Correction to nisbett et Al. (2012).

Article *in* American Psychologist · February 2012

DOI: 10.1037/a0027240 · Source: PubMed

THIS ARTICLE HAS BEEN CORRECTED. SEE LAST PAGE

Intelligence

New Findings and Theoretical Developments

Richard E. Nisbett — *University of Michigan*
Joshua Aronson and Clancy Blair — *New York University*
William Dickens — *Northeastern University*
James Flynn — *University of Otago*
Diane F. Halpern — *Claremont McKenna College*
Eric Turkheimer — *University of Virginia*

We review new findings and new theoretical developments in the field of intelligence. New findings include the following: (a) Heritability of IQ varies significantly by social class. (b) Almost no genetic polymorphisms have been discovered that are consistently associated with variation in IQ in the normal range. (c) Much has been learned about the biological underpinnings of intelligence. (d) "Crystallized" and "fluid" IQ are quite different aspects of intelligence at both the behavioral and biological levels. (e) The importance of the environment for IQ is established by the 12-point to 18-point increase in IQ when children are adopted from working-class to middle-class homes. (f) Even when improvements in IQ produced by the most effective early childhood interventions fail to persist, there can be very marked effects on academic achievement and life outcomes. (g) In most developed countries studied, gains on IQ tests have continued, and they are beginning in the developing world. (h) Sex differences in aspects of intelligence are due partly to identifiable biological factors and partly to socialization factors. (i) The IQ gap between Blacks and Whites has been reduced by 0.33 SD in recent years. We report theorizing concerning (a) the relationship between working memory and intelligence, (b) the apparent contradiction between strong heritability effects on IQ and strong secular effects on IQ, (c) whether a general intelligence factor could arise from initially largely independent cognitive skills, (d) the relation between self-regulation and cognitive skills, and (e) the effects of stress on intelligence.

Keywords: intelligence, fluid and crystallized intelligence, environmental and genetic influences, heritability, race and sex differences

In 1994, a controversial book about intelligence by Richard Herrnstein and Charles Murray called *The Bell Curve* was published. The book argued that IQ tests are an accurate measure of intelligence; that IQ is a strong predictor of school and career achievement; that IQ is highly heritable; that IQ is little influenced by environmental factors; that racial differences in IQ are likely due at least in part, and perhaps in large part, to genetics; that environmental effects of all kinds have only a modest effect on IQ; and that educational and other interventions have little impact on IQ and little effect on racial differences in IQ. The authors were skeptical about the ability of public policy initiatives to have much impact on IQ or IQ-related outcomes.

The Bell Curve sold more than 300,000 copies and was given enormous attention by the press, which was largely uncritical of the methods and conclusions of the book. The Science Directorate of the American Psychological Association felt it was important to present the consensus of intelligence experts on the issues raised by the book, and to that end a group of experts representing a wide range of views was commissioned to produce a summary of facts that were widely agreed upon in the field and a survey of what the experts felt were important questions requiring further research. The leader of the group was Ulrich Neisser, and the article that was produced was critical of *The Bell Curve* in some important respects (Neisser et al., 1996). The article was also an excellent summary of what the great majority of experts believed to be the facts about intelligence at the time and important future directions for research.

Fifteen years after publication of the review by Neisser and colleagues (1996), a great many important new facts about intelligence have been discovered. It is our intent in this review to update the Neisser et al. article (which remains in many ways a good summary of the field

This article was published Online First January 2, 2012.

Richard E. Nisbett, Institute for Social Research, University of Michigan; Joshua Aronson and Clancy Blair, Department of Applied Psychology, New York University; William Dickens, Department of Economics, Northeastern University; James Flynn, Department of Psychology, University of Otago, Dunedin, New Zealand; Diane F. Halpern, Department of Psychology, Claremont McKenna College; Eric Turkheimer, Department of Psychology, University of Virginia.

The writing of this article and much of the research that went into it were supported by a generous grant from the Russell Sage Foundation, by National Institute on Aging Grant 1 R01 AG029509-01A2, and by National Science Foundation Grant 2007: BCS 0717982. The views presented here are not necessarily those of the National Science Foundation.

We thank Angela Duckworth, Richard Haier, Susanne Jaeggi, John Jonides, Scott Kaufman, John Protzko, Carl Shulman, Robert Sternberg, and Oscar Ybarra for their critiques of an earlier version of this article.

Correspondence concerning this article should be addressed to Richard E. Nisbett, Institute for Social Research, 3229 East Hall, University of Michigan, Ann Arbor, MI 48109. E-mail: nisbett@umich.edu

Vol. 67, No. 2, 130–159 DOI: 10.1037/a0026699

of intelligence). There are three chief respects in which our review differs importantly from that of Neisser and colleagues: (a) Due in part to imaging techniques, a great deal is now known about the biology of intelligence. (b) Much more is known about the effects of environment on intelligence, and a great deal of that knowledge points toward assigning a larger role to the environment than did Neisser and colleagues and toward a more optimistic attitude about intervention possibilities. (c) More is now known about the effects of genes on intelligence and on the interaction of genes and the environment. Our article also presents a wide range of new theoretical questions and reviews some attempted solutions to those questions. We do not claim to represent the full range of views about intelligence. We do maintain, however, that few of the findings we report have been widely contradicted. Where we are aware of controversy, we provide sources where readers can be exposed to alternative views. We acknowledge that the theoretical questions we raise might not be the ones that every expert would agree are the most important ones, and we recognize that not every expert will agree with our views on these questions. We have referenced alternative views where we are aware that such exist.

The article is organized under the rubrics of genes and the environment, new knowledge about the effects of the environment, new knowledge about interventions, the biology of intelligence, group differences in IQ, and important unresolved issues. Our working definition of intelligence is essentially that offered by Linda Gottfredson (1997):

> [Intelligence] . . . involves the ability to reason, plan, solve problems, think abstractly, comprehend complex ideas, learn quickly and learn from experience. It is not merely book learning, a narrow academic skill, or test-taking smarts. Rather it reflects a broader and deeper capability for comprehending our surroundings—"catching on," "making sense" of things, or "figuring out" what to do. (p. 13)

The measurement of intelligence is one of psychology's greatest achievements and one of its most controversial. Critics complain that no single test can capture the complexity of human intelligence, all measurement is imperfect, no single measure is completely free from cultural bias, and there is the potential for misuse of scores on tests of intelligence. There is some merit to all these criticisms. But we would counter that the measurement of intelligence—which has been done primarily by IQ tests—has utilitarian value because it is a reasonably good predictor of grades at school, performance at work, and many other aspects of success in life (Gottfredson, 2004; Herrnstein & Murray, 1994). For example, students who score high on tests such as the SAT and the ACT, which correlate highly with IQ measures (Detterman & Daniel, 1989), tend to perform better in school than those who score lower (Coyle & Pillow, 2008). Similarly, people in professional careers, such as attorneys, accountants, and physicians, tend to have high IQs. Even within very narrowly defined jobs and on very narrowly defined tasks, those with higher IQs outperform those with lower IQs on average, with the effects of IQ being largest for those occupations and tasks that are most demanding of cognitive skills (F. L. Schmidt & Hunter, 1998, 2004). It is important to remain vigilant for misuse of scores on tests of intelligence or any other psychological assessment and to look for possible biases in any measure, but intelligence test scores remain useful when applied in a thoughtful and transparent manner.

IQ is also important because some group differences are large and predictive of performance in many domains. Much evidence indicates that it would be difficult to overcome racial disadvantage if IQ differences could not be ameliorated. IQ tests help us to track the changes in intelligence of different groups and of entire nations and to measure the impact of interventions intended to improve intelligence.

Types of intelligence other than the analytic kind examined by IQ tests certainly have a reality. Robert Sternberg and his colleagues (Sternberg, 1999, 2006) have studied *practical intelligence*, which they define as the ability to solve concrete problems in real life that require searching for information not necessarily contained in a problem statement, and for which many solutions are possible, as well as *creativity*, or the ability to come up with novel solutions to problems and to originate interesting questions. Sternberg and his colleagues maintain that both practical intelligence and creativity can be measured, that they correlate only moderately with analytic intelligence as measured by IQ tests, and that they can predict significant amounts of variance in academic and occupational achievement over and above what can be predicted by IQ measures alone. Early claims by Sternberg were disputed by other intelligence researchers (Brody, 2003; Gottfredson, 2003a, 2003b). Subsequent work by Sternberg (2006, 2007) improved on the original evidence base and showed that measuring nonanalytic aspects of intelligence could significantly improve the predictive power of intelligence tests. See also Hunt (2011) and Willis, Dumont and Kaufman (2011).

The chief measure that we focus on in this article is IQ, because it is for that measure that the bulk of evidence pertinent to intelligence exists. When relevant, we distinguish between IQ and *g*—often identified as the first factor extracted in a factor analysis of IQ subtests and with which all IQ subtests correlate. Many intelligence investigators place great importance on the difference between *g* and IQ on the grounds that *g* tends to predict some academic and life outcomes and group differences better than does IQ and because it correlates with some biological measures better than does IQ (Jensen, 1998). We do not in general share the view that *g* is importantly different from IQ, and we do not interpret correlations between *g* and life outcomes, group differences, and biological measures as having the same import as do many other investigators. Our differences with those scientists will be noted at several points in this article.

An important distinction commonly made in the literature is between crystallized intelligence, *g*(C), or the individual's store of knowledge about the nature of the world and learned operations such as arithmetical ones which can be drawn on in solving problems, and fluid intelligence,

g(F), which is the ability to solve novel problems that depend relatively little on stored knowledge as well as the ability to learn. A test that is often considered the best available measure of g(F) is Raven's Progressive Matrices. This test requires examination of a matrix of geometric figures that differ from one another according to a rule to be identified by the individual being tested. This rule is then used to generate an answer to a question about what new geometrical figure would satisfy the rule. Some of the recent advances in intelligence research, particularly those in the area of the neurobiology of intelligence, have tended to strongly support the distinction between g(F) and g(C) (Blair, 2006; Horn & McArdle, 2007). Although much research on intelligence continues to emphasize a single dimension, whether Full Scale IQ or factor analytically derived g, research on the neural basis for intelligence and also on the development of intelligence suggests that IQ is best represented by at least two dimensions rather than one.[1] We refer the reader to a volume edited by Sternberg and Grigorenko (2002) on the topic of g in which proponents and opponents debated the existence and utility of the g construct.

Genes and the Environment

When the Neisser et al. (1996) article appeared, the controversy over whether genes influence intelligence was mainly in the past. That controversy has faded still further in the intervening years, as scientists have learned that not only intelligence but practically every aspect of behavior on which human beings differ is heritable to some extent. Several strands of evidence, however, suggest that the effects of genes on intelligence, though undeniable, are not nearly as determinative as hereditarians might have hoped or as environmentalists feared 25 years ago.

Heritability is the proportion of variability in a phenotype that is "accounted for" (in the usual regression sense) by variation in genotype. Most studies estimate that the heritability of IQ is somewhere between .4 and .8 (and generally less for children), but it really makes no sense to talk about a single value for the heritability of intelligence. The heritability of a trait depends on the relative variances of the predictors, in this case genotype and environment. The concept of heritability has its origins in animal breeding, where variation in genotype and environment is under the control of the experimenter, and under these conditions the concept has some real-world applications. In free-ranging humans, however, variability is uncontrolled, there is no "true" degree of variation to estimate, and heritability can take practically any value for any trait depending on the relative variability of genetic endowment and environment in the population being studied. In any naturally occurring population, the heritability of intelligence is not zero (if genotype varies at all, it will be reflected in IQ scores) and it is not one (if environment varies at all, it will be reflected in IQ scores). That the heritability of intelligence is between zero and one has one important consequence: Without additional evidence, correlations between biologically related parents and children cannot be unambiguously interpreted as either genetic or (as is more frequently attempted) environmental.

Social Class and Heritability of Cognitive Ability

One example of the population dependence of heritability is the claim that the heritability of intelligence test scores differs as a function of age, with heritability increasing over the course of development (Plomin, DeFries, & McClearn, 1990). Another example of population dependence is that the heritability of intelligence test scores is apparently not constant across different races or socioeconomic classes. Sandra Scarr (Scarr-Salapatek, 1971) published a report of twins in the Philadelphia school system showing that the heritability of aptitude and achievement test scores was higher for White children than Black children and for twins raised in relatively richer homes than for twins raised in poorer ones. This report, although it received some positive attention at the time, also faced serious criticism (Eaves & Jinks, 1972).

Aside from a partial replication conducted by Scarr (1981) and a report from Sweden by Fischbein (1980), the hypothesis of group differences in heritability lay mostly fallow for a 20-year period encompassing the time when the Neisser et al. (1996) article was written. Interest in the phenomenon was rekindled in 1999 when Rowe, Jacobson, and Van den Oord (1999) analyzed data from the National Longitudinal Study of Adolescent Health, a large, representative sample of American youth, then in early adolescence, who were administered a version of the Peabody Picture Vocabulary Test. Rowe et al.'s analysis showed that most of the variance in families with poorly educated mothers was explained by the shared environment. (Shared environment constitutes the environment that is shared by siblings in the same family and that differs from one family to another, as opposed to aspects of the environment that can differ among siblings, such as being a firstborn versus a later-born child.) Most of the variance for children from well-educated families was explained by genes.

Turkheimer, Haley, Waldron, D'Onofrio, and Gottesman (2003) conducted an analysis of socioeconomic status (SES) by heritability interactions in the National Collaborative Perinatal Project (NCPP). The NCPP is particularly well-suited for this purpose because it comprised a representative sample of twins, many of them raised in poverty. A well-validated measure of SES with good psychometric properties is available in the NCPP dataset (Myrianthopoulos & French, 1968). Structural equation modeling demonstrated large statistically significant interactions for Full Scale and Performance IQ (PIQ) but not for Verbal IQ (VIQ), although the effects for VIQ were in the same direction. For families at the lowest levels of SES, shared environment accounted for almost all of the variation in IQ, with genes accounting for practically none. As SES in-

[1] Horn (1989) discussed several other dimensions of intelligence at the same level as g(F) and g(C). We do not doubt the reality of these other dimensions, but they have not been sufficiently well researched to justify considering them at length.

creased, the contribution of shared environment diminished and the contribution of genes increased, crossing in lower middle-class families. Finally, in the most socioeconomically advantaged families (who were not wealthy), practically all of the variation in IQ was accounted for by genes, and almost none was accounted for by shared environment.

There have been several attempted replications of the SES by heritability interaction since the Turkheimer et al. (2003) study was published, with mixed results. (A study by Nagoshi and Johnson [2005] has been cited as a failure to replicate the SES interaction [Rushton & Jensen, 2010], but it is not. Nagoshi and Johnson used the Hawaii Family Study to demonstrate that there is no change in parent–child correlations for intelligence test scores as a function of family income. Parent–child correlations, however, are a combination of genetic and shared environmental factors. Every instance of the interaction that has been reported to date has shown that genetic and shared environmental components change in opposite directions as a function of SES, so one would expect them to cancel each other out in parent–child correlations.)

Harden, Turkheimer, and Loehlin (2007) reanalyzed the Loehlin and Nichols (1976) National Merit Scholar Qualifying Test (NMSQT) twin data. This sample of 839 twin pairs was drawn from the population of nearly 600,000 adolescents who completed the NMSQT in 1962. Around 40% of the variance was accounted for by both additive genetics and the shared environment in the families with the lowest incomes and levels of education, whereas in the richer and better-educated families, slightly more than 50% of the variance was accounted for by genetics and about 30% was accounted for by the shared environment. A puzzling aspect of this study is that few of the children in the sample were actually poor, as they had been selected for participation in the NMSQT.

A recent study of 750 pairs of twins in the Early Childhood Longitudinal Study, Birth Cohort (Tucker-Drob, Rhemtulla, Harden, Turkheimer, & Fask, 2011) identified a gene by SES interaction in the emergence of genetic variance in early childhood. For the Bayley Scales of Infant Development administered at 10 months, there was no heritable variation at any level of SES. But when the test was repeated at two years of age, significant genetic variance emerged, with more genetic variance at higher levels of parental SES.

There are mixed reports about SES by heritability interactions for adults. Kremen, Jacobson, and Xian (2005) identified a significant interaction between parental education and word recognition scores on the Wide Range Achievement Test among 690 adult twins in the Vietnam Era Twin Registry. Descriptive analyses showed that for the twins with the least educated parents, additive genetics and shared environment each accounted for 36% of the variability in reading scores. For the twins with the best educated parents, additive genetics accounted for 56% of the variability and shared environment for 12%. The effect appeared to depend solely on decreases in shared environmental variation as a function of parental education. The Kremen et al. study is the only one to date that has documented the SES by heritability interaction in adults. In contrast, a study of the cognitive ability test given at the time of military induction to a Vietnam Era Twin Registry sample that was part of a larger sample of 3,203 pairs (which included the pairs included in Kremen et al., 2005) showed no interaction with parental education (Grant et al., 2010).

There are also mixed results for European studies. As noted earlier, Fischbein (1980) found the typical SES by heritability interaction with 12-year-olds in Sweden. More recently, Asbury, Wachs, and Plomin (2005) studied a sample of 4,446 four-year-old British twins from the Twins Early Development Study in London. The only interaction they found was an interaction in the opposite direction (i.e., children in high-risk impoverished environments showed higher heritabilities). However, their measure of intelligence was based on a child ability scale administered to parents over the telephone. A second study (Docherty, Kovas, & Plomin, 2011), conducted using 1,800 of the children from the Asbury et al. study at age 10, examined interactions between environmental variables and a set of 10 single nucleotide polymorphisms (SNPs) identified in earlier studies in the prediction of mathematics ability measured over the Internet. The set of SNPs had a main effect on mathematics ability, accounting for 2.7% of the variance, and showed a variety of small interactions with environmental measures, mostly in the direction of larger genetic effects in negative and chaotic environments. A new analysis of the same dataset extending the analysis through age 14 (Hanscombe et al., 2012) has found significant interactions in the original direction for the environmental term. The investigators concluded that shared environmental experiences have greater impact on intelligence in low-SES families.

Van der Sluis, Willemsen, de Geus, Boomsma, and Posthuma (2008) examined Gene × Environment interactions for cognitive ability in 548 adult twins and 207 of their siblings from older and younger cohorts of the Netherlands Twin Registry. Mostly small and nonsignificant interactions were observed between biometric components of IQ and a variety of environmental variables, including neighborhood, income, and parental and spousal education levels. There was a substantial interaction between parental education and shared environmental effects, in the opposite direction from the original findings: Older males from more highly educated families showed larger shared environmental effects.

A recent study suggests that the most commonly found interaction may operate on the level of the cerebral cortex. Chiang et al. (2011) assessed cortical white matter integrity with diffusion tensor imaging in 705 twins and their siblings. They demonstrated that white matter integrity was highly heritable and, moreover, that there were significant Gene × Environment interactions, such that heritabilities were higher among twins with higher SES and higher IQ scores.

In summary, it appears reasonable to conclude that the heritability of cognitive ability is attenuated among impoverished children and young adults in the United States.

There is mixed evidence as to whether the effect occurs in other countries, and there is contradictory evidence about whether the effect persists into adulthood. One can only speculate about why these differences among studies might occur. It appears, for example, that socioeconomic differences in intelligence are not as pronounced in modern Europe as they are in the United States. In the Turkheimer et al. (2003) study, the correlation of SES with IQ was −.70; in Asbury et al. (2005), it was about −.2. In van der Sluis et al. (2008), there was only a 5-point IQ difference between the groups of twins with the most and least educated parents. Studies of adults must contend with the low magnitude of shared environmental components overall, and it may be difficult to detect interactions when there are low shared environment effects to work with.

One interpretation of the finding that heritability of IQ is very low for lower SES individuals is that children in poverty do not get to develop their full genetic potential. If true, there is room for interventions with that group to have large effects on IQ. That this interpretation of the finding is correct is indicated by an actual intervention study (Turkheimer, Blair, Sojourner, Protzko, & Horn, 2012). The Infant Health and Development Program (IHDP) was a broad-based intervention program designed to improve the cognitive function and school performance of approximately 1,000 low birth weight infants. There were 95 pairs of identical and fraternal twins who were incidentally included in the program. About a third of the pairs were randomly assigned to the experimental treatment group. Their families were assigned to receive weekly home visits from a clinically trained staff person who delivered a curriculum of child development and parenting education, a program of mental health counseling and support, and referral to social services available in the community. From ages 1 to 3, the treatment-group twin pairs were eligible to attend a free, full-day, high-quality child development center established and run by IHDP staff. The other twin pairs did not receive home visits or access to the child development centers. At 96 months, the children were administered a battery of standardized tests of cognitive ability and school achievement, including the Wechsler Intelligence Scale for Children, the Woodcock-Johnson Achievement Scales, and Raven's Progressive Matrices. On the basis of studies of natural variation in SES, it was hypothesized that the heritability of intelligence would be higher in the group randomly selected for exposure to the enriched environment. Heritabilities were significantly greater than 0 in the intervention group on seven of eight tests and were higher in the intervention group than in the control group on all seven.

The underrepresentation of low-SES individuals in behavioral genetic studies causes a problem for studies of heritability. The estimates of heritability just discussed are based on studies of twins. Another way to estimate the relative importance of genes and environment is to compare the correlation between adopted children's IQ and that of their birth parents with the correlation between adopted children's IQ and that of their adoptive parents. The former correlation is generally higher than the latter, sometimes much higher. Many have concluded on the basis of such findings that environments are relatively unimportant in determining IQ, since variations in the environments of adoptive families are not very highly associated with variation in children's IQ. But work by Stoolmiller (1999) shows that estimates of the relative contributions of genes and environment may be very sensitive to the inclusion of disadvantaged populations in a given study. Adoption studies may tend to underestimate the role of environment and overstate the role of genetics due to the restricted social class range of adoptive homes. Adoptive families are generally of relatively high SES. Moreover, observation of family settings by the HOME technique (Home Observation for Measurement of the Environment; Bradley et al., 1993; Phillips, Brooks-Gunn, Duncan, Klebanov, & Crane, 1998) shows that the environments of adoptive families are much more supportive of intellectual growth than are those of nonadoptive families. The restriction of range (as much as 70% in some studies; Stoolmiller, 1999) means that the possible magnitude of correlations between adoptive parents' IQ and that of their children is curtailed.

Stoolmiller's (1999) conclusions have been questioned by Loehlin and Horn (2000) and McGue et al. (2007). Loehlin and Horn pointed to a number of implications of Stoolmiller's analysis that are inconsistent with facts Stoolmiller did not consider, but they provided no formal tests of the significance of these inconsistencies, so it is impossible to know how important these inconsistencies are. McGue et al. showed that regressions of IQ on a few characteristics that were restricted in range in their data show those variables to have no effect. But the variables they examined are certainly not the only ones with notably restricted range relative to the whole population, many of which are not represented in their data. Perhaps more important, McGue and colleagues were looking at the effects of restriction of range on a sample whose range was already restricted with respect to the population from which it was drawn. Their sample consisted of intact families of relatively high SES.

