Studying Intellectual Outliers : Are There Sex Differences, and Are the Smart Getting Smarter?

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Studying Intellectual Outliers: Are There Sex Differences, and Are the Smart Getting Smarter?

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Abstract

By studying samples of intellectual outliers across 30 years, researchers can leverage right-tail data (i.e., samples at or above the 95th percentile on tests of ability) to uncover missing pieces to two psychological puzzles: whether there are sex differences in cognitive abilities among smart people, and whether test scores are rising (a phenomenon known as the Flynn effect) among smart people. For the first puzzle, data indicate that the high male-to-female ratio among extremely high scorers on measures of math ability has decreased dramatically, but is still likely one factor among many explaining female underrepresentation in some professions. For the second puzzle, data indicate that the right tail has risen at a similar rate as the general (or middle portion of the) distribution; it is thus likely that the *entire* curve is rising at a relatively constant rate, consistent with the Flynn effect, which may explain why a greater number of gifted students have been identified in recent years. However, the causes for these gains and whether they reflect *real* gains in intelligence continue to remain a mystery. We show how these two puzzles are linked and stress the importance of paying attention to the entire distribution when attempting to address some scientific questions.

Keywords

cognitive abilities, Flynn effect, right tail, sex differences, historical examination

What can we learn by studying smart people? Biographers examine the individual lives of brilliant people to uncover the way their minds tick, often opening a window into the reasons why some people are cognitively exceptional. But what if, rather than studying individual minds, we systematically studied large samples of smart people? What if we took a group of *intellectual outliers* at the right tail of the cognitive-ability distribution—the top 5% of scorers on measures of intelligence—and examined their scores over time?

By studying samples of intellectual outliers across long periods of time, we can leverage these data to uncover missing pieces to two psychological puzzles. One puzzle concerns whether there are sex differences in various cognitive abilities among smart people and, if so, whether those differences have changed over time and how they might explain the dearth of women in high-level math and science careers in fields such as engineering and physics (Wai, Cacchio, Putallaz, & Makel, 2010). Another puzzle concerns whether smart people are getting smarter at the same rate as everyone else, whether increasing scores on measures of intelligence reflect real gains in intelligence or are due to other factors, and what the causes of these increases might be (Wai & Putallaz, 2011).

Why Are There Fewer Women Than Men in High-Level Math and Science Careers?

In the engineering or physics departments of universities, you are unlikely to see equivalent numbers of female and male professors. Why is that? The problem of female underrepresentation in math and science careers is extremely complicated and likely due to multiple interlocking factors, such as sociocultural factors and gender-based differences in interests (Ceci, Williams, & Barnett, 2009; Halpern et al., 2007).

Thus, when addressing this question, we cannot rule out potential biases and barriers, but in a competitive global economy, it is not wise to underdevelop half of our world's population for math and science fields. However, one other potential factor is sex differences in math and science reasoning among the smartest intellectual outliers. Why focus on the intellectual outliers? Research suggests that the people who end up as

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professors and innovators in these fields do not typically have an average level of math ability, but instead are extremely smart (Ceci & Williams, 2010; Lubinski & Benbow, 2006). Moreover, even within the top 1% of math-ability scorers, differences in ability between those in the top quarter of the percentile and those in the bottom quarter can make a difference between whether or not individuals earn a math or science PhD, a patent, publication, and even tenure at a top university (Wai, Lubinski, & Benbow, 2005). These findings of sex differences in math ability within groups of intellectual outliers suggest that math ability may play a role in explaining why there are fewer women than men in high-level math and science fields.

A landmark study using a Johns Hopkins University database from the early 1980s (Benbow & Stanley, 1983) showed that among intellectually talented seventh-grade students who were in the top 0.01% in math ability on the SAT-Math (with scores of 700 or higher), there were 13 males for every female.[1] The authors suggested this 13-to-1 ratio might partly explain the dearth of females in high-level math and science careers. But have things changed since that time?

