

*Special Section: Doing Psychological Science*

# Study of Mathematically Precocious Youth After 35 Years

## Uncovering Antecedents for the Development of Math-Science Expertise

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**ABSTRACT**—*This review provides an account of the Study of Mathematically Precocious Youth (SMPY) after 35 years of longitudinal research. Findings from recent 20-year follow-ups from three cohorts, plus 5- or 10-year findings from all five SMPY cohorts (totaling more than 5,000 participants), are presented. SMPY has devoted particular attention to uncovering personal antecedents necessary for the development of exceptional math-science careers and to developing educational interventions to facilitate learning among intellectually precocious youth. Along with mathematical gifts, high levels of spatial ability, investigative interests, and theoretical values form a particularly promising aptitude complex indicative of potential for developing scientific expertise and of sustained commitment to scientific pursuits. Special educational opportunities, however, can markedly enhance the development of talent. Moreover, extraordinary scientific accomplishments require extraordinary commitment both in and outside of school. The theory of work adjustment (TWA) is useful in conceptualizing talent identification and development and bridging interconnections among educational, counseling, and industrial psychology. The lens of TWA can clarify how some sex differences emerge in educational settings and the world of work. For example, in the SMPY cohorts, although more mathematically precocious males than females entered math-science careers, this does not necessarily imply a loss of talent because the women secured similar proportions of advanced degrees and high-level careers in areas more correspondent with the multidimensionality of their ability-preference pattern*

*(e.g., administration, law, medicine, and the social sciences). By their mid-30s, the men and women appeared to be happy with their life choices and viewed themselves as equally successful (and objective measures support these subjective impressions). Given the ever-increasing importance of quantitative and scientific reasoning skills in modern cultures, when mathematically gifted individuals choose to pursue careers outside engineering and the physical sciences, it should be seen as a contribution to society, not a loss of talent.*

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Society is becoming more knowledge based, technological, and international (Friedman, 2005); the physical and social systems within which people operate are increasingly complex and dynamic, and economies are built upon ideas. Those countries that flourish will be the ones most effective in developing their human capital and in nurturing individuals who will come up with the best ideas and innovations of tomorrow. A recent report issued by the National Academy of Sciences (2005), *Rising Above the Gathering Storm*, highlights the importance of these trends for all countries concerned about their future prosperity and speaks to the importance of developing intellectual talent. Indeed, identifying and developing talent for science, technology, engineering, and mathematics (STEM) was the dominant reason that Julian C. Stanley founded the Study of Mathematically Precocious Youth (SMPY) in 1971. Longitudinal findings emerging out of SMPY have special relevance today as the United States considers, for example, launching an American Competitiveness Initiative (2006).

The purpose of this article is twofold. First, we outline the SMPY longitudinal study and how its findings over the past 35 years have informed both basic and applied psychological science on identifying and nurturing intellectual talent. Much has been learned about effective ways to identify potential for and to facilitate the development of scientific expertise.

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Because the work on educational facilitation has been summarized elsewhere (Benbow & Lubinski, 1996; Benbow & Stanley, 1996; Stanley, 2000),<sup>1</sup> our second purpose is to focus attention on the critical personal antecedents for developing outstanding scientific careers. Which individuals are most likely to become exceptional STEM professionals? We say less here on how to facilitate the educational development of such individuals.

SMPY was not designed for, nor is this article about, enhancing the scientific literacy of the general population. Enhancing scientific literacy is clearly important. The public needs to make informed decisions on topics ranging from whether evolution should be taught in the schools to whether tax dollars should be used to fund stem cell research. Fostering scientific literacy, however, is different from identifying future scientific leaders and creating supportive environments for them. Although the two certainly have common components, the talent and commitment necessary to develop as a scientific leader require both personal attributes and learning environments that are truly beyond the norm. The intellectual abilities, personal commitment, and educational experiences needed to ameliorate global warming or to create an environmentally safe, oil-independent energy source are of a much different order of magnitude than those required for developing scientific literacy (Simonton, 1994; Zuckerman, 1977).

An overabundance of STEM leaders has emerged from SMPY. Their distinguishing psychological characteristics and the developmental choices structuring the paths they traversed from age 12 have become evident from experiential and personal data collected at earlier time points. Not surprisingly, the personal attributes of future STEM leaders reveal that it takes much more than exceptional abilities to develop truly exceptional scientific expertise.

### SMPY

SMPY was founded by Stanley on September 1, 1971, at Johns Hopkins University (Keating & Stanley, 1972; Stanley, 1996). The study moved to Iowa State University in 1986, and was directed by Camilla P. Benbow from 1986 to 1990; from 1991 through 1998, we co-directed SMPY at Iowa State, and then in 1998, we moved it to Peabody College of Vanderbilt University. The initial idea motivating SMPY was to conduct research while providing services to intellectually talented adolescents, particularly those with mathematical talent. The underlying philosophy driving this study is based on the best educational practices for all students, namely, “appropriate developmental placement” (Lubinski & Benbow, 2000, p. 138)—providing students with educational opportunities tailored to their rates of learning (Benbow & Stanley, 1996; Colangelo, Assouline, &

Gross, 2004). In the words of Stanley (2000), the idea is to teach students “only what they don’t already know” (p. 216).

From the beginning, SMPY focused as much on serving the social and emotional well-being of intellectually precocious youth as on experimenting with differential opportunities for promoting intellectual development (Benbow, Lubinski, & Suchy, 1996). To inform these two agendas, Stanley planned an after-high-school follow-up that ultimately evolved into a 50-year longitudinal study, which currently includes more than 5,000 intellectually talented individuals identified over a 25-year period (1972–1997). The aim of this research is to develop a better understanding of the unique needs of intellectually precocious youth, the determinants of the varying developmental trajectories they display, and the role of education in talent development. “Study of Mathematically Precocious Youth” has become a bit of a misnomer, however, because many of our participants are more verbally than mathematically talented, and the participants are now all adults. Nevertheless, to maintain consistency, we have chosen not to rename the study.

### Above-Level Testing and Criteria Used to Identify SMPY Participants

The members of four of SMPY’s five cohorts were selected (primarily) at around age 12 or 13, when they were in the seventh or eighth grade (a fifth cohort of top math-science graduate students was identified for longitudinal study as well). The selection process was tiered: Almost all students were first required to earn scores within the top 3% on a conventional achievement test routinely administered in their schools (e.g., the Iowa Test of Basic Skills). This select group was then given the opportunity to take the SAT through a talent search (TS; Benbow & Stanley, 1996; Colangelo et al., 2004; Keating & Stanley, 1972; Stanley, 1996). The SAT was designed for college-bound high school juniors and seniors, to assess mathematical (SAT-M) and verbal (SAT-V) reasoning abilities critical for college work (Donlon, 1984). Because few of the potential cohort members had received formal training in algebra or more advanced mathematics, and because they were 4 to 5 years younger than the population for whom the SAT was designed, this assessment falls into the category of above-level testing.

SAT-M and SAT-V score distributions among seventh and eighth graders in the top 3% are indistinguishable from the score distributions observed among high school students (Benbow, 1988). This finding is especially noteworthy for SAT-M, because despite a lack of formal training in algebra, geometry, and other areas of math tested, several of these seventh and eighth graders score above the admissions cutoff for many elite universities. Given the abstract nature of this measuring tool and the sheer novelty of the problems for this population, the SAT functions at more of an analytical reasoning level for these students than it does for older students who have been explicitly exposed to SAT content through course work in high school (Benbow, 1983; Stanley & Benbow, 1986; Brody & Benbow, 1990; Minor & Benbow, 1996).

<sup>1</sup>Many findings from SMPY’s first decade have been reported in edited volumes published by the Johns Hopkins University Press (Benbow & Stanley, 1983; Fox, Brody, & Tobin, 1980; George, Cohn, & Stanley, 1979; Keating, 1976; Stanley, George, & Solano, 1977; Stanley, Keating, & Fox, 1974). Stanley’s *Festschrift* (Benbow & Lubinski, 1996) concluded this series (cf. Benbow & Lubinski, 2006; “In Appreciation,” 2005).

Conventional age- or grade-based achievement tests routinely administered in schools are insensitive to much of the individuality of intellectually talented young adolescents. Normatively based instruments do not have high enough ceilings for these students, and most of their ability and achievement scores pile up at the top, with profile variation masked. This fosters an underappreciation not only of their potential, but also of their unique strengths and relative weaknesses. Superficial inferences based on such assessments amount to erroneous attributions of “multipotentiality,” namely, that they are all equally good at everything and can do almost anything (cf. Achter & Lubinski, 2005; Achter, Lubinski, & Benbow, 1996). In reality, this special population (like almost all special populations) contains an enormous amount of psychological diversity, including diversity in relative strengths and weaknesses.