The findings on the interaction between SES and genetic influences described above suggest that the problem goes beyond the concerns about restrictions of range addressed by Stoolmiller (1999). If there is heterogeneity in the importance of environment in different social groups, then exclusion of participants from poor socioeconomic backgrounds can have a much more profound effect than what might appear based on the reduction of variance in SES alone. Since environment has a larger impact on outcomes among lower SES individuals, then removing them from the sample not only reduces the variance of environment but also reduces the average impact of environment on outcomes in the sample, thereby causing a reduction in the measured role of environment for two separate reasons. Thus, in addition to the bias introduced into the estimates of environmental effects by the restriction of range in SES, excluding participants from the lowest SES levels would also bias the results by omitting the portion of the distribution for which environmental effects are known to be strongest (Turkheimer, Harden, D'Onofrio, & Gottesman, 2009).

The Search for Genes for IQ

A major development since the Neisser et al. (1996) report has been the mapping of the human genome and the increasing availability and practicality of genotyping technology. The high heritability of cognitive ability led many to believe that finding specific genes that are responsible for normal variation would be easy and fruitful.

So far, progress in finding the genetic locus for complex human traits has been limited. Whereas 282 individual genes responsible for specific forms of mental retardation have been identified (Inlow & Restifo, 2004), very little progress has been made in finding the genes that contribute to normal variation (Butcher, Davis, Craig, & Plomin, 2008). For example, a recent large study—a genome-wide scan using 7,000 subjects (Butcher et al., 2008)—found only six genetic markers (SNPs) associated with cognitive ability, and only one of those remained statistically significant once the critical values were adjusted for multiple tests. When the six markers were considered together they barely explained 1% of the variance in general cognitive ability. Further, in the many studies of a similar nature that have purported to find genes for cognitive ability, the (very slight) influence of only one gene has been consistently replicated in subsequent studies (Butcher et al., 2008).

This is an unfortunately common circumstance in the search for genes for a wide range of human traits. When there is a single gene responsible for individual variation it is easy to find, but when a trait is more than slightly polygenic (many genes contribute) finding genes that explain more than a tiny fraction of the variance in the trait has so far proved daunting (Goldstein, 2009). Perhaps the best example of this is height, for which a recent genome-wide scan with 30,000 subjects found only 20 markers, and these collectively explained less than 3% of the variance in height. This was the case despite the fact that height is over 90% heritable in the population studied (Weedon et al., 2008).

Figuring out why it has proved so difficult to identify the specific genes responsible for genetic variation in highly heritable behavioral traits is the most challenging problem facing contemporary behavioral genetics.[2] The possible explanations can be divided into two broad classes. The difficulty may originate either in technical problems in specifying the genetic sequence or in broader problems involving the prediction of complex human behavior more generally, or both.

Despite the astonishing gains that have been made in the specification of the human genetic sequence over the last two decades, the technologies that have been brought to bear on the identification of specific genes related to complex traits are still at some distance from the actual genetic sequence. Linkage methods, the first to be applied to traits such as intelligence, can query the entire genome, but they have relatively low statistical power and only identify chromosomal regions that may include relevant genes. Candidate gene association studies estimate the associations between specific genes and a behavioral outcome but are necessarily limited to the relatively small number of candidate genes that can be tested. The most recent method, genome-wide association studies (GWAS), scan the genome for associations between outcomes and variation in individual chromosomal markers known as SNPs. GWAS is as close as researchers have come to examining relations between the actual genetic sequence and intelligence, but there are still limitations. Only relatively common SNPs are included in GWAS, and relations between densely packed SNPs and the genes with which they are associated are quite complex.

Another class of technical difficulties includes the possibility that a linear specification of the genetic sequence does not capture all of the information contained in the genome. Statistical interactions or nonlinear associations among genes, or between genes and particular environments, could foil an effort to understand intelligence by simply adding up the small effects of many genes.

In the end, the most likely explanation of the missing genes problem is the most straightforward, but unfortunately it is also likely to be the most difficult to remedy. It may simply be that that the number of genes involved in an outcome as complex as intelligence is very large, and therefore the contribution of any individual locus is just as small as the number of genes is large and thus very difficult to detect without huge samples. This problem is not likely to be solved by advances in genetic technology that are foreseeable at present.

New Knowledge About the Effects of the Environment

Much new knowledge about relationships between environmental factors and intelligence has accrued since the Neisser et al. (1996) report appeared, especially regarding the interplay of biological and social factors, which thus has blurred the line between biological and environmental effects on intelligence.

Biological Factors

A wide range of environmental factors of a biological nature influence intelligence. Most of the known factors are detrimental, having to do with a lack of micronutrients and the presence of environmental toxins, and they were reviewed briefly by Neisser et al. (1996). Little of note concerning these effects has been uncovered since then, but there is not much research in this area.

There is, however, one biological factor that seems to increase intelligence and that occurs early in life. Breastfeeding may increase IQ by as much as 6 points (Anderson, Johnstone, & Remley, 1999; Mortensen, Michaelsen, Sanders, & Reinisch, 2002) for infants born with normal weight and by as much as 8 points for those born prematurely (Anderson et al., 1999; Lucas, Morley, Cole, Lister,

[2] For those who are interested in more detail on these questions, the April 23, 2009, issue of the *New England Journal of Medicine* (Vol. 360, No. 17) carried a symposium on this issue.

& Leeson-Payne, 1992), and the advantage seems to persist into adulthood (Mortensen et al., 2002). One meta-analysis found only a 3-point effect of breastfeeding on IQ when social class and IQ of the mother were controlled (Anderson et al., 1999), and another found essentially no effect on academic achievement scores when the mother's IQ was controlled except for a modest effect for children breastfed for more than seven months (Der, Batty, & Deary, 2006).

It is far from clear, however, that a confound between social class and mother's IQ is what accounts for the relationship between breastfeeding and IQ. Human breast milk contains fatty acids that are not found in formula and that have been shown to prevent neurological deficits in mice (Catalan et al., 2002). An important study indicates that breastfeeding is effective in raising IQ by about six points, but only for the large portion of the population having one of two alleles at a particular site that regulates fatty acids and is influenced by breast milk (Caspi et al., 2007). Those having another allele at that site did not benefit from breastfeeding, but people with that allele are in a small minority. This finding of genetic contingency speaks against the possibility of a social-class confound in the breastfeeding–IQ relationship, because the benefit of breastfeeding occurred for children with the two more common alleles regardless of the mother's social class and did not occur for children with the less common allele, again regardless of social class. Moreover, it was only the child's allele at the relevant site, not the mother's, that mediated the influence on IQ. Another study manipulated breastfeeding in a large randomized control study and also found about a 0.5 *SD* difference in IQ (Kramer, 2008).

The breastfeeding issue remains in doubt. There are some contradictions in the literature up to this point. Nevertheless, the prudent recommendation for new mothers is that, absent any contraindications, they should breastfeed.

Social Factors

We can be confident that the environmental differences that are associated with social class have a large effect on IQ. We know this because adopted children typically score 12 points or more higher than comparison children (e.g., siblings left with birth parents or children adopted by lower SES parents), and adoption typically moves children from lower to higher SES homes. A meta-analysis available at the time of the Neisser et al. (1996) article found an effect of adoption of lower SES children by upper-middle-class parents of 12 points (Locurto, 1990). A subsequent adoption study by Duyme, Dumaret, and Tomkiewicz (1999) found that the IQ difference between children adopted by upper-middle-class parents and those adopted by lower SES parents was about 12 points. A recent meta-analysis by van IJzendoorn, Juffer, and Klein Poelhuis (2005) found an average effect of adoption of 18 points. However, these authors considered some studies in which adoption was compared with extremely deprived institutional settings.

Class and race differences in socialization for intellectual abilities. The evidence from adoption studies that social class greatly affects the IQ of children raises questions about exactly what correlates of SES affect IQ.

Some recent evidence indicates that there are marked differences, beginning in infancy, between the environment of higher SES families and lower SES families in factors that plausibly influence intellectual growth. One of the more important findings about cognitive socialization concerns talking to children. Hart and Risley (1995) showed that the child of professional parents has heard 30 million words by the age of three, the child of working-class parents has heard 20 million words, and the vocabulary is much richer for the higher SES child. The child of unemployed African American mothers has heard 10 million words by the age of three. Hart and Risley also found a large difference in the ratio of encouraging comments made to children versus reprimands. The child of professional parents received six encouragements for every reprimand, the child of working-class parents received two encouragements per reprimand, and the child of unemployed African American mothers received two reprimands per encouragement.

The Hart and Risley (1995) findings are amplified by studies using the HOME (Home Observation for Measurement of the Environment) technique mentioned earlier. HOME researchers assess family environments for the amount of intellectual stimulation that is present, as indicated by how much the parent talks to the child; how much access there is to books, magazines, newspapers, and computers; how much the parents read to the child; how many learning experiences outside the home (trips to museums, visits to friends) there are; the degree of warmth versus punitiveness of parents' behavior toward the child; and so on (Bradley et al., 1993; Phillips et al., 1998). These studies find marked differences between the social classes, and they find that the association between HOME scores and IQ scores is very substantial. A 1 *SD* difference in summed HOME scores is associated with a 9-point difference in IQ.

It should be acknowledged, however, that at present there is no way of knowing how much of the IQ advantage for children with excellent environments is due to the environments per se and how much is due to the genes that parents creating those environments pass along to their children. In addition, some of the IQ advantage of children living in superior environments may be due to the superior genetic endowment of the child producing a phenotype that rewards the parents for creating excellent environments for intellectual development (Braungart, Plomin, DeFries, & David, 1992; Coon, Fulker, DeFries, & Plomin, 1990; Plomin, Loehlin, & DeFries, 1985). To the extent that such processes play a role, the IQ advantage of children in superior environments might be due to their own superior genes rather than to the superior environments themselves.

It is almost surely the case, however, that a substantial fraction of the IQ advantage is due to the environments independent of the genes associated with them. This is because we know that adoption adds 12–18 points to the IQ of unrelated children, who are usually from lower SES backgrounds. Home environments are not the only candidates for explaining shared environment effects. Home environments are correlated with neighborhood, peer, and school environments. These likely are also important components of the shared environment effects that are reflected in the adoption outcomes for children in families of different social classes. But we stress that we have no direct evidence of the impact of any particular environmental factor on IQ.

Shared environment effects in childhood and adulthood. Shared environment effects are those shared by all members of a given family but that differ between families. For example, social class is likely to be shared by all family members. The children from one randomly selected family will differ on average by about 1.13 *SD* in SES from the children of another randomly selected family.

Shared environment effects are sometimes reported to be very low or even zero by adulthood (Bouchard, 2004; Johnson, 2010; McGue & Bouchard, 1998). If shared environment effects were really this low in adulthood, it would prompt pessimistic conclusions about the degree to which interventions in childhood would have enduring effects. One basis for the claim that shared environment effects are zero in adulthood is a review of three studies in 1993 by McGue, Bouchard, Iacono, and Lykken (1993), which has been frequently cited since (e.g., Bouchard & McGue, 2003; Rushton & Jensen, 2005a). But a large range of shared environment effects has been reported. Bouchard and McGue (2003) reproduced the 1993 review figure with its assessment of zero adult shared environment effects, but they also found a shared environment effect in excess of .25 for 16–20-year-olds. Johnson (2010) reported that shared environment effects are zero in adulthood (but did not provide sources) and in the same year reported a study showing that the shared environment effect was .07 for 17-year-olds in Minnesota and .26 for 18-year-olds in Sweden (Johnson, Deary, Silventoinen, Tynelius, & Rasmussen, 2010). Another recent study found shared environment effects of .26 for 20-year-olds and .18 for 55-year-olds (Lyons et al., 2009), and yet another found shared environment effects of .20 for Swedish conscripts (Beauchamp, Cesarini, Johannesson, Erik Lindqvist, & Apicella, 2011). A recent review of six well-conducted studies found shared environment effects in adulthood to be .16 on average (Haworth et al., 2009).

Finally, it should be noted that most if not all twin studies, especially studies of adults, likely result in higher estimates of genetic effects and lower estimates of environmental effects than would be found with genuine random samples of all twins in a given population. This is because lower SES individuals are difficult to recruit to laboratories and testing sites (Dillman, 1978). Many studies of heritability give no information about SES, and even those that claim to have representative samples of the various social-class groups may have self-selection problems: The lower SES individuals who volunteer may resemble higher SES individuals on variables relevant to overestimation of heritability effects. On the other hand, nearly all studies fail to take into account the effects of assortative mating. Beauchamp et al. (2011) suggested that assortative mating may completely offset their estimate of .2 for Swedish conscripts, leaving shared environmental effects at zero.

A comprehensive review of all studies providing evidence about shared environment effects across the life span, despite the obvious importance of such an enterprise, has yet to be conducted. What we can say with some confidence at present is that shared environment effects, as typically measured, remain high at least through the early 20s. After that age, data are sparse and longitudinal studies almost nonexistent except for much older adults.

Within-family effects (nonshared environment effects). Differences in IQ for siblings within a family are partly due to differential environmental experiences, including changes in the social-class status of a given family, neighborhood differences over time, differences in the character of peer associations between children in the same family, and birth order differences. There is a large and contentious literature on the question of birth order and IQ, with some researchers finding that firstborns have higher IQs (Zajonc, 1976) and other researchers not finding this to be the case (Wichman, Rodgers, & MacCallum, 2006). Zajonc and Sulloway (2007) maintained that the difference in findings could be explained by the fact that the birth order effect is typically not found until late adolescence. Some recent evidence from a particularly rigorous study indicates that there is in fact a difference in IQ of 3 points in early adulthood favoring firstborn children over later-born children that may be understandable in terms of differences in the home environment (Kristensen & Bjerkedal, 2007).That it is social order of birth and not biological order of birth that results in the difference in IQ is indicated by the fact that second-born children in families in which the firstborn child died early in life have IQs as high as firstborns at age 18 (Kristensen & Bjerkedal, 2007); thus genetic or gestational factors do not account for the difference. Zajonc and others have argued that the intellectual environment of the firstborn is superior to that of the later-born, partly because the firstborn has the full attention of the parents for a period of time.

Interventions

A large number of interventions have been shown to have substantial effects on IQ and academic achievement. In particular, there is clear evidence that school affects intelligence.

Education and Other Environmental Interventions

It was known at the time of the Neisser et al. (1996) article that school has a great impact on IQ (Ceci, 1991). Natural experiments in which children are deprived of school for an extended period of time show deficits in IQ of as much as 2 *SD*. A child who enters fifth grade approximately a year earlier than a child of nearly the same age who enters fourth grade will have a Verbal IQ more than 5 points higher at the end of the school year (Cahan & Cohen, 1989) and as much as 9 percentiles higher in eighth grade, as found in an international study of Organisation for Economic Cooperation and Development countries studied by Bedard and Dhuey (2006). Such children are more likely to enter high-tracked high school programs and more likely to go to college than are late starters (Bedard & Dhuey, 2006). Children who miss a year of school show a drop of several points in IQ. Children lose IQ and academic skills over the summer (Ceci, 1991; Jencks et al., 1972). But the seasonal change in intellectual skills, as we might expect given the different home environments of children of different social classes, is much greater for lower SES children. Indeed, the knowledge and skills of children in the upper fifth in family SES actually increase over the summer (Burkam, Ready, Lee, & LoGerfo, 2004; Cooper, Charlton, Valentine, & Muhlenbruck, 2000), an effect that is likely due to enriched activities for the higher SES children. This effect is so marked that by late elementary school, much of the difference in academic skills between lower and higher SES children may be due to the loss of skills over the summer for lower SES children versus the gains for higher SES children (K. L. Alexander, Entwisle, & Olson, 2001). The beneficial effects of schooling apparently continue at least through junior high school. Brinch and Galloway (2011) took advantage of the natural experiment created in Norway when an extra two years of schooling beyond the seventh grade began to be required. Effects on IQ were substantial at age 19—equal to one third the size of the Flynn effect (the marked secular gain seen in developed countries, which we discuss in detail later) in Norway at the time.

The best prekindergarten programs for lower SES children have a substantial effect on IQ, but this typically fades by late elementary school, perhaps because the environments of the children do not remain enriched. There are two exceptions to the rule that prekindergarten programs have little effect on later IQ. Both are characterized by having placed children in average or above-average elementary schools following the prekindergarten interventions. Children in the Milwaukee Project (Garber, 1988) program had an average IQ 10 points higher than those of controls when they were adolescents. Children in the intensive Abecedarian prekindergarten program had IQs 4.5 points higher than those of controls when they were 21 years old (Campbell, Ramey, Pungello, Sparling, & Miller-Johnson, 2002).[3]

Whether or not high-quality intervention programs have sustained IQ effects, the effects on academic achievement and life outcomes can be very substantial. The gains are particularly marked for intensive programs such as the Perry School Project (Campbell, Pungello, Miller-Johnson, Burchinal, & Ramey, 2001; Schweinhart et al., 2005; Schweinhart & Weikart, 1980; Schweinhart & Weikart, 1993) and the Abecedarian program (Campbell et al., 2001; Campbell & Ramey, 1995; C. T. Ramey et al., 2000; S. L. Ramey & Ramey, 1999). By adulthood, individuals who had participated in such interventions were about half as likely to have repeated a grade in school or to have been assigned to special education classes and were far more likely to have completed high school, attended college, and even to own their own home. The discrepancy between school achievement effects and IQ effects (after early elementary school) is sufficiently great to suggest to some that the achievement effects are produced more by attention, self-control, and perseverance gains than by intellectual gains per se (Heckman, 2011; Knudsen, Heckman, Cameron, & Shonkoff, 2006).

Quality of teaching in kindergarten also has a measurable impact on academic success and life outcomes. Chetty et al. (2010) examined data from Project STAR in Tennessee. Students who had been randomly assigned to small kindergarten classrooms were more likely to subsequently attend college, attend a higher ranked college, and have better life outcomes in a number of respects. Students who had more experienced teachers had higher earnings as adults, as did students for whom the quality of teaching as measured by test scores was higher. Academic gains due to having more experienced, superior teachers faded in later grades, but noncognitive gains persisted, much as for the pre-elementary intervention just discussed.

First-grade teaching quality also has a significant impact on academic achievement in later grades. Hamre and Pianta (2001) found that children who were at risk for poor elementary school performance by virtue of relatively low SES had achievement scores 0.4 *SD* higher if their first-grade teacher was one whose teaching quality was considered to be in the top third as opposed to the bottom third. Indeed, the performance of the children with the better teachers was not significantly worse than that of children with well-educated parents.

Many interventions in elementary school, including lengthened schoolday, decreased class size, and interactive computer programs, have been found to markedly affect academic skills (Nisbett, 2009). The only enhanced schooling program that we know to have affected IQ was reported on by Neisser et al. (1996). This was a year-long program teaching a variety of reasoning skills to seventh-grade children in Venezuela (Herrnstein, Nickerson, Sanchez, & Swets, 1986). The program had a very substantial effect on the individual reasoning skills taught and had a 0.4 *SD* effect on intellectual ability as measured by typical tests. There has been no exact replication of this study, although Sanz de Acedo Lizarraga, Ugarte, Iriarte, & Sanz de Acedo Baquedano (2003) devised an extensive educational intervention that used the Herrnstein et al. (1986) materials. Sanz de Acedo Lizarraga et al. found substantial increases in several measures of intelligence, including the Culture Fair Intelligence Test (Cattell, 1973), a matrix test similar to Raven's Progressive Matrices. Their intervention included a variety of tasks intended to enhance self-regulation, so it is unclear which aspects of their intervention

[3] Another program similar to the Abecedarian program was carried out with low birth weight infants. Rather than starting at six months and continuing to age 5, the program started at age 1 and continued to age 3. Improvement in IQ was modest for children with birth weights of more than 2,000 grams and continued through adolescence. For children with birth weights less than 2,000 grams, and for the entire sample, the control group was not significantly different from the intervention group.

increased IQ. As we discuss below, attempts to improve matrix reasoning of the Raven's sort by providing working memory training have proven quite successful.

Interventions to Raise Fluid Intelligence

Recent research has shown that *g*(F) can be enhanced by training people in working memory skills. For example, Jaeggi, Buschkuehl, Jonides, and Perrig (2008) used a dual *n*-back working memory task that required participants to remember both verbal and visuospatial information over varying numbers of trials. In an *n*-back task, participants are required to view sequential presentations of individual letters or a stimulus in a specific location and to indicate when one of the letters or locations is the same as that presented on the previous one, two, or three presentations. That is, in the 1-back condition, the participant indicates if a letter is the same as that presented on the immediately preceding presentation; on the 2-back, the same as that on the presentation before last; on the 3-back, the same as that presented two presentations before last; and so forth. Jaeggi et al. (2008) found that participants who spent one month training on a version of the *n*-back that required simultaneously remembering both a stimulus location presented visually and a letter presented auditorily improved their scores on the Bochumer Matrizen-Test, a matrix reasoning test of fluid intelligence. This finding was taken as support for the claim that training working memory leads to an improvement in *g*(F). Jaeggi et al. (2010) replicated this finding and extended it to include scores on Raven's Progressive Matrices.

Klingberg, Forssberg, and Westerberg (2002) provided memory training to both children with attention-deficit/hyperactivity disorder (ADHD) and to adults and found marked improvement in performance on Raven's Progressive Matrices for both groups. Rueda, Rothbart, McCandliss, Saccomanno, and Posner (2005) provided children with attention control training and found an increase of 0.5 *SD* for a matrices task. Work by Mackey and her colleagues (Mackey, Hill, Stone, & Bunge, 2011) showed that working memory training of low-SES children using a variety of computer and noncomputer games resulted in IQ gains of 10 points on a matrix reasoning task. Research with aged participants showed that training with a computer game that involved executive control skills improved performance on a variety of tasks measuring executive functioning, including Raven's Progressive Matrices (Basak, Boot, Voss, & Kramer, 2008). Similar effects for elderly participants have been found by other investigators using a working memory training paradigm, with significant transfer of training and maintenance of gains on *g*(F) tasks over an eight-month period (Borella, Carretti, Riboldi, & De Beni, 2010). Gains in the range of 0.5 to 1 *SD* have been found for transfer of task switching training in children, young adults, and the elderly (Karbach & Kray, 2009). See also Schmiedek, Lövdén, and Lindenberger (2010), Tranter and Koutstaal (2007), and Stephenson and Halpern (2012) for similar effects resulting from interventions involving multiple tasks targeting executive control.

As might be expected, executive functioning and working memory training have been shown to improve only fluid intelligence performance and have little or no effect on crystallized abilities or verbal reasoning.