Samples

We recently addressed these questions using three major data sets (Wai et al., 2010; Wai & Putallaz, 2011) from the Duke University Talent Identification Program Talent Search (Duke TIP; Putallaz, Baldwin, & Selph, 2005). Most prior studies in this area have used cognitive-ability measures with insufficient measurement room at the top (i.e., *headroom*) for intellectual outliers and have not explicitly sampled from a group of intellectual outliers. We administered tests designed for older, typical students to younger, intellectually talented students to allow enough headroom to reveal potential sex differences and to differentiate the smart from the extremely smart. The first study examined the top 0.01% of scorers as well as the top 5%. The second study examined the top 5%.

The overall sample consisted of more than 1.7 million students, with roughly equal numbers of males and females. These participants included seventh graders who had taken the SAT between 1981 and 2010 ($N = 1{,}173{,}342$), seventh graders who had taken the ACT between 1990 and 2010 ($N = 440{,}380$), and fifth and sixth graders who had taken the EXPLORE test between 1995 and 2010 ($N = 89{,}470$). (The EXPLORE test is similar to the ACT but is designed for typical eighth- and ninth-grade students.) Each of these individual samples represented populations at about the top 5% of ability. We examined composite SAT scores, as well as scores on the math and verbal subtests of the SAT; composite ACT scores, as well as scores on the math, science, English, and reading subtests of the ACT; and composite EXPLORE scores, as well as scores on the math, science, English, and reading subtests of the EXPLORE. Further description of the samples and tests can be found in Wai et al. (2010) and Wai and Putallaz (2011).

Are There Sex Differences Among Intellectual Outliers?

Figure 1a shows the number of males for every female among the top math-ability scorers over the past 30 years, using the Duke TIP database, which included an independent sample of seventh-grade students similar to those in the original study. The red line represents the number of males for every female among the top 0.01% of scorers on the SAT-Math. The male-to-female ratio was 13.5 to 1 in the early 1980s and rapidly dropped to about 4 to 1 by the early 1990s, where it has remained fairly stable. Our results using the Duke TIP data replicated the early 13-to-1 ratio and showed it has since dropped.

In addition to the SAT-Math, what about gender ratios among students at similar ability levels on the ACT-Math (black line in Fig. 1a) and the EXPLORE-Math (green line in Fig. 1a)? The male-to-female ratios among the top scorers on these tests were slightly lower than the ratio for the SAT-Math, at about 3 to 1 and 2 to 1, respectively, but they have also remained fairly stable across the past 20 years. Additionally, the science-reasoning measures (blue and purple lines in Fig. 1a) showed fairly stable male-to-female ratios at similar levels. The fact that we continue to find sex differences in math ability within the very smartest group means that sex differences in math ability are likely part of the explanation for female underrepresentation in high-level math and science careers. In addition, sex differences in science-reasoning ability should also be considered as part of the discussion (Wai et al., 2010).

The Pattern of Sex Differences More Broadly

What about sex differences in verbal ability among the top 0.01% of scorers? As shown in Figure 1b, across multiple measures, females tended to have a small advantage over males. These ratios primarily favored females, ranging between one and two females for every male, and like the gender ratios for math-ability scores, they also appear to have been stable across time.

Going beyond male-to-female ratios within the top 0.01% of scorers, what about average male-female differences within the top 5% of scorers? Figures 2 and 3 illustrate male-female differences on multiple measures. Overall, males (blue lines) scored higher than females on the measures of math and science ability, and females (red lines) scored higher than males on the measures of verbal ability, English, and reading. This general pattern has also been found in other studies of sex differences in cognitive abilities that focused on not just the right tail but the general population (Lohman & Lakin, 2009; Strand, Deary, & Smith, 2006), and showed that males were higher than females in top percentiles of the measures of math ability. However, see Hyde and Linn (2006) for an alternative perspective.