Above-level tests offer the kind of measuring stick needed for assessing the learning rates of highly able students because such tests can uncover the profound range of individual differences in learning readiness that these students display. SMPY chose the SAT for this purpose, but other instruments can be used in this way as well. The SAT’s high ceiling for this age group distinguishes the able from the exceptionally able and, simultaneously, assesses their relative math and verbal strengths. Capturing the level and pattern of their intellectual potential more precisely than is possible with grade-level tests allows one to harness the nature and scope of their precocity to inform practice (Benbow & Stanley, 1996; Colangelo et al., 2004), research (Corno et al., 2002; Vale & Vale, 1969), and theory development (Lubinski, 1996, 2000, 2004; Lubinski & Benbow, 2000; Underwood, 1975).

For example, intellectually able adolescents scoring 500 or higher on SAT-M or SAT-V before age 13 (top 1 in 200) can assimilate a full high school course (e.g., chemistry, English, mathematics) in 3 weeks at a summer residential program for intellectually precocious youth; yet exceptionally able adolescents, those scoring 700 or more (top 1 in 10,000), can assimilate at least twice this amount (Benbow & Stanley, 1996; Colangelo et al., 2004; Stanley, 2000).<sup>2</sup> Above-level assessments are

<sup>2</sup>That cognitive abilities can be enhanced through learning is, of course, true, but a common finding is that the relationship is not linear. When all students are provided with opportunities to learn at their desired rate, those who begin with more ability typically profit more from these opportunities (Ceci & Papierno, 2005; Gagne, 2005; Jensen, 1991, p. 178; Kenney, 1975; Robinson, Abbott, Berninger, & Busse, 1996; Robinson, Abbott, Berninger, Busse, & Mukhopadhyah, 1997). This nonlinearity is intensified when one considers the full range of ability. Students with developmental delays assimilate much less than typically developing students even in the best of conditions, yet this fanning out in achievement is observed throughout the ability spectrum and within these populations as well (D. Fuchs et al., 2001; L.S. Fuchs, Fuchs, Karns, Hamlett, & Kataroff, 1999). The idea that opportunities for optimal growth expand individual differences in achievement has been discussed periodically for decades (e.g., Pressey, 1946, 1955; Seashore, 1922; Thorndike, 1911; Thurstone, 1948), yet it is conspicuously absent in many modern treatments. Two excellent exceptions, however, are articles by Ceci and Papierno (2005) and Gagne (2005). Ceci and Papierno depicted this phenomenon nicely by subtitled their treatment “When the ‘Have Nots’ Gain but the ‘Haves’ Gain Even More.” With this in mind, consider the following proposal for evaluating schools: “The good school, as I have suggested, does not diminish individual differences; it increases them. It raises the mean and increases the variance” (Eisner, 1999, p. 660).

critical, therefore, for properly structuring educational curricula and being responsive to individuality. The exceptionally able certainly require different opportunities for optimal development than the able (Lubinski, Webb, Morelock, & Benbow, 2001; Muratori et al., 2006), the former needing a more abstract, deeper, and faster-paced curriculum to avoid boredom. Furthermore, individual differences in learning rates between the able and the exceptionally able portend commensurate differences in occupational accomplishments many years later. Like their earlier academic accomplishments, the occupational accomplishments of the profoundly gifted tend to develop at an accelerated pace and with greater depth. The profoundly gifted simply have greater capacity for accomplishment and creative contributions.

In our 20-year follow-up studies of adolescents identified at age 12, for example, 30% of participants with SAT-M or SAT-V scores of 500 or above secured doctorates, compared with 50% of those scoring 700 or above (Benbow, Lubinski, Shea, & Eftekhari-Sanjani, 2000; Lubinski, Benbow, Webb, & Bleske-Rechek, 2006). The base rate for earning a doctorate (i.e., J.D., M.D., or Ph.D.) in the United States is 1%. That a 2-hr test can identify 12-year-olds who will earn this ultimate educational credential at 50 times base-rate expectations is remarkable. Moreover, a 200-point difference in SAT scores at age 12 (500 vs. 700) eventuates, by middle age, in marked differences in income, patents earned, and tenure-track academic positions secured at top U.S. universities (cf. Lubinski et al., 2006; Wai, Lubinski, & Benbow, 2005). More than one third of the ability range is found within the top 1% of ability, above-level testing affords valid assessments of individual differences within this range, and these differences make a difference in school, work, and life. Models of exceptional human development need to incorporate these individual differences.

### The Five SMPY Cohorts

SMPY’s five cohorts were formed using different selection criteria (see Table 1). The first three cohorts are successively more able (top 1.0%, 0.5%, and 0.01% in ability, respectively). The fourth cohort consists of participants who met a top-3% criterion, but a large subset of these participants took the SAT at age 12 or 13 and achieved scores within the top 0.5%. Finally, a fifth cohort consists of top first- and second-year graduate students in math and science; they were selected for a retrospective test of, among other things, the fidelity of TS procedures for identifying scientific talent. Collectively, these five cohorts include more than 5,000 participants.

## THEORETICAL MODEL

Given the number of variables facilitating the development of talent, we used a model from counseling psychology to help organize findings and structure our longitudinal research and

**TABLE 1**  
*The Five Cohorts of the Study of Mathematically Precocious Youth*

Cohort	<i>N</i>	Years when identified	Students' age when identified	Identification criteria
1	2,188	1972–1974	12–13	SAT-M $\geq$ 390 or SAT-V $\geq$ 370 (top 1 in 100)
2	778	1976–1979	12	SAT-M $\geq$ 500 or SAT-V $\geq$ 430 (top 1 in 200)
3	501	1980–1983	12	SAT-M $\geq$ 700 or SAT-V $\geq$ 630 (top 1 in 10,000)
4	1,130	1992–1997	12–14	Top 3% on any subtest of a grade-level achievement test
5	714	1992	23–25	Enrollment as a 1st- or 2nd-year student in a graduate program at a top-ranked engineering, math, or science department in the United States

**Note.** SAT-M = score on the mathematics subtest of the SAT; SAT-V = score on the verbal subtest of the SAT. (Cutting scores were established before the SAT-V was recentered in the mid-1990s.) The cutoffs selected for Cohort 1 represented the average performance of a random sample of high school girls and also represented approximately the top 1% in ability when achieved by age 13. Participants were drawn primarily from the state of Maryland, with a heavy concentration in the greater Baltimore area. Cohort 2 was drawn from the mid-Atlantic states, and Cohort 3 is national in its representation. Cohort 4 consisted primarily of Midwesterners; a subset of these participants, in addition to achieving a top-3% score on a subtest of a grade-level achievement test, also took the SAT and met at least one of the top-0.5% criteria (i.e., SAT-V  $\geq$  430 or SAT-M  $\geq$  500). Talent-search participants have been or are to be followed up at ages 18, 23, 33, 50, and 65. Cohorts 1, 2, and 3 have completed follow-ups through age 33 (Benbow, Lubinski, Shea, & Eftekhari-Sanjani, 2000; Lubinski, Benbow, Webb, & Bleske-Rechek, 2006). An age-50 follow-up of Cohort 1 will be launched in approximately 3 years. The age-18 follow-up (after high school) for Cohort 4 is complete (Webb, Lubinski, & Benbow, in press). A 10-year follow-up of Cohort 5 was conducted simultaneously with the 20-year follow-up of Cohort 3 (Lubinski et al., 2006).

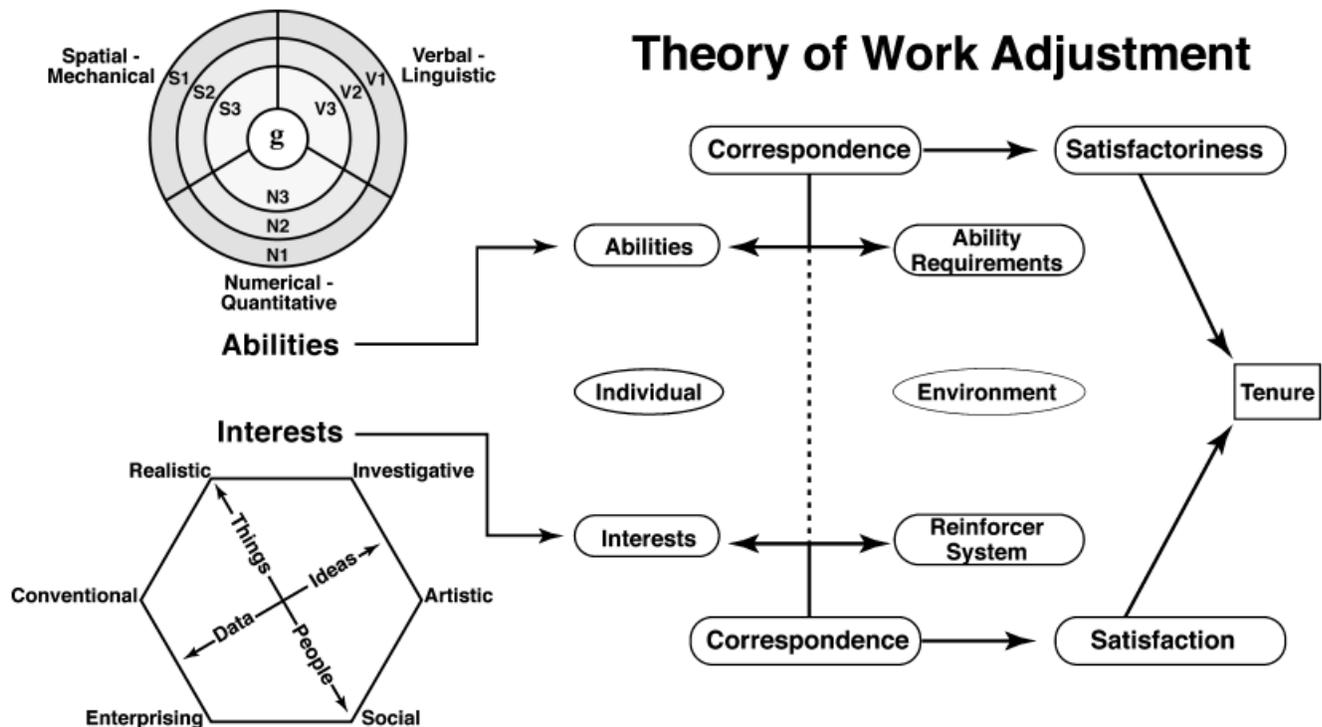
educational interventions (Lubinski & Benbow, 2000). Specifically, we extended the theory of work adjustment (TWA; Dawis & Lofquist, 1984; Lofquist & Dawis, 1969, 1991) to education and talent development (Lubinski & Benbow, 1992; Lubinski & Humphreys, 1990b), just as Katzell (1994) drew on TWA for modeling phenomena in industrial-organizational psychology. From our point of view, the applied psychological precincts of educational, counseling, and industrial psychology may be viewed sequentially from a life-span developmental perspective (Scarr & McCartney, 1983). All three specialties involve the scientific study of how individual differences may be used to structure interventions or opportunities to enhance positive psychological growth, but each area concentrates on a somewhat different stage of development. TWA organizes important variables common to all three areas (Lubinski & Benbow, 2000).