Cognitive-Enhancing Pharmaceuticals

There is a rapidly increasing trend by healthy, normal individuals to take drugs that can improve "memory, concentration, planning and reduce impulsive behavior and risky decision making" (Sahakian & Morein-Zamir, 2007, p. 1157). The majority of these drugs are being used "off-label," which means that they are being used in ways that were not approved by drug administration agencies. For example, methylphenidate (Ritalin) is routinely prescribed for people with ADHD, but increasingly people without ADHD are taking this drug for cognitive enhancement. One survey found that 25% of college students on some campuses use stimulants in this way in a given year (McCabe, Knight, Teter, & Wechsler, 2005). Modest enhancements in attention, working memory, and executive function in healthy, normal adults have been found with a variety of stimulant drugs, with Modafinil, which is approved for the treatment of narcolepsy, and with Aricept, which is approved for use for Alzheimer's disease (Greely et al., 2008). There are many indications that the use of cognitive-enhancing pharmaceuticals among normal individuals is increasing.

There are multiple unknowns regarding the use of cognitive-enhancing drugs, including the long-term benefits and risks of these drugs for both the populations for which they were developed and for their use in normal populations. The use of cognitive-enhancing pharmaceuticals is likely to be an emerging area of research and debate. We already know about the beneficial effects of education, exercise, and sound nutrition. A major question is whether pharmaceutical interventions are similar to these noncontroversial interventions or whether they offer unknown risks that make their use qualitatively different from other types of interventions.

Exercise and Aging

Physical exercise. A meta-analysis of a large number of studies has shown that aerobic exercise, at least for the elderly, is very important for maintaining IQ, especially for executive functions such as planning, inhibition, and scheduling of mental procedures (Colcombe & Kramer, 2003). The effect of exercise on these functions is more than 0.5 *SD* for the elderly (more for those past age 65 than for those younger). It is possible to begin cardiovascular exercise as late as the seventh decade of life and substantially reduce the likelihood of Alzheimer's disease (Aamodt & Wang, 2007).

Cognitive exercise. Cognitive exercise does not literally prevent cognitive abilities from declining with age (G. D. Cohen, 2005; Maguire et al., 2000; Melton, 2005; Salthouse, 2006). But many studies show that the cognitive skills of the elderly can be trained in the short term (Salthouse, 2010). And there is some evidence that training older adults in memory, processing speed, and particular narrow reasoning skills produces substantial improvements in these skills that remain over a period of years (Ball et al., 2002). The evidence cited above in the section on training of fluid intelligence includes two studies of the elderly showing very significant transfer effects and one study showing improvement on tasks requiring substantial transfer maintained over an eight-month period. Additional evidence that cognitive exercise slows down the process of intellectual decay comes from a study of retirement. Episodic memory, which is memory for personally relevant events, is not usually regarded as an aspect of intelligence, but it is a cognitive ability of a sort and is among the first to show a decline with age. A study of the effects of retirement on episodic memory was conducted with men aged 50 to 54 and aged 60 to 64 (Adam, Bonsang, Germain, & Perelman, 2007). Twelve nations were ranked in terms of the persistence of employment into old age. If the percentage of men still working dropped by 90% from the 50–54 age range to the 60–64 age range (Austria, France), there was a 15% decline in episodic memory. If the percentage still working dropped by 25% (United States, Sweden), the decline was only 7%. See also Rohwedder and Willis (2010). These findings are consistent with correlational evidence from a study in the United Kingdom showing that an extra year of work was associated with a delay in the onset of Alzheimer's on average by six weeks (Adam et al., 2007; Lupton et al., 2010).

Massive IQ Gains Over Time

Flynn's (1987) research showing that 14 nations had made huge IQ gains from one generation to another was known to Neisser et al. (1996). Data on IQ trends now exist for 30 nations. Gains differ as a function of the degree of modernity that characterizes different nations. For nations that were fully modern by the beginning of the 20th century, IQ gains have been on the order of 3 points per decade (Flynn, 2007). Nations that have recently begun to modernize, such as Kenya (Daley, Whaley, Sigman, Espinosa, & Neumann, 2003) and the Caribbean nations (Meisenberg, Lawless, Lambert, & Newton, 2005), show extremely high rates of gain. In Sudan, large fluid gains (on the Performance Scale of the Wechsler Adult Intelligence Scale, or WAIS) have accompanied a small loss for crystallized intelligence (Khaleefa, Sulman, & Lynn, 2009).

Nations where modernization began during the early to mid-20th century show large and persistent gains. Urban Argentines (ages 13 to 24) made a 22-point gain on Raven's Progressive Matrices between 1964 and 1998 (Flynn & Rossi-Casé, 2011). Children in urban Brazil between 1930 and 2002 (Colom, Flores-Mendoza, & Abad, 2007), in Estonia between 1935 and 1998 (Must, Must, & Raudik, 2003), and in Spain between 1970 and 1999 (Colom, Lluis-Font, & Andrés-Pueyo, 2005) have gained at a rate of about 3 points per decade.

Results for nations that began modernization as far back as the 19th century suggest that its effects on IQ can reach an asymptote. Scandinavian nations show IQ peaking or even in mild decline (Emanuelsson, Reuterberg, & Svensson, 1993; Sundet, Barlaug, & Torjussen, 2004; Teasdale & Owen, 1989, 2000). Other highly developed nations have not as yet experienced diminished gains. The gains of British children on Raven's Progressive Matrices were at least as high from 1980 to 2008 as they were from 1943 to 1980 (Flynn, 2009a). Both American children (as measured by the Wechsler Intelligence Scale for Children, or WISC, 1989–2002) and adults (WAIS, 1995–2006) are gaining at their historic rate of 3 points per decade (Flynn, 2009b, 2009c).

If Sweden represents the asymptote that we are likely to see for modern nations' gains, the IQ gap between developing and developed nations could close by the end of the 21st century and falsify the hypothesis that some nations lack the intelligence to fully industrialize. In 1917, Americans matched the lowest IQs found in the developing world today. It seems plausible that the first step toward modernity raises IQ a bit, which paves the way for the next step, which raises IQ a bit more, and so forth.

It is important to note that Flynn's (2007) review showed that gains on tests generally considered to measure fluid intelligence showed substantially greater gains (18 points in IQ-equivalence terms) than tests considered to measure crystallized intelligence (10 points).

The causes of IQ gains are still debated. Lynn (1989) has proposed that they are due to improvements in nutrition. In the developed world, better nutrition was probably a factor before 1950, but probably not since. The nutrition hypothesis posits greater IQ gains in the lower half of the IQ distribution than the upper half because one would assume that even in the past the upper classes were well fed, whereas the nutritional deficiencies of the lower classes have gradually diminished. IQ gains have indeed been concentrated in the lower half of the curve in Denmark, Spain, and Norway, but not in France, the Netherlands, and the United States. Norway is actually a counterexample: Height gains were larger in the upper half of their distribution, whereas IQ gains were higher in the lower half. It is unlikely that enhanced nutrition over time had a positive effect on IQ but a negative effect on height. British trends are quite incompatible with the nutrition hypothesis. They do not show the IQ gap between the top and bottom halves reducing over time. Differences were large on the eve of the Great Depression, contracted from 1940 to 1942, expanded from 1964 to 1971, contracted from 1972 to 1977, and have expanded ever since (Flynn, 2009a, 2009c).

People who marry within a small group suffer inbreeding depression, which lowers IQ scores. It has been proposed that less isolation of a breeding population might contribute to IQ gains by way of "hybrid vigor" (Mingroni, 2004). Data from Norway comparing IQ scores for siblings of different ages show IQ trends mirroring those of the larger society (Sundet, Eriksen, Borren, & Tambs, 2010). Since siblings cannot differ in the degree of inbreeding, this indicates that hybrid vigor has not been a factor in modern Scandinavia. Flynn (2009c) has shown that high mobility in America dates back at least as far as 1872. Thus the hypothesis that a trend from substantial isolation to little isolation lies behind IQ gains seems implausible.

It is easier to eliminate causes than to provide a convincing causal scenario. It seems likely that the ultimate cause of IQ gains is the Industrial Revolution, which produced a need for increased intellectual skills that modern societies somehow rose to meet. The intermediate causes of IQ gains may include such factors as a more favorable ratio of adults to children, better schooling, more cognitively demanding jobs, and more cognitively challenging leisure. Flynn (2009c) has argued that one proximate cause is the adoption of a scientific approach to reasoning with an attendant emphasis on classification and logical analysis. Blair and colleagues (Blair, Gamson, Thorne, & Baker, 2005) have shown that the teaching of mathematics, beginning very early in school, has shifted from instruction in mere counting and arithmetical operations to presentation of highly visual forms of objects and geometrical figures with patterns children have to figure out. Such instruction seems a plausible explanation for at least part of the gain in fluid intelligence of the kind measured by Raven's Progressive Matrices.

Analysis of trends on various Wechsler subtests and Raven's Progressive Matrices for the United States may be helpful in understanding what the real-world implications of IQ gains might be.

Raven's Progressive Matrices. The very large gains in performance on the Raven test—nearly 2 *SD* in the period from 1947 to 2002—indicate that reasoning about abstractions has improved in a very real way. The very large gains for the Raven test render implausible the claim that the test is "culture free."

Similarities. The very large gains on the Similarities subtest imply that skills in classification (dogs are similar to owls because they are both animals) have increased. This seems likely to be helpful for scientific reasoning and for preparation for tertiary education.

Performance subtests. These subtests, which require operating on stimuli by means of manipulation or detection of differences, such as creating a three-dimensional representation of a two-dimensional picture, have shown very large gains. These gains are more difficult to interpret. Certainly, the gains on the Block Design subtest indicate that there has been enhanced ability to solve problems on the spot that require more than the mere application of learned rules.

Comprehension. Since 1947, adults have gained the equivalent of almost 14 IQ points and children have gained 11 points ($SD = 15$) on the Comprehension subtest. This subtest measures the ability to comprehend how the concrete world is organized (e.g., why streets are numbered in sequence, why doctors go back to get more education). These increases represent a real gain in ability to understand the world one lives in.

Information. There have been gains for the Information subtest of over 8 points for adults but only 2 points for children. It seems likely that the gain for adults reflects the influence of the expansion of tertiary education.

Vocabulary. The vocabulary of adults has increased by over 1 *SD*, but children's has increased only trivially (Flynn, 2010). The gain for adults likely reflects the influence of increased tertiary education and more cognitively demanding work roles.

Arithmetic. There have been very small gains for arithmetic for both adults and children. Perhaps this is because education in recent decades has not increased its emphasis on these skills.

Obsolescence of IQ test norms has an important real-world consequence. Someone who took an obsolete test might get an IQ score of 74, whereas their IQ measured on a more current test would be 69. Since 70 is the cutting point for immunity from the death penalty in America, obsolete tests have literally cost lives (Flynn, 2009b).

Biology of Intelligence

As presaged in the original Neisser et al. (1996) article, advances in brain imaging research, including structural as well as functional magnetic resonance imaging (fMRI) and positron emission tomography, have resulted in a great deal of research reporting brain correlates of intelligence.

Relationship Between IQ and Brain Structure and Function

One of the clear findings of brain research over the past decade, both in imaging research and in clinical neuropsychology, has been a confirmation of an association between activity in prefrontal cortex (PFC) and performance on fluid reasoning and executive function and working memory tasks. Perhaps the most compelling demonstrations of the association between PFC and fluid, visual-spatial reasoning are those indicating profound impairment on reasoning tasks such as the Raven's Progressive Matrices and the highly similar Cattell Culture Fair Intelligence Test in individuals with damage to their PFCs (Duncan, Burgess, & Emslie, 1995; Waltz et al., 1999). A remarkable result in these studies is that other aspects of mental ability—namely, well-learned and acculturated abilities such as vocabulary knowledge that are grouped together as crystallized intelligence, or *g*(C)—appear to be surprisingly little affected when there is damage to the PFC (Waltz et al., 1999). Indeed, individuals with average crystallized intelligence functioning can have fluid functioning as much 2 *SD* below average (Blair, 2006).

These studies suggest that the PFC is necessary for the solution of visual-spatial reasoning tasks in which the information is novel and nonsemantic but that the PFC is less involved in tasks that require crystallized abilities. In confirmation of the distinction in clinical research between brain areas important for *g*(F) and those important for *g*(C), a large number of neuroimaging studies have demonstrated that performance on fluid reasoning tasks of the type required by Raven's Progressive Matrices, such as working memory and executive function, is dependent on neural circuitry associated with the PFC that also extends throughout the neocortex—including the superior parietal temporal and occipital cortex, as well as subcortical regions, particularly the striatum (Duncan et al., 2000; Gray, Chabris, & Braver, 2003; Jung & Haier, 2007; Olesen, Westerberg, & Klingberg, 2004). Consistency across studies in brain areas associated with reasoning, however, is limited. Patterns of activation in response to various fluid reasoning tasks are diverse, and brain regions activated in response to ostensibly similar types of reasoning (inductive, deductive) appear to be closely associated with task content and context. The evidence is not consistent with the view that there is a unitary reasoning neural substrate (Goel, 2007; Kroger, Nystrom, Cohen, & Johnson-Laird, 2008).

Similarly, functional and structural imaging studies indicate that brain regions associated with aspects of crystallized intelligence, such as verbal ability, are located in specific frontal and posterior temporal and parietal areas and, as with fluid reasoning, are closely tied to task content (Sowell et al., 2004). Common brain regions associated with both fluid and crystallized abilities have been identified (Colom & Jung, 2004); however, there appears to be limited similarity across studies searching for the neural substrate for *g*. For example, direct comparison of the structural correlates of *g* derived from two different intelligence test batteries revealed only limited overlap in brain regions identified (Haier, Colom, et al., 2009).

Although evidence for a single underlying neural basis for intelligence appears mixed, it may be that the issue is not one of identifying the relevant brain regions so much as the possibility that individuals vary in how they use areas of the brain that form the neural basis for intelligence when engaging in a given mental task (Haier, Karama, Leyba, & Jung, 2009). This possibility is suggested by a review of 37 structural and functional neuroimaging studies of "intelligence and reasoning tests" by Jung and Haier (2007) in which they proposed a parieto-frontal integration theory of intelligence (P-FIT) that was based on the identification of specific overall frontal and parietal brain regions as well as specific temporal and occipital areas that were reliably activated across most studies reviewed. The authors, as well as several commentators on the theory, however, noted the considerable heterogeneity in the findings of the various studies included in the review. Many brain regions were implicated by a small percentage of the studies, whereas relatively few were identified by more than 50% of the studies (Colom, 2007).

Overall, the conclusion seems to be that there is great heterogeneity in the findings of imaging studies examining the functional and structural basis of intelligence. An important area for future research on the neural basis for intelligence will be the mapping of individual variation in brain function and structure onto individual variation in mental test performance. An important goal for this research will be to determine the extent to which information about brain structure and function can be used to accurately estimate a given individual's overall level of mental ability (Colom, Karama, Jung, & Haier, 2010).

An additional indication of the potential limits of identifying relations between brain structure and function and general intelligence is provided by twin studies examining the heritability of both gray and white matter and intelligence. Although the samples included in these studies are very small ($N < 25$), brain imaging with adults who vary in degree of relatedness (monozygotic [MZ] twins, dizygotic [DZ] twins, and unrelated individuals) has demonstrated that regional structural variation in the brain is, like cognitive abilities themselves, substantially heritable (Chiang et al., 2009; Hulshoff Pol et al., 2006; Thompson et al., 2001; Toga & Thompson, 2005; van Leeuwen et al., 2009). Gray matter in frontal, parietal, and occipital cortex in MZ twins is, as with most aspects of morphology in these individuals, essentially identical (within-pair correlation $>.95$.) In DZ twins, however, a very high but somewhat lesser degree of similarity is observed in gray matter in parietal-occipital cortex and areas of frontal cortex associated with language. As with gray matter, similarity in white matter between MZ twins is (relatively) high ($r = .45–.80$), whereas many white matter regions, particularly frontal and parietal, are actually uncorrelated in DZ twins ($r = .01–.19$) (Chiang et al., 2009).

Although neuroimaging studies have established the very high heritability of brain structure, the correlation of brain volume to IQ in twin studies, as in all studies relating brain structure to IQ, is moderate, at about .33 (McDaniel, 2005). It is not clear, however, that the relation between brain size and IQ is causal. There is conflicting evidence as to whether there is a correlation between siblings' brain size and IQ. A study by Jensen (1994) found a correlation of .32 between head circumference and *g* for a small sample of MZ twins and a correlation of .31 for DZ twins. But several other studies found a weak or no relationship between sibling brain size and sibling IQ. Jensen and Johnson (1994) found a correlation of −.06 between head circumference of siblings at age 4 and a .11 correlation for siblings at age 7, but even the very weak positive relation at age 7 is based on adjusting head size by height and weight, and the truth is we have no idea of what is the appropriate way to adjust for these variables. One small *N* study found a correlation of .15 between brain volume and IQ for siblings (Gignac, Vernon, & Wickett, 2003), but another study with the same design and a larger *N* found a correlation of −.05 between brain volume and the first principal component of a battery of IQ subtests (Schoenemann, Budinger, Sarich, & Wang, 2000).

Cognitive Ability and Neural Efficiency

An important finding of brain imaging research over the past decade is that individuals of higher ability exhibit greater efficiency at the neural level. That is, high-ability individuals are able to solve simple and moderately difficult problems more quickly and with less cortical activity, particularly in PFC, than lower ability individuals (Neubauer & Fink, 2009). Relations between neural activity and intelligence, however, are related to task difficulty in a manner characterized by an inverted U shape. For example, one of the earliest imaging studies to examine the relation of brain activity to fluid intelligence found that more intelligent individuals exhibit less, rather than more, whole brain activity (measured using glucose metabolic rate) when completing items from Raven's Progressive Matrices

(Haier et al., 1988). However, when task difficulty was matched to ability level, individuals with high *g*(F) exhibited increased brain activity relative to individuals with low *g*(F) (Larson, Haier, LaCasse, & Hazen, 1995). Subsequent fMRI studies have confirmed that high-ability individuals are more efficient problem solvers at the neural level and that, as task difficulty increases, high-ability individuals exhibit increasing neural activity in PFC, whereas lower ability individuals exhibit decreasing activity (Callicott et al., 1999; Rypma et al., 2006).

The inverted U relation between neural activity and IQ helps to clarify the findings of neuroimaging studies designed to identify the functional neural correlates of individual differences in intelligence. For example, in a widely cited fMRI study, neural activity in PFC and parietal cortex in response to a working memory task was correlated with fluid intelligence measured with Raven's Progressive Matrices (Gray et al., 2003). This correlation was present, however, only on the most difficult items of the working memory task, in which interference from distracting items was very high. Similarly, a second study also found a correlation between intelligence, using the Raven test, and activation in frontal and parietal regions in response to complex relative to simple visual-spatial reasoning items. Regions most strongly associated with *g*(F), however, were located in posterior parietal cortex (PPC) bilaterally rather than in PFC (Lee et al., 2006). These findings suggest that even on ostensibly more difficult problems, higher ability individuals are able to solve matrices-type reasoning problems more efficiently through visual-spatial attention systems of the PPC rather than more effortful working memory processes associated with PFC. As task difficulty increases, however, as with the most difficult working memory trials in the study of Gray et al. (2003), high-ability individuals exhibit increased prefrontal activity relative to individuals with lower ability.

Although much has been learned about the neural basis for cognitive abilities through the proliferation of neuroimaging studies, the results of these studies provide a somewhat disjointed picture of the neural basis for intelligence. There is much that remains to be learned about the neural basis for the specific cognitive abilities important for intelligence test performance. It appears, however, that like most aspects of behavior, intelligence test performance is multiply determined and that a single neural substrate for intelligence that is activated in similar ways across diverse individuals is not likely to be found.

Differentiation of g(F) and g(C)

In any case, the research to date does makes it clear that *g*(F) and *g*(C) are different sets of abilities, subserved by different parts of the brain: *g*(F) seems to be substantially mediated by the PFC, whereas *g*(C) is not. This is not surprising in view of the following facts, most of which were reviewed by Blair (2006): (a) *g*(F) declines much more rapidly with age than does *g*(C). (b) The PFC deteriorates with age more rapidly than does the rest of the cortex. (c) Severe damage to PFC is associated with marked impairment of *g*(F) but little or no impairment of *g*(C). (d) Severe impairment of *g*(C), such as occurs in autism, is often associated with near-normal or even superior *g*(F). (f) Gains in mental abilities in recent decades have been much less for crystallized abilities (the equivalent of about 10 points in IQ) than for fluid abilities (about 18 points), and they have been particularly dramatic for performance on Raven's Progressive Matrices (28 points), which has traditionally been considered a measure of pure fluid *g* (Flynn, 2007)[4] (g) Training specifically in executive functions such as attention control and working memory can have a marked effect on fluid intelligence as measured by Raven's Progressive Matrices while having little or no effect on crystallized intelligence. (h) Changes in *g*(F) and *g*(C) across the teenage years can be substantial, and those changes are independent of one another and are associated with changes in gray matter in different parts of the brain (Ramsden et al., 2011). It is important to note that of 35 investigators who replied to Blair's (2006) article pointing to evidence that *g*(F) and *g*(C) are quite separate constellations of abilities, only two challenged this contention, and none defended the strong view of *g* as being psychologically unitary and subserved by a single neural network. See also Hunt (2011).

There is a complex relationship between aging and relative declines of *g*(F) versus *g*(C) (J. R. Flynn, 2009c). Intelligence declines in old age, but do brighter individuals decline less or more? We do not have longitudinal data on the question, but cross-sectional data from the WAIS tables indicate that there may be a "bright tax" for fluid intelligence. After age 65, the brighter the person the greater the decline: Whereas those at the median lose an extra 6.35 points (*SD* = 15) compared to those 1 *SD* below the median, those 1 *SD* above the median lose an extra 6.20 points compared to those at the median, and those 2 *SD*s above the median lose an extra 3.40 points compared to those 1 *SD* above. Those who are very bright, rather than below average, pay a total penalty of 16 IQ points. The reverse is true of verbal ability, where there is a "bright bonus" of 6.30 points.

Reciprocal Causation Between Brain Morphology and Intellectual Function

It is important to recognize that the causal arrow between intellectual functioning and brain morphology points in both directions. Exercise of particular skills increases the size of particular areas of the brain. The hippocampus mediates navigation in three-dimensional space. London taxicab drivers have hippocampi that are enlarged—and enlarged in proportion to the amount of time they have been on the job (Maguire et al., 2000). Similarly, the process of learning how to juggle over a three-month period increased the size of gray matter in the mid-temporal area and the left posterior intra-parietal sulcus (Draganski et al., 2004). The extent of structural gray matter growth

[4] German-speaking countries may constitute an exception to the rule for other societies that gains have been greater for fluid than for crystallized intelligence (Pietschnig, Voracek, & Formann, 2010).

was correlated with increased juggling ability. Three months after ceasing to juggle, the size of gray matter expansions was reduced. Three months of playing the visual-spatial game Tetris resulted in increases in cortical thickness in two regions and also in functional changes (though functional changes were not in the same areas as structural changes; Haier, Karama, et al., 2009).

