end to physician, engineer, college professor, and radio station owner at the high end of the scale. Most occupations were in the middle range of carpenter and printer to insurance agent and building contractor. (p. 678).

All the children had been adopted prior to 12 months of age.

Thus these were early-adopted children, now entering early adulthood (mean age = 18½ years), who had had years of exposure to varied rearing environments—years that should have acted to make the unrelated children reared together alike in IQ, and also to make them resemble their adoptive parents in intellectual abilities. The statistical results were unkind to this expectation. In the biological families, the IQ correlations were as follows: father–child, .40; mother–child, .41; and sibling, .35. In the adoptive families, they were .16, .09, and –.03, respectively. Consider now the interpretation of the unrelated siblings' correlation, –.03. Siblings who had been raised together for an average of 18½ years, but who lacked biological relatedness, were no more alike than randomly paired children raised in different families of similar social class backgrounds. Scarr and Weinberg (1978) drew the substantive conclusion revealed in these bare statistics:

> If we observe that professional families take their children to the theater more often than working-class families, or hang mobiles above their cribs more frequently, some social scientists feel justified in recommending to everyone that they take in plays frequently, rather than play baseball in the backyard, or hang mobiles over the crib, rather than carry the baby about wherever they go. Since these are the child-rearing practices of the professional class, whose children excel at IQ tests and in school, all parents are advised to alter their child-rearing practices to follow suit. *It has not been demonstrated that these variations in child rearing are functionally different in their effects on the children. . . .* (p. 690; italics in original)

Another new adoption study was started in Denver, Colorado, in the early 1970s. The Colorado Adoption Project (Cyphers, Fulker, Plomin, & DeFries, 1989) employed a full adoption design, with the biological parents of the adopted-away children tested through a private adoption agency prior to the birth of their children. The children's average age at placement was just 27 days. Added to the adoptive families and the biological parents of the adoptees was another set of families—biological families matched for social class, child's gender, and family size with the adoptive families. The most unusual aspect of this study is a near-absence of selective placement: The IQs of the adoptive parents were unassociated with those of the biological parents who had relinquished their children for adoption. The social class range of the families was more restrictive than in Scarr and Weinberg's (1978) study, with adoptive fathers having a mean of 15.7 years of schooling (Plomin, DeFries, & Fulker, 1988, p. 46); nonetheless, educational levels did vary in the range from the working to professional social classes.

Although the children were young when tested, rearing influence in the family did not appear to affect their IQ scores. As Cypher et al. dryly wrote, "Environmental resemblance between parents and offspring is nonsignificant for all four specific cognitive abilities as well as the general [IQ] composite" (1989, p. 380). Consistent with McCartney et al.'s (1990) meta-analysis, heritabilities increased with the children's age: at 3 years, .13; at 4 years, .18; and at 7 years, 28%. Thus as the children became older, their IQ scores expressed their genotypic potentials more strongly and their influences in the rearing families not at all.

Ideally, we should find a diminishment of rearing influences in one group of children as they grow up. The Texas Adoption Study, described in Chapter 2 and 3, provides this rare opportunity because the same adopted children were tested once when they were 3 to 14 years old and a second time when they were 13 to 24 years old (Loehlin, Horn, & Willerman, 1989). As in the other adoption studies, the Texas adoptive families represented a social class range without extreme deprivation; nearly all the adoptive fathers had at least a high school education (Horn, Loehlin, & Willerman, 1982). Table 4.2 shows the mean correlations for adoptive parent and adopted child and for unrelated siblings (either more than one adoptee in a family or an adoptee and a biological child of the adoptive parents). When the children mostly attended elementary school, rearing influence accounted for 16% of IQ variation ($r = .16$ in both cases); at the follow-up, however, when the children were in high school or had graduated, rearing accounted for none of the variance ($r = -.01$ or .08). More complex model-fitting analyses of the total adoptive data set, including data on the biological mothers of the adoptees, arrived at this same conclusion—no influence of variation in rearing on the IQs of the older children.

As implied in Scarr and Weinberg's (1978) remarks quoted above, our estimates of rearing variation (c^2) are far more important for a sense of the malleability of IQ than are estimates of heritability. If different rearing makes a difference, IQ may be very malleable despite considerable heritability, because the final level of intellectual attainment will be dependent on the additive effects of rearing environment and heredity. If the rearing environments imposed on children in the family make little difference, then IQ cannot be significantly altered by the kinds of social interventions we can foresee—because adoption is probably the most comprehensive, practical intervention for changing a child's level of intellectual stimulation that can be imagined. A compensatory preschool educational intervention lasts 1 or 2 years (at most, a few years); adoption covers the entire childhood. Moreover, a compensatory educational intervention chiefly changes curriculum, although some such interventions also work with families; adoption can put a child from a working-class background into a family with high-IQ parents who have large

TABLE 4.2. Rearing Influence on IQ in the Texas Adoption Study

	Round 1		Round 2	
	Mean *r*	Mean no. of pairs	Mean *r*	Mean no. of pairs
Adoptive parent and adoptee	.16	250	.08	250
Unrelated siblings reared together	.16	91	−.01	91

Note. The data are from Loehlin, Horn, & Willerman (1989).

vocabularies, intellectual tastes and preferences, and access to good schools of the professional class. The aggregate data presented first in Table 4.1, with the rearing environment effects of .19–.34, raise bright hopes for rearing influence. However, the results from the Minnesota, Colorado, and Texas adoption studies, and from other adoption work not detailed here, inevitably reduce the estimate of rearing influence to some small value when rearing environments fall in the range from the working to professional social classes. Indeed, the consensus estimate is *zero* influence of rearing variation for adolescents and young adults (McGue, Bouchard, Iacono, & Lykken, 1993).