TWA is predicated on devoting equal attention to assessing the individual and assessing the environment (see Fig. 1). The individual's learning or work personality is parsed into two major components, abilities and preferences (interests and values), whereas the environment is parsed into commensurate domains of ability requirements (for meeting performance expectations) and reinforcer systems (for acknowledging and compensating performance). Profound individual differences in capability and motivation exist within cultures and subcultures, and even among siblings (Lubinski, 2000, 2004; Murray, 1998; Rowe, 1994; Scarr, 1996), and these differences eventuate in important outcome differences in education and the world of work. This is why assessing individual differences in psychological attributes is so important for both personal and professional development (Dawis, 1992, 2001; Lubinski, 1996; Roe, 1956, p. ii; Tyler,

1974; Williamson, 1965).<sup>3</sup> According to TWA, educational commitment and occupational tenure are a joint function of two major dimensions of correspondence: *satisfaction* (correspondence between needs and rewards) and *satisfactoriness* (correspondence between ability and ability requirements). The former is determined subjectively (or intra-individually) by students and workers and is based on their feelings; the latter is determined objectively (or interindividually) by teachers and supervisors and is based on performance.

Satisfaction determines how much an individual is motivated to maintain contact with a particular environment (commitment to a discipline or occupation), whereas satisfactoriness determines how much the people in the environment who evaluate performance are motivated to keep the person (or are committed to retaining the person). Both must be present for the individual to remain in the environment. If satisfaction is in place but satisfactoriness is not, the person will be asked to leave (although the person may like to stay), whereas if the inverse is the case, the person will choose to leave (although people in the environment may want to keep him or her). Satisfaction and satisfactoriness determine the extent to which the person-environment relationship is likely to maintain harmony and reciprocally nurture personal and organizational development over extended time frames (resulting in lengthy tenure). (For

<sup>3</sup>There are many different kinds of cognitive abilities, but it is generally agreed that they are hierarchically organized (Carroll, 1993; Snow & Lohman, 1989). In our treatment of specific abilities, we focus on those that are longitudinally stable and that have been shown to be widely generalizable in multiple contexts and to be related to individual differences in learning in educational settings, as well as to learning and performance in the world of work.



**Fig. 1.** The theory of work adjustment (TWA). In this framework, personal attributes (abilities and interests) and the environment (abilities requirements and reinforcer system) are given equal emphasis; occupational tenure is a joint function of the correspondence between abilities and ability requirements (satisfactoriness) and of the correspondence between interests and the reinforcer system (satisfaction). We have extended TWA to the domain of talent development. The diagrams on the left illustrate how cognitive abilities and interests have been conceptualized in our model (Lubinski & Benbow, 2000). In the diagram of the radex scaling of cognitive abilities, each region of concentration is denoted by a different letter, and higher numbers indicate increasing complexity. The diagram of Holland's (1996) hexagon of interests (referred to as RIASEC, after the initial letters of the interests) shows a simplification following Prediger (1982); in this simplification, interests are modeled by a two-dimensional structure of independent dimensions: people-things and data-ideas.

further information about this model and its extension to other domains, see Achter & Lubinski, 2003, 2005; Dawis, 2005; Dawis & Lofquist, 1984; Katzell, 1994; Lofquist & Dawis, 1991; and Lubinski & Benbow, 2000.)

### SMPY'S EMPIRICAL FINDINGS

We open this section by discussing cognitive abilities. First, we present descriptive data highlighting the individual differences in cognitive ability among young adolescents in the top 1% of quantitative reasoning ability and showing that these individual differences made a difference in education, the world of work, and creative accomplishments. We deal with this topic first because there is a long-standing and widely held supposition of an "ability threshold" in the scientific literature (i.e., an assumption that beyond a certain point, more ability does not matter; Getzels & Jackson, 1962; Howe, 2001; Renzulli, 1986). Second, the psychological significance of ability pattern is explicated. After treating cognitive abilities, we discuss the incremental validity of adding preferences to ability assessment for modeling intellectual development more comprehensively and then review the importance of time devoted to work and time willing to devote to work. Next, the role of special educational

programs and the developmental particulars of top math-science graduate students are touched upon. A focus on the math-science pipeline is maintained throughout, but the personal attributes relevant to other kinds of expertise are also covered. The role of sex differences is also a focus of the discussion, and we provide an appendix with some normative data illustrating how sex differences in level and dispersion can collectively operate to create disparate male:female ratios at high as well as low extremes of ability. And finally, a concluding section places our model and longitudinal findings in a broader historical context and underscores the importance of the developmental sciences and human-capital initiatives incorporating concepts and findings from the study of individual differences.

### Cognitive Abilities

#### *Ability Level*

The statement that more than one third of the ability range is contained in the top 1% gives one pause initially, but consider the following for a familiar illustration. Modern talent searches and educational programs for intellectually talented students have moved well beyond IQ, but let us take IQ as a reference point. IQs in the top 1% begin at approximately

137 and extend beyond 200 (an IQ range of more than 63 points is thus found in the top 1%). (The same phenomenon occurs in physical measurements such as height and weight.) The important psychological question is, do ability differences within the top 1% make a difference in life? To answer this question, we examine educational credentials, occupational outcomes, and creative accomplishments as a function of SAT-M scores at age 13 (not all of our participants had SAT-V scores available).

Table 2 contains 20-year follow-up data from Cohorts 1 and 2 (Benbow et al., 2000) and Cohort 3 participants with SAT-M scores of 700 and above (Lubinski et al., 2006). All three cohorts had SAT-M means more than 100 points beyond the cutting score for the top 1% by age 13, but the three cohorts were successively more able. Their mean SAT-M scores by age 13 were as follows: 537 and 505 for Cohort 1 males and females, 567 and 519 for Cohort 2 males and females, and 729 and 732 for Cohort 3 males and females. By age 33, approximately 25% of Cohort 1 had secured doctorates, in comparison with more than 30% for Cohort 2 and more than 50% for Cohort 3. Moreover, within each cohort, roughly equal proportions of males and females achieved advanced degrees, but the sexes were represented disproportionately across areas: Females were more likely to secure degrees in the humanities, life sciences, and social sciences than in mathematics, computer science, engineering, and the physical sciences, whereas the reverse was true for males. It should be noted, too, that these educational choices,

when reflected on later in life, engendered uniformly high ratings of satisfaction with educational and subsequent career choices, among both sexes (Benbow et al., 2000; Lubinski et al., 2006). By their mid-30s, both male and female participants expressed few regrets about their educational and career choices, and the nature of the regrets that were expressed did not covary with sex.