Group Differences in IQ

Two types of group differences in IQ have been exhaustively explored. These are the differences between males and females and the differences between Blacks and Whites (mostly in the United States). Differences between Asians and Westerners have been less well explored, and differences between Jews and non-Jews still less well explored. We summarize the evidence for all four types of differences below. Little is known of any value about Hispanic and American Indian IQs other than that they are lower than those of White Americans and slightly higher than those of Blacks. Estimates of the Hispanic/White gap range from two thirds the size of the Black/White gap for IQ tests to only slightly less than the Black/White gap for academic achievement as measured by the National Assessment of Educational Progress.

Sex Differences in Intelligence

Questions about sex differences in intelligence differ from other group differences because there are some fundamental biological differences between males and females and, despite sex-related differences in socialization practices, both sexes share home environments and SES. However, as for questions about racial differences, the topic is incendiary because the answers we provide have political ramifications that include how and whom we educate, hire, and select as leaders.

Some public school districts have begun to segregate girls and boys on the basis of the belief that they are so different intellectually that they need to be educated separately, a belief that stems from faulty extrapolations from research on sex differences in intelligence. An extensive review conducted by the U.S. Department of Education (Mael, Alonso, Gibson, Rogers, & Smith, 2005) found that the majority of studies comparing single-sex with coeducational schooling reported either no difference or mixed results, and other reviews reported a host of negative consequences associated with single-sex education, including increased sex role stereotyping, which may harm both boys and girls (Halpern et al., 2011; Karpiak, Buchanan, Hosey, & Smith, 2007). As reviewed below, there are some cognitive areas that show average sex differences, but the data from the research literature on intelligence and cognitive skills do not indicate that different learning environments for females and males would be advisable.

Visuospatial, verbal, and quantitative abilities. Jensen (1998) addressed the question of female–male differences in intelligence by analyzing tests that "load heavily on *g*" but were not normed to eliminate sex differences. He concluded, "No evidence was found for sex differences in the mean level of *g* or in the variability of *g*. . . . Males, on average, excel on some factors; females on others" (Jensen, 1998, pp. 531–532). Jensen's conclusion that no overall sex differences exist for intelligence has been bolstered by researchers who assessed intelligence with a battery of 42 mental ability tests (Johnson & Bouchard, 2007). They found that most of the tests showed little or no sex differences. There were, however, several tests that showed a difference between males and females of 0.5 *SD* or more. These differences included an advantage for females for verbal abilities such as fluency and memory abilities and an advantage for males on visuospatial abilities such as object rotation. These researchers recommended that the usual partition of intelligence into fluid and crystallized components be replaced with a model that partitions intelligence into verbal, perceptual, and visuospatial rotation. When this model is used, females excel at verbal and perceptual tasks; males excel at visuospatial tasks.

Sex differences favoring males in mental rotation, which is the ability to imagine what an object would look like if it were rotated, can be found in infants as young as three months of age (Quinn & Liben, 2008). Although this very early difference suggests a strong biological basis for the large sex differences in mental rotation, there is also strong evidence for a large sociocultural/learning contribution. For example, when female and male college students were trained with computer games that required use of spatial visualization, this intervention reduced the gap between male and female performance, though it was not completely eliminated (Feng, Spence, & Pratt, 2007). Likewise, when male and female college students were primed with positive stereotypes ("I'm a student from a selective college") before taking an object rotation task, the gender gap in performance was nearly eliminated. When gender was primed before the test, the gender gap widened (McGlone & Aronson, 2006).

Language difficulties associated with stuttering, dyslexia, and autism are much more prevalent in males than in females (Wallentin, 2009). There is a large female advantage in reading that is found internationally, with girls significantly outscoring boys on the Progress in International Reading Literacy Study in fourth grade and at age 15 in all of the 25 countries that participated in 2003 and in 38 of the 40 countries that participated in 2006 (with no significant between-sex differences in the other two countries (Mullis, Martin, Gonzalez, & Kennedy, 2003). There are also large advantages favoring girls in writing achievement, with "the writing scores of female 8th graders . . . comparable with those of 11th grade males'" (Bae, Choy, Geddes, Sable, & Snyder, 2000, p. 18).

By contrast, mean differences on tests of quantitative achievement tend to be small or nonexistent when measured with standardized tests that reflect the mathematics content that is taught in school (Hyde, Lindberg, Lilnn, Ellis, & Williams, 2008). On average, boys taking the SAT have scored consistently about one third of a standard deviation higher than girls over the last 25 years (College Board, 2004; Halpern et al., 2007), but those values can be misleading because many more girls than boys take the SAT (Hyde et al., 2008).[5]

There are many more mentally retarded (i.e., IQ below 70) males than females, which suggests an X-linked genetic locus for many categories of mental retardation. A review of the literature placed the ratio of males to females at 3.6:1 across several categories of mental retardation (Volkmar & Sparrow, 1993). Males are also more variable in their performance on some tests of quantitative abilities, which results in more males at both the high and low ends of the distribution. The excess of males among the highest scorers received considerable media attention three decades ago when researchers found a 12:1 ratio of boys to girls scoring above 700 on the mathematics portion of the SAT for samples of highly gifted adolescents (Benbow & Stanley, 1983). However, more recent assessments now place the ratio of boys to girls somewhere between 4:1 and 3:1, a very significant reduction that can best be explained by increases in the number and level of mathematics courses that girls and women take (Wai, Cacchio, Putallaz, & Makel, 2010).

Raven's Progressive Matrices is considered the best measure of fluid *g*. Lynn and Irving (2004) reported that males begin to show a significant advantage on Raven's Progressive Matrices at age 15. Flynn and Rossi-Casé (2011) analyzed large and recent samples from five advanced nations. They showed that females matched males on Raven's Progressive Matrices at maturity as well as in childhood. Samples that show a female deficit are biased by the fact that more males drop out of secondary school than females or by the fact that the university intake of females has a lower IQ average than the male intake. Israel was an instructive exception: The small female deficit there was entirely a result of the low scores of Orthodox Jewish women secluded from the modern world.

Causes of sex differences in intelligence. For evolutionary psychologists, the answer to the "why" questions about sex differences lies in the division of labor in hunter-gatherer societies. For example, being able to imagine what something looks like from different angles (spatial rotation) might be more useful to a hunter than a gatherer, and males traditionally do more hunting in primitive societies. Although we recognize the importance of evolutionary pressures in shaping modern humans, modern mathematics and writing had no counterpart in early human societies, and the changing nature of sex differences in many intellectual tasks over the last century cannot necessarily be explained with direct appeals to our evolutionary past.

Because of the complexity of influences on intellectual development, we endorse a biopsychosocial model that recognizes the mutual influences of biological and psychosocial effects. Consider, for example, sex differences in the human brain. Overall, female and male brains are similar in organization and structure, but closer inspection shows that most areas are sexually dimorphic (Giedd, Castellanos, Rajapakse, Vaituzis, & Rapoport, 1997). On average, the male brain is between 8% and 14% larger than the female brain, a difference that is comparable to the sex difference in the mass of other organs such as the heart (Sarikouch et al., 2010) and kidney (I. M. Schmidt, Molgaard, Main, & Michaelsen, 2001). Overall brain size does not plausibly account for differences in aspects of intelligence because all areas of the brain are not equally important for cognitive functioning. In general, females have more gray matter (neuronal cell bodies and dendrites) and males have more white matter in different regions of the brain (Eliot, 2011), and different patterns of gray and white matter correlate with intelligence for males and females (Haier, Jung, Yeo, Head, & Alkire, 2005). Haier and colleagues (2005) concluded, "Men and women apparently achieve similar IQ results with different brain regions, suggesting that there is no singular underlying neuroanatomical structure to general intelligence and that different types of brain designs may manifest equivalent intellectual performance" (p. 320).

Steroidal hormones also play a role in intellectual ability. Prenatal hormones are critical to normal brain development. As Neisser et al. (1996) noted, both prenatal and postnatal hormones influence behavior, including cognition, in characteristically male or female directions.

Sex hormones have effects on cognition throughout life, with many studies showing that higher estrogen levels slightly enhance some cognitive functions, particularly verbal memory in older women, and lower testosterone levels are weakly associated with better verbal fluency in older men (Wolf & Kirschbaum, 2002). In general, the effects of sex steroids on intelligence are small and inconsistent (Luine, 2008) because hormones interact in complex ways that can enhance or diminish cognitive abilities. Contrary to expectations, the Women's Health Initiative, a large randomized control study of hormone replacement therapy, found that dementia rates were higher for women who took hormone supplements; however, many researchers have pointed out serious flaws in this study, including the fact that the women in the hormone group were older, heavier, and less compliant than those in the placebo control group. A leading theory at this time is that there is a critical period (close in time to menopause) when hormone therapy will

[5] The state of Illinois requires all high school juniors to take the ACT, which is a standardized test used for college admissions decisions. Unlike the SAT, its content is more closely aligned with content that is likely to be taught in school. Data from 2009 show that 52% of test takers from Illinois were girls, so even with the requirement that all students take this test, more girls take the ACT. There are four separate scores, with girls scoring slightly higher on English and reading and boys scoring higher on mathematics and science. Although results are in the same general direction as found with the SAT, the effect sizes are small. The ACT also reports the percentages of students who are ready for college-level work in different subjects. The data from Illinois were as follows: 64% for boys and 68% for girls in English, 44% for boys and 37% for girls in mathematics, 48% for both boys and girls in reading, and 30% for boys and 19% for girls in science. Colorado also requires that all high school juniors take the ACT. As in Illinois, girls in Colorado scored higher than boys in English and reading and boys scored higher than girls in math, but not by very much (d = approximately .1); there was no difference in science. Thus, the direction of the sex differences is the same, and the differences are generally smaller than those found with the SAT, which includes a larger sample of girls than boys.

be beneficial for verbal and working memory for women (Luine, 2008) There have been fewer studies of the effects of sex steroids on male cognition, and as with the literature for female participants, hormonal effects are inconsistent and generally small for men as well. In a review article, Janowsky, Chavez, and Orwol (2000) concluded that men with higher testosterone to estrogen ratios have better working memories, but this conclusion is tentative and may change as we gain a better understanding of the cumulative lifetime effects of sex hormones on intelligence.

We are far from understanding the intricate interplay of hormones, brain structures, and intelligence. This is an active area of research, and we can expect important findings in the near future.

Black–White Differences in IQ

About the Black–White difference in IQ, which at the time was about 15 points, the Neisser et al. (1996) article stated, "There is not much direct evidence on this point, but what there is fails to support a genetic hypothesis." That conclusion stands today: There has been no new direct evidence on the question. (See Rushton & Jensen, 2005a, 2005b, Gottfredson, 2005, and Lynn & Vanhanen, 2002, for the view that the Black–White IQ difference is owing substantially to genetic differences between the races and that indirect evidence having to do with such factors as reaction time and brain size is probative. See Nisbett, 2005, 2009, for the view that the direct evidence indicates that the difference between the races is entirely due to environmental factors and that the indirect evidence has little value.) Nisbett (2009) maintains that there is actually a substantial amount of direct evidence stemming from the fact that the "Black" gene pool in the United States contains a large amount of European genes. He maintains that almost all the research indicates no higher IQs for Blacks with a significant degree of European heritage than for those with much less. One of the most telling of the studies was available at the time of the Neisser et al. (1996) report but was apparently not known to them. This is an adoption study by Moore (1986). She examined the IQs of Black and mixed-race children averaging 8½ years of age who were adopted by middle-class families who were either Black or White. The children who were of half-European origin had virtually the same average IQ as the children who were of exclusively Black origin. Hence European genes were of no advantage to this group of "Blacks." Children (both Black and mixed-race) adopted by White families had IQs 13 points higher on average than those adopted by Black families, indicating that there were marked differences in the environments of Black and White families relevant to socialization for IQ; indeed, the differences were large enough to account for virtually the entire Black–White gap in IQ at the time of the study.[6]

Brain size and IQ. The evidence cited by supporters of the genetic view that has received the most attention is the claim that because brain size is related to IQ for both Whites and Blacks and because Blacks have smaller brains than Whites, lower IQ for Blacks is genetically determined and mediated by brain size. As indicated above, it is not clear that the brain size correlation with IQ is genetically mediated. Moreover, a within-group correlation does not establish that between-group differences have the same origin. Brain size differences between men and women are much greater than the race differences in brain size, yet men and women have the same average IQ. Brain size of full-term Black and White infants is the same at birth (Ho, Roessmann, Hause, & Monroe, 1981), and several postnatal factors known to reduce brain size are more common for Blacks than for Whites (Bakalar, 2007; Ho et al., 1981; Ho, Roessmann, Straumfjord, & Monroe, 1980a, 1980b). Finally, sheer brain size is a rather blunt measure of brain differences, which may be less predictive of IQ than measures of the size of particular regions or measures such as the ratio of gray matter to white matter. It is noteworthy, for example, that at a given level of IQ, Chinese have smaller frontal cortexes than Americans (Chee, Zheng, Goh, & Park, 2011), although Chinese brains as a whole may be larger than those of Americans (Rushton, 2010). Even with brain size equated between Chinese and Americans, the frontal cortex is larger in Americans (Chee et al., 2011).

Black gains in IQ. Dickens and Flynn (2006a) analyzed data from nine standardization samples for four major tests of cognitive ability. They found that Blacks gained 5.5 IQ points on Whites between 1972 and 2002. The gap between Blacks and Whites on a measure of *g* had narrowed almost to the same degree, that is, by 5.13 points.

This reduction in the measured *g* gap occurred even though the magnitude of Black gains on Whites by subtest did not correlate highly with Wechsler subtest *g* loadings. This is scarcely surprising, because the *g* loadings of Wechsler subtests are very similar. If one multiplies the Black on White gains by the *g* loadings of the subtests, and then takes a weighted average, the downward shift from IQ to "*g*Q" is very slight. Because all subtests measure *g* either directly or indirectly, Blacks simply could not have gained on Whites unless they had also gained in measured *g*. If Blacks eliminate the racial IQ gap, the measured *g* gap must at least be greatly reduced. Evidence for this comes from Eyferth (1961), who compared the children fathered by Black and White U.S. soldiers in Germany after World War II. His data show that the half-Black children matched the White children not only for IQ but also for measured *g* (J. R. Flynn, 2008).

It is important to note that there is a dramatic decline of Black IQ with age. Four-year-old Blacks are only about 5 points below Whites of the same age, whereas at age 24, Blacks are 17 points below Whites. This could be, as it seems, a loss with age. But it could be that younger cohorts

[6] The sole study consistent with the possibility that European genes are advantageous for Blacks was an adoption study by Scarr and colleagues (Scarr & Weinberg, 1976; Weinberg, Scarr, & Waldman, 1992). But their study was characterized by many flaws acknowledged by the authors. The most serious flaw was that Black children were adopted much later than other children, and age of adoption is strongly negatively associated with IQ.

of Blacks (those born five years ago) have had more favorable life histories than older cohorts of Blacks (born 24 years ago). If it is an age effect, it could have either environmental causes (the Black environment becomes progressively worse and worse relative to the White environment) or genetic causes (genes dictate that Black cognitive growth with age is slower than that of Whites).

The evidence for Black gains on Whites has been challenged in terms of the selection of studies, the magnitude of the gains, and their implications. Readers are directed to the exchange between Rushton and Jensen (2006) and Dickens and Flynn (2006b). A major objection of Rushton and Jensen was that Dickens and Flynn failed to analyze the standardization sample of the Woodcock-Johnson III IQ test. Murray (2006) did that analysis and found Black gains of a magnitude similar to those found by Dickens and Flynn on the four other tests, though the gains on the Woodcock-Johnson test came at an earlier time period than those on the other tests.

One other recent study supports an environmental hypothesis. Fagan and Holland (2007) studied different samples of Blacks and Whites and found that whereas the Blacks were substantially lower than the Whites in word knowledge, they were equally capable of learning new concepts and of making inferences. It may be that knowledge is more influenced by environmental factors than are learning or inferential ability. This result seems to contradict the finding that Blacks tend to underperform Whites on more heavily *g*-loaded tasks such as Raven's Progressive Matrices, and it will be interesting to see if it can be replicated.

Stereotype Threat

Our understanding of group differences in intellectual ability is furthered by the very large literature on psychological reactions to negative stereotypes. Steele and Aronson (1995) argued that when test takers are aware of widespread stereotypes that impugn a group's intelligence (e.g., "Black people are stupid," "Girls can't do math"), they frequently experience the threat of devaluation—by the self, by others, or by both. The resulting arousal and anxiety can impair executive functioning on complex tasks such as standardized aptitude tests. Steele and Aronson called this response *stereotype threat* and demonstrated in a series of experiments that Black test takers scored considerably better—sometimes far better—on intellectual tests when the test was presented in a manner that downplayed ability evaluation or downplayed the relevance of race. Since the publication of Steele and Aronson's 1995 article, some 200 replications of the effect have been published, extending the findings to women and mathematics abilities, Latinos and verbal abilities, elderly individuals and short-term memory abilities, low-income students and verbal abilities, and a number of nonacademic domains as well. See Steele, Spencer, and Aronson (2002) and Aronson and McGlone (2009) for reviews of the literature.

Two recent meta-analyses reported by Walton and Spencer (2009) that included the data from nearly 19,000 students indicate that stereotype threat can cause tests to underestimate the true abilities of students likely to experience stereotype threat (Walton & Spencer, 2009). Walton and Spencer's analysis suggests a conservative estimate that women's math performance and Black students' verbal performance are suppressed by about 0.2 *SD*. In a number of the individual studies, however, the suppression was closer to a full standard deviation.

The stereotype threat formulation has led to a variety of simple educational interventions conducted in schools and colleges that have substantially raised the achievement of Black students (e.g., Aronson, Fried, & Good, 2002; G. L. Cohen, Garcia, Apfel, & Master, 2006) and the achievement of girls in mathematics (Blackwell, Trzesniewski, & Dweck, 2007; Good, Aronson, & Inzlicht, 2003). The studies suggest that stereotype threat suppresses real-world intellectual achievements. Some of the interventions seem remarkably minor on the surface yet produce substantial gains in academic achievement. For example, simple efforts at persuading minority students that their intelligence is under their control to a substantial extent have nontrivial effects on academic performance (Aronson et al., 2002; Blackwell et al., 2007).

A critique of the Steele–Aronson research by Sackett, Hardison, and Cullen (2004) suggests caution in attributing Black–White test score gaps to stereotype threat. In short, the design and analysis of the studies leave the findings open to an alternative interpretation, namely, that inducing stereotype threat in the laboratory simply widens the existing Black–White gap but that reducing stereotype threat leaves this preexisting gap intact. This is indeed a possibility. However, if stereotype threat had no influence on test scores, it would be hard to explain why the interventions specifically targeted to reduce stereotype threat and its effects would have such strong effects on reducing real-world test and achievement gaps. Thus, the weight of the evidence suggests that stereotype threat probably accounts for some of the Black–White difference on intelligence-related tests under some circumstances. At the least, these effects should give one considerable pause when interpreting group differences in intelligence test scores and academic achievement potential.

Asian–White Differences in IQ

The academic achievements and high occupational profile of Chinese and Japanese Americans have inspired speculation about genetic superiority (Lynn, 1987; Rushton, 1995; Weyl, 1969). Flynn (1991) analyzed data from the Coleman Report for the high school graduating class of 1966. That large representative sample included a substantial number of Asian Americans. The Asian Americans had about the same mean IQ as White Americans (actually slightly lower) but scored one third of a standard deviation higher on the SAT than did White Americans. SAT scores may reflect motivational differences—for example, taking more and higher level math courses—to a greater degree than do IQ tests. Remarkably, Chinese Americans in the class of 1966 attained occupations of a professional, managerial, or technical nature at a rate 62% higher than White Americans. The picture that results is that Asian Americans capitalize on a given level of intellectual ability much more than do European Americans.

The differences in achievement between Asian Americans and White Americans are not hard to explain on cultural grounds. East Asians are members of cultures having a Confucian background. An endemic belief in those cultures is that intelligence is primarily a matter of hard work (Chen & Stevenson, 1995; Choi & Markus, 1998; Choi, Nisbett, & Norenzayan, 1999; Heine et al., 2001; Stevenson et al., 1990). For thousands of years in China it was possible for the poorest villager to become the highest magistrate in the land through study. Families with a Confucian background exert far more influence on their children than do most families of European culture (Fiske, Kitayama, Markus, & Nisbett, 1998; Markus & Kitayama, 1991). They can demand of their children excellence in education and preparation for high-status careers and expect their children to try to comply. Matters in the United States have changed since the passage of immigration laws in the late 1960s that encouraged the immigration of highly skilled workers. That change resulted in a huge inflow of talented East and South Asians. These people bring on average very substantial educational and cultural capital and undoubtedly some genetic advantage over the general U.S. population.

Jewish–Non-Jewish Differences in IQ

There is little good evidence about just what IQ levels are typical for Ashkenazi Jews. (There is even less evidence available for Sephardic Jews, and in the rest of this section "Jews" should be taken to mean "Ashkenazi Jews of European descent.") Jewish IQs have been variously estimated to be 7–15 points higher than those of White non-Jews in Britain and America (Flynn, 1991; Lynn, 2004, 2006). All available studies, however, are based on samples of convenience.

It is not clear to what we should attribute the greater overall intellectual ability popularly attributed to Jews and supported by (weak) data. It is certainly possible to invoke cultural explanations, and there are numerous armchair genetic theories as well. One genetic theory may have more substance to it than the others. This is the "sphingolipid" theory of Cochran, Hardy, and Harpending (2005). Cochran et al. noted that Jews are subject to several distinctive genetic conditions that involve an excess of sphingolipids—the substance that forms part of the insulating outer sheaths that allow nerve cells to transmit electrical signals and encourage growth of dendrites. These illnesses include Tay-Sachs disease, Niemann-Pick disease, and Gaucher's disease. Having too many of these sphingolipids is fatal or at least likely to result in serious illness that can prevent reproduction. Why does natural selection not eliminate these diseases? Cochran et al. enlisted the sickle-cell anemia analogy. The sickle-cell gene produces illness for individuals who have two copies of it (one from each parent). But those with only one copy of the gene are provided with protection against malaria. Cochran et al. argued that because Jews were segregated into trade and finance since their arrival in Europe in the 8th century AD, intelligence conferred a larger reproductive advantage for them than for others. The main evidence in favor of the sphingolipid theory is that Jews with Gaucher's disease are more likely to be working in occupations demanding extremely high IQ than are other Jews. No direct test of the association of the genes for these diseases with intelligence has been made, so the theory remains merely an intriguing suggestion.