Although these are not directly comparable to correlational data, the mean IQ scores of adoptive children are not any more encouraging for a belief in IQ malleability (Locurto, 1990). The mean IQ of adoptees across eight adoption studies was 106, only six points greater than the population mean of 100. It was considerably less than the mean of the biological children of adoptive parents (114 in three studies) with whom the adoptees were raised, suggesting that they failed to reach the intellectual potential afforded by their rearing environments. If we ignore the possible methodological flaws detailed in Locurto's article, the adoption studies indicate gains or losses in only the 10- to 12-point range—a rearing influence "far less than the predictions made during the early 1960s by Hunt . . . and Bloom . . . who spoke of changes on the order of 50 to 70 points," and "more cautious still than recent estimates which have been described as occupying a more middle ground but which nonetheless average 20 to 25 points" (Locurto, 1990, p. 290).

This lack of rearing influence may come as a shock to readers used to hearing the successes of compensatory educational programs for young children touted in the popular press. The sad reality is that findings from compensatory educational programs do not contradict the present conclusions, because the universal pattern is only a short-term gain in IQ (on the order of 10–20 points immediately after a compensatory educational program), followed by the loss of these IQ gains in first, second, or third grade. In the winter 1969 issue of the *Harvard Educational Review*, Arthur Jensen became an apostate to the educational establishment by challenging the value of these intervention programs:

> The chief goal of compensatory education—to remedy the educational lag of disadvantaged children and thereby narrow the achievement gap between "minority" and "majority" pupils—has been utterly unrealized in any of the large compensatory education programs that have been evaluated so far. (cited in Jensen, 1972, p. 69)

At the time, Jensen was pilloried for disputing the conventional wisdom with such frank and uncompromising language, but his iconoclastic views no longer lie outside the mainstream (Spitz, 1986; Haskins, 1989).

Consider first Haskins's (1989) sympathetic review of compensatory education outcomes. He concluded that both for Head Start and for "model" compensatory education programs, "gains on standardized IQ and achievement tests as well as on tests of socioemotional development decline within a few years (or even less in the case of Head Start studies)" (p. 278). And he went on to caution that it has not been proven on the basis of available evidence that Head Start-type programs improve either the school performance or life chances of poor children, noting that "policy recommendations call for humility" (p. 280).

In a review of broader scope and more critical intent, Spitz (1986) considered efforts to raise the IQs of mildly retarded individuals (IQs = 50–75) from the 1800s to the present, noting throughout a cycle of bright hopes followed by profound disappointments as program after program was found to be either fraudulent or empirically unfounded. Under his cold gaze, even the claims of "model" compensatory educational programs seem hollow. For example, in the widely publicized Perry Preschool Program, 58 disadvantaged black children aged 2–4 years in the experimental group received 2 years of a special preschool program, whereas 65 children in the control group received none. The experimental group showed a rise in the typical IQ after the program, but a fall by 9 to 10 years of age, so positive reports of the study have since focused on late-adolescent (19-year) outcomes that appear on the surface to be more favorable. Haskins (1989) picked several such outcomes from the Perry study to report:

> By the time they reached age 19, 31% of Weikart's [Perry] program children as compared with 51% ($p < .02$) of control children had been arrested or detained. Moreover, 12% of program children but 25% of control children had been arrested three or more times, and program children had 42 arrests for nonminor crimes whereas controls had 80 such arrests. (p. 276)

But Spitz (1986) added to these observations other findings from the original research reports:

- The average grade of the experimental group was C; that for the control group was C–.
- Both groups earned poverty-level wages.

- The groups did not differ in the number of criminal *convictions*.
- The experimental and control groups had equal IQs.
- Although 35% of the control group versus 15% of the experimental group were classified as mentally retarded, the experimental children spent more time receiving "remedial education."

Certainly neither the Perry project nor others like it have broken the cycle of poverty. Spitz (1986) concluded that people have taken the self-evident fact that extreme social isolation or physical barriers (e.g., deafness) can lead to reversible mental retardation, and have come to the logical but not empirical conclusion that most intellectual retardation in children living in economically poor but socially rich social environments is therefore reversible. This last belief has been unsupported by 180 years of efforts in compensatory interventions.

The temporary rise in IQ produced by early intervention programs still requires explanation. It may be partly an exposure effect, as is the early environmental advantage of adopted children placed in adoptive homes of higher socioeconomic status. In this case, the advantage should diminish as other children receive equivalent exposures at later ages in normal school and home settings. Other processes, though, may contribute to perceived program influence. One is a statistical artifact called "regression to the mean," whereby a group of children selected for very low test scores tends to score higher on retaking the test without any intervention. I call statistical regression the "George Steinbrenner effect," after the owner of the New York Yankees who liked to buy the league's best batters from other teams, only to find the next year that their batting averages failed to meet the banner performance of the previous one; they were still good players, but Lady Luck chose someone else. In the case of low-scoring test takers, performance improves because any bad luck resulting in an extremely low score does not select the same children again; of course, the children are still intellectually retarded, but they score 5–10 points higher on the IQ test on the second test occasion than on the first. Finally, some programs teach the test or frankly give answers to test questions—a method that can raise test scores at any level (Spitz, 1986).[1]

In an adoption study with aims like those of early intervention studies, two French scientists looked at the intellectual outcomes for a small group of children (average age = 14 years) born to biological parents of either extremely high or low social class, and then adopted by adoptive

parents of extremely high or low social class (Capron & Duyme, 1989). The four combinations of biological parentage and rearing backgrounds produced a "cross-fostering" design with which to examine the relative impacts of biological and adoptive parentage. For both types of parentage, high social class was advantageous for the IQs of the adoptees, with the environmental difference between the poor and well-to-do families increasing IQ by about 12 points (high social class, IQ = 111.6; low social class, IQ = 99.95). These adoptive placements represented environmental extremes, and we see that they had an effect (although the nature of the environmental influence remains unknown and could be anything from diet to schooling; McGue, 1989). However, the effect size (12 points) is more modest than many policy makers would have imagined.