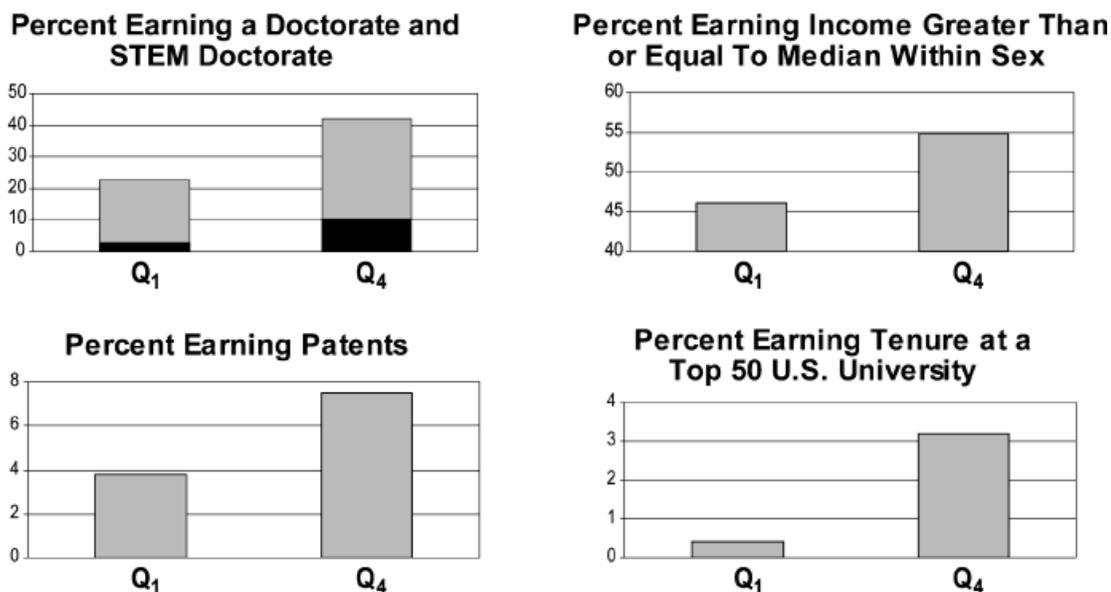
However, these three cohorts were identified over a 10-year period, and their 20-year follow-ups were offset by the same number of years. Did cohort differences (as well as more ability) contribute to the greater educational achievement of the more recent cohorts?

To ascertain more precisely the importance of ability level, we joined with Wai to conduct a within-cohort analysis of Cohorts 1 and 2 (Wai et al., 2005). Using 20-year follow-up data, we compared students in the top and bottom quartiles for SAT-M scores within the top 1%, by cohort and sex, on an array of outcome criteria having both high ceilings and low base rates: earning a doctorate (J.D., M.D., or Ph.D.), earning a STEM Ph.D., earning a high income, securing a patent, and achieving tenure at a U.S. university ranked within the top 50. For the latter variable, we examined the university Web sites of the academics in our sample to ascertain who among them had achieved an associate professorship with tenure by the year 2004. "America's Best Colleges 2004" (2003) was used to generate a reasonable list of the top 50 U.S. universities. Findings combined across cohorts and sexes are presented in Figure 2.

**TABLE 2**  
*Academic Credentials Secured by Age 33: Cohorts 1, 2, and 3*

Major	Cohort 1 (840 males, 543 females)						Cohort 2 (403 males, 189 females)						Cohort 3 (269 males, 24 females)					
	Bachelor's		Master's		Doctorate		Bachelor's		Master's		Doctorate		Bachelor's		Master's		Doctorate	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
Mathematics	7.5	6.3	1.0	0.9	0.4	0.2	10.3	9.7	2.2	2.1	2.2	0.5	30.6	13.6	7.4	9.1	8.7	0.0
Engineering	22.9	8.1	9.3	3.5	1.6	0.6	35.0	15.6	13.6	5.3	5.2	0.0	20.6	9.1	8.7	9.1	4.6	0.0
Computer science	7.0	4.4	3.9	2.4	1.2	0.0	10.3	2.7	6.5	0.5	2.0	0.0	13.1	4.5	9.6	0.0	5.5	0.0
Physical sciences	9.3	4.4	2.5	0.7	2.4	0.6	10.3	7.0	3.7	1.6	3.7	1.6	17.9	18.2	4.3	9.1	9.2	10.0
Biological sciences	8.1	13.5	0.5	2.4	1.1	1.3	5.8	9.6	0.5	1.6	2.2	2.1	7.1	27.3	1.3	0.0	1.8	0.0
Medicine, health	0.7	7.7	0.5	2.0	9.9	10.7	0.3	1.6	0.5	1.1	7.4	11.6	0.3	0.0	0.0	0.0	7.8	35.0
Social sciences	17.3	19.6	2.5	2.8	1.2	0.6	9.8	19.3	2.2	6.9	0.7	2.6	11.1	4.5	1.3	0.0	1.8	0.0
Arts, humanities	10.1	14.8	2.1	3.7	0.5	0.6	12.3	24.8	3.9	6.3	1.5	1.6	13.5	31.8	3.5	4.5	0.9	5.0
Law	—	—	—	—	7.9	6.5	—	—	—	—	6.7	11.6	—	—	—	—	8.6	10.0
Business	10.5	12.0	12.4	10.9	0.4	0.0	2.8	4.3	9.1	8.4	0.2	0.5	0.3	0.0	6.5	4.5	0.0	0.0
Education	0.5	3.1	1.1	3.1	0.1	0.2	0.0	1.6	0.0	2.6	0.0	0.0	0.0	0.0	1.3	4.5	0.4	0.0
Other fields	3.7	5.7	2.5	4.8	0.4	0.2	4.0	5.3	3.5	4.2	0.2	0.0	2.4	4.5	1.7	13.6	0.0	0.0
Combined majors																		
Math, inorganic sciences	<b>46.7</b>	23.2	<b>16.7</b>	7.5	<b>5.6</b>	1.4	<b>65.9</b>	35.0	<b>26.0</b>	9.5	<b>13.1</b>	2.1	<b>82.2</b>	45.4	<b>30.0</b>	27.3	<b>28.0</b>	10.0
Life sciences, humanities	36.2	<b>55.6</b>	5.6	<b>10.9</b>	12.7	<b>13.2</b>	28.2	<b>55.3</b>	7.1	<b>15.9</b>	11.8	<b>17.9</b>	32.0	<b>63.6</b>	6.1	<b>4.5</b>	12.3	<b>40.0</b>
All majors	86.9	89.5	36.8	36.1	26.2	20.7	95.2	97.3	43.2	40.2	31.1	31.9	96.0	100	38.3	50.0	50.0	60.0

**Note.** For Cohort 3, only participants who scored at least 700 on the mathematics subtest of the SAT were included in this analysis. Numbers shown are percentages. In the summary statistics, boldface type highlights a gender-differentiating trend for math and inorganic sciences and for life sciences and humanities: Males tended to receive more degrees in the former, females in the latter. F = females; M = males.



**Fig. 2.** Outcomes as a function of ability level (top vs. bottom quartile of scores on the SAT math subtest). The graphs show the percentage of Cohort 1 and 2 participants who earned a doctorate (upper left; doctorate in science, technology, engineering, or math—STEM—is indicated by black shading), had an income equal to or greater than the median for their sex, earned a patent, and achieved tenure at a top-50 U.S. university. The mean SAT scores, at age 12, were 455 for the bottom quartile (Q<sub>1</sub>) and 620 for the top quartile (Q<sub>4</sub>). Outcomes were assessed 20+ years later. Adapted from Wai, Lubinski, and Benbow (2005).

Figure 2 reveals that the top quartile of the top 1% in ability outperformed the bottom quartile. Note especially the proportion of tenured faculty within top U.S. universities. Individual differences in the top 1% make a difference. It is important to bear in mind that these participants were initially assessed by the SAT before age 13. By the time they reached high school, both quartiles were bumping their heads on the ceiling of the SAT (and the exceptionally able were not readily distinguished from the able). Thus, when highly talented youth reach high school, the SAT is no longer sensitive to the full range of their intellectual capabilities; for them, the SAT in high school functions like age- or grade-based achievement tests did when they were in seventh grade.

Data from Cohort 3, SMPY's most able cohort (the top-1-in-10,000 group), reinforce this idea (Lubinski et al., 2006). Some of these participants bumped their heads on the SAT's ceiling as young adolescents! As a group, they are more able than the top quartile analyzed in the study just described (Wai et al., 2005), and their adult accomplishments are correspondingly more impressive. We compared their outcomes at their 20-year follow-up with the 10-year outcomes for SMPY's Cohort 5: first- and second-year graduate students attending the top 15 STEM programs in the United States in 1992 (Lubinski, Benbow, Shea, Eftekhari-Sanjani, & Halvorson, 2001).

When the follow-up data were collected (Lubinski et al., 2006), the mean ages of the TS participants and the graduate students were 33.6 and 35.4, respectively. Figure 3 graphs the percentages of participants securing each of two important outcomes (each parsed into three gradations): a tenure-track

position (at a U.S. university ranked within the top 25, from 26 through 50, or 51 or lower) or a high annual income (\$100,000–\$249,000, \$250,000–\$499,000, or \$500,000+). Although the TS participants were identified merely by having one very high test score by age 13, and the graduate students were identified after they had secured admission to a world-class STEM department, their achievements are highly comparable.

Achieving tenure, and especially a full professorship, at a top-ranked university requires internal and external evaluations by leaders in the field, who look for documentation of creativity and advancing the discipline. Indeed, at such institutions, promotion to associate professor with tenure is considered around a \$3 million investment in human capital. That above-level assessments can identify young adolescents who will achieve top-50 tenure-track positions at rates comparable to those of graduate students attending the top U.S. math, science, and engineering doctoral programs is truly remarkable. Arguably, the TS participants could be viewed as a bit more successful overall, inasmuch as by their mid-30s, 21.7% of the TS participants who were in tenure-track positions in the top 50 U.S. universities were already full professors, compared with “only” 6.5% of the graduate students. Moreover, an inordinate number of TS participants earned especially high incomes (e.g., \$500,000+), although the graduate students were 1.8 years older than them at the follow-up.