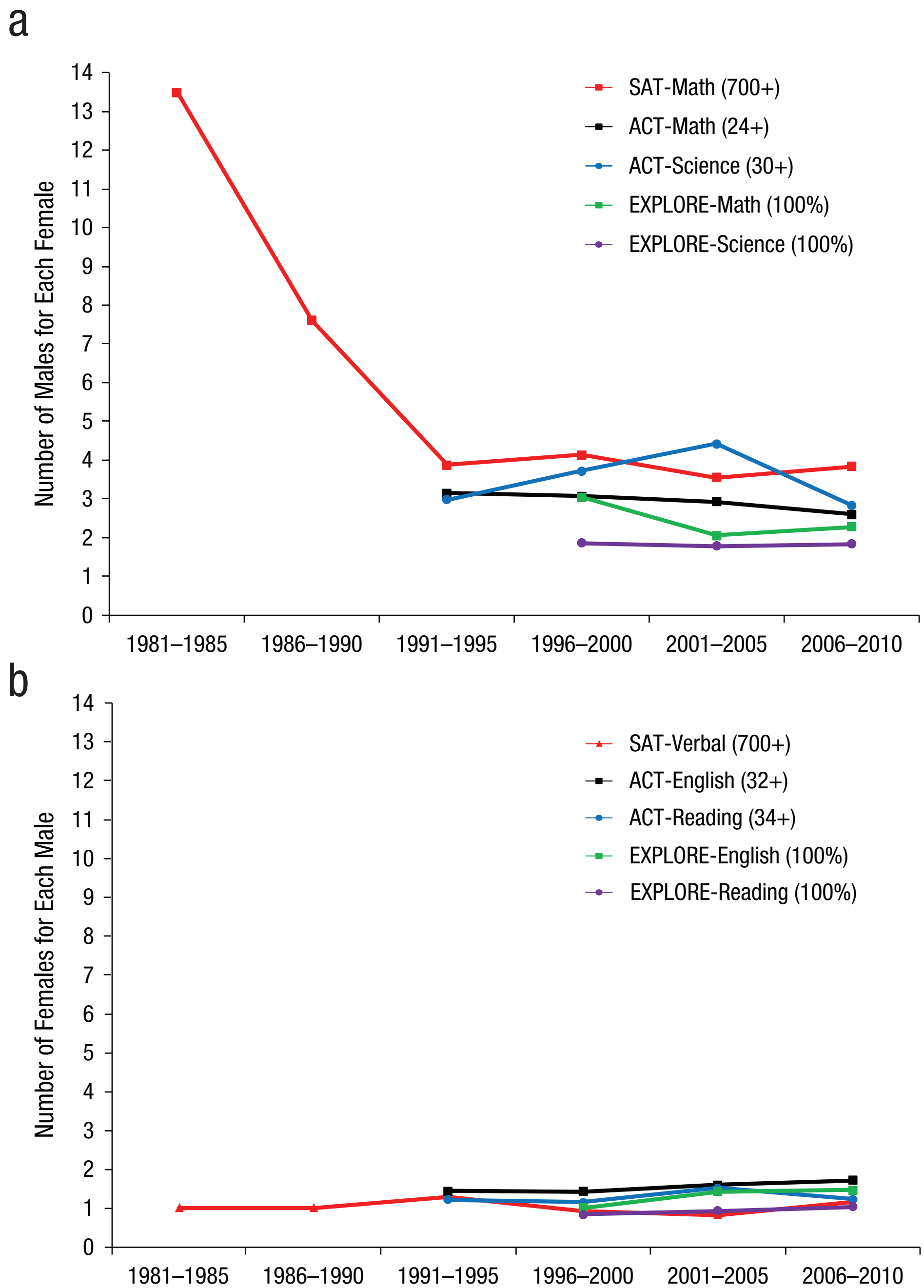


Fig. 1. Sex differences among intellectual outliers. Panel a shows the number of males for each female among the top 0.01% of scorers on the mathematics and science subtests of the SAT, ACT, and EXPLORE from 1981 to 2010, in five-year groups. Samples consisted of students who scored 700 or higher on the SAT-Math, students who scored 24 or higher on the ACT-Math and 30 or higher on the ACT-Science, and students with perfect scores on the EXPLORE-Math and on the EXPLORE-Science. Panel b shows the number of females for each male among the top 0.01% of scorers on the verbal, English, and reading subtests of the SAT, ACT, and EXPLORE from 1981 to 2010, in five-year groups. Samples consisted of students who scored 700 or higher on the SAT-Verbal, students who scored 32 or higher on the ACT-English and 34 or higher on the ACT-Reading, and students with a perfect score on the EXPLORE-English and on the EXPLORE-Reading.