In summary, the accumulated data fail to demonstrate that variation in rearing influences IQ, once children are older. Nor do compensatory educational intervention programs offer any "quick fixes" for the low IQs of children reared in poverty. No large-scale adoption study has observed children from the poorest areas raised later in the richest ones, but the few data that do exist suggest only modest IQ gains. If there are limits to malleability, why should social scientists attempt to deny them, any more than a physical scientist would want to wish away the principles of theromodynamics that outlaw the existence of perpetual motion machines? We live in a world of very real biological and physical limits, even if the fecundity of human imagination is boundless. It should be remembered, though, that "retardation" on IQ tests is not equivalent to failure in life. As Spitz (1986) has observed:

> It has been shown that even when IQ remains the same over a 40-year period, most persons in the mildly retarded and borderline range of intelligence are no longer labelled retarded when they leave school and enter the work force. . . . They are better able to adjust to the lesser intellectual demands of unskilled and semi-skilled jobs than to the academic demands of the classroom. (p. 219)

The other lesson of this review is that exposure to intellectual stimulation is crucial for intellectual development. As Ceci (1990a) maintains, increases in vocabulary, problem-solving skills, and general knowledge all depend on environmental exposures—but on ones *outside* the family (particularly schooling, but also television, peers, and personal efforts to improve oneself intellectually). The rate of intellectual growth does not appear to be primarily limited by the number or quality of exposures available to the intellectually curious child. Moreover, as part of rearing environment, schools of widely different per-student dollar expenditure are functionally equivalent in their influence on the rate of intellectual development. Thus as children grow older, phenotypic IQ becomes much more diagnostic of genotypic potential and much less diagnostic of family rearing environments. These facts imply that children who differ in IQ make more or less *effective* use of their intellectual environments—a supposition supported by information-processing approaches to the analysis of IQ.

Studies of IQ, Speed, and Capacity

In successive generations of computer equipment, users have noticed two areas of dramatic improvement: speed and capacity. The clock cycle of a computer is a timed electrical circuit that coordinates all activities of its memory and its central computational processor. Improvements in computer chip design have decreased the clock cycle, so that many more activities can be run in the same period of time on a newer computer than on an obsolescent model. Computer programs are brought into the active memory of the computer from some type of long-term storage device (e.g., magnetic disk, optical disk), and the size of a program that a computer can run cannot exceed the capacity of its active memory store. With the huge increase in active memory capacity in the last several generations of computers, larger programs with greater capabilities and more features can now be run—programs that would disable a computer with less of this capacity.

Although the computer is mechanically very different from the mind—a collection of transistors and wires as opposed to nerve cells and axons—some differences in brain "wetware" may account for differences in IQ. Indirect evidence for this thesis can be found in cognitive science, which probes the operation of the brain through elemental tasks that measure the processes of cognition, including the speed and capacity of mental operations. We now have evidence that people who score higher on traditional tests of IQ tend to share two advantages over people who score less well: Their minds (or brains) are faster and have greater working memory capacity. A full review of the human information-processing literature is beyond the scope of this book, but some highlights can serve to illustrate the growing connections between older, psychometric notions of intelligence and information-processing theories concerning the disassembly of complex thoughts into simpler, component processes.

Thoughts, though quick, are not instantaneous. In less than a second, the brain can send commands to the feet that propel a world-class basketball player 3 feet into the air. For a full mental operation, 0.001 second is not enough time, but 0.2 second is. As children get older, their brains operate more rapidly; their speed on a variety of timed tasks has been found to improve developmentally. Kail (1991) discovered a natural developmental law: a single curve describing the speeding up of mental operations across diverse cognitive and noncognitive tasks, such as tapping a finger, mental addition, quickly releasing a button, and picture matching. On all tasks, improvement was "exponential," meaning that most of the increase in response speed occurred early (between the ages of 7 and 13 years), followed by a slowing of the rate of improvement until the rate leveled out during the later teens.^{2}

Figure 4.1 shows the developmental change in reaction times on Kail's tapping task—tapping a key as rapidly as possible with one finger. Seven-year-olds emitted a tap about every 0.4 second; 21-year-olds, about every 0.2 second. Kail's interpretation of these results uses a computer metaphor like the one I have offered above:

> If two computers have identical software but one machine has a slower cycle time (i.e., the time for the central processor to execute a single instruction), that machine will execute all processes more slowly. . . . The human analog to cycle time might be the time to scan the productions . . . in working memory. . . . (1991, p. 266)

If development produces greater intelligence and also produces greater speed of response, then perhaps at any one age response speed will correlate with IQ—an inference now confirmed in studies using many different reaction time paradigms. Not that reaction time explains all the variation in IQ; the information-processing basis of IQ is likely to be composed of multiple processes, each one making its own independent contribution to intelligence.