Other outcome criteria in this study are noteworthy because they underscore the creative accomplishments of both groups. For example, earning patents is an excellent indicator of creativity, or “inventive and scientific productivity” (Huber,

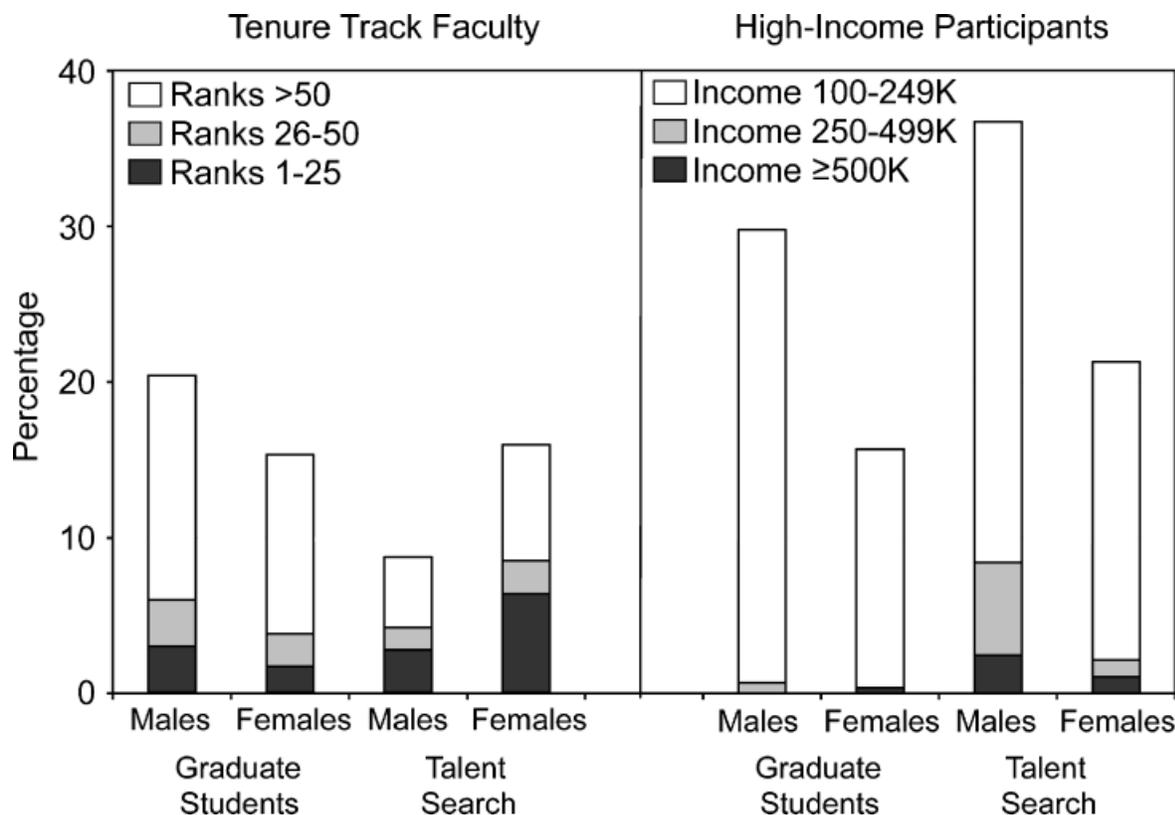


Fig. 3. Percentage of graduate students (Cohort 5) and talent-search participants (Cohort 3, top 1 in 10,000) with tenure-track or tenured positions (left) and annual incomes of \$100,000 or more (right) at follow-up. The data shown here are based on samples of 299 and 287 male and female graduate students, respectively, and 286 and 94 male and female talent-search participants, respectively. From Lubinski, Benbow, Webb, and Bleske-Rechek (2006).

1999, p. 49). Discussing the documentation on what constitutes intellectual property, Huber (1998) remarked, "It would be hard to find a field of study where so much effort has been expended in establishing a definition. Perhaps the definition of invention is the most solid definition in the field of creativity" (p. 61). The percentages of graduate students (males: 32.1%, females: 20.9%) and TS participants (males: 17.8%, females: 4.3%) who had earned patents was well beyond base-rate expectations. Approximately 1% of the entire adult U.S. population holds at least one patent (J.C. Huber, personal communication, October 27, 2004). Epidemiologists and other scientists take notice when base rates double (Lubinski & Humphreys, 1997); therefore, these percentages reflect an exceptional degree of creative accomplishment in science and technology. Graduate students earned more patents than TS participants overall (26.6% vs. 14.5%, respectively),  $\chi^2(1, N = 966) = 19.9, p < .001$ , which is not surprising given that the graduate students were selected from career tracks in which patents are commonly achieved, and some TS participants were identified on the basis of their SAT-V, rather than SAT-M, scores. When analyses were restricted to TS participants who qualified on the basis of top-1-in-10,000 SAT-M scores, the percentages of males and females who earned patents rose to 20.1% and 9.1%, respectively; the difference in the rates for graduate students and TS participants was still

statistically significant, but diminished (26.6% vs. 19.0%, respectively),  $\chi^2(1, N = 807) = 5.0, p < .05$ .<sup>4</sup>

SMPY's findings on ability level are useful for multiple reasons. Perhaps the most important is that they call into question the ability-threshold hypothesis, the belief in which has been

<sup>4</sup>This analysis illustrates the differential validity of measures of quantitative versus verbal reasoning ability for creative technical accomplishments. In student selection, specific abilities also have differential validity in identifying contrasting potentialities. For example, in what is arguably psychology's most famous longitudinal study (Terman, 1925, 1954), two future Nobel laureates were assessed but rejected for longitudinal tracking (Shurkin, 1992): Luis Alvarez and William Shockley both came in under the cutting score on Terman's highly verbal Stanford-Binet. Contemporary TS programs have broadened talent-identification procedures by assessing both quantitative and verbal reasoning, and an assessment of the former undoubtedly would have identified both of these distinguished individuals during adolescence. One of our most exceptional participants was identified well before adolescence using an above-level assessment of quantitative reasoning, SAT-M (Muratori et al., 2006); just a few months ago, at age 31, he was awarded the Fields Medal (equivalent to the Nobel prize in mathematics). But talent searches still could do better. They could be expanded to include spatial ability, because talent searches currently miss approximately 50% of the top 1% in three-dimensional spatial visualization (Humphreys, Lubinski, & Yao, 1993; Shea, Lubinski, & Benbow, 2001; Webb, Lubinski, & Benbow, in press). Although modern talent searches are probably missing few people with the quantitative potential of Alvarez and Shockley (Lubinski, Benbow, et al., 2001), because of the inclusion of mathematical-reasoning measures, they are undoubtedly missing a number of people with the intellectual strengths in nonverbal ideation characterizing individuals such as Thomas Edison and Henry Ford, because of the exclusion of spatial-ability measures (Lubinski, 2004).

hard to shake. A recent letter published in *Science*, and signed by 79 academic administrators and research scientists, working primarily at major universities (Muller et al., 2005), stated: "There is little evidence that those scoring at the very top of the range in standardized tests are likely to have more successful careers in the sciences. Too many other factors are involved" (p. 1043). However, SMPY findings falsify this idea. The SMPY longitudinal follow-ups have resolved the methodological difficulties historically encountered in falsifying an ability threshold (Lubinski & Dawis, 1992), such as securing an appreciable sample of individuals within the top 1% of ability, being able to distinguish the exceptionally able from the able (within the top 1%), finding criteria with sufficiently high ceilings and low base rates, and implementing an appreciable longitudinal delay so that extraordinary accomplishments can develop. All of these design features were met in the studies discussed in this section.

To be sure, factors other than ability level are important, and we review a number of them later in this section. Nevertheless, other things being equal, more ability is always better, and there was evidence to suggest this long before the letter appeared in *Science* (Benbow, 1992; Benbow & Lubinski, 1996; Lubinski & Humphreys, 1990b; Lubinski, Webb, et al., 2001). In addition to *Science*, psychological outlets routinely disregard the importance of distinguishing between the able and the exceptionally able in modeling outstanding achievement. For example, a recent article in the *American Psychologist* stated:

Standardized tests are thus not sufficiently predictive of future performance. Individuals are not necessarily more meritorious if they obtain the highest scores on standardized tests, thus rendering invalid the argument that students with the highest scores should have priority in admissions. (Vasquez & Jones, 2006, p. 138)

This is simply not the case.