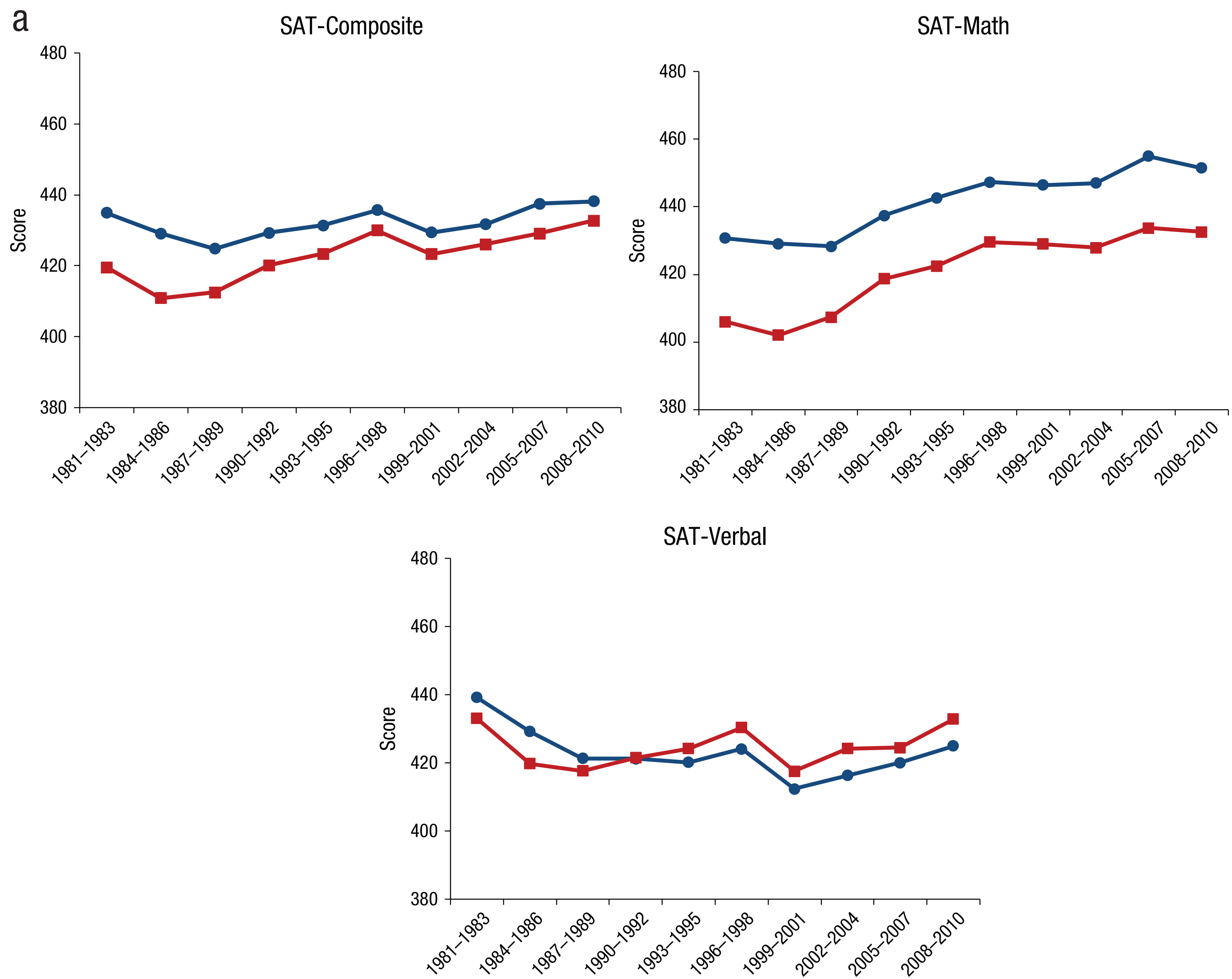