To illustrate the IQ–reaction time association, I use the Hick task, a simple test of reaction time that requires the subject to lift his or her finger from a "home" button when one of a set of lights comes on and then to push another button to terminate the light (see Figure 4.2). "Reaction time" is how long it takes to lift the finger. "Movement time" is how long it takes to turn the light out (i.e., to move from the "home" button to the one next to the light). Although this is not self-evident,

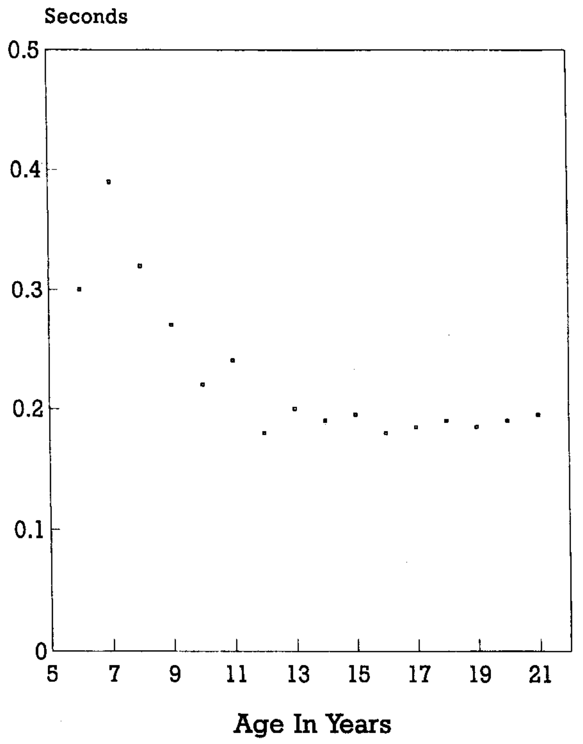

FIGURE 4.1. The relation of speed of finger tapping and age. Adapted from Kail (1991). Copyright 1991 by the American Psychological Association. Adapted by permission.

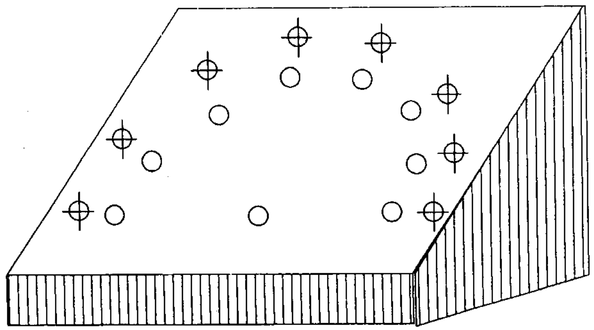

FIGURE 4.2. An apparatus for testing reaction time. Adapted from Jensen (1987). Copyright 1987 by Ablex Publishing Corporation. Adapted by permission.

reaction times are slowed by the mere presence of several lights: Reaction times are slower when six or eight lights are showing on the apparatus, as opposed to just two or four lights.

Faster movement and reaction times on the Hick task were associated with higher IQ scores (Jensen & Vernon, 1986). These associations became stronger when the apparatus was made more complex (six or eight lights) than when it was simpler (two or four lights). Averaged over three studies, the Hick reaction times correlated –.15, –.23, –.27, and –.40 with IQ for two, four, six, and eight presented lights, respectively. The Hick task is just one of many simple tasks (in the sense that most respondents have little trouble making correct responses) on which faster responding has been associated with higher IQ scores (Vernon, 1987).

In research on infants, the use of tasks closer to the physiological bases of intelligence has resulted in a breakthrough—the prediction of childhood IQ from tests given to infants under 1 year of age. Whereas traditional infant tests assessed motor development and (crudely) attention, and failed to reliably predict later IQ in early childhood, the new tests focus on infants' cognitive responses to simple stimuli, which predict later intelligence. One robust measure of abilities in the first year is "duration of fixation" (Colombo, Mitchell, Coldren, & Freeseman, 1991). Older infants look more briefly at a novel stimulus than younger infants do. Corresponding with this developmental trend, smarter babies also have shorter fixation times than duller ones in a simple habituation task, such as viewing a projected color slide of a woman's face. Surreptitiously, the duration of a baby's gaze at the woman's face is recorded; this is averaged over all looks until interest in the face stimulus has been lost (i.e., until the baby has habituated to the stimulus). At 4 months of age, the duration of gaze ranges from about 5 seconds to 2 minutes per fixation. Babies with quick fixation times ("short-look" babies) outperform babies with long fixation times ("long-look" babies) on other cognitive tasks and on later IQ tests. Although the exact process underlying these performance differences is still being investigated, one interpretation is that it represents a global superiority in information processing time: ". . . the findings lend support to the interpretation that fixation duration reflect[s] differences in the speed with which visual stimuli are processed, such that short lookers simply process stimuli more rapidly than long lookers" (Colombo et al., 1991, p. 1255).