It is important to note that even at the highest estimates we have of Jewish IQ, Jewish accomplishment exceeds what would be predicted on the basis of IQ alone. Nisbett (2009) has argued that the numbers of Jewish Ivy Leaguers, professors at elite colleges, Supreme Court clerks, and Nobel Prize winners are greater than one would expect even if average Jewish IQ were 115. He has also noted that remarkable as the superior achievement of Jews is, the achievement difference between Jews and non-Jews is far less extreme than differences between groups in many other comparisons that cannot be explained on purely genetic grounds, such as the achievements of the Italians versus the English in the 15th century, of the English versus the Italians after the 18th century, of Arabs versus Europeans in the 8th century, of Europeans versus Arabs after the 14th century, and of New Englanders versus Southerners throughout American history.

Important Unresolved Issues

We can discuss some broad issues with greater clarity than was possible at the time of the Neisser et al. (1996) review. First, it has been proposed that working memory is essentially identical to fluid intelligence. We discuss the evidence on both sides of this issue. Second, the massive Flynn effect gains in IQ seem to contradict the data indicating that IQ is substantially heritable. We report an attempted resolution of the paradox. Third, several recent theories may throw new light on the concept of *g*. Fourth, there is growing evidence that self-regulation or self-control abilities may have as much effect on academic and other life outcomes as IQ. We explore the relationship between self-regulation and IQ and examine possible mechanisms through which self-control influences intellectual achievement. Fifth, the issue of the effect of stress on the central nervous system has become a focus of attention recently, but many questions arise concerning its importance, the mechanisms by which it operates, and whether class and race differences in stress contribute to group differences in IQ.

The Relationship Between Working Memory and Intelligence

Over the last two decades, many researchers have noted that working memory and fluid intelligence, *g*(F), are highly related concepts. Working memory is the active processing system that simultaneously stores and manipulates relevant information, often in the face of distracting or competing information or the need to inhibit incorrect responses (Engle, 2002). The predominant model of working memory posits verbal, visuospatial, and episodic memory as three subsystems that are coordinated by an executive that is often conceptualized as attentional control (Baddeley, 2002; Baddeley & Hitch, 1974). The capacity of working memory is measured with tests that require participants to keep verbal or visuospatial information in memory while solving problems such as sentence comprehension, arithmetic, and abstract reasoning. Scores on tests of working memory capacity have high correlations with reading comprehension, reasoning abilities, and scores on the SAT (Daneman & Carpenter, 1980; Kyllonen & Christal, 1990; Turner & Engle, 1989).

The relation between working memory and the general factor of intelligence has reached identity ($r = 1.00$) in some studies using latent variable analysis (Gustafsson, 1984; Süβ, Oberauer, Wittmann, Wilhelm, & Schulze, 2002) and is, on average, .72 (Kane, Hambrick, & Conway, 2005). The extent of the relation between working memory and general intelligence, however, remains in dispute. Primary points of contention concern the specific definition of working memory (Ackerman, Beier, & Boyle, 2005) and the extent to which speed of processing rather than working memory best explains individual differences in intelligence (Conway, Cowan, Bunting, Therriault, & Minkoff, 2002; Fry & Hale, 2000; Salthouse, 1996; Salthouse & Pink, 2008; Sampson, 1988).

The argument about whether working memory explains individual differences in *g*(F) is important because of the close association of *g*(F) with *g*. Following from this association, as we noted earlier, scientists have recently shown that *g*(F) can be markedly enhanced by training people to increase the capacity of their working memory. However, the research establishing this fact provides no indication that training of these functions influences *g*(C). Thus the case for identifying either working memory or *g*(F) with *g* is rendered implausible. Nevertheless, the relations among working memory and other executive functions, *g*(F), and *g* are clearly complex, and much remains to be learned.

Reconciling IQ Gains and Heritability

The discovery of IQ gains over time created a seeming paradox. Identical twin studies (and other kinship studies) indicated that genetic influence on IQ is strong and the effects of environment on IQ are weak. But Dutch males gained 20 IQ points on a test composed of 40 items from Raven's Progressive Matrices between 1952 and 1982, which seems to imply environmental factors of enormous potency. How can environment be so weak and so potent at the same time? Dickens and Flynn (2001a, 2001b) offered a model that distinguishes the dynamics of a situation in which two separated twins develop highly similar IQs and of a situation in which a whole society shows a huge IQ gain over time.

When identical twins are separated at birth, they initially share only common genes. But soon those common genes begin to access environments far more alike than those of randomly selected individuals. If both twins are taller and quicker than average, although raised in different cities, they are more likely to play basketball a lot, get selected for their school team, and get professional coaching. There is a dynamic interplay each step of the way, whereby better than average ability accesses an enriched environment, which enhances the ability advantage, which accesses an even more enriched environment, and so forth. Similarly, if twins have slightly better brains than average, although raised apart, they are both more likely to enjoy school, get into an honors stream, go to a top university, and so forth.

Dickens and Flynn (2001a, 2001b) call this process the *individual multiplier*. Thanks to the individual multiplier, the fact that separated twins have powerful environmental factors in common is "masked," and their common genes get all of the credit for their highly similar IQs.

Between generations, the quality of genes is relatively constant, and the potency of environment is clearly revealed. A persistent environmental factor like the advent of TV can enhance the popularity of basketball, so that more people play it more enthusiastically. This raises the average performance, and the rising performance develops its own momentum. There is a second kind of dynamic interaction whereby the rising mean (some people learn to shoot with either hand) encourages every individual to improve (more people begin to shoot with either hand), which raises the mean further, which influences the individual further, and there is a great escalation of skills over time. If the Industrial Revolution puts a premium on credentials, and lucrative cognitive work expands, the more people in general need increased cognitive skills. This seems likely to result in increasing cognitive challenges in educational and entertainment settings and an explosion of college enrollments.

Dickens and Flynn (2001a, 2001b) call this process the *social multiplier*. Thanks to the social multiplier, the evolving environment can cause huge cognitive gains over time with no assistance from better genes. The two multipliers are operating simultaneously—genetic differences between individuals that are rendered potent by individual multipliers (registering in the twin studies) and environmental differences between the generations that are rendered potent by the social multiplier (registering huge IQ gains over time).

To the extent that Blacks and Whites interact mainly with members of their own groups, potent social multipliers could be exacerbating the existing differences in intelligence. If the primary environmental causes (e.g., discrimination in jobs and housing) are removed, the multiplier effects should unwind; that is, the removal of small persistent environmental differences between groups could have large effects on group differences in IQ.

Rowe and Rodgers (2002) argued that the Dickens–Flynn model implies that IQ variance should have increased at the same time that mean IQ increased. Loehlin (2002) generalized the model and faulted the family of models presented for failure to specify the time scale involved and for failure to address developmental aspects. Dickens and Flynn (2002) contended that the model does not imply increased variance and is consistent with plausible theories of development. Rushton and Jensen (2005a) criticized the model on the grounds that it (a) implied mistakenly that Black–White differences in IQ should increase over the course of development and (b) could not explain the rise in heritability from 0.4 during childhood to 0.8 at maturity. Dickens (2009) replied as follows: (a) In fact, the Black–White gap does increase with age, but even if it did not, whether or not one could detect the increase would depend on how quickly the multipliers work. If they worked quickly enough, one might not see any change in the Black–White difference once children were old enough to test. (b) The model was actually proposed in part to explain why heritability should increase with age. Mingroni (2007) criticized the model on multiple grounds and Dickens (2009) responded.

We emphasize that the Dickens–Flynn model, while good at explaining a wide range of facts about intelligence, has not been subject to very much empirical testing.

What Is g?

Some have suggested that whatever the cause of societal gains in cognitive ability, they are irrelevant to debates about the malleability of cognitive ability because they are not *g* gains (Gottfredson, 2007; Rushton, 1999, 2000; Rushton & Jensen, 2005a). It is argued that IQ tests derive their predictive power from their ability to measure *g* and that if secular gains are not *g* gains, then they have no practical value.

In a simple model in which all cognitive abilities are a linear function of one important underlying ability, an increase in that unitary ability would lead the abilities that derive from it to increase in proportion to their dependence on that underlying cause. The gain on each ability would be proportional to its loading on the first factor derived from an analysis of all the abilities (i.e., the abilities' *g* loadings). Various studies using the method of correlated vectors reach different conclusions about the extent to which secular gains are proportional to (correlated with) *g* loadings,[7] but Wicherts, Jelte, Dolan, and Hessen (2004) rejected the hypothesis that secular gains on different tests are purely *g* gains. However, the same can be said for the trajectory of abilities as children develop and as ability declines in old age. A single-factor *g* model cannot explain either the pattern of growth in ability or the pattern of decline in ability (Finkel, Reynolds, McArdle, & Pedersen, 2007; McArdle, Ferrer-Caja, Hamagami, & Woodcock, 2002; McArdle, Hamagami, Meredith, & Bradway, 2000).

This lack of a relationship between *g* loading and improving subtest scores across a range of different dimensions is not terribly damaging to the notion of a dominant underlying ability so long as one has a more nuanced view as to how that general ability relates to the specific abilities measured by the subtests. Cattell (1971) viewed fluid *g* as the ability to solve new problems on the spot and the ability to learn new things. Crystallized *g* was the knowledge that one accumulated by applying one's fluid ability in different areas. Someone who always had more fluid *g* would also have more crystallized *g*, but crystallized *g* could grow while fluid *g* remained constant, and if fluid *g* began to fall, crystallized *g* could still continue to rise as long as the rate of building crystallized *g* surpassed the rate at which it was lost. Thus, there would be no reason to expect tests of crystallized and fluid abilities to rise and decline at the same time or rate.

Studies of the rate of decline of different cognitive abilities are consistent with such a view (McArdle et al., 2002). Individuals' scores on tests that tap mainly fluid abilities (such as Raven's Progressive Matrices) decline with age much earlier and more rapidly on average than do their scores on tests of crystallized abilities such as vocabulary or general knowledge. However, studies that attempt to determine whether fluid ability can predict changes in crystallized abilities tell a more complicated story. McArdle and colleagues (2000) found that fluid ability does not predict crystallized ability (operationalized as vocabulary) in individuals, but memory does, and memory is somewhat influenced by fluid ability. Ferrer and McArdle (2004) used a broader set of measures of crystallized ability. Like McArdle et al. (2000), they found no evidence that fluid abilities predict changes in vocabulary in individuals, but they did find that fluid ability predicted academic knowledge and quantitative abilities. Finally, Hambrick, Pink, Meinz, Pettibone, and Oswald (2008) estimated a structural equation model of the relationship between a number of factors to see what could predict gains in knowledge of current events. They found that *g*(F) predicts the initial level of knowledge and that the initial level of knowledge predicts gains, but they found no direct role for *g*(F) in predicting gains.

These studies suggest a complex interplay of different abilities in the dynamics both of early life development and of later life decline. What then explains the relatively stable factor structure of abilities described by Carroll (1993)? Several recent papers have suggested how a *g* factor could arise despite the independence of its components (Bartholomew, Deary, & Lawn, 2009; Dickens, 2007; van der Maas et al., 2006). Dickens (2007) showed that a general intelligence factor would appear because people who are better at any given cognitive skill are more likely to end up in environments that cause them to develop a wide range of skills. He attempted to account for the important facts about *g* without postulating any underlying physiological base for the correlation of abilities. People may indeed have physiological advantages over one another for one or more cognitive skills, but Dickens showed that even if these skills are initially largely independent of one another, after people interact with their environments, these skills

[7] Colom, Juan-Espinosa, and Garcia (2001) and Juan-Espinosa et al. (2000) found strong correlations between *g* loadings and IQ gains. Jensen (1998, pp. 320–321) reviewed a number of studies of the relation between subtest gains and *g* loadings, all of which showed weak positive correlations. Rushton (1999, 2000) found that a measure of *g* developed on the WISC has loadings that are negatively correlated with subtest gains in several countries. But Flynn (2006) argued that IQ gains are greatest on tests of fluid *g* rather than crystallized *g*, and he found a positive (although statistically insignificant) correlation between a measure of fluid *g* he developed and IQ gains in the same data used by Rushton. Must et al. (2003) found no correlation between *g* loadings and gains on two tests in Estonia, but these were achievement tests with a strong crystallized bias.

will no longer be independent. Someone who is good at any intellectual skill is more likely to end up in environments where all skills will be practiced, which will lead to the development of all skills. It should be noted that if a process such as this helps to explain the correlation of different abilities, then there would be no reason to expect that secular societal gains on IQ subtests would be proportional to *g* loadings for those subtests. (See also Hunt, 2011.)

Van der Maas and colleagues (2006) also proposed a model of the origin of *g* that introduces many interesting properties. Initially uncorrelated abilities become more correlated over time because they are mutually reinforcing. However, the model of van der Maas et al. does not distinguish between genetic and environmental effects. Integration of that model with Dickens's (2007) model could provide a more compelling description of the development process. Again, if the van der Maas model explains the correlation across different abilities, there would be no reason to expect that secular gains on different tests would come in proportion to their *g* loadings.

Bartholomew et al. (2009) provided a description of how uncorrelated underlying abilities might be combined by different test items, producing a *g* factor. As in the other models of *g* just referred to, the underlying abilities are assumed to be uncorrelated. A *g* factor emerges because any test item taps multiple abilities. Thus there will be a tendency for items that tap some of the same abilities to be correlated, resulting in a correlation matrix between test items having all positive elements. Such a matrix will always yield a first principal factor that loads positively on all test items. As in the van der Maas et al. (2006) model, no explicit recognition is given to the role of genetics in shaping *g,* and thus many of the issues that Dickens (2007) addressed, such as the correlation of *g* loadings and the heritability of different abilities, are unaddressed in the Bartholomew et al. model. As with both the Dickens and van der Maas models, there is no reason to expect that secular gains in ability would be proportional to factor loadings.

Self-Regulation and Schooling

What is it about school and preschool that enhances intelligence and academic abilities? Content knowledge (e.g,, learning about climate in different places in the world) and procedural knowledge (e.g., sorting shapes) are of course important, but increasingly scientists are recognizing the importance of developing self-regulatory skills and other noncognitive traits as requisite for high-level intellectual functioning (Blair, 2002; Calero, Garcia-Martin, Jimenez, Kazen, & Araque, 2007; Chetty et al., 2010; Diamond, Barnett, Thomas, & Munro, 2007; Heckman, 2006, 2011). Self-regulatory skills include behaviors such as being able to wait in line, inhibiting the desire to call out in class, and persevering at a task that may be boring or difficult. There are many terms in the literature for the general idea that people can recognize, alter, and maintain changes in their behaviors and moods in ways that advance cognitive performance. These terms include *self-discipline* (Duckworth & Seligman, 2005), the ability to *delay gratification* (Mischel, Shoda, & Peake, 1988), and *self-regulated learning* (P. A. Alexander, 2008).

In a classic study of self-regulation, Mischel et al. (1988) found that four-year-old children who delayed the immediate gratification of eating one marshmallow so that they would be allowed to eat two marshmallows later scored higher on the SAT they took for college entrance over a decade later. A study with similar implications was conducted with eighth-grade students at a magnet public school (Duckworth & Seligman, 2005). Students were given envelopes that contained $1. They could either spend the dollar or exchange the envelope for one containing $2 the following week. In addition, students were rated on numerous other measures of self-discipline. The authors reported that scores on a composite measure of self-discipline predicted academic performance and learning gains over the academic year in which the study was conducted and did so better than IQ tests. Similar studies with college students at Ivy League schools, students at a military academy, and spelling bee participants found that self-discipline and ability to delay gratification predicted success across a variety of academic measures (Duckworth, Peterson, Matthews, & Kelly, 2007).

Several cognitive variables that could explain the effect of self-regulation on intellectual tasks have been investigated. For example, individuals with larger working memory capacities are better able to regulate their emotions (Schmeichel, Volokhov, & Demaree, 2008), and individuals who are better able to suppress their emotions have higher scores than their more impulsive peers on the Raven's Progressive Matrices, a standard measure of *g*(F) (Shamosh & Gray, 2007). There are at least three possible explanations for the relationship between self-regulation and higher scores on tests of *g*(F): (a) The ability to self-regulate could be a manifestation of intelligence; (b) these constructs could share common variance such that they are both affected by a third variable; or (c) self-regulation could be one of the processes that facilitate the development of intelligence.

There is evidence that self-control, or at any rate some set of nonintellective motivational factors, contributes not only to life outcomes but to IQ scores themselves. Duckworth, Quinn, Lynam, Loeber, and Stouthamer-Loeber (2011) have shown in a meta-analysis of over 40 samples that incentives for good test performance improve IQ scores by about 10 points. For samples for which the average baseline IQ was less than 100, the gain due to incentives was about 14 points. The lower the baseline IQ, the greater the gain due to incentives, and the larger the incentives offered, the larger the IQ gain. The investigators also examined the correlates of assessed test-taking motivation (based on refusal to attempt parts of the test, responding rapidly with "I don't know" answers, etc.) for a group of middle-school boys. IQ predicted academic outcomes in adolescence and total years of education by the age of 24. So did the nonintellective traits, though to a lesser degree. Nonintellective traits predicted nonacademic outcomes—criminal convictions and employment in adulthood—as well as did IQ.

The influence of nonintellective factors on life outcomes is revealed by the sobering (to Americans, at least) scores of 12th-graders on mathematics and science in the Third International Mathematics and Science Study of 41 nations. The United States came in last for both fields of study. Test motivation, as indicated by the number of optional self-report questions answered in a background questionnaire, accounted for 53% of between-nation variance and 22% of between-classroom variance within nations (Boe, May, & Boruch, 2002).

Additional motivational issues for future examination include the following: (a) If self-regulation is what lies behind the academic success obtained by children who were in the experimental conditions in effective preschool interventions, as many have suggested, then it indicates that self-regulation has aspects that are not directly related to IQ, as these programs typically have little sustained effect on IQ. (b) Would interventions designed specifically to increase self-control improve performance on IQ tests and—more importantly—on academic achievement tests?

Stress, Intelligence, and Social Class

One factor that Neisser and colleagues (1996) did not deal with extensively is stress. Chronic, continuous stress—what can be considered as "toxic" stress—is injurious over time to organ systems, including the brain. Chronically high levels of stress hormones damage specific areas of the brain—namely, the neural circuitry of PFC and hippocampus—that are important for regulating attention and for short-term memory, long-term memory, and working memory (McEwen, 2000). Although the extent to which the effect of early stress on brain development and stress physiology may affect the development of intelligence is not currently known, we do know that (a) stress is greater in low-income home environments (Evans, 2004) and (b) a low level of stress is important for self-regulation and early learning in school (Blair & Razza, 2007; Ferrer & McArdle, 2004; Ferrer et al., 2007).

Research suggests that part of the Black–White IQ gap may be attributable to the fact that Blacks, on average, tend to live in more stressful environments than do Whites. This is particularly the case in urban environments, where Black children are exposed to multiple stressors. Sharkey (2010), for example, has recently found that Black children living in Chicago (ages 5–17) scored between 0.5 and 0.66 *SD* worse on tests (both the WISC-Revised and the Wide Range Achievement Test-3) in the aftermath of a homicide in their neighborhood. Sharkey's data show that debilitating effects were evident among children regardless of whether they were witnesses to the homicide or had simply heard about it.

An impressive study by Eccleston (2011) indicates that even stress on the pregnant mother may have enduring effects on her children. The children born to women in New York City who were in the first six months of pregnancy when 9/11 occurred had lower birth weights than children born before 9/11 or well after it, and the boys at the age of six were more than 7% more likely to be in special education and more than 15% more likely to be in kindergarten rather than first grade. Oddly, girls' academic status was unaffected by mothers' stress. Investigation of relations between early stress and intelligence thus seems an important direction for future research. A particularly important issue concerns the degree to which the effects of stress on the brain are reversible.

These five unresolved issues are merely examples of some of the important contemporary paradoxes and unknowns in intelligence research. It is to be hoped that as much progress on these and other issues will be made in the next 15 years as has been made on some of the paradoxes and unknowns since the time of the Neisser et al. (1996) review.

REFERENCES

Aamodt, S., & Wang, S. (2007, November 8). Exercise on the brain. *The New York Times.* Retrieved from http://www.nytimes.com/2007/11/08/opinion/08aamodt.html?ref=opinion

Ackerman, P. L., Beier, M. E., & Boyle, M. O. (2005). Working memory and intelligence: The same or different constructs? *Psychological Bulletin, 131,* 30–60. doi:10.1037/0033-2909.131.1.30

Adam, S., Bonsang, E., Germain, S., & Perelman, S. (2007). *Retirement and cognitive reserve: A stochastic frontier approach to survey data* (CREPP Working Paper 2007/04). Liège, Belgium: Centre de Recherche en Économie et de la Population.

Alexander, K. L., Entwisle, D. R., & Olson, L. S. (2001). Schools, achievement, and inequality: A seasonal perspective. *Educational Evaluation and Policy Analysis, 23,* 171–191. doi:10.3102/01623737023002171

Alexander, P. A. (2008). Why this and why now? Introduction to the special issue on metacognition, self-regulation, and self-regulated learning. *Educational Psychology Review, 20,* 369–372. doi:10.1007/s10648-008-9089-0

Anderson, J. W., Johnstone, B. M., & Remley, D. T. (1999). Breast-feeding and cognitive development: A meta-analysis. *American Journal of Clinical Nutrition, 70,* 525–535.

Aronson, J., Fried, C. B., & Good, C. (2002). Reducing stereotype threat and boosting academic achievement of African-American students: The role of conceptions of intelligence. *Journal of Experimental Social Psychology, 38,* 113–125. doi:10.1006/jesp.2001.1491

Aronson, J., & McGlone, M. (2009). Stereotype and social identity threat. In T. D. Nelson (Ed.), *Handbook of prejudice, stereotyping, and discrimination* (pp. 153–178). New York, NY: Psychology Press.

Asbury, K., Wachs, T. D., & Plomin, R. (2005). Environmental moderators of genetic influence on verbal and nonverbal abilities in early childhood. *Intelligence, 33,* 643–661. doi:10.1016/j.intell.2005.03.008

Baddeley, A. D. (2002). Is working memory still working? *European Psychologist, 7,* 85–97. doi:10.1027//1016-9040.7.2.85

Baddeley, A. D., & Hitch, G. J. (1974). Working memory. In G. H. Bower (Ed.), *The psychology of learning and motivation* (Vol. 8, pp. 47–89). New York, NY: Academic Press.

Bae, Y., Choy, S., Geddes, C., Sable, J., & Snyder, T. (2000). *Trends in educational equity of girls & women* (NCES 2000–30). Washington, DC: U.S. Government Printing Office.