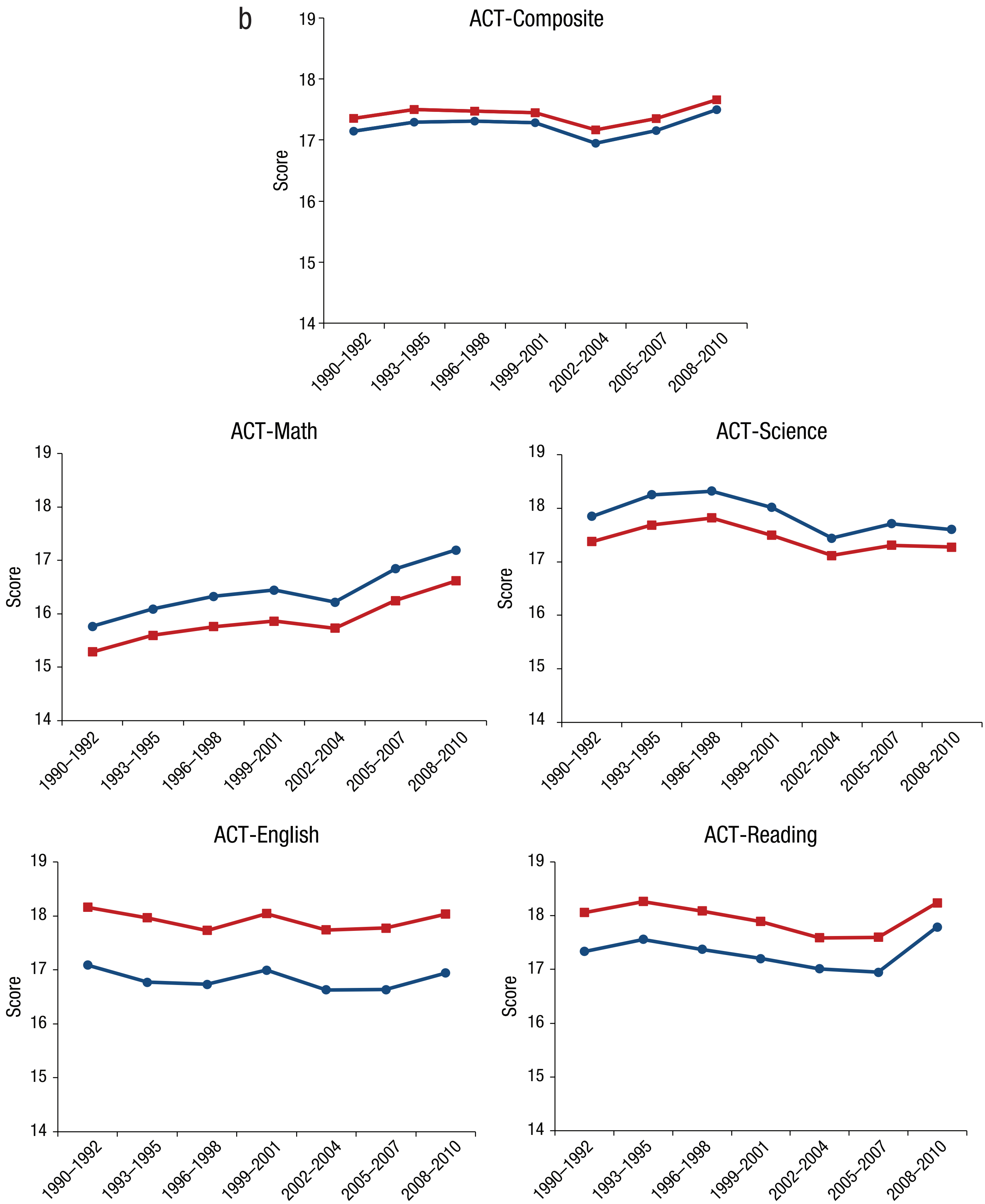