Although speed is good, it is not the sole component in an explanation of intellectual abilities. Cognitive capacity—the ability to juggle several pieces of information simultaneously in working memory—is also important. One simple task of memory capacity is Digit Span, one of the subtests of the WAIS and WISC described earlier. Like processing speed, Digit Span performance increases developmentally: At the start of elementary school, children can repeat back only four to five digits immediately after hearing them, but high school students can repeat back six to eight digits. Better reliability can be obtained by combining several measures of working memory capacity. For example, another simple measure is alphabet recoding. Several letters are computer-presented, and the one that follows next in the alphabet must be supplied. The computer might show the following: S L R + 1 = ? For a correct response, these letters must first be reordered in memory (L R S + 1 = ?), leading to the answer, T. Holding and reordering the letters in memory tax working memory capacity, and thus test for the relevant ability.[3]

In contrast to the mentally taxing but intellectually barren tests of working memory, tests of reasoning ability seem to capture the essence of human intelligence. What is poetry without deftly drawn analogies and metaphors? Among the most widely used tests of reasoning abilities are verbal analogies. For young children, these may be mundane ("Brother is to boy as sister is to _________"). At the college level, they may be more subtle and sophisticated ("Bench is to judge as pulpit is to _________") or more poetic ("Sand is to beach as star is to _________"). Other higher-order reasoning tasks would include the use of mathematics, grammatical understanding, and reasoning about numbers. The ability to reason well, in general, correlates with measures of "crystallized" intelligence such as general word and science knowledge—again, the generality of human intelligence (g).

In an article provocatively entitled "Reasoning Ability Is (Little More Than) Working-Memory Capacity?!," the intercorrelations of sets of working memory tests and sets of reasoning tests in four separate studies were explored (Kyllonen & Christal, 1990). The amazing result was that the simple tasks of working memory correlated, as a set, about .80 with a set of reasoning tests. Working memory and the capacity to reason abstractly are therefore virtually identical.

In developing a general theory of working memory capacity, Just and Carpenter (1992) were able to simulate differences between good and poor comprehenders of verbal material with a computer program. Good comprehenders were assumed to possess greater working memory capacity. Just and Carpenter's theory predicted the specific kinds of verbal material that overtax the abilities of those individuals with less memory capacity than others. For instance, sentences with embedded clauses (e.g., "The reporter *whom the senator attacked* admitted the error") pose greater information-processing demands than simple ones, and individuals with less memory capacity have more difficulty with these sentences than those with greater memory capacity. Just and Carpenter's computer program was able to simulate the exact point in a sentence at which comprehension is most influenced by differences in memory capacity. On some sentences, greater memory capacity leads to *longer* processing time, because it allows the individual to explore possible interpretations that are simply missed by individuals with less capacity. Finally, because performance degradation and enhancement, under different conditions of verbal complexity, are exact processes, this theory tends to rule out motivational explanations sometimes offered for a lack of comprehension of verbal material.

In summary, both speed and capacity are essential components of intelligence as measured in traditional tests of intellectual abilities. Behavior geneticists have recently turned their attention to the genetics of information-processing speed (Baker, Vernon, & Ho, 1991). Their main discovery has been that variation in the more componential information-processing abilities, like IQ score variation, is heritable (but with little evidence of rearing influence). The statistical association of the componential abilities with IQ scores appears to be attributable to the same set of genes underlying both phenotypic measures of performance; in other words, the same physiology that affects reaction time and memory capacity also affects IQ. But what is this physiology? I next turn briefly to this question.

Preliminary Research on Physiology and IQ

The ultimate biological understanding of individual differences in IQ will come only when both the underlying genes and the physiological basis of human intelligence have been discovered. Although the 1990s have been called the "decade of the brain" in neuroscience research, progress toward understanding the biology of human intelligence is just now beginning (Matarazzo, 1992).

One correlation is striking: that between brain size and intelligence. This correlation is remarkable because, *a priori*, it would seem unlikely that the gross anatomy of the brain would predict individual differences in IQ in the normal range, where no brain damage is evident.

The mere mention of this association, however, conjures up the most reprehensible forms of biological determinism and the (in retrospect) ludicrous claims of 19th-century scientists that every aspect of human character could be inferred from the shape of the cranium. Gould (1981) has taken some delight in dismantling the 19th- and early 20th-century evidence on this association. On postmortem examination, the brain sizes of men of eminence violated the hypothesis that bigger is always better. Gould cites the example of Anatole France, who in 1924 "opted for the other end of Turgenev's [brain size > 2,000 grams] fame and clocked in at a mere 1,017 grams" (p. 92). If nothing else, Gould's summation of the 19th-century data shows that the correlation of brain size and IQ is far from perfect; however, one would not expect a single parameter of brain anatomy or function to predict more than a small fraction of total IQ variability. To address the issue, one needs to collect better data than postmortem results on elderly novelists—results confounded by different procedures for preparing the brain, the decrease in brain size associated with aging, and the haphazard sampling of brains. With the new technologies of brain imaging, better methods now exist for examining the brain size–IQ association, and such an empirical question should be addressed by more refined technologies and data collection. Gould's approach—embarrassing the 19th-century advocates of the IQ–brain size association—is a kind of science that would make Francis Bacon roll over in his grave.

The brain size–IQ association has been recently replicated by means of magnetic resonance imaging (MRI)—a medical technique for visualizing the anatomy of the brain within a living person, which can be applied to taking measurements of brain areas in healthy people (Andreasen et al., 1993; Willerman, Schultz, Rutledge, & Bigler, 1991). In the study by Willerman and his colleagues (1991) forty students at the University of Texas–Austin were put on an MRI machine at a local medical facility. Each MRI brain image caught a slice of the brain about 0.2 inch thick. The students selected were either very bright (IQs ≥ 130) or close to average (IQs about 90). The sample selection ruled out possible confounding explanations of brain size, such as variation in body size: The average-IQ students were actually taller than the high-IQ students, and associations of brain size with height or weight were statistically controlled even though they were quite weak (*r* = .09 to .10). Both groups came from middle-class backgrounds (the parents had an average education level of 2 years of college), rendering undernutrition explanations of brain size variation implausible.