#### *Ability Pattern*

That quantitative reasoning ability contributes to securing an advanced degree and, in particular, an advanced degree in STEM areas is unquestionably true. However, given the generality of quantitative reasoning ability (Rivera-Batiz, 1992), ability level speaks primarily to level of achievement, rather than to the nature of achievement. To predict the latter, more complex models are needed, and ability configuration is an important consideration. Analyses reveal that patterns of spatial and verbal abilities among mathematically gifted adolescents, as for students in general (Humphreys, Lubinski, & Yao, 1993), are critical for understanding qualitative differences in their development (e.g., development that moves toward the humanities vs. the sciences vs. business, corporate, and marketing arenas). The following description illustrates how.

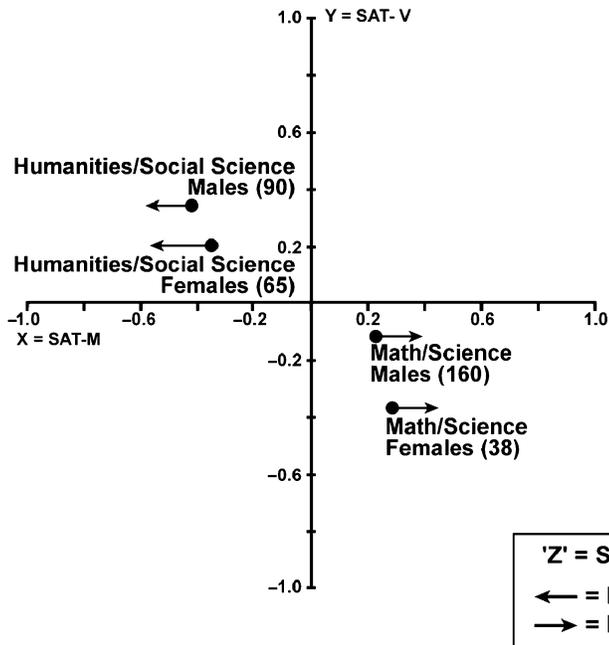
A subset of Cohort 2 participants (393 males, 170 females) was assessed during early adolescence on all three ability dimensions found in our model (see Fig. 1): mathematical, verbal,

and spatial reasoning abilities (Shea, Lubinski, & Benbow, 2001). Figure 4 presents 5-, 10-, and 20-year longitudinal findings on four criteria: favorite and least favorite high school course (reported at age 18), college major (at age 23), and occupation (at age 33). These outcomes are graphed as a function of all three abilities. The *x*-axis represents mathematical ability (SAT-M), the *y*-axis represents verbal ability (SAT-V), and the *z*-axis represents spatial ability. Position on the *z*-axis is indicated by the direction and length of the arrow emanating from each data point; a right-pointing arrow indicates spatial ability above the grand mean, and a left-pointing arrow indicates spatial ability below the grand mean. The arrows were scaled on the same units of measurement as the SAT scores (viz., *z* scores, or standard deviation units).

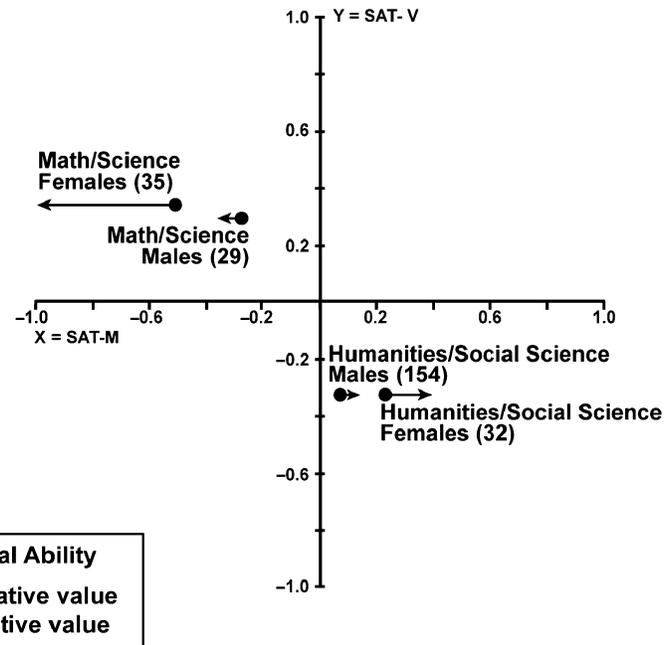
Figure 4 shows that across all three time frames, exceptional verbal ability, relative to mathematical and spatial ability, is characteristic of participants whose favorite courses, college majors, and occupations were in the social sciences and humanities, whereas higher levels of math and spatial abilities, relative to verbal abilities, characterize participants whose favorite courses, college majors, and occupations were in engineering and math or computer science. Physical sciences appear to require appreciable amounts of all three abilities. These developmentally sequenced outcomes tell an important story. Among other things, they illustrate that individual differences factor into life outcomes whether or not they are used in selecting individuals for opportunities with the potential to lead to these outcomes. Indeed, spatial ability is rarely, if ever, assessed among applicants for advanced degree programs. Moreover, although bright students are well aware of the importance of scoring high on quantitative and verbal reasoning abilities in order to gain access to subsequent educational opportunities, educational counselors and academic selection committees hardly ever take spatial ability into consideration or even mention it. Yet individual differences in this attribute markedly influence whether students approach or avoid STEM domains.

The importance of taking ability pattern into account also holds for profoundly gifted individuals. Focusing exclusively on one ability is never wise, because it could pale when viewed alongside a stronger ability. Consider the following study. We (Lubinski, Webb, et al., 2001) divided Cohort 3 participants (top 1 in 10,000) into three groups based on their ability pattern: Two groups had contrasting intellectual strengths, with greater ability in one area than the other (i.e., SAT-M score more than 1 *SD* above SAT-V score or vice versa; high-math and high-verbal groups), and one group was more intellectually uniform (i.e., SAT-M and SAT-V scores within 1 *SD* of each other; high-flat group). These three ability patterns, determined from assessments at age 12, eventuated in distinct developmental trajectories 10 years later. For example, the ability profiles predicted differential course preferences among these three groups in high school and college (see Fig. 5). On average, the high-math group

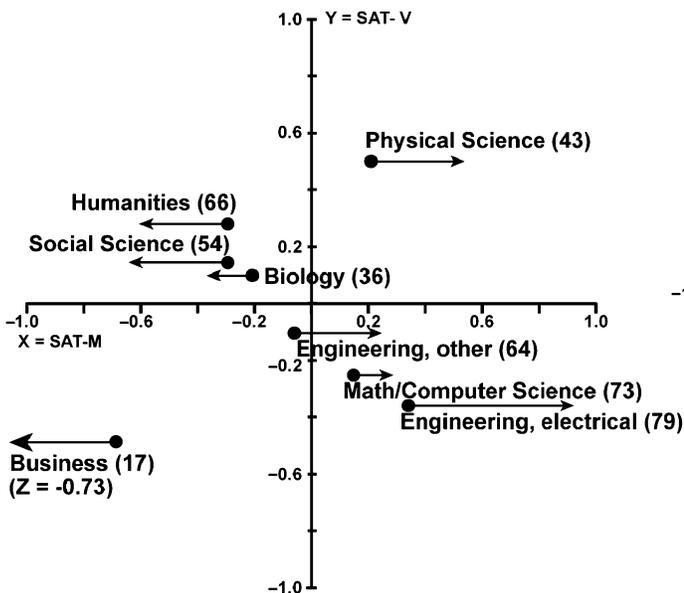
## Favorite High School Course (Age 18)