Fig. 2. Scores for males and females on the SAT and ACT and each of their respective subtests from 1981 to 2010 (SAT) or from 1990 to 2010 (ACT), in three-year groups. Blue lines with circles indicate scores for males and red lines with squares indicate scores for females.

(continued)

Fig. 2. (continued)



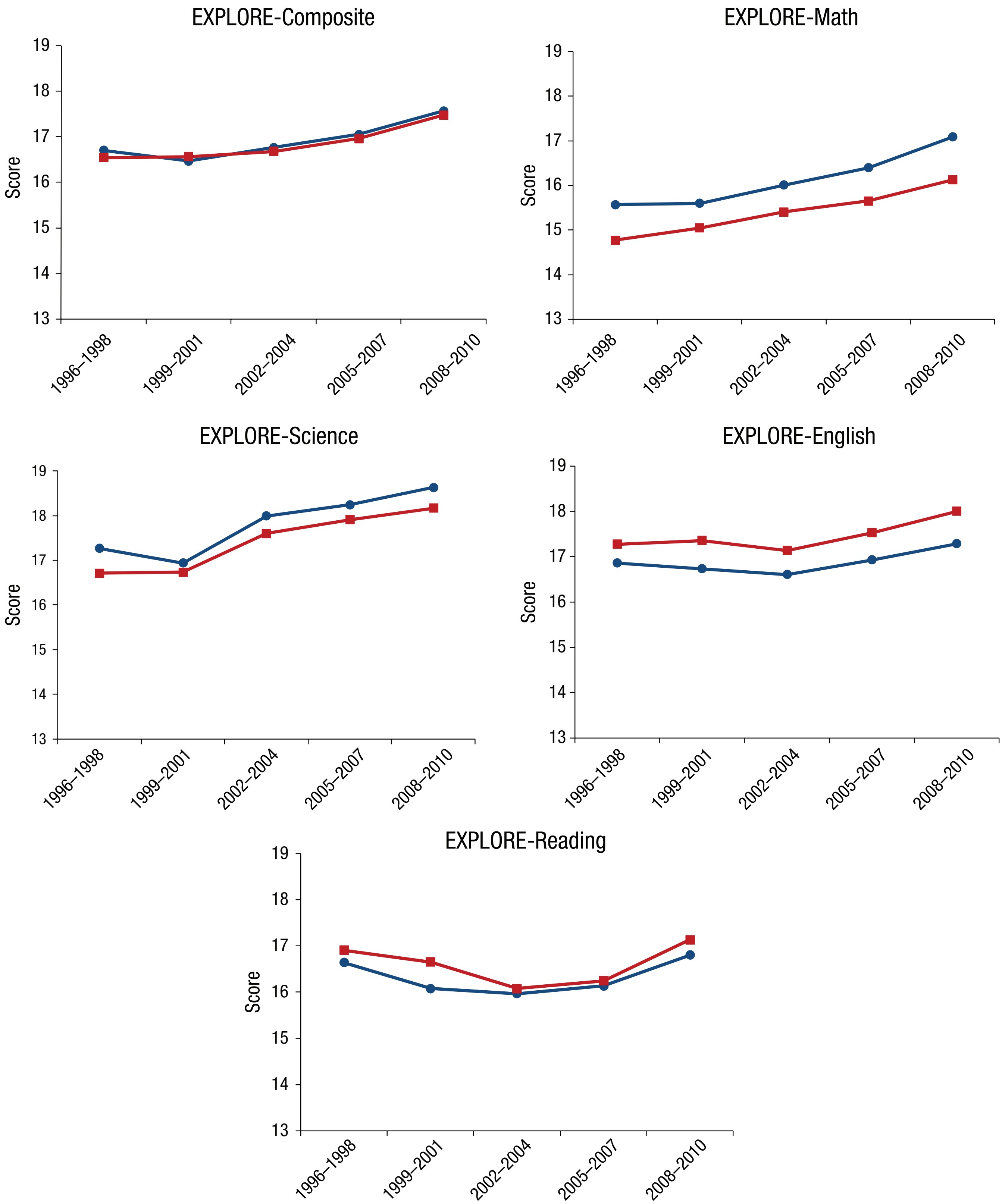


Fig. 3. Scores for males and females on the EXPLORE and each of its subtests from 1996 to 2010, in three-year groups. Blue lines with circles indicate scores for males, and red lines with squares indicate scores for females.

Some Questions That Remain Unanswered

Why the ratio of males to females among the top 0.01% of math scorers dropped so rapidly and why it has remained stable across the past two decades remain unexplained (see Fig. 1a). Sociocultural factors likely played a role in the drop, but it is unclear why the ratio appears to be stable. Of course, sex differences in abilities are only one factor among many that may contribute to the dearth of women in high-level math and science fields, and to get the full context, one must know that the left tail is also male dominated (Johnson, Carothers, & Deary, 2008). In addition, interests likely play a large role (Su, Rounds, & Armstrong, 2009). Therefore, these findings are probably best explained by frameworks that examine multiple perspectives simultaneously (Ceci et al., 2009; Halpern et al., 2007).