Within each "slice" of brain, a computer counted the total amount of dark area containing brain cells, and this served as an index of brain area. As shown in Figure 4.3, high-IQ students had larger brains (adjusted for body size) than average-IQ students; moreover, males had larger brains than females.[4] The magnitude of the brain area difference varied with brain region, with the largest brain area differences in the brain regions that include the neural substrates of language. The overall correlation between brain area and IQ was .51, accounting for 26% of IQ variance. Using a statistical adjustment yielded a correlation of .35

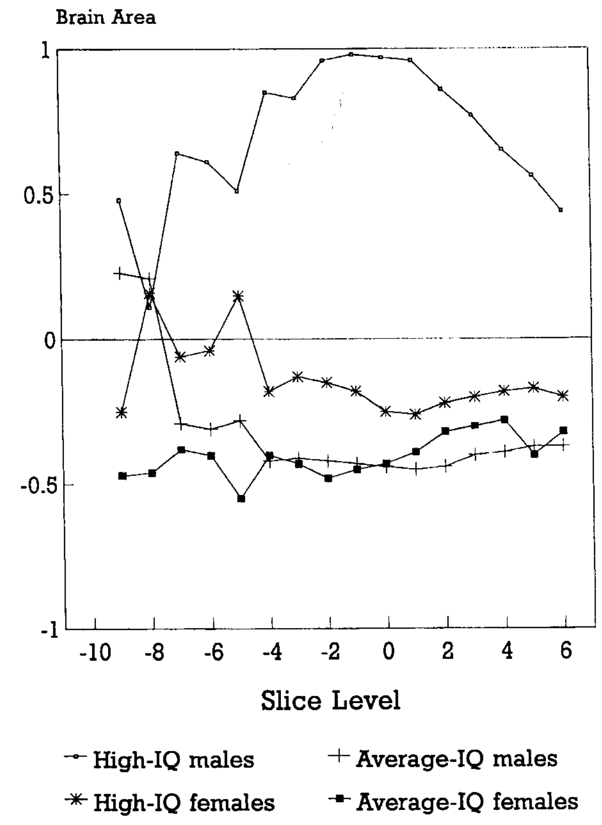

FIGURE 4.3. The relationship between IQ level and brain area. Adapted from Holden (1991). Copyright 1991 by the American Association for the Advancement of Science. Adapted by permission.

between brain area and IQ in more representative samples. The exact explanation for the area difference is, at this time, unknown; it could reflect greater myelination of brain axons, a greater number of nerve or glial cells, less neuronal death in the brains of brighter individuals, or a combination of processes.

Another new imaging technique—positron emission tomography (PET)—also yields physiological correlates of intelligence (Haier et al., 1988). PET scanning produces images of areas of the brain that are more or less metabolically active, according to how much they draw radioactive sugar from the blood for cell metabolism. Higher-IQ subjects (again, all subjects put through the PET scanning machine had normal-range IQs) used less sugar in those brain regions involving higher cognitive functions while they solved IQ test items. Thus, their brains appeared to be more efficient in the processing of information than those of lower-IQ individuals.

Given the kinds of results just outlined, neuroscience is clearly on a frontier of discovery of the biological basis of intelligence. As Haier (1990) has said in an article addressed to psychologists, "Sooner or later, however, all psychology research leads into the human brain. The search for brain mechanisms that are relevant to intelligence is no more reductionistic than a search for cultural or social mechanisms" (p. 373).

Genes and IQ: Possibilities for Future Research

The genes determining IQ lie buried among the 100,000 genes estimated to exist in our 46 chromosomes. Even if two-thirds of human genes were monomorphic (and hence unable to contribute to variation in IQ), the remainder of 33,000 genes would be a vast domain to search. To use a simile employed in Chapter 2, the IQ-determining genes are like needles in a haystack.

As of this writing, the IQ genes remain undiscovered, but strategies exist for eventually locating them. Already, more than 200 genes expressed solely in the human brain have been placed into bacterial colonies from which they can be extracted and used to identify the genotype of an individual. If genotypes are known for brain-expressed genes, their association with IQ scores can be examined directly by correlating individuals' genotypic scores (e.g., AA = 1, Aa = 0, and aa = –1) against their IQs. Genotypes that predict IQs can be flagged for further investigation. Known genotypes can also be used in linkage analysis, in which the association of particular alleles with IQ is followed through family pedigrees.

At the present time, it is difficult to know whether we should be optimistic or pessimistic about these efforts to find specific genes. True, a small number of gene pairs can generate tremendous genetic variability. As few as five gene pairs, with some measurement error added, could conceivably produce a normal-looking trait distribution, with each pair contributing about 20% of the total genetic variability. Yet it is hard to imagine that as few as five loci contribute all genetic variability in a trait as complex as IQ; more likely, many more gene pairs are responsible for IQ variation. If specific loci contributing to IQ are to be detected successfully, they must contribute at least 1–3% to the genetic variation in IQ, and preferably more. Given that it is unlikely that all genetic loci have *equally* small effects, there is hope that some loci will contribute more than others and thus will be over a threshold of detectability. We can be cautiously optimistic that some loci contributing to IQ variability will be discovered with molecular genetic techniques, but no single, spectacular discovery is to be expected.

A Model of Intelligence

Figure 4.4 summarizes many of the ideas presented in this chapter. The left side of the figure depicts the "ultimate" causal influences on IQ variation: unshared experiences and genes. Genes influence the development of the nervous system, as well as its ability to interact with the broad social environment, by creating nervous system differences in speed, capacity, and perhaps as-yet-undiscovered mental operations. Once exposed to a social environment, these physiological differences influence variation in the latent trait of "intelligence" that is assessed through verbal and mathematical test scores (boxes on the right).