Bakalar, N. (2007, February 27). Study points to genetics in disparities in preterm births. *The New York Times.* Retrieved from http://query.nytimes.com/gst/fullpage.html?res=9E01E5DC1E3EF934A15751C0A9619C8B63&sec=&spon=&pagewanted=all

Ball, K., Berch, D. B., Helmers, K. F., Jobe, J. B., Leveck, M. D., Marsiske, M., . . . Willis, S. L. (2002). Effects of cognitive training interventions with older adults: A randomized controlled trial. *JAMA: Journal of the American Medical Association, 288,* 2271–2281. doi:10.1001/jama.288.18.2271

Bartholomew, D. J., Deary, I. J., & Lawn, M. (2009). A new lease on life for Thomson's bonds model of intelligence. *Psychological Review, 116,* 567–579. doi:10.1037/a0016262

Basak, C., Boot, W. R., Voss, M. W., & Kramer, A. F. (2008). Can training in a real-time strategy video game attenuate cognitive decline in older adults? *Psychology and Aging, 23,* 765–777. doi:10.1037/a0013494

Beauchamp, J. P., Cesarini, D., Johannesson, M., Erik Lindqvist, E., & Apicella, C. (2011). On the sources of the height–intelligence correlation: New insights from a bivariate ACE model with assortative mating. *Behavior Genetics, 41,* 242–252. doi:10.1007/s10519-010-9376-7

Bedard, K., & Dhuey, E. (2006). The persistence of early childhood maturity: International evidence of long-run age effects. *Quarterly Journal of Economics, 121,* 1437–1472.

Benbow, C. P., & Stanley, J. C. (1983, December 2). Sex differences in mathematical reasoning ability: More facts. *Science, 222,* 1029–1031. doi:10.1126/science.6648516

Blackwell, L. S., Trzesniewski, K., & Dweck, C. S. (2007). Implicit theories of intelligence predict achievement across an adolescent transition: A longitudinal study and an intervention. *Child Development, 78,* 246–263. doi:10.1111/j.1467-8624.2007.00995.x

Blair, C. (2002). School readiness: Integrating cognition and emotion in a neurobiological conceptualization of children's functioning at school entry. *American Psychologist, 57,* 111–127. doi:10.1037/0003-066X.57.2.111

Blair, C. (2006). How similar are fluid cognition and general intelligence? A developmental neuroscience perspective on fluid cognition as an aspect of human cognitive ability. *Behavioral and Brain Sciences, 29,* 109–125. doi:10.1017/S0140525X06009034

Blair, C., Gamson, D., Thorne, S., & Baker, D. (2005). Rising mean IQ: Cognitive demand of mathematics education for young children, population exposure to formal schooling, and the neurobiology of the prefrontal cortex. *Intelligence, 33,* 93–106. doi:10.1016/j.intell.2004.07.008

Blair, C., & Razza, R. P. (2007). Relating effortful control, executive function, and false belief understanding to emerging math and literacy ability in kindergarten. *Child Development, 78,* 647–663. doi:10.1111/j.1467-8624.2007.01019.x

Boe, E. E., May, H., & Boruch, R. F. (2002). *Student task persistence in the Third International Mathematics and Science Study: A major source of achievement differences at the national, classroom, and student levels* (Research Rep. No. 2002-TIMSS1). Philadelphia, PA: University of Pennsylvania, Graduate School of Education, Center for Research and Evaluation in Social Policy. Retrieved from http://www.gse.upenn.edu/cresp/pdfs/20070130151136207.pdf

Borella, E., Carretti, B., Riboldi, F., & De Beni, R. (2010). Working memory training in older adults: Evidence of transfer and maintenance effects. *Psychology and Aging, 25,* 767–778. doi:10.1037/a0020683

Bouchard, T. J. (2004). Genetic influence on human psychological traits. *Current Directions in Psychological Science, 13,* 148–151. doi:10.1111/j.0963-7214.2004.00295.x

Bouchard, T. J., & McGue, M. (2003). Genetic and environmental influences on human psychological differences. *Journal of Neurobiology, 54,* 4–45. doi:10.1002/neu.10160

Bradley, R. H., Whiteside, L., Caldwell, B., Casey, P. H., Kelleher, K., Pope, S., . . . Cross, D. (1993). Maternal IQ, the home environment, and child IQ in low birthweight, premature children. *International Journal of Behavioral Development, 16,* 61–74. doi:10.1177/016502549301600104

Braungart, J. M., Plomin, R., DeFries, J. C., & David, W. (1992). Genetic influence on tester-rated infant temperament as assessed by Bayley's Infant Behavor Record: Nonadoptive and adoptive siblings and twins. *Developmental Psychology, 28,* 40–47. doi:10.1037/0012-1649.28.1.40

Brinch, C. N., & Galloway, T. A. (2011). *Schooling in adolescence raises IQ.* Oslo, Norway: Research Department of Statistics Norway.

Brody, N. (2003). Construct validation of the Sternberg Triarchic Abilities Test: Comment and reanalysis. *Intelligence, 31,* 319–329. doi:10.1016/S0160-2896(01)00087-3

Burkam, D. T., Ready, D. D., Lee, V. E., & LoGerfo, L. F. (2004). Social-class differences in summer learning between kindergarten and first grade: Model specification and estimation. *Sociology of Education, 77,* 1–31. doi:10.1177/003804070407700101

Butcher, L. M., Davis, O. S. P., Craig, I. W., & Plomin, R. (2008). Genome-wide quantitative trait locus association scan of general cognitive ability using pooled DNA and 500K single nucleotide polymorphism microarrays. *Genes, Brains and Behavior, 7,* 435–446. doi:10.1111/j.1601-183X.2007.00368.x

Cahan, S., & Cohen, N. (1989). Age vs. schooling effects on intelligence development. *Child Development, 60,* 1239–1249. doi:10.2307/1130797

Calero, M. D., Garcia-Martin, M. B., Jimenez, M. I., Kazen, M., & Araque, A. (2007). Self-regulation advantage for high-IQ children: Findings from a research study. *Learning and Individual Differences, 17,* 328–343. doi:10.1016/j.lindif.2007.03.012

Callicott, J. H., Mattay, V. S., Bertolino, A., Finn, K., Coppola, R., & Frank, J. A. (1999). Physiological characteristics of capacity constraints in working memory as revealed by functional MRI. *Cerebral Cortex, 9*(1), 20–26. doi:10.1093/cercor/9.1.20

Campbell, F. A., Pungello, E. P., Miller-Johnson, S., Burchinal, M., & Ramey, C. T. (2001). The development of cognitive and academic abilities: Growth curves from an early childhood educational experiment. *Developmental Psychology, 37,* 231–242. doi:10.1037/0012-1649.37.2.231

Campbell, F. A., & Ramey, C. T. (1995). Cognitive and school outcomes for high-risk African-American students at middle adolescence: Positive effects of early intervention. *American Educational Research Journal, 32*(4), 743–772.

Campbell, F. A., Ramey, C. T., Pungello, E., Sparling, J., & Miller-Johnson, S. (2002). Early childhood education: Young adult outcomes from the Abecedarian Project. *Applied Developmental Science, 6,* 42–57. doi:10.1207/S1532480XADS0601_05

Carroll, J. B. (1993). *Human cognitive abilities: A survey of factor-analytic studies.* New York, NY: Cambridge University Press. doi:10.1017/CBO9780511571312

Caspi, A., Williams, B., Kim-Cohen, J., Craig, I. W., Milne, B. J., Poulton, R., . . . Moffitt, T. E. (2007). Moderation of breastfeeding effects on the IQ by genetic variation in fatty acid metabolism. *Proceedings of the National Academy of Sciences, USA, 104,* 18860–18865. doi:10.1073/pnas.0704292104

Catalan, J., Moriguchi, T., Slotnick, B., Murthy, M., Greiner, R. S., & Salem, N., Jr. (2002). Cognitive deficits in docosahexaenoic acid-deficient rats. *Behavioral Neuroscience, 116,* 1022–1031. doi:10.1037//0735-7044.116.6.1022

Cattell, R. B. (1971). *Abilities: Their structure, growth and action.* Boston, MA: Houghton-Mifflin.

Cattell, R. B. (1973). *Measuring intelligence with the Culture Fair Tests: Manual for Scales 2 and 3.* Champaign, IL: Institute for Personality and Ability Testing.

Ceci, S. J. (1991). How much does schooling influence general intelligence and its cognitive components? A reassessment of the evidence. *Developmental Psychology, 27,* 703–722. doi:10.1037/0012-1649.27.5.703

Chee, M. W. L., Zheng, H., Goh, J. O. S., & Park, D. (2011). Brain structure in young and old East Asians and Westerners: Comparisons of structural volume and cortical thickness. *Journal of Cognitive Neuroscience, 23,* 1065–1079. doi:10.1162/jocn.2010.21513

Chen, C., & Stevenson, H. W. (1995). Motivation and mathematics achievement: A comparative study of Asian-American, Caucasian-American, and East-Asian high school students. *Child Development, 66,* 1215–1234. doi:10.1111/j.1467-8624.1995.tb00932.x

Chetty, R., Friedman, J. N., Hilger, N., Saez, E., Schanzenbach, D. H., & Yagan, D. (2010). *How does your kindergarten classroom affect your earnings? Evidence from Project Star.* Cambridge, MA: National Bureau of Economic Research.

Chiang, M.-C., Barysheva, M., Shattuck, D. W., Lee, A. D., Madsen, S. K., Avedissian, C., . . . Thompson, P. M. (2009). Genetics of brain fiber architecture and intellectual performance. *Journal of Neuroscience, 29*(7), 2212–2224. doi:10.1523/JNEUROSCI.4184-08.2009

Chiang, M. C., McMahon, K. L., de Zubicaray, G. I., Martin, N. G., Hickie, I., Toga, A. W., . . . Thompson, P. M. (2011). Genetics of white matter development: A DTI study of 705 twins and their siblings aged 12 to 29. *NeuroImage, 54,* 2308–2317.

Choi, I., & Markus, H. R. (1998). *Implicit theories and causal attribution East and West.* Unpublished manuscript, University of Michigan.

Choi, I., Nisbett, R. E., & Norenzayan, A. (1999). Causal attribution

across cultures: Variation and universality. *Psychological Bulletin, 125,* 47–63. doi:10.1037/0033-2909.125.1.47
Cochran, G., Hardy, J., & Harpending, H. (2005). Natural history of Ashkenazi intelligence. *Journal of Biological Science, 38,* 659–693. doi:10.1017/S0021932005027069
Cohen, G. D. (2005). *The mature mind: The positive power of the aging brain.* New York, NY: Basic Books.
Cohen, G. L., Garcia, J., Apfel, N., & Master, A. (2006, September 1). Reducing the racial achievement gap: A social-psychological intervention. *Science, 313,* 1307–1310. doi:10.1126/science.1128317
Colcombe, S., & Kramer, A. F. (2003). Fitness effects on the cognitive function of older adults: A meta-analytic study. *Psychological Science, 14,* 125–130. doi:10.1111/1467-9280.t01-1-01430
College Board. (2004). Table 2: Average SAT scores of entering college classes, 1967–2004. Retrieved from http://www.collegeboard.com/prod_downloads/about/news_info/cbsenior/yr2004/table_2_average_sat_scores.pdf
Colom, R. (2007). Intelligence? What intelligence? *Behavioural and Brain Sciences, 30,* 155–156.
Colom, R., Flores-Mendoza, C. E., & Abad, F. J. (2007). Generational changes on the Draw-a-Man Test: A comparison of Brazilian urban and rural children tested in 1930, 2002, and 2004. *Journal of Biosocial Science, 39,* 79–89. doi:10.1017/S0021932005001173
Colom, R., Juan-Espinosa, M., & Garcia, L. F. (2001). The secular increase in test scores is a "Jensen effect." *Personality and Individual Differences, 30,* 553–559. doi:10.1016/S0191-8869(00)00054-4
Colom, R., Jung, R. E., & Haier, R. J. (2006). Distributed brain sites for the *g*-factor of intelligence. *NeuroImage, 31,* 1359–1365. doi:10.1016/j.neuroimage.2006.01.006
Colom, R., Karama, S., Jung, R. E., & Haier, R. J. (2010). Human intelligence and brain networks. *Dialogues in Clinical Neuroscience, 12,* 489–501.
Colom, R., Lluis Font, J. M., & Andrés-Pueyo, A. (2005). The generational intelligence gains are caused by decreasing variance in the lower half of the distribution: Supporting evidence for the nutrition hypothesis. *Intelligence, 33,* 83–91. doi:10.1016/j.intell.2004.07.010
Conway, A. R. A., Cowan, N., Bunting, M. F., Therriault, D. J., & Minkoff, S. R. B. (2002). A latent variable analysis of working memory capacity, short-term memory capacity, processing speed, and general fluid intelligence. *Intelligence, 30,* 163–183. doi:10.1016/S0160-2896(01)00096-4
Coon, H., Fulker, D. W., DeFries, J. C., & Plomin, R. (1990). Home environment and cognitive ability of 7-year-old children in the Colorado Adoption Project: Genetic and environmental etiologies. *Developmental Psychology, 26,* 459–468. doi:10.1037/0012-1649.26.3.459
Cooper, H. M., Charlton, K., Valentine, J. C., & Muhlenbruck, L. (2000). Making the most of summer school: A meta-analytic and narrative review. *Monographs of the Society for Research in Child Development, 65*(1, Serial No. 260).
Coyle, T. R., & Pillow, D. R. (2008). SAT and ACT predict GPA after removing *g*. *Intelligence, 36,* 719–729. doi:10.1016/j.intell.2008.05.001
Daley, T. C., Whaley, S. E., Sigman, M. D., Espinosa, M. P., & Neumann, C. (2003). IQ on the rise: The Flynn effect in rural Kenyan children. *Psychological Science, 14,* 215–219. doi:10.1111/1467-9280.02434
Daneman, M., & Carpenter, P. A. (1980). Individual differences in working memory and reading. *Journal of Verbal Learning and Verbal Behavior, 19,* 450–466. doi:10.1016/S0022-5371(80)90312-6
Der, G., Batty, G. D., & Deary, I. J. (2006, November 4). Effect of breast feeding on intelligence in children: Prospective study, sibling pairs analysis, and meta-analysis. *BMJ: British Medical Journal, 333,* 945–948. doi:10.1136/bmj.38978.699583.55
Detterman, D. K., & Daniel, M. H. (1989). Correlations of mental tests with each other and with cognitive variables are highest for low IQ groups. *Intelligence, 13,* 349–359. doi:10.1016/S0160-2896(89)80007-8
Diamond, A., Barnett, W. S., Thomas, J., & Munro, S. (2007, November 30). Preschool program improves cognitive control. *Science, 318,* 1387–1388. doi:10.1126/science.1151148
Dickens, W. T. (2007). *What is g?* Washington, DC: Brookings Institution.
Dickens, W. T. (2009). A response to recent critics of Dickens and Flynn (2001). Retrieved from http://www.brookings.edu/~/media/Files/rc/articles/2001/0401IQ_critics_dickens/0401IQ_critics_dickens.pdf
Dickens, W. T., & Flynn, J. R. (2001a). Great leap forward: A new theory of intelligence. *New Scientist, 21,* 44–47.
Dickens, W. T., & Flynn, J. R. (2001b). Heritability estimates versus large environmental effects: The IQ paradox resolved. *Psychological Review, 108,* 346–369. doi:10.1037/0033-295X.108.2.346
Dickens, W. T., & Flynn, J. R. (2002). The IQ paradox is still resolved: Reply to Loehlin (2002) and Rowe and Rodgers (2002). *Psychological Review, 109,* 764–771. doi:10.1037/0033-295X.109.4.764
Dickens, W. T., & Flynn, J. R. (2006a). Black Americans reduce the racial IQ gap: Evidence from standardization samples. *Psychological Science, 17,* 913–920. doi:10.1111/j.1467-9280.2006.01802.x
Dickens, W. T., & Flynn, J. R. (2006b). Common ground and differences. *Psychological Science, 17,* 923–924. doi:10.1111/j.1467-9280.2006.01804.x
Dillman, D. A. (1978). *Mail and telephone surveys: The Total Design Method.* New York, NY: Wiley.
Docherty, S. J., Kovas, Y., & Plomin, R. (2011). Gene–environment interaction in the etiology of mathematical ability using SNP sets. *Behavior Genetics, 41,* 141–154. doi:10.1007/s10519-010-9405-6
Draganski, B., Gaser, C., Busch, V., Schuierer, G., Bogdahn, U., & May, A. (2004). Changes in grey matter induced by training. *Nature, 427,* 311–312. doi:10.1038/427311a
Duckworth, A. L., Peterson, C., Matthews, M. D., & Kelly, D. R. (2007). GRT: Perseverence and passion for long-term goals. *Journal of Personality and Social Psychology, 92,* 1087–1101. doi:10.1037/0022-3514.92.6.1087
Duckworth, A. L., Quinn, P. D., Lynam, D. R., Loeber, R., & Stouthamer-Loeber, M. (2011). Role of test motivation in intelligence testing. *Proceedings of the National Academy of Sciences, USA.* Advance online publication. doi:10.1073/pnas.1018601108
Duckworth, A. L., & Seligman, M. E. P. (2005). Self-discipline outdoes IQ in predicting academic performance of adolescents. *Psychological Science, 16,* 939–944. doi:10.1111/j.1467-9280.2005.01641.x
Duncan, J., Burgess, P., & Emslie, H. (1995). Fluid intelligence after frontal lobe lesions. *Neuropsychologia, 33,* 261–268. doi:10.1016/0028-3932(94)00124-8
Duncan, J., Seitz, R. J., Kolodny, J., Bor, D., Herzog, H., & Ahmed, A. (2000, July 21). A neural basis for general intelligence. *Science, 289,* 457–460. doi:10.1126/science.289.5478.457
Duyme, M., Dumaret, A., & Tomkiewicz, S. (1999). How can we boost IQs of "dull" children? A late adoption study. *Proceedings of the National Academy of Sciences, USA, 96,* 8790–8794. doi:10.1073/pnas.96.15.8790
Eaves, L. J., & Jinks, J. L. (1972). Insignificance of evidence for differences in heritability of IQ between races and social classes. *Nature, 240,* 84–88. doi:10.1038/240084a0
Eccleston, M. (2011). *In utero exposure to maternal stress: Effects of the September 11th terrorist attacks in New York City on birth and early schooling outcomes.* Cambridge, MA: Harvard University. Retrieved from http://www.people.fas.harvard.edu/~mecclest/papers/jmp.pdf
Eliot, L. (2011). Single-sex education and the brain. *Sex Roles.*Advance online publication. doi:10.1007/s11199-011-0037-y
Emanuelsson, I., Reuterberg, S.-E., & Svensson, A. (1993). Changing differences in intelligence? Comparisons between groups of thirteen-year-olds tested from 1960 to 1990. *Scandinavian Journal of Educational Research, 37,* 259–277. doi:10.1080/0031383930370401
Engle, R. W. (2002). Working memory as executive attention. *Current Directions in Psychological Science, 11,* 19–23. doi:10.1111/1467-8721.00160
Evans, G. W. (2004). The environment of childhood poverty. *American Psychologist, 59,* 77–92. doi:10.1037/0003-066X.59.2.77
Eyferth, K. (1961). Leistungern verschiedener Gruppen von Besatzungskidern in Hamburg-Wechsler Intelligenztest für Kinder (HAWIK). *Archiv für die gesamte Psychologie, 113,* 222–241.
Fagan, J. F., & Holland, C. R. (2007). Racial equality in intelligence: Predictions from a theory of intelligence as processing. *Intelligence, 35,* 319–334. doi:10.1016/j.intell.2006.08.009
Feng, J., Spence, I., & Pratt, J. (2007). Playing an action video game reduces gender differences in spatial cognition. *Psychological Science, 18,* 850–855. doi:10.1111/j.1467-9280.2007.01990.x
Ferrer, E., & McArdle, J. J. (2004). An experimental analysis of dynamic hypotheses about cognitive abilities and achievement from childhood to

early adulthood. *Developmental Psychology, 40,* 935–952. doi:10.1037/0012-1649.40.6.935

Ferrer, E., McArdle, J. J., Shawitz, B. A., Holahan, J. N., Marchione, K., & Shawitz, S. E. (2007). Longitudinal models of developmental dynamics between reading and cognition from childhood to adolescence. *Developmental Psychology, 43,* 1460–1473. doi:10.1037/0012-1649.43.6.1460

Finkel, D., Reynolds, C. A., McArdle, J. J., & Pedersen, N. L. (2007). Age changes in processing speed as a leading indicator of cognitive aging. *Psychology and Aging, 22,* 558–568. doi:10.1037/0882-7974.22.3.558

Fischbein, S. (1980). IQ and social class. *Intelligence, 4,* 51–63. doi:10.1016/0160-2896(80)90006-9

Fiske, A. P., Kitayama, S., Markus, H. R., & Nisbett, R. E. (1998). The cultural matrix of social psychology. In D. T. Gilbert, S. T. Fiske, & G. Lindzey (Eds.), *Handbook of social psychology* (4th ed., pp. 915–981). Boston, MA: McGraw-Hill.

Flynn, J. R. (1987). Massive IQ gains in 14 nations: What IQ tests really measure. *Psychological Bulletin, 101,* 171–191. doi:10.1037/0033-2909.101.2.171

Flynn, J. R. (1991). *Asian Americans: Achievement beyond IQ.* Hillsdale, NJ: Erlbaum.

Flynn, J. R. (2006). Tethering the elephant: Capital cases, IQ, and the Flynn effect. *Psychology, Public Policy, and Law, 12,*170–189. doi:10.1037/1076-8971.12.2.170

Flynn, J. R. (2007). *What is intelligence? Beyond the Flynn effect.* New York, NY: Cambridge University Press.

Flynn, J. R. (2008). *Where have all the liberals gone? Race, class and ideals in America.* Cambridge, England: Cambridge University Press. doi:10.1017/CBO9780511490835

Flynn, J. R. (2009a). Requiem for nutrition as the cause of IQ gains: Raven's gains in Britain 1938–2008. *Economics and Human Biology,* 7, 18–27. doi:10.1016/j.ehb.2009.01.009

Flynn, J. R. (2009b). The WAIS-III and WAIS-IV: Daubert motions favor the certainly false over the approximately true. *Applied Neuropsychology, 16,* 1–7. doi:10.1080/09084280902864360

Flynn, J. R. (2009c). *What is intelligence? Beyond the Flynn effect* (enlarged paperback ed.). Cambridge, England: Cambridge University Press.

Flynn, J. R. (2010). Problems with IQ gains: The huge vocabulary gap. *Journal of Psychoeducational Assessment, 28,* 412–433. doi:10.1177/0734282910373342

Flynn, J. R., & Rossi-Casé, L. (2011). Modern women match men on Raven's Progressive Matrices. *Personality and Individual Differences, 50,* 799–803. doi:10.1016/j.paid.2010.12.035

Fry, A. F., & Hale, S. (2000). Relationships among processing speed, working memory, and fluid intelligence in children. *Biological Psychology,54,* 1–34. doi:10.1016/S0301-0511(00)00051-X

Garber, H. L. (1988). *The Milwaukee Project: Preventing mental retardation in children at risk.* Washington, DC: American Association on Mental Retardation.