Are Intellectual Outliers Getting Smarter?

Measures such as the SAT and ACT are known to be reasonable proxies for measures of general cognitive ability (Frey & Detterman, 2004). Thus, it is interesting to examine whether scores on these tests have fluctuated over time, like IQ scores have. As Flynn (1984, 1987) has demonstrated, IQ scores rose 0.33 points per year on average for much of the 20th century, a phenomenon that has been termed the Flynn effect and constitutes an important puzzle in the field of intelligence.

The Flynn effect has appeared in the general populations of multiple countries (Flynn, 1984, 1987; Neisser, 1998). However, a missing puzzle piece is whether the Flynn effect occurs for groups of right-tail intellectual outliers (Rodgers, 1998). Many explanations for the effect have been proposed, but the utility of these explanations depends largely on which parts of the distribution are showing the gains. For example, large gains have appeared in some left-tail studies involving samples with relatively low IQ scores, and some researchers have suggested that nutrition (Lynn, 1990) is the primary cause for those gains (Colom, Lluis-Font, & Andres-Pueyo, 2005). Other explanations concern improvements in education (Ceci, 1991; Flynn, 1984), increased test sophistication (Brand, 1987), increased cognitive stimulation arising from increased exposure to television and video games (Schooler, 1998), and environmental and social factors (Dickens & Flynn, 2001).

However, the question of whether the Flynn effect occurs among right-tail intellectual outliers remains. And, regardless of whether the answer to that question is yes or no, what does it tell us about the likely causes of the effect?

The data shown in Figures 2 and 3 suggest an answer to the first question (Wai & Putallaz, 2011). Using multiple measures from the SAT, ACT, and EXPLORE tests, we examined whether the Flynn effect occurred for the intellectual outliers (i.e., the top 5% of scorers). Overall, the effect appeared to be concentrated on the measures of math (or nonverbal) ability, with small gains or no gains on the other measures. The gains on these measures of math ability (amounting to an increase of 0.33 IQ points per year) are similar to the average rate of gain found in studies focusing on the general distribution (Flynn, 2012; Rodgers, 1998); therefore, this right-tail finding links directly with the broader literature on the general population, as well as literature on the lower tail (Kanaya & Ceci, 2011). This value of 0.33 points per year was calculated by adding the rate-of-gain IQ values for the SAT-Math (0.17), the ACT-Math (0.45), and the EXPLORE-Math (0.37) and dividing by three (see Table 1).

These findings demonstrate for the first time that scores among *the entire distribution* (including the right tail) have risen at a relatively constant rate. The Flynn effect may also explain why an increased number of gifted students has been identified in recent years (Otterman, 2010; Wai & Putallaz, 2011): Gifted programs often have cutoff scores that do not change over time, which may correspondingly lead to a higher proportion of students attaining that cutoff score.[2] What implications do these results have for potential causes of the Flynn effect? Although many researchers have proposed individual causes for the effect, most of them would agree that a *multiplicity* or package of factors operate together to explain it (Jensen, 1998). These findings also hold two possibilities for potential causes. First, if the whole curve is rising, then the package of causal factors likely all have the same weight in influencing everyone—from those in the left tail to those in the right tail. For example, if enhanced nutrition and cognitive stimulation were the only factors contributing to the Flynn effect, they would contribute equally to the gains for everyone. Alternatively, the causes of the effect in the left tail may be different from the causes of the effect in the right tail. For example, enhanced cognitive stimulation may play a larger role in the right-tail gains, and enhanced nutrition may play a larger role in the left-tail gains.