## Least Favorite High School Course (Age 18)



## College Major (Age 23)



## Occupation (Age 33)

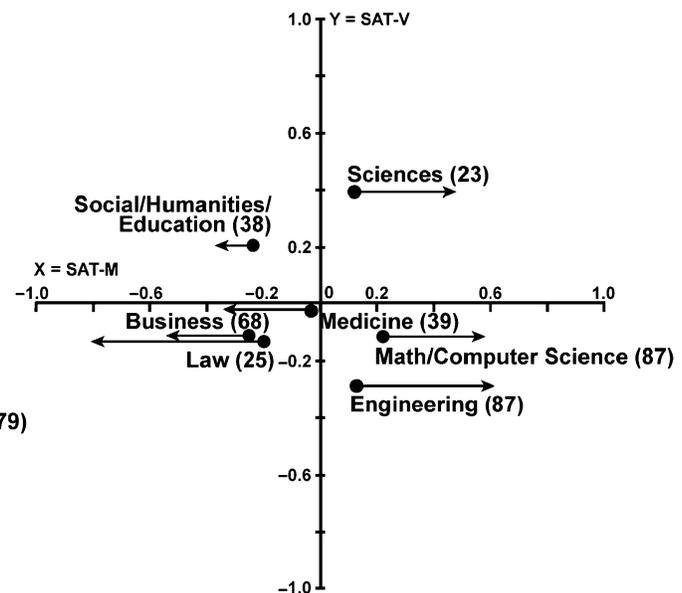
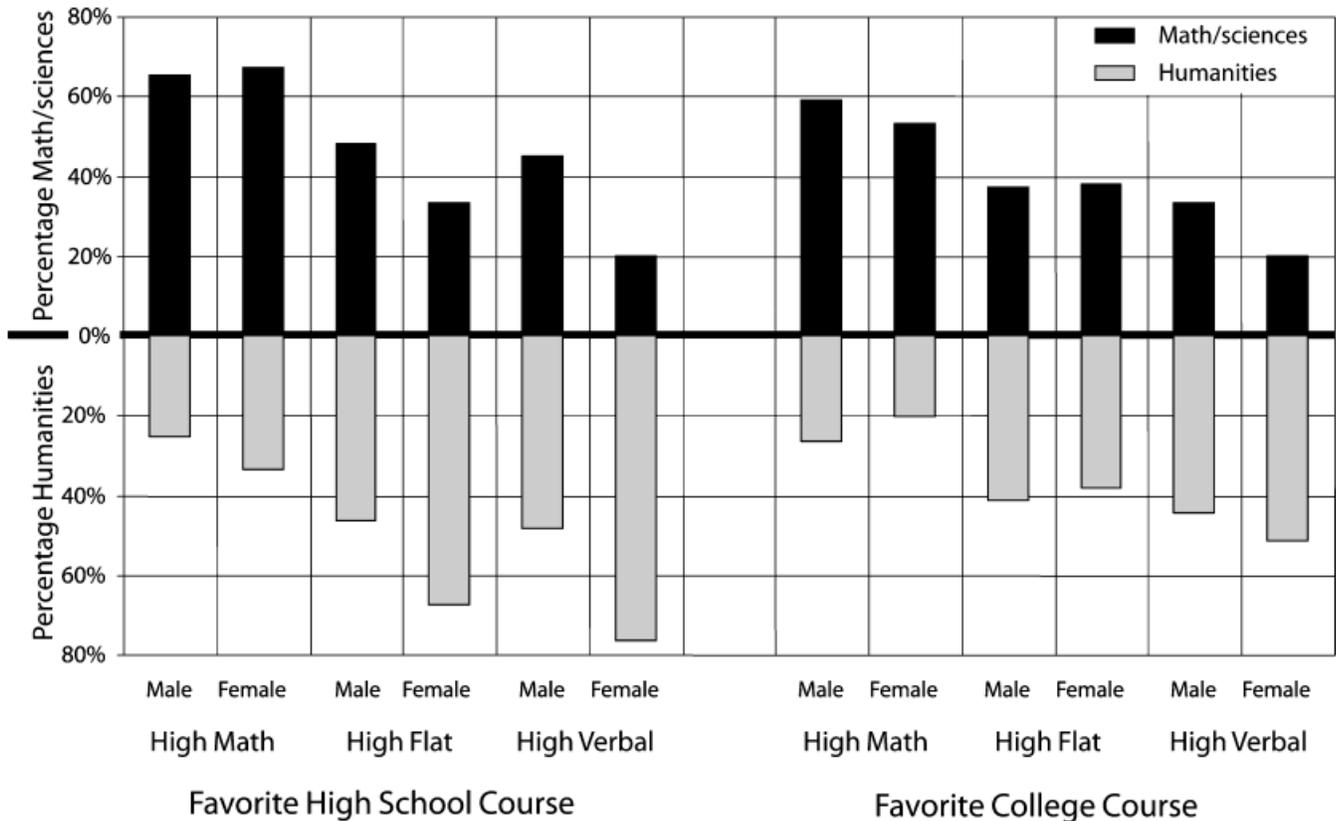


Fig. 4. The relation between ability patterns and four educational and occupational outcomes: favorite high school class at age 18, least favorite high school class at age 18, major of conferred bachelor's degree at age 23, and occupation at age 33. The graph for each outcome plots the mean verbal, math, and spatial ability of participants within various subcategories. Group *ns* are in parentheses. Verbal ability was measured by the verbal subtest of the SAT (SAT-V), math ability was measured by the mathematics subtest of the SAT (SAT-M), and spatial ability was measured by the combined score on two subtests of the Differential Aptitude Test (Space Relations and Mechanical Reasoning). Results for high school courses are standardized within sexes, and those for majors and occupations are standardized between sexes. Like the SAT-M and SAT-V scores, spatial-ability scores, indicated by the lengths of the arrows, are scaled in standard deviation units. Just as the bivariate points for the SAT scales illustrate how far apart the groups are in two-dimensional space, as a function of their standing on math and verbal abilities, these arrowheads enable readers to envision how far apart the groups are in three-dimensional space, as a function of all three abilities. The arrowhead for business majors has been enlarged to indicate that this group's relative weakness in spatial ability was actually twice as great as that indicated by the length shown. Adapted from Shea, Lubinski, and Benbow (2001).



**Fig. 5.** Cohort 3 participants' favorite course in high school and in college as a function of ability profile (Lubinski, Webb, Morelock, & Benbow, 2001). Participants in the high-math group had SAT-math (SAT-M) scores more than 1 standard deviation above their SAT-verbal (SAT-V) scores, and participants in the high-verbal group had the reverse profile; participants in the high-flat group had SAT-M and SAT-V scores within 1 standard deviation of each other. Percentages in a given column do not necessarily sum to 100% because only data from participants indicating math-science or humanities courses are displayed.

preferred math and science courses to humanities courses, whereas the inverse was true for the high-verbal group; results for the high-flat group were intermediate.

We grouped participants' responses to open-ended queries about their accomplishments and awards into three clusters: humanities and arts, science and technology, and unclassifiable ("other"; see Tables 3 and 4) and then went back to ascertain whether these three clusters were occupied differentially by the three ability groups (Lubinski, Webb, et al., 2001). Table 4 reveals that three fourths of the classifiable accomplishments and awards of high-math participants were in science and technology; by comparison, two thirds of the classifiable accomplishments of high-verbal participants were in the humanities and arts. High-flat participants reported similar numbers of accomplishments in the two clusters. It appears that ability pattern relates to the time and effort devoted to various activities.

These findings on course preferences, individual awards, and creative pursuits illustrate a common finding in counseling and vocational psychology: Ability pattern is critical for choice (Dawis, 1992; Dawis & Lofquist, 1984; Gottfredson, 2003; Humphreys et al., 1993). Administering one test in isolation to a group of talented adolescents is not enough to appreciate their

psychological diversity. All three groups in the study just discussed had impressive mathematical and verbal abilities, but tilted profiles were highly related to differential development. If, for instance, one were to focus exclusively on the quantitative reasoning abilities of the high-verbal group (viz., mean SAT-M = 556 before age 13), extraordinary promise for STEM domains might be readily inferred. Yet despite the impressive quantitative reasoning abilities of these students, their even more exceptional verbal prowess appears to have pushed their development in other directions.

### Preferences

The foregoing review of ability level and pattern is helpful in understanding the magnitude of development of the exceptionally able and the distinct educational and occupational niches that individuals with contrasting ability profiles seek out and ultimately occupy. But there is more to the story. Abilities capture only one class of TWA person variables: those relevant to satisfactoriness. Also important are preferences, the person variables relevant to satisfaction. Although research has demonstrated a number of small correlations between abilities and

**TABLE 3**  
*Awards and Special Accomplishments of Cohort 3*

<u>Science and technology</u>
Published scientific work (11)
Developed software (8)
Patented an invention (4)
Received National Science Foundation fellowship (2)
Designed image-correlation system for navigation for Mars Landing Program (1)
Received the American Physical Society's Apker Award (1)
Graduated from MIT in 3 years at age 19 with a perfect grade point average and graduated from Harvard Medical School (M.D.) at age 23 (1)
Received teaching award for "Order of Magnitude Physics" (1)
<u>Humanities and arts</u>
Published creative writing (7)
Created noteworthy art or music (6)
Received Fulbright award (2)
Wrote proposal for a novel voting system for the new South African Constitution (1)
Made solo violin debut (age 13) with the Cincinnati Symphony Orchestra (1)
Named Mellon Fellow in the Humanities (1)
Named Presidential Scholar for Creative Writing (1)
Received Hopwood writing award (1)
Received Creative Anachronisms Award of Arms (1)
Won first place in medieval-medieval poetry (1)
Received fellowship for foreign-language study (1)
Received international predissertation award (1)
<u>Other</u>
Inducted into Phi Beta Kappa (71)
Inducted into Tau Beta Pi (30)
Inducted into Phi Kappa Phi (14)
Received award for entrepreneurial enterprises (2)
Inducted into Omicron Delta Kappa (1)
Received Olympiad silver medal (1)
Finished bachelor's and master's degrees in 4 years (1)
Received private pilot's license in 1 month at age 17 (1)

**Note.** The numbers in parentheses indicate the number of participants with each accomplishment (also see Table 4). Adapted from Lubinski, Webb, Morelock, and Benbow (2001).

interests (Ackerman, 1996; Ackerman & Heggestad, 1997; Schmidt, Lubinski, & Benbow, 1998), they are sufficiently uncorrelated that they must be assessed independently for optimal educational and vocational counseling (Dawis, 1992, 2001; Lubinski, 1996, 2001; Savickas & Spokane, 1999).

Holland's (1996) hexagon of interests (referred to as the RIASEC model because the six interests are Realistic, Investigative, Artistic, Social, Enterprising, and Conventional) is the most widely accepted model of educational-vocational interests (Day & Rounds, 1998). We use this framework to represent the preference component in our model (Fig. 1), although other preference inventories could be used instead (Dawis, 1991; Dawis & Lofquist, 1984; Savickas & Spokane, 1999).