Giedd, J. N., Castellanos, F. X., Rajapakse, J. C., Vaituzis, A. C., & Rapoport, J. L. (1997). Sexual dimorphism of the developing human brain. *Progress in Neuro-Psychopharmacology & Biological Psychiatry, 21,* 1185–1201. doi:10.1016/S0278-5846(97)00158-9

Gignac, G., Vernon, P. A., & Wickett, J. C. (2003). Factors influencing the relationship between brain size and intelligence. In H. Nyborg (Ed.), *The scientific study of general intelligence: Tribute to Arthur R. Jensen* (pp. 93–106). London, England: Elsevier.

Goel, V. (2007). Anatomy of deductive reasoning. *Trends in Cognitive Sciences, 11*(10), 435–441. doi:10.1016/j.tics.2007.09.003

Goldstein, D. B. (2009). Common genetic variation and human traits. *New England Journal of Medicine, 360,* 1696–1698. doi:10.1056/NEJMp0806284

Good, C., Aronson, J., & Inzlicht, M. (2003). Improving adolescents' standardized test performance: An intervention to reduce the effects of stereotype threat. *Applied Developmental Psychology, 24,* 645–662. doi:10.1016/j.appdev.2003.09.002

Gottfredson, L. S. (1997). Mainstream science on intelligence: An editorial with 52 signatories, history, and bibliography. *Intelligence, 24*(1), 13–23.

Gottfredson, L. S. (2003a). Dissecting practical intelligence: Its claims and evidence. *Intelligence, 31,* 343–397. doi:10.1016/S0160-2896(02)00085-5

Gottfredson, L. S. (2003b). On Sternberg's "Reply to Gottfredson." *Intelligence, 31,* 415–424. doi:10.1016/S0160-2896(03)00024-2

Gottfredson, L. S. (2004). *Social consequences of group differences in cognitive ability.* Newark, DE: University of Delaware. Retrieved from http://www.udel.edu/educ/gottfredson/reprints/2004socialconsequences.pdf

Gottfredson, L. S. (2005). What if the hereditarian hypothesis is true? *Psychology, Public Policy, and Law, 11,* 311–319. doi:10.1037/1076-8971.11.2.311

Gottfredson, L. S. (2007). Shattering logic to explain the Flynn effect. *Cato Unbound.* Retrieved from http://www.cato-unbound.org/2007/11/08/linda-s-gottfredson/shattering-logic-to-explain-the-flynn-effect/

Grant, M. D., Kremen, W. S., Jacobson, K. C., Franz, C. E., Xian, H., & Lyons, M. J. (2010). Does parental education have a moderating effect on the genetic and environmental influences of general ability in early adulthood? *Behavior Genetics, 40,* 438–446. doi:10.1007/s10519-010-9351-3

Gray, J. R., Chabris, C. F., & Braver, T. S. (2003). Neural mechanisms of general fluid intelligence. *Nature Neuroscience, 6*(3), 316–322. doi:10.1038/nn1014

Greely, H., Sahakian, B., Harris, J., Kessler, R. C., Gazzaniga, M., Campbell, P., & Farah, M. J. (2008). Towards responsible use of cognitive-enhancing drugs by the healthy. *Nature, 456,* 702–705. doi:10.1038/456702a

Gustafsson, J. E. (1984). A unifying model for the structure of mental abilities. *Intelligence, 8,* 179–203. doi:10.1016/0160-2896(84)90008-4

Haier, R. J., Colom, R., Schroeder, D. H., Condon, C. A., Tang, C., & Eaves, E. (2009). Gray matter and intelligence factors: Is there a neuro-g? *Intelligence, 37*(2), 136–144. doi:10.1016/j.intell.2008.10.011

Haier, R. J., Jung, R., Yeo, R. A., Head, K., & Alkire, M. T. (2005). The neuroanatomy of general intelligence: Sex matters. *NeuroImage, 25,* 320–327. doi:10.1016/j.neuroimage.2004.11.019

Haier, R. J., Karama, S., Leyba, L., & Jung, R. E. (2009). MRI assessment of cortical thickness and functional activity changes in adolescent girls following three months of practice on a visual-spatial task. *BMC Research Notes, 2,* 174. doi:10.1186/1756-0500-2-174

Haier, R. J., Siegel, B. V., Nuechterlein, K. H., Hazlett, E., Wu, J. C., & Paek, J. (1988). Cortical glucose metabolic rate correlates of abstract reasoning and attention studied with positron emission tomography. *Intelligence, 12,* 199–217. doi:10.1016/0160-2896(88)90016-5

Halpern, D. F., Benbow, C. P., Geary, D. C., Gur, R. C., Hyde, J. S., & Gernsbacher, M. A. (2007). The science of sex differences in science and mathematics. *Psychological Science in the Public Interest, 8,* 1–51. doi:10.1111/j.1529-1006.2007.00032.x

Halpern, D. F., Eliot, L., Bigler, R. S., Fabes, R. A., Hanish, L. D., Hyde, J., . . . Martin, C. L. (2011, September 23). The pseudoscience of single-sex schooling. *Science, 333,* 1706–1707. doi:10.1126/science.1205031

Hambrick, D. Z., Pink, J. E., Meinz, E. J., Pettibone, J. C., & Oswald, F. L. (2008). The roles of ability, personality, and interests in acquiring current events knowledge: A longitudinal study. *Intelligence, 36,* 261–278. doi:10.1016/j.intell.2007.06.004

Hamre, B. K., & Pianta, R. C. (2001). Early teacher–child relationships and the trajectory of children's school outcomes through eighth grade. *Child Development, 72,* 625–638. doi:10.1111/1467-8624.00301

Hanscombe, K. B., Trzaskowski, M., Haworth, C. M. A., Davis, O. S. P., Dale, P. S., & Plomin, R. (2012). *Socioeconomic status (SES) and children's intelligence: A large UK-representative twin study finds SES moderation of the environmental, not genetic, effect on IQ.* Manuscript submitted for publication.

Harden, K. P., Turkheimer, E., & Loehlin, J. C. (2007). Genotype by environment interaction in adolescents' cognitive aptitude. *Behavior Genetics, 37,* 273–283. doi:10.1007/s10519-006-9113-4

Hart, B., & Risley, T. (1995). *Meaningful differences.* Baltimore, MD: Brookes.

Haworth, C. M. A., Wright, M. J., Luciano, M., Martin, N. G., de Geus, E. J. C., van Beijsterveldt, C. E. M., . . . Plomin, R. (2010). The heritability of general cognitive ability increases linearly from childhood to young adulthood. *Molecular Psychiatry, 15,* 1112–1120. doi:10.1038/mp.2009.55

Heckman, J. J. (2006, June 30). Skill formation and the economics of investing in disadvantaged children. *Science, 312,* 1900–1902. doi:10.1126/science.1128898

Heckman, J. J. (2011). The American family in Black & White: A post-racial strategy for improving skills to promote equality. *Daedalus, 140*(2), 70–89. doi:10.1162/DAED_a_00078

Heine, S. J., Kitayama, S., Lehman, D. R., Takata, T., Ide, E., Lueng, C., & Matsumoto, H. (2001). Divergent consequences of success and failure in Japan and North America: An investigation of self-improving motivations and malleable selves. *Journal of Personality and Social Psychology, 81,* 599–615. doi:10.1037/0022-3514.81.4.599

Herrnstein, R. J., & Murray, C. (1994). *The bell curve: Intelligence and class structure in American life.* New York, NY: Free Press.

Herrnstein, R. J., Nickerson, R. S., Sanchez, M., & Swets, J. A. (1986). Teaching thinking skills. *American Psychologist, 41,* 1279–1289. doi:10.1037/0003-066X.41.11.1279

Ho, K.-C., Roessmann, U., Hause, L., & Monroe, G. (1981). Newborn brain weight in relation to maturity, sex, and race. *Annals of Neurology, 10,* 243–246. doi:10.1002/ana.410100308

Ho, K.-C., Roessmann, U., Straumfjord, J. V., & Monroe, G. (1980a). Analysis of brain weight. I. Adult brain weight in relation to sex, race, and age. *Archives of Pathology and Laboratory Medicine, 104,* 635–639.

Ho, K.-C., Roessmann, U., Straumfjord, J. V., & Monroe, G. (1980b). Analysis of brain weight. II. Adult brain weight in relation to body height, weight, and surface area. *Archives of Pathology and Laboratory Medicine, 104,* 640–645.

Horn, J. L. (1989). Models for intelligence. In R. Linn (Ed.), *Intelligence: Measurement theory and public policy* (pp. 29–73). Urbana, IL: University of Illinois Press.

Horn, J. L., & McArdle, J. J. (2007). Understanding human intelligence since Spearman. In R. Cudeck & R. MacCallum (Eds.), *Factor analysis at 100 years* (pp. 205–247). Mahwah, NJ: Erlbaum.

Hulshoff Pol, H. E., Schnack, H. G., Posthuma, D., Mandl, R. C. W., Baare, W. F., van Oel, C., . . . Kahn, R. S. (2006). Genetic contributions to human brain morphology and intelligence. *Journal of Neuroscience, 26*(40), 10235–10242. doi:10.1523/JNEUROSCI.1312-06.2006

Hunt, E. (2011). *Human intelligence.* New York, NY: Cambridge University Press.

Hyde, J. S., Lindberg, S. M., Lilnn, M. C., Ellis, A. B., & Williams, C. C. (2008, July 25). Gender similarities characterize math performance. *Science, 321,* 494–495. doi:10.1126/science.1160364

Inlow, J. K., & Restifo, L. L. (2004). Molecular and comparative genetics of mental retardation. *Genetics, 166,* 835–881. doi:10.1534/genetics.166.2.835

Jaeggi, S. M., Buschkuehl, M., Jonides, J., & Perrig, W. J. (2008). Improving fluid intelligence with training on working memory. *Proceedings of the National Academy of Sciences, USA, 105,* 6829–6833. doi:10.1073/pnas.0801268105

Jaeggi, S. M., Studer-Luethi, B., Buschkuehl, M., Su, Y.-F., Jonides, J., & Perrig, W. J. (2010). The relationship between n-back performance and matrix reasoning – implications for training and transfer. *Intelligence, 38,* 625–635. doi:10.1016/j.intell.2010.09.001

Janowsky, J. S., Chavez, B., & Orwoll, E. (2000). Sex steroids modify working memory. *Journal of Cognitive Neuroscience, 12,* 407–414. doi:10.1162/089892900562228

Jencks, C., Smith, M., Acland, H., Bane, M. J., Cohen, D., Gintis, H., Heyns, B., & Michelson, S. (1972). *Inequality: A reassessment of the effect of family and schooling in America.* New York, NY: Harper & Row.

Jensen, A. R. (1994). Psychometric *g* related to differences in head size. *Personality and Individual Differences, 17,* 597–606. doi:10.1016/0191-8869(94)90132-5

Jensen, A. R. (1998). *The g factor.* Westport, CT: Praeger.

Jensen, A. R., & Johnson, F. W. (1994). Race and sex differences in head size and IQ. *Intelligence, 18,* 309–333. doi:10.1016/0160-2896(94)90032-9

Johnson, W. (2010). Understanding the genetics of intelligence: Can height help? Can corn oil? *Current Directions in Psychological Science, 19,* 177–182. doi:10.1177/0963721410370136

Johnson, W., & Bouchard, T. J., Jr. (2007). Sex differences in mental abilities: *g* masks the dimensions on which they lie. *Intelligence, 35,* 23–39. doi:10.1016/j.intell.2006.03.012

Johnson, W., Deary, I. J., Silventoinen, K., Tynelius, P., & Rasmussen, F. (2010). Family background buys an education in Minnesota but not in Sweden. *Psychological Science, 21,* 1266–1273. doi:10.1177/0956797610379233

Juan-Espinosa, M., García, L. F., Colom, R., & Abad, F. J. (2000). Testing the age related differentiation hypothesis through the Wechsler's scales. *Personality and Individual Differences, 29,* 1069–1075. doi:10.1016/S0191-8869(99)00254-8

Jung, R. E., & Haier, R. J. (2007). The parieto-frontal integration theory (P-FIT) of intelligence: Converging neuroimaging evidence. *Behavioral and Brain Sciences, 30,* 135–187. doi:10.1017/S0140525X07001185

Kane, M. J., Hambrick, D. Z., & Conway, A. R. A. (2005). Working memory capacity and fluid intelligence are strongly related constructs: Comment on Ackerman, Beier, and Boyle (2005). *Psychological Bulletin, 131,* 66–71. doi:10.1037/0033-2909.131.1.66

Karbach, J., & Kray, J. (2009). How useful is executive control training? Age differences in near and far transfer of task-switching training. *Developmental Science, 12,* 978–990. doi:10.1111/j.1467-7687.2009.00846.x

Karpiak, C. P., Buchanan, J. P., Hosey, M., & Smith, A. (2007). University students from single-sex and coeducational high schools: Differences in majors and attitudes at a Catholic university. *Psychology of Women Quarterly, 31,* 282–289. doi:10.1111/j.1471-6402.2007.00371.x

Khaleefa, O., Sulman, A., & Lynn, R. (2009). An increase of intelligence in Sudan, 1987–2007. *Journal of Biosocial Science, 41,* 279–283. doi:10.1017/S0021932008003180

Klingberg, T., Forssberg, H., & Westerberg, H. (2002). Training of working memory in children with ADHD. *Journal of Clinical and Experimental Neuropsychology, 24,* 781–791. doi:10.1076/jcen.24.6.781.8395

Knudsen, E. I., Heckman, J. J., Cameron, J. L., & Shonkoff, J. P. (2006). Economic, neurobiological, and behavioral perspectives on building America's future workforce. *Proceedings of the National Academy of Sciences, USA, 103,* 10155–10162. doi:10.1073/pnas.0600888103

Kramer, M. S. (2008). Breastfeeding and child cognitive development. *Archives of General Psychiatry, 65,* 578–584. doi:10.1001/archpsyc.65.5.578

Kremen, W. S., Jacobson, K. C., & Xian, H. (2005). Heritability of word recognition in middle-aged men varies as a function of parental education. *Behavior Genetics, 35,* 417–433. doi:10.1007/s10519-004-3876-2

Kristensen, P., & Bjerkedal, T. (2007, June 22). Explaining the relation between birth order and intelligence. *Science, 316,* 1717. doi:10.1126/science.1141493

Kroger, J. K., Nystrom, L. E., Cohen, J. D., & Johnson-Laird, P. N. (2008). Distinct neural substrates for deductive and mathematical processing. *Brain Research, 1243,* 86–103. doi:10.1016/j.brainres.2008.07.128

Kyllonen, P. C., & Christal, R. E. (1990). Reasoning ability is (little more than) working-memory capacity?! *Intelligence, 14,* 389–433. doi:10.1016/S0160-2896(05)80012-1

Larson, G. E., Haier, R. J., LaCasse, L., & Hazen, K. (1995). Evaluation of a "mental effort" hypothesis for correlations between cortical metabolism and intelligence. *Intelligence, 21*(3), 267–278. doi:10.1016/0160-2896(95)90017-9

Lee, K. H., Choi, Y. Y., Gray, J. R., Cho, S. H., Chae, J. H., & Lee, S. (2006). Neural correlates of superior intelligence: Stronger recruitment of posterior parietal cortex. *NeuroImage, 29*(2), 578–586. doi:10.1016/j.neuroimage.2005.07.036

Locurto, C. (1990). The malleability of IQ as judged from adoption studies. *Intelligence, 14,* 275–292. doi:10.1016/S0160-2896(10)80001-7

Loehlin, J. C. (2002). The IQ paradox: Resolved? Still an open question. *Psychological Review, 109,* 754–758. doi:10.1037/0033-295X.109.4.754

Loehlin, J. C., & Horn, J. M. (2000). Stoolmiller on restriction of range in adoption studies: A comment. *Behavior Genetics, 30,* 245–247. doi:10.1023/A:1001922509893

Loehlin, J. C., & Nichols, R. C. (1976). *Heredity, environment, and personality: A study of 850 sets of twins.* Austin, TX: University of Texas Press.

Lucas, A., Morley, R., Cole, T. J., Lister, G., & Leeson-Payne, C. (1992). Breast milk and subsequent intelligence quotient in children born preterm. *The Lancet, 339,* 261–264. doi:10.1016/0140-6736(92)91329-7

Luine, V. N. (2008). Sex steroids and cognitive function. *Journal of Neuroendocrinology, 20,* 866–872. doi:10.1111/j.1365-2826.2008.01710.x

Lupton, M. K., Stahl, D., Archer, N., Foy, C., Poppe, M., Lovestone, S.,

. . . Powell, J. F. (2010). Education, occupation and retirement age effects on the age of onset of Alzheimer's disease. *International Journal of Geriatric Psychiatry, 25,* 30–36. doi:10.1002/gps.2294

Lynn, R. (1987). The intelligence of Mongoloids: A psychometric, evolutionary, and neurological theory. *Personality and Individual Differences, 8,* 813–844. doi:10.1016/0191-8869(87)90135-8

Lynn, R. (1989). Positive correlation between height, head size and IQ: A nutrition theory of the secular increases in intelligence. *British Journal of Psychology, 59,* 372–377.

Lynn, R. (2004). The intelligence of American Jews. *Personality and Individual Differences, 36,* 201–206. doi:10.1016/S0191-8869(03)00079-5

Lynn, R. (2006). On the high intelligence and cognitive achievements of Jews in Britain. *Intelligence, 34,* 541–547. doi:10.1016/j.intell.2006.03.011

Lynn, R., & Irving, P. (2004). Sex differences on the Progressive Matrices: A meta-analysis. *Intelligence, 32,* 481–498. doi:10.1016/j.intell.2004.06.008

Lynn, R., & Vanhanen, T. (2002). *IQ and the wealth of nations.* Westport, CT: Praeger.

Lyons, M. J., York, T. P., Franz, C. E., Grant, M. D., Eaves, L. J., Jacobson, K. C., . . . Kremen, W. S. (2009). Genes determine stability and the environment determines change in cognitive ability during 35 years of adulthood. *Psychological Science, 20,* 1146–1152. doi:10.1111/j.1467-9280.2009.02425.x

Mackey, A. P., Hill, S. S., Stone, S. I., & Bunge, S. A. (2011). Differential effects of reasoning and speed training in children. *Developmental Science, 14,* 582–590. doi:10.1111/j.1467-7687.2010.01005x

Mael, F., Alonso, A., Gibson, D., Rogers, K., & Smith, M. (2005). *Single-sex versus coeducational schooling: A systematic review.* Washington, DC: U.S. Department of Education, Office of Planning, Evaluation and Policy Development, Policy and Program Studies Service. Retrieved from http://www2.ed.gov/rschstat/eval/other/single-sex/single-sex.pdf

Maguire, E. A., Gadian, D. G., Johnsrude, I. S., Good, C. D., Ashburner, J., Frackowiak, R. S. J., & Frith, C. D. (2000). Navigation-related structural change in the hippocampi of taxi drivers. *Proceedings of the National Academy of Sciences, USA, 97,* 4398–4403. doi:10.1073/pnas.070039597

Markus, H. R., & Kitayama, S. (1991). Culture and the self: Implications for cognition, emotion, and motivation. *Psychological Review, 98,* 224–253. doi:10.1037/0033-295X.98.2.224

McArdle, J. J., Ferrer-Caja, E., Hamagami, F., & Woodcock, R. (2002). Comparative longitudinal structural analyses of the growth and decline of multiple intellectual abilities over the life span. *Developmental Psychology, 38,* 115–142. doi:10.1037/0012-1649.38.1.115

McArdle, J. J., Hamagami, F., Meredith, W., & Bradway, K. P. (2000). Modeling the dynamic hypotheses of Gf–Gc theory using longitudinal life-span data. *Learning and Individual Differences, 12,* 53–79. doi:10.1016/S1041-6080(00)00036-4

McCabe, S. E., Knight, J. R., Teter, C. J., & Wechsler, H. (2005). Non-medical use of prescription stimulants among US college students: Prevalence and correlates from a national survey. *Addiction, 100,* 96–106. doi:10.1111/j.1360-0443.2005.00944.x

McDaniel, M. A. (2005). Big-brained people are smarter: A meta-analysis of the relationship between in vivo brain volume and intelligence. *Intelligence, 33,* 337–346. doi:10.1016/j.intell.2004.11.005

McEwen, B. S. (2000). The neurobiology of stress: From serendipity to clinical relevance. *Brain Research, 886,* 172–189. doi:10.1016/S0006-8993(00)02950-4

McGlone, M. S., & Aronson, J. (2006). Stereotype threat, identity salience, and spatial reasoning. *Journal of Applied Developmental Psychology, 27,* 486–493. doi:10.1016/j.appdev.2006.06.003

McGue, M., & Bouchard, T. J. (1998). Genetic and environmental influences on human behavioral differences. *Annual Review of Neuroscience, 21,* 1–24. doi:10.1146/annurev.neuro.21.1.1

McGue, M., Bouchard, T. J., Jr., Iacono, W. G., & Lykken, D. T. (1993). Behavioral genetics of cognitive ability: A life-span perspective. In R. Plomin & G. E. McClearn (Eds.), *Nature, nurture and psychology* (pp. 59–76). Washington, DC: American Psychological Association. doi:10.1037/10131-003

McGue, M., Keyes, M., Sharma, A., Elkins, I., Legrand, L., Johnson, W., & Iacono, W. G. (2007). The environments of adopted and non-adopted youth: Evidence on range restriction from the sibling interaction and behavior study (SIBS). *Behavior Genetics, 37,* 449–462. doi:10.1007/s10519-007-9142-7

Meisenberg, G., Lawless, E., Lambert, E., & Newton, A. (2005). The Flynn effect in the Caribbean: Generational change in test performance in Dominica. *Mankind Quarterly, 46,* 29–70.

Melton, L. (2005, December 17). Use it, don't lose it. *New Scientist, 188,* 32–35.