Another influence on the test scores themselves is measurement error, which includes everything from mistakenly darkening the wrong box on an answer sheet to unexpected social influences such as a moment's distraction. Thus test scores do not absolutely indicate the genetic characteristics of any individual, although they are strongly associated with them. Measurement error is represented by the arrows entering the "Verbal Test Score" and "Math Test Score" boxes from above and below.

Rearing influences have been omitted from Figure 4.4 because, in

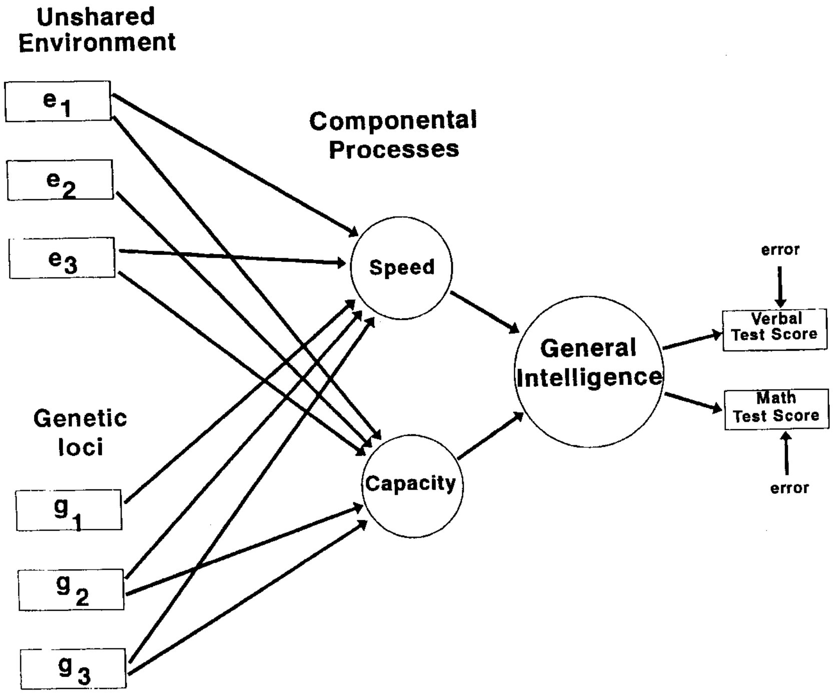

FIGURE 4.4. A model of general intelligence.

the range from the working to professional classes, they wash out as children enter their teenage years. Contrary to what is widely believed by the U.S. public, the literature review in this chapter shows that home environments from that of a factory or clerical worker to that of a doctor or lawyer offer *equivalent* environmental stimulation for intellectual growth. In concrete terms, a near-zero IQ correlation for older "unrelated siblings reared together" means that two (adoptive) children in a doctor's family do differ on the average by as much as 17 IQ points (the average difference of randomly paired children). And a lack of association between adoptive parents' and adolescent adoptees' IQs means that the adoptee raised by a carpenter has a 50–50 chance of obtaining a higher IQ score than a lawyer's adoptee. Some three-quarters of American families fall into this range of social class categories, where rearing effects have been proven weak, despite massive differences in levels of funding for their public schools and massive differences in home intellectual environments. Of course, I do not intend to imply that intelligence develops without exposure to schools, books, television shows, magazines, and good conversations. I mean simply that these exposures can be found in three-quarters of American society in significant abundance to support full intellectual growth.[5]

I know that my conclusion is counterintuitive, because we can listen to the differences in speech patterns in working- and professional-class parents; because we are aware of their different habits and life interests; and because we can see a resemblance of a bright child to professional-class parents. How easy it is, then, to fall into the trap of inferring causality from behavioral resemblance—to assume that because a child is like a parent in intellectual abilities, some parental action has produced this outcome. I am reminded of a news report about an Asian boy who won a prestigious Westinghouse award for achievement in science. The reporter constantly referred to the work ethic of Asian families and the strong encouragement of achievement in Asian culture. But this adolescent boy politely reminded the reporter that his own efforts deserved credit—that excellence in science was a personal goal he had long sought. When social sciences offers counterintuitive discoveries, the lay public, not to mention some social scientists, have difficulty grasping them because reasoning and gut reaction may differ. These discoveries also oppose widespread cultural beliefs that parental treatments environmentally mold children's traits. Cultural beliefs, however ancient and pervasive, can be misleading. We must instead dependably infer causation from experimental and quasi-experimental studies, as we have been painstakingly trained to do in the conduct of science.

Figure 4.4 omits the process of gene–environment correlation, such as that of the Asian boy determined to excel in science who read advanced science texts, or the chess prodigy studying position after position and badgering adults for games. Gene–environment correlation has not been shown diagrammatically because it can be read in the figure as genetic variation: The genotype and environment become so correlated as to become inseparable by ordinary experimental methods.