Following from the latter perspective, and building on the idea that a multiplicity of factors explain the gains, we propose

Table 1. Mean Yearly Rates of Change in IQ as Indexed by Scores on the SAT, ACT, and EXPLORE

Test	Males	Females	Total Sample
SAT-Composite	0.02	0.09	0.06
ACT-Composite	0.11	0.10	0.10
EXPLORE-Composite	0.22	0.25	0.23
SAT-Math	0.15	0.19	0.17
ACT-Math	0.46	0.43	0.45
EXPLORE-Math	0.39	0.37	0.37
ACT-Science	−0.08	−0.03	−0.05
EXPLORE-Science	0.37	0.40	0.39
SAT-Verbal	−0.10	0.00	−0.05
ACT-English	−0.05	−0.04	−0.06
EXPLORE-English	0.10	0.19	0.14
ACT-Reading	0.14	0.06	0.09
EXPLORE-Reading	0.01	0.02	0.01

Note: *SD* = 15 for all results.

that there may be many factors operating with different weights for different parts of the distribution, but that give a similar *Flynn-effect dose* (Wai & Putallaz, 2011). We think our findings suggest that enhanced cognitive stimulation may play a role in the right-tail gains (Flynn, 1984, 1987). For example, the rise of digital culture and video games may be involved.

By studying the reasons behind these right-tail gains, we may uncover ways to one day even enhance intelligence (Detterman, 1996). However, we ultimately do not know what factors are responsible for the Flynn effect or why this effect is concentrated primarily in nonverbal domains. It is also unclear whether these gains are *real* gains in general intelligence or reflect other variables. All intelligence tests measure general intelligence in addition to other factors. If the gains in scores are due to gains in general intelligence, they would be considered "real," but if they are due to something like increased test sophistication, then they would not be considered real. To date, findings across multiple studies have remained inconclusive as to whether these gains are real (Flynn, 2007; Howard, 1999; Wicherts et al., 2004). However, these findings might hold some clues that lead to important future breakthroughs in understanding intelligence (Nisbett et al., 2012).

How These Two Puzzles Are Linked

In contrast to the male-to-female ratios (Fig. 1) and average scores for males and females (Figs. 2 and 3) across multiple measures of cognitive ability showing sex differences, the Flynn effect across these same measures shows striking sex *similarities*. The math measures were also where rapid change occurred in the male-to-female ratios among high scorers, as well as where the Flynn-effect gains were concentrated. Finally, we cannot predict whether the ratios and gains will remain stable or change in the future, so future investigations will be needed, perhaps in the next 30 years.

Leveraging Intellectual-Outlier Data to Answer Scientific Questions

Beyond providing missing pieces to two psychological puzzles, these findings help illustrate a method of leveraging data on intellectual outliers to address complex scientific questions. Most researchers examine the general distribution. We purposefully examined the right tail and discovered that the sex differences among these intellectual outliers were not the same as those in the general distribution (an answer to the first puzzle), but that gains in intelligence among these outliers were the same as in the general distribution (an answer to the second puzzle). This pattern highlights the need for researchers to pay attention to the entire distribution.

The right tail has been demonstrated to predict a variety of important societal outcomes (Rindermann & Thompson, 2011; Wai et al., 2005). Studying the very smartest people creates the potential to gain insight into the mind's mysteries more generally. Unlocking the keys to the brain's secrets might depend, at least in part, in better understanding the deep complexity of some of our society's most intellectually talented minds.

Recommended Reading

Ceci, S. J., & Williams, W. M. (2010). (See References). A clearly written, user-friendly, and balanced synthesis of what is known about sex differences and women in math and science.

Flynn, J. R. (1984). (See References). A historical classic and one of the first papers to raise attention to the Flynn effect.

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Kaufman, A. S., & Weiss, L. G. (Eds.). (2010). The Flynn effect [Special issue]. *Journal of Psychoeducational Assessment*, 28, 379–505. A special issue devoted to the current status of the research on the Flynn effect.

Rodgers, J. L. (1998). (See References). A classic paper that lays the groundwork for what we need to know about the Flynn effect.

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Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

Notes

1. It is important to remember that tests (e.g., the SAT, the ACT, and the EXPLORE) reflect self-sought and external opportunities to accumulate knowledge and not just raw ability, and that they are also subject to measurement error. However, these tests that have been designed to measure achievement in older students may better measure reasoning ability in younger students (Benbow, 1988).
2. In addition to the reports of more gifted students being identified in New York City, we also confirmed in our samples (which cover a 16-state region) that more gifted students are being identified in recent years (see Wai & Putallaz, 2011, p. 449).

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