Mingroni, M. A. (2004). The secular rise in IQ: Giving heterosis a closer look. *Intelligence, 32,* 65–83. doi:10.1016/S0160-2896(03)00058-8

Mingroni, M. A. (2007). Resolving the IQ paradox: Heterosis as the cause of the Flynn effect and other trends. *Psychological Review, 114,* 806–829. doi:10.1037/0033-295X.114.3.806

Mischel, W., Shoda, Y., & Peake, P. K. (1988). The nature of adolescent competencies predicted by preschool delay of gratification. *Journal of Personality and Social Psychology, 54,* 687–696. doi:10.1037/0022-3514.54.4.687

Moore, E. C. J. (1986). Family socialization and the IQ test performance of traditionally and trans-racially adopted Black children. *Developmental Psychology, 22,* 317–326. doi:10.1037/0012-1649.22.3.317

Mortensen, E. L., Michaelsen, K. M., Sanders, S. A., & Reinisch, J. M. (2002). The association between duration of breastfeeding and adult intelligence. *JAMA: Journal of the American Medical Association, 287,* 2365–2371. doi:10.1001/jama.287.18.2365

Mullis, I. V. S., Martin, M. O., Gonzalez, E. J., & Kennedy, A. M. (2003). *PIRLS 2001 International Report: IEA's study of reading literacy achievement in primary school in 35 countries.* Chestnut Hill, MA: Boston College, Lynch School of Education, TIMSS & PIRLS International Study Center. Retrieved from http://timss.bc.edu/pirls2001i/PIRLS2001_Pubs_IR.html

Murray, C. (2006). Changes over time in the Black–White difference on mental tests: Evidence from the children of the 1979 cohort of the National Longitudinal Survey of Youth. *Intelligence, 34,* 527–540. doi:10.1016/j.intell.2006.07.004

Must, O., Must, A., & Raudik, V. (2003). The secular rise in IQs: In Estonia, the Flynn effect is not a Jensen effect. *Intelligence, 31,* 461–471. doi:10.1016/S0160-2896(03)00013-8

Myrianthopoulos, N. C., & French, K. S. (1968). An application of the U.S. Bureau of the Census socioeconomic index to a large diversified population. *Social Science and Medicine, 2,* 283–299. doi:10.1016/0037-7856(68)90004-8

Nagoshi, C. T., & Johnson, R. C. (2005). Socioeconomic status does not moderate the familiality of cognitive abilities in the Hawaii Family Study of Cognition. *Journal of Biosocial Science, 37,* 773–781. doi:10.1017/S0021932004007023

Neisser, U., Boodoo, G., Bouchard, T. J., Jr., Boykin, A. W., Brody, N., Ceci, S. J., . . . Urbina, S. (1996). Intelligence: Knowns and unknowns. *American Psychologist, 51,* 77–101. doi:10.1037/0003-066X.51.2.77

Neubauer, A., & Fink, A. (2009). Intelligence and neural efficiency: Measures of brain activity versus measures of functional connectivity in the brain. *Intelligence, 37,* 223–229. doi:10.1016/j.intell.2008.10.008

Nisbett, R. E. (2005). Heredity, environment, and race differences in IQ: A commentary on Rushton and Jensen. *Psychology, Public Policy, and Law, 11,* 302–310. doi:10.1037/1076-8971.11.2.302

Nisbett, R. E. (2009). *Intelligence and how to get it: Why schools and cultures count.* New York, NY: Norton.

Olesen, P. J., Westerberg, H., & Klingberg, T. (2004). Increased prefrontal and parietal activity after training of working memory. *Nature Neuroscience, 7,* 75–79. doi:10.1038/nn1165

Phillips, M., Brooks-Gunn, J., Duncan, G. J., Klebanov, P. K., & Crane, J. (1998). Family background, parenting practices, and the Black–White test score gap. In C. Jencks & M. Phillips (Eds.), *The Black–White test score gap* (pp. 102–145). Washington, DC: Brookings Institution Press.

Pietschnig, J., Voracek, M., & Formann, A. K. (2010). Pervasiveness of the IQ rise: A cross-temporal meta-analysis. *PLoS ONE, 5,* e14406. doi:10.1371/journal.pone.0014406

Plomin, R., DeFries, J. C., & McClearn, G. E. (1990). *Behavioral genetics: A primer*(2nd ed.). New York, NY: Freeman.

Plomin, R., Loehlin, J. C., & DeFries, J. C. (1985). Genetic and environmental components of "environmental" influences. *Developmental Psychology, 21,* 391–402. doi:10.1037/0012-1649.21.3.391

Quinn, P. C., & Liben, L. S. (2008). A sex difference in mental rotation in young infants. *Psychological Science, 19,* 1067–1070. doi:10.1111/j.1467-9280.2008.02201.x

Ramey, C. T., Campbell, F. A., Burchinal, M., Skinner, M. L., Gardner, D. M., & Ramey, S. L. (2000). Persistent effects of early childhood education on high-risk children and their mothers. *Applied Developmental Science, 4,* 2–14. doi:10.1207/S1532480XADS0401_1

Ramey, S. L., & Ramey, C. T. (1999). Early experience and early intervention for children "at risk" for developmental delay and mental retardation. *Mental Retardation and Developmental Disabilities Research Reviews, 5,* 1–10. doi:10.1002/(SICI)1098-2779(1999)5:1<1::AID-MRDD1>3.0.CO;2-F

Ramsden, S., Richardson, F. M., Josse, G., Thomas, M. S. C., Ellis, C., Shakeshaft, C., . . . Price, C. J. (2011, November 3). Verbal and nonverbal intelligence changes in the teenage brain. *Nature, 479,* 113–116. doi:10.1038/nature10514

Rohwedder, S., & Willis, R. J. (2010). Mental retirement. *Journal of Economic Perspectives, 24,* 119–138. doi:10.1257/jep.24.1.119

Rowe, D. C., Jacobson, K. C., & Van den Oord, E. J. C. G. (1999). Genetic and environmental influences on vocabulary IQ. *Child Development, 70,* 1151–1162. doi:10.1111/1467-8624.00084

Rowe, D. C., & Rodgers, J. L. (2002). Expanding variance and the case of historical changes in IQ means: A critique of Dickens and Flynn (2001). *Psychological Review, 109,* 759–763. doi:10.1037/0033-295X.109.4.759

Rueda, M. R., Rothbart, M. K., McCandliss, B. D., Saccomanno, L., & Posner, M. I. (2005). Training, maturation, and genetic influences on the development of executive attention. *Proceedings of the National Academy of Sciences, USA, 102,* 14931–14936. doi:10.1073/pnas.0506897102

Rushton, J. P. (1995). *Race, evolution and behavior: A life history perspective.* New Brunswick, NJ: Transaction.

Rushton, J. P. (1999). Secular gains in IQ not related to the *g* factor and inbreeding depression—unlike Black–White differences: A reply to Flynn. *Personality and Individual Differences, 26,* 381–389.

Rushton, J. P. (2000). Flynn effects not genetic and unrelated to race differences. *American Psychologist, 55,* 542–543. doi:10.1037/0003-066X.55.5.542

Rushton, J. P. (2010). Brain size as an explanation of national differences in IQ, longevity, and other life-history variables. *Personality and Individual Differences, 48,* 97–99. doi:10.1016/j.paid.2009.07.029

Rushton, J. P., & Jensen, A. R. (2005a). Thirty years of research on race differences in cognitive ability. *Psychology, Public Policy, and Law, 11,* 235–294. doi:10.1037/1076-8971.11.2.235

Rushton, J. P., & Jensen, A. R. (2005b). Wanted: More race realism, less moralistic fallacy. *Psychology, Public Policy, and Law, 11,* 328–336. doi:10.1037/1076-8971.11.2.328

Rushton, J. P., & Jensen, A. R. (2006). The totality of available evidence shows the race IQ gap still remains. *Psychological Science, 17,* 921–922. doi:10.1111/j.1467-9280.2006.01803.x

Rushton, J. P., & Jensen, A. R. (2010). Race and IQ: A theory-based review of the research in Richard Nisbett's *Intelligence and How to Get It. The Open Psychology Journal, 3,* 9–35. doi:10.2174/1874350101003010009

Rypma, B., Berger, J. S., Prabhakaran, V., Bly, B. M., Kimberg, D. Y., & Biswal, B. B. (2006). Neural correlates of cognitive efficiency. *NeuroImage, 33*(3), 969–979. doi:10.1016/j.neuroimage.2006.05.065

Sackett, P. R., Hardison, C. M., & Cullen, M. J. (2004). On interpreting stereotype threat as accounting for African American–White differences on cognitive tests. *American Psychologist, 59,* 7–13. doi:10.1037/0003-066X.59.1.7

Sahakian, B., & Morein-Zamir. (2007, December 20). Professor's little helper. *Nature, 450,* 1157–1159. doi:10.1038/4501157a

Salthouse, T. A. (1996). The processing-speed theory of adult age differences in cognition. *Psychological Review, 103,* 403–428. doi:10.1037/0033-295X.103.3.403

Salthouse, T. A. (2006). Mental exercise and mental aging: Evaluating the "use it or lose it" hypothesis. *Perspectives on Psychological Science, 1,* 68–87. doi:10.1111/j.1745-6916.2006.00005.x

Salthouse, T. A. (2010). *Major issues in cognitive aging.* New York, NY: Oxford University Press.

Salthouse, T. A., & Pink, J. E. (2008). Why is working memory related to fluid intelligence? *Psychonomic Bulletin and Review, 15,* 364–371. doi:10.3758/PBR.15.2.364

Sampson, E. E. (1988). The debate on individualism: Indigenous psychologies of the individual and their role in personal and societal functioning. *American Psychologist, 43,* 15–22. doi:10.1037/0003-066X.43.1.15

Sanz de Acedo Lizarraga, M. L., Ugarte, M. D., Iriarte, M. D., & Sanz de Acedo Baquedano, M. T. (2003). Immediate and long-term effects of a cognitive intervention of intelligence, self-regulation, and academic achievement. *European Journal of Psychology of Education, 18,* 59–74. doi:10.1007/BF03173604

Sarikouch, S., Peters, B., Gutberiet, M., Leismann, B., Kelter-Kloepping, A., Koerperich, H., . . . Beerbaum, P. (2010). Sex-specific pediatric percentiles for ventricular size and mass as reference values for cardiac MRI: Assessment by steady-state free-precession and phase-contrast MRI flow. *Circulation: Cardiovascular Imaging, 3,* 65–76. doi:10.1161/CIRCIMAGING.109.859074

Scarr, S. (1981). *Race, social class, and individual differences in IQ: New studies of old issues.* Hillsdale, NJ: Erlbaum.

Scarr, S., & Weinberg, R. A. (1976). IQ test performance of Black children adopted by White parents. *American Psychologist, October,* 726–739. doi:10.1037/0003-066X.31.10.726

Scarr-Salapatek, S. (1971). Race, social class, and IQ. *Science, 174,* 1285–1295. doi:10.1126/science.174.4016.1285

Schmeichel, B. J., Volokhov, R. N., & Demaree, H. A. (2008). Working memory capacity and the self-regulation of emotional expression and experience. *Journal of Personality and Social Psychology, 95,* 1526–1540. doi:10.1037/a0013345

Schmidt, F. L., & Hunter, J. E. (1998). The validity and utility of selection methods in personnel psychology: Practical and theoretical implications of 85 years of research findings. *Psychological Bulletin, 124,* 262–274. doi:10.1037/0033-2909.124.2.262

Schmidt, F. L., & Hunter, J. E. (2004). General mental ability in the world of work: Occupational attainment and job performance. *Journal of Personality and Social Psychology, 86,* 162–173. doi:10.1037/0022-3514.86.1.162

Schmidt, I. M., Molgaard, C., Main, K. M., & Michaelsen, K. F. (2001). Effect of gender and lean body mass on kidney size in healthy 10-year-old children. *Pediatric Nephrology, 16,* 366–370. doi:10.1007/s004670100568

Schmiedek, F., Lövdén, M., & Lindenberger, U. (2010). Hundred days of cognitive training enhance broad cognitive abilities in adulthood: Findings from the COGITO study. *Frontiers in Aging Neuroscience, 2,* 1–10. doi:10.3389/fnagi.2010.00027

Schoenemann, P. T., Budinger, T. F., Sarich, V. M., & Wang, W. S.-Y. (2000). Brain size does not predict general cognitive ability within families. *Proceedings of the National Academy of Sciences, USA, 97,* 4932–4937. doi:10.1073/pnas.97.9.4932

Schweinhart, L. J., Montie, J., Xiang, Z., Barnett, W. S., Belfield, C. R., & Nores, M. (2005). *Lifetime effects: The High/Scope Perry Preschool Study through age 40* (Monographs of the HighScope Educational Research Foundation, No. 14). Ypsilanti, MI: High/Scope Press.

Schweinhart, L. J., & Weikart, D. P. (1980). *Young children grow up: The effects of the Perry Preschool Program on youths through age 15* (Monographs of the HighScope Educational Research Foundation, No. 7). Ypsilanti, MI: High/Scope Press.

Schweinhart, L. J., & Weikart, D. P. (1993). Success by empowerment: The High/Scope Perry Preschool Study through age 27. *Young Children, 49,* 54–58.

Shamosh, N. A., & Gray, J. R. (2007). The relation between fluid intelligence and self-regulatory depletion. *Cognition and Emotion, 21,* 1833–1843. doi:10.1080/02699930701273658

Sharkey, P. (2010). The acute effect of local homicides on children's cognitive performance. *Proceeedings of the National Academy of Sciences, USA, 107,* 11733–11738. doi:10.1073/pnas.1000690107

Sowell, E. R., Thompson, P. M., Leonard, C. M., Welcome, S. E., Kan, E., & Toga, A. W. (2004). Longitudinal mapping of cortical thickness and brain growth in normal children. *Journal of Neuroscience, 24*(38), 8223–8231. doi:10.1523/JNEUROSCI.1798-04.2004

Steele, C. M., & Aronson, J. (1995). Stereotype threat and the intellectual test performance of African Americans. *Journal of Personality and Social Psychology, 69,* 797–811. doi:10.1037/0022-3514.69.5.797

Steele, C. M., Spencer, S., & Aronson, J. (2002). Contending with group image: The psychology of stereotype and social identity threat. *Ad-*

vances in Experimental Social Psychology, 37, 379–440. doi:10.1016/S0065-2601(02)80009-0

Stephenson, C. L., & Halpern, D. F. (2012). *Improved fluid intelligence limited to increasing working memory capacity using intensive n-back tasks with a visuospatial component.* Manuscript submitted for publication.

Sternberg, R. J. (1999). The theory of successful intelligence. *Review of General Psychology, 3,* 292–316. doi:10.1037/1089-2680.3.4.292

Sternberg, R. J. (2006). The Rainbow Project: Enhancing the SAT through assessments of analytic, practical, and creative skills. *Intelligence, 34,* 321–350. doi:10.1016/j.intell.2006.01.002

Sternberg, R. J. (2007, July 6). Finding students who are wise, practical, and creative. *The Chronicle of Higher Education,* p. B11. Retrieved from http://chronicle.com/article/Finding-Students-Who-Are-Wise/15549

Sternberg, R. J., & Grigorenko, E. L. (Eds.). (2002). *The general factor of intelligence: How general is it?* Mahwah, NJ: Erlbaum.

Stevenson, H. W., Lee, S. Y., Chen, C., Stigler, J. W., Hsu, C. C., & Kitamura, S. (1990). Contexts of achievement: A study of American, Chinese, and Japanese children. *Monographs for the Society for Research in Child Development, 55*(1–2, Serial No. 221).

Stoolmiller, M. (1999). Implications of the restricted range of family environments for estimates of heritability and nonshared environment in behavior-genetic adoption studies. *Psychological Bulletin, 125,* 392–409. doi:10.1037/0033-2909.125.4.392

Sundet, J. M., Barlaug, D. G., & Torjussen, T. M. (2004). The end of the Flynn effect? A study of secular trends in mean intelligence test scores of Norwegian conscripts during half a century. *Intelligence, 32,* 349–362. doi:10.1016/S0160-2896(04)00052-2

Sundet, J. M., Eriksen, W., Borren, I., & Tambs, K. (2010). The Flynn effect in sibships: Investigating the role of age differences between siblings. *Intelligence, 38,* 38–44. doi:10.1016/j.intell.2009.11.005

Süβ, H., Oberauer, K., Wittmann, W. W., Wilhelm, O., & Schulze, R. (2002). Working-memory capacity explains reasoning ability—and a little bit more. *Intelligence, 30,* 261–288. doi:10.1016/S0160-2896(01)00100-3

Teasdale, T. W., & Owen, D. R. (1989). Continued secular increases in intelligence and a stable prevalence of high intelligence levels. *Intelligence, 13,* 255–262. doi:10.1016/0160-2896(89)90021-4

Teasdale, T. W., & Owen, D. R. (2000). Forty-year secular trends in cognitive abilities. *Intelligence, 28,* 115–120. doi:10.1016/S0160-2896(99)00034-3

Thompson, P. M., Cannon, T. D., Narr, K. L., van Erp, T., Poutanen, V. P., & Huttunen, M. (2001). Genetic influences on brain structure. *Nature Neuroscience, 4*(12), 1253–1258. doi:10.1038/nn758

Toga, A. W., & Thompson, P. M. (2005). Genetics of brain structure and intelligence. *Annual Review of Neuroscience, 28,* 1–23. doi:10.1146/annurev.neuro.28.061604.135655

Tranter, L. J., & Koutstaal, W. (2007). Age and flexible thinking: An experimental demonstration of the beneficial effects of increased cognitively stimulating activity on fluid intelligence in healthy older adults. *Neuropsychology, Development, and Cognition. Section B, Aging, Neuropsychology and Cognition, 15,* 184–207.

Tucker-Drob, E. M., Rhemtulla, M., Harden, K. P., Turkheimer, E., & Fask, D. (2011). Emergence of a gene × socioeconomic status interaction on infant mental ability between 10 months and 2 years. *Psychological Science, 22,* 125–133. doi:10.1177/0956797610392926

Turkheimer, E., Blair, C., Sojourner, A., Protzko, J., & Horn, E. (2012). *Gene environment interaction for IQ in a randomized clinical trial.* Unpublished manuscript, Department of Psychology, University of Virginia, Charlottesville.

Turkheimer, E., Haley, A., Waldron, M., D'Onofrio, B., & Gottesman, I. I. (2003). Socioeconomic status modifies heritability of IQ in young children. *Psychological Science, 14,* 623–628. doi:10.1046/j.0956-7976.2003.psci_1475.x

Turkheimer, E., Harden, K. P., D'Onofrio, B., & Gottesman, I. I. (2009). The Scarr–Rowe interaction between measured socioeconomic stautus and the heritability of cognitive ability. In K. McCartney & R. A. Weinberg (Eds.), *Experience and development: A festschrift in honor of Sandra Wood Scarr* (pp. 81–97). New York, NY: Psychology Press.

Turner, M. L., & Engle, R. W. (1989). Is working memory capacity task dependent? *Journal of Memory and Language, 28,* 127–154. doi:10.1016/0749-596X(89)90040-5

van der Maas, H. L., Dolan, C. V., Grasman, R. P., Wicherts, J. M., Huizenga, H. M., & Raijmakers, M. E. (2006). A dynamical model of general intelligence: The positive manifold of intelligence by mutualism. *Psychological Review, 113,* 842–861. doi:10.1037/0033-295X.113.4.842

van der Sluis, S., Willemsen, G., de Geus, E. J. C., Boomsma, D. I., & Posthuma, D. (2008). Gene–environment interaction in adults' IQ scores: Measures of past and present environment. *Behavior Genetics, 38,* 348–360. doi:10.1007/s10519-008-9212-5

van IJzendoorn, M. H., Juffer, F., & Poelhuis, C. W. K. (2005). Adoption and cognitive development: A meta-analytic comparison of adopted and nonadopted children's IQ and school performance. *Psychological Bulletin, 131,* 301–316. doi:10.1037/0033-2909.131.2.301

van Leeuwen, M., Peper, J. S., van den Berg, S. M., Brouwer, R. M., Hulshoff Pol, H. E., & Kahn, R. S. (2009). A genetic analysis of brain volumes and IQ in children. *Intelligence, 37*(2), 181–191. doi:10.1016/j.intell.2008.10.005

Volkmar, F. R., & Sparrow, S. S. (1993). Sex differences in pervasive developmental disorders. *Journal of Autism and Developmental Disorders, 23,* 579–591. doi:10.1007/BF01046103

Wai, J., Cacchio, M., Putallaz, M., & Makel, M. C. (2010). Sex differences in the right tail of cognitive abilities: A 30 year examination. *Intelligence, 38,* 412–423. doi:10.1016/j.intell.2010.04.006

Wallentin, M. (2009). Putative sex differences in verbal abilities and language cortex: A critical review. *Brain and Language, 108,* 175–183. doi:10.1016/j.bandl.2008.07.001

Walton, G. M., & Spencer, S. J. (2009). Latent ability: Grades and test scores systemically underestimate the intellectual ability of negatively stereotyped students. *Psychological Science, 20,* 1132–1139. doi:10.1111/j.1467-9280.2009.02417.x

Waltz, J. A., Knowlton, B. J., Holyoak, K. J., Boone, K. B., Mishkin, F. S., & de Menezes Santos, M. (1999). A system for relational reasoning in human prefrontal cortex. *Psychological Science, 10*(2), 119–125. doi:10.1111/1467-9280.00118

Weedon, M. N., Lango, H., Lindgren, C. M., Wallace, C., Evans, D. M., Mangino, M., et al. (2008). Genome-wide association analysis identifies 20 loci that influence adult height. *Nature Genetics, 40,* 575–583. doi:10.1038/ng.121

Weinberg, R. A., Scarr, S., & Waldman, I. D. (1992). The Minnesota Transracial Adoption Study: A follow-up of IQ test performance at adolescence. *Intelligence, 16,* 117–135. doi:10.1016/0160-2896(92)90028-P

Weyl, N. (1969). Some comparative performance indexes of American ethnic minorities. *Mankind Quarterly, 9,* 106–119.

Wicherts, J. M., Jelte, M., Dolan, C. V., & Hessen, D. J. (2004). Are intelligence test measurements invariant over time? Investigating the nature of the Flynn effect. *Intelligence, 32,* 509–537. doi:10.1016/j.intell.2004.07.002

Wichman, A. L., Rodgers, J. L., & MacCallum, R. C. (2006). A multilevel approach to the relationship between birth order and intelligence. *Personality and Social Psychology Bulletin, 32,* 117–127. doi:10.1177/0146167205279581

Willis, J. O., Dumont, R., & Kaufman, A. S. (2011). Factor-analytic models of intelligence. In R. J. Sternberg & S. B. Kaufman (Eds.), *The Cambridge handbook of intelligence* (pp. 39–57). Cambridge, England: Cambridge University Press.

Wolf, O. T., & Kirschbaum, C. (2002). Endogenous estradiol and testosterone levels are associated with cognitive performance in older women and men. *Hormones and Behavior, 41,* 259–266. doi:10.1006/hbeh.2002.1770

Zajonc, R. B. (1976, April 16). Family configuration and intelligence. *Science, 192,* 227–236. doi:10.1126/science.192.4236.227

Zajonc, R. B., & Sulloway, F. J. (2007). The confluence model: Birth order as a within-family or between-family dynamic? *Personality and Social Psychology Bulletin, 33,* 1187–1194. doi:10.1177/0146167207303017

Correction to Nisbett et al. (2012)

In the article "Intelligence: New Findings and Theoretical Developments," by Richard E. Nisbett, Joshua Aronson, Clancy Blair, William Dickens, James Flynn, Diane F. Halpern, and Eric Turkheimer (*American Psychologist,* Vol. 67, No. 2, pp. 130–159; this issue), two correlational values are incorrect in the 10th line on p. 134. The relevant sentences should read, "It appears, for example, that socioeconomic differences in intelligence are not as pronounced in modern Europe as they are in the United States. In the Turkheimer et al. (2003) study, the correlation of SES with IQ was .46; in Asbury et al. (2005), it was about .2."

DOI: 10.1037/a0027240