A conspicuous sex difference in interests and values, one that goes back at least to Thorndike (1911), involves the prominence

**TABLE 4**  
*Number of Accomplishments and Awards Classified as Science-Technology Versus Arts-Humanities as a Function of Ability Group in Cohort 3*

Group	Sciences and technology	Humanities and arts
High math	16	5
High flat	6	6
High verbal	7	13

**Note.** High flat = participants with SAT-mathematics (SAT-M) and SAT-verbal (SAT-V) scores within 1 standard deviation of each other; high math = participants with SAT-M scores more than 1 standard deviation beyond their SAT-V scores; high verbal = participants with SAT-V scores more than 1 standard deviation beyond their SAT-M scores. All participants earned an SAT-V score of 630 or more or an SAT-M score of 700 or more (or both) by age 13. The outcome data were collected in their 10-year after-college follow-up.

of a people-versus-things dimension (Lippa, 1998, 2006; Lubinski, 2000). This dimension runs from Social (people contact) to Realistic (things and gadgets) in Holland's hexagon, and it is salient in other preference instruments and models as well. Females and males consistently display a mean difference larger than 1 standard deviation on this dimension. Girls and women, on average, tend to prefer to learn about and work with people (or, more generally, organic content), whereas boys and men, on average, tend to prefer to learn about and work with things (or, more generally, inorganic content). Unfortunately, the contemporary social science literature often fails to highlight the relevance of male-female differences on this dimension for STEM pursuits, despite voluminous evidence supporting its importance for these pursuits (Achter et al., 1996; Campbell, 1971; Savickas & Spokane, 1999; Strong, 1943; Tyler, 1974; Williamson, 1965).

Lippa (1998), for example, published three studies on this robust dimension of individuality and discussed the role it plays in personality development. Examining the effect of gender on preference for people versus things, he obtained an effect size (female minus male) of 1.20 standard deviation units or greater in each study (Lippa, 2006). This preference difference between men and women, which is also conspicuous in intellectually precocious samples, undoubtedly contributes to the preponderance of females with profound mathematical gifts who choose to become physicians rather than engineers and physical scientists (see Table 2). Highly talented males, by contrast, are much more likely to become STEM professionals.

#### *Preference Findings from SMPY*

Over the 1990s, a series of articles documented the utility of conducting above-level preference assessments with intellectually precocious youth (i.e., studying this population using preference questionnaires initially developed on older adolescents and young adults). In a study of Cohort 4, Achter et al. (1996) documented the amount of their psychological diversity on the

**TABLE 5**  
*Rank Order of Preferences for Cohorts 1 through 4*

Rank order	Interest/Value theme											
	Investigative/Theoretical		Artistic/Aesthetic		Enterprising/Economic		Social/Social		Realistic/Political		Conventional/Religious	
	M	F	M	F	M	F	M	F	M	F	M	F
1	52/45	37/19	5/7	35/22	7/15	3/7	2/8	9/29	19/21	4/12	18/10	16/15
2	24/27	27/16	11/8	26/19	11/28	7/12	5/11	21/25	22/22	5/18	28/5	15/13
3	11/15	19/18	11/9	9/20	22/21	15/13	10/18	22/18	20/26	18/18	27/9	18/10
4	8/7	10/20	17/22	11/13	29/17	20/20	11/24	16/14	19/17	19/20	15/10	21/12
5	4/5	6/15	24/22	9/14	22/13	26/26	30/28	14/10	13/11	26/16	7/20	17/16
6	1/2	2/12	32/32	11/12	10/6	29/22	42/12	18/4	7/3	27/16	4/47	13/33

**Note.** The table presents the percentage of male (M) and female (F) participants for whom each preference had the indicated rank. Themes designed to measure conceptually similar constructs were aligned as much as possible. In each cell, results for the Strong-Campbell Interest Inventory (RIASEC dimensions) are given first, followed by results from the aligned dimension from the Study of Values (SOV). The data come from the initial assessments of Cohorts 1 through 4. For the SOV,  $n = 611$  for males and 348 for females; for the Strong-Campbell inventory,  $n = 474$  for males and 211 for females.

individual differences indexed by the Strong-Campbell Interest Inventory's RIASEC dimensions (Harmon, Hansen, Borgen, & Hammer, 1994) and the Study of Values (SOV; Allport, Vernon, & Lindzey, 1970). Table 5 reports the rank orders of the six themes on each instrument, among all participants in Cohorts 1 through 4 at their initial assessment (but for Cohort 4, only participants with abilities in the top 1% were included in this analysis). Counselors tend to focus on the top two or three themes in working with students and clients, and it is clear from these rank orders that the sexes differ in their priorities. For example, 72% of males and 35% of females had Theoretical values ranked as one of their top two SOV dimensions. In contrast, 16% of males and 61% of females had Artistic interests ranked as one of their top two RIASEC dimensions, and 15% of males and 41% of females had Aesthetic values ranked as one of their top two SOV dimensions. Social interests and values were nearly 3 times as likely to be in the top two for females as for males, whereas males were 4 times as likely as females to rank Realistic interests as one of their top two themes. Clearly, these results show a people-versus-things sex difference. (Contrast these findings with the lack of sex differences on these measures among top math-science graduate students, discussed later, in Top STEM Graduate Students.)

Two independent investigations documented the longitudinal stability of scores on these instruments for intellectually talented youth. RIASEC preferences were examined for Cohort 2 ( $N = 162$ , age 13 to age 28; Lubinski, Benbow, & Ryan, 1995), and SOV preferences were examined for Cohort 1 ( $N = 202$ , age 13 to age 33; Lubinski, Schmidt, & Benbow, 1996). Not only do these studies support the temporal stability of scores on these instruments, but the variability of the scores highlights the breadth of psychological diversity among intellectually talented youth on a class of variables that are relatively independent of abilities and relevant to educational-vocational choice (Dawis, 1991, 1992). Other studies have provided evidence for the construct validity of these preference measures (Schmidt et al., 1998)—including the improvement in prediction obtained by

including preferences along with abilities in forecasting college degree major 10 years later (Achter, Lubinski, Benbow, & Eftekhari-Sanjani, 1999) and occupation 20 years later (Wai et al., 2005). The findings of the latter two studies are sufficiently noteworthy to justify further review.

#### *Teaming Abilities and Preferences*

We conducted one of these studies (Achter et al., 1999) to ascertain whether the SOV provides incremental validity beyond the SAT in predicting college majors. Across SMPY Cohorts 1, 2, and 3, a total of 432 participants had scores for both instruments and had reported earning a college degree by their 10-year follow-up. These participants were grouped into three categories based on whether they secured their degree in the humanities, math or science, or something else. Then, we conducted a discriminant function analysis, utilizing the SAT and SOV scores, to uncover the psychological variables differentiating these groups.

Table 6 provides the discriminant function loadings of the two dimensions derived from this analysis. These loadings form distinct math-science and humanities amalgams, with math ability and Theoretical values loading most strongly on Function 1 (coupled with negative loadings for Social and Religious values), and verbal ability and Aesthetic values loading most strongly on Function 2. Incremental-validity analyses revealed the SAT-M and SAT-V measures accounted for 10% of the variance among these three groups, and the five SOV scales accounted for an additional 13% of the variance. Given the heterogeneity within these three broad degree groupings, and considering that the assessment occurred a decade earlier at age 13, the fact that the scores accounted for 23% of the variance is impressive. By showing that age-13 preference assessments provided incremental validity to SAT assessments in predicting educational outcomes at age 23, this study established the importance of assessing both abilities and preferences for working with talented youth in applied psychological services and for

**TABLE 6**  
*Discriminant Function Structure Matrix Containing Two Functions for Predicting College Degree (Humanities, Math-Science, or Other)*

Variable	Function 1	Function 2
SAT verbal score	.09	.56
SAT math score	.59	-.12
Study of Values		
Theoretical	.87	-.03
Aesthetic	-.13	.81
Social	-.60	-.01
Religious	-.56	.03
Economic	.47	-.29

**Note.** The bivariate group means (Function 1 followed by Function 2) were  $-.29$  and  $.60$  for humanities degrees,  $.43$  and  $-.05$  for math-science degrees, and  $-.57$  and  $-.21$  for other degrees. From Achter, Lubinski, Benbow, and Eftekhari-Sanjani (1999).

modeling their development theoretically in the context of TWA. It should be noted, however, that the participants in the math-science group were more readily distinguishable from the two other groups than those two groups were from each other: Function 1 accounted for 75% of the predictable variance, and Function 2 accounted for the remaining 25%.

Figure 6 shows the three groups' bivariate means on these two functions. Lines connecting these three bivariate means form the unshaded triangle, and lines from each point running through the midpoint of the other two parse the two-dimensional space formed by these functions into three exhaustive regions, where participants earning degrees in the humanities (top left), science (right), and other disciplines (bottom left) would be expected to fall (see Achter et al., 1999, for further details). Subsequently, the generalizability of these regions for later stages of development was examined.