The only environmental influence shown explicitly in the diagram is unshared environment. Unshared experiences certainly influence IQ: MZ twins differ (nongenetically) by 6–8 IQ points, and not all of that difference is attributable to measurement error. My lack of attention to unshared environment reflects the difficulty of identifying just what these environmental influences are. These influences are not the active efforts by which children increase their knowledge; as mentioned earlier, active gene–environment correlations are associated with genotypes and are counted in genetic variation in most behavior genetic models. Rather, they influence each child uniquely, are uncorrelated (by mathematical definition) with family background, and are also uncorrelated with genotype (a good genotype does not accrue more good unshared effects than a poor one). And they may consist of both social and biological processes. During embryogenesis, randomly occurring environmental events trigger different developmental pathways, so that even the nervous systems of identical twins fail to match exactly at birth. Random somatic mutations in DNA can further slightly reduce the identity of MZ twins' genotypes in all body cells. Such environmentally induced differences in brain function may contribute to IQ variation. Moreover, numerous social influences may contribute to the unshared effect: an inspiring teacher who, at the right time and with the right child, fires enthusiasm for an intellectual subject; a child's stumbling on a personal area of interest (e.g., a future paleontologist's initial fascination with dinosaurs); an unexpected failure on an important test that leads a child to abandon one academic route for another; a car accident, resulting in debilitating brain damage; and many other, more minor environmental influences that lead children apart, step by step, year after year. Unlike family backgrounds (for which variation in environments are easily discernible, although they lack effects on IQ variation), the unshared experiences have effects on IQ but are difficult to observe and measure.

I have focused mainly on IQ because IQ tests have been the center of controversy for so long. The same conclusions stated for IQ, however, apply with equal force to academic achievement in general. Indeed, IQ and achievement tests fall on a continuum of item specificity. General information items on IQ tests are ones that come up more frequently than items that must be learned in a specialized class (e.g., "Who is Charles Darwin?" vs. "Who ruled England in 1350?"); the problem-solving items require less specialized knowledge about a particular field than would an achievement test in physics or chemistry. No IQ test is independent of cultural experience, but some tests make more specialized demands than others. Because academic achievement is so dependent on underlying intelligence, however, conclusions about components of variance are not different for the two types of outcomes. Scarr and Weinberg (1983) found that unrelated siblings correlated –.11 and .11 for math and reading achievement, respectively, as compared with .35 and .27 in a matched sample of biological siblings.

This chapter has not discussed the policy implications of these findings. Understanding that for most individuals IQ score differences represent mainly genetic differences, with a pound of unshared environment and several ounces of measurement error, does not mean that IQ tests should necessarily be used either in the selection of individuals for jobs or in the placement of children into special classes for the educationally retarded. Such decisions must reflect our values and goals as a society. Nonetheless, any reasonable choice of policy alternatives must acknowledge that ignoring IQ differences has potential costs for economic productivity, as mentioned earlier, and that variation in rearing has limited effects. Let us not, as social scientists, sell the "snake oil" of unrealistic expectations for changing educational performance merely by placing children in schools with Olympic-sized swimming pools and with a cadre of well-educated teachers. Nature develops via nurture, but we must be modest about our control over children's fates while making our best efforts to secure their futures.

Notes

[1] Occasional newspaper stories suggest that some reports of rapidly rising test scores may be fraudulant. For instance, rising test scores in an upper-middle-class school on Chicago's North Side led to the following allegations against the principal, Linda Chase:

> Two third grade teachers . . . testified that last spring Chase gave them an essay question used on a standardized written examination and told them to familiarize students with the question before the exam . . . a third grade teacher said that four years ago Chase told her to change answers on completed tests . . . (*Arizona Daily Star*, 1992, p. 9)

[2] My example deals with improvement during childhood in mental speed and capacity. But a less sanguine analysis can be made of the latter part of the lifespan: During adulthood, decreases in speed and working memory capacity may be primarily responsible for declining reasoning and problem-solving powers (Salthouse, 1991).

[3] In his book *On Intelligence . . . More or Less,* Ceci (1990a) attacks the line of reasoning put forward in this chapter. One of the flaws of his argument—his neglect of temporal order—has been noted earlier in this chapter. Another flaw—his lack of appreciation of environmental variance estimates in behavior genetic studies—is, of course, a broad theme of this book. But Ceci is also critical of information-processing research because massive training can improve performance on some information-processing tasks. For example, after hundreds of training trials, a college student managed to increase his digit span memory from

the usual 6–8 digits to 80 digits! Eleven-year-old children, given 3,000 training trials, managed to rotate images of letters and numbers mentally back to their original orientations as quickly as adults did. But the way in which tasks are done mentally also changes with extreme training, as Kail (1991) has commented: "Greater task experience means that performance is more likely to reflect retrieval of a stored response, which means that speed is no longer constrained by available resources" (p. 266).

A point-by-point rebuttal to Ceci's book would take this work too far afield. I do not deny that much remains to be learned about human information processing—and the tasks used, although simple on the surface, are not simple at the level of mental actions. But I think Ceci himself senses that his position is a defensive one, because the argument for a biological basis to intelligence has been strengthened by the new evidence. In an editorial in *Intelligence*, he complained:

> It is not a simplification to assert that the once disreputable slogan "biology is destiny" has returned with a vengeance. As we enter the 1990s the evidence for this position is more abundant and more interconnected than was true when Herrnstein proffered a version of it 20 years ago. (1990b, p. 143)

The interested reader may peruse references cited in this chapter and in Ceci's (1990a) book to form an independent judgment of what the evidence means.

[4] A sex difference in brain size, after height and weight were controlled for, was an unexpected result. Willerman et al. (1991) cite some evidence that men and women have the same number of cortical neurons, despite differences in overall brain size. There is increasing evidence for sex differences in brain organization and function; a popular account of this research is given by Moir and Jessel (1991).

[5] Flynn (1987) documented IQ gains ranging from 5 to 25 points in the post-World War II period in 14 industrialized countries. If real, these historical gains may have many causes, including biological ones (e.g., better nutrition and the conquest of childhood infectious diseases). Further exploration of historical IQ change is a worthy research endeavor.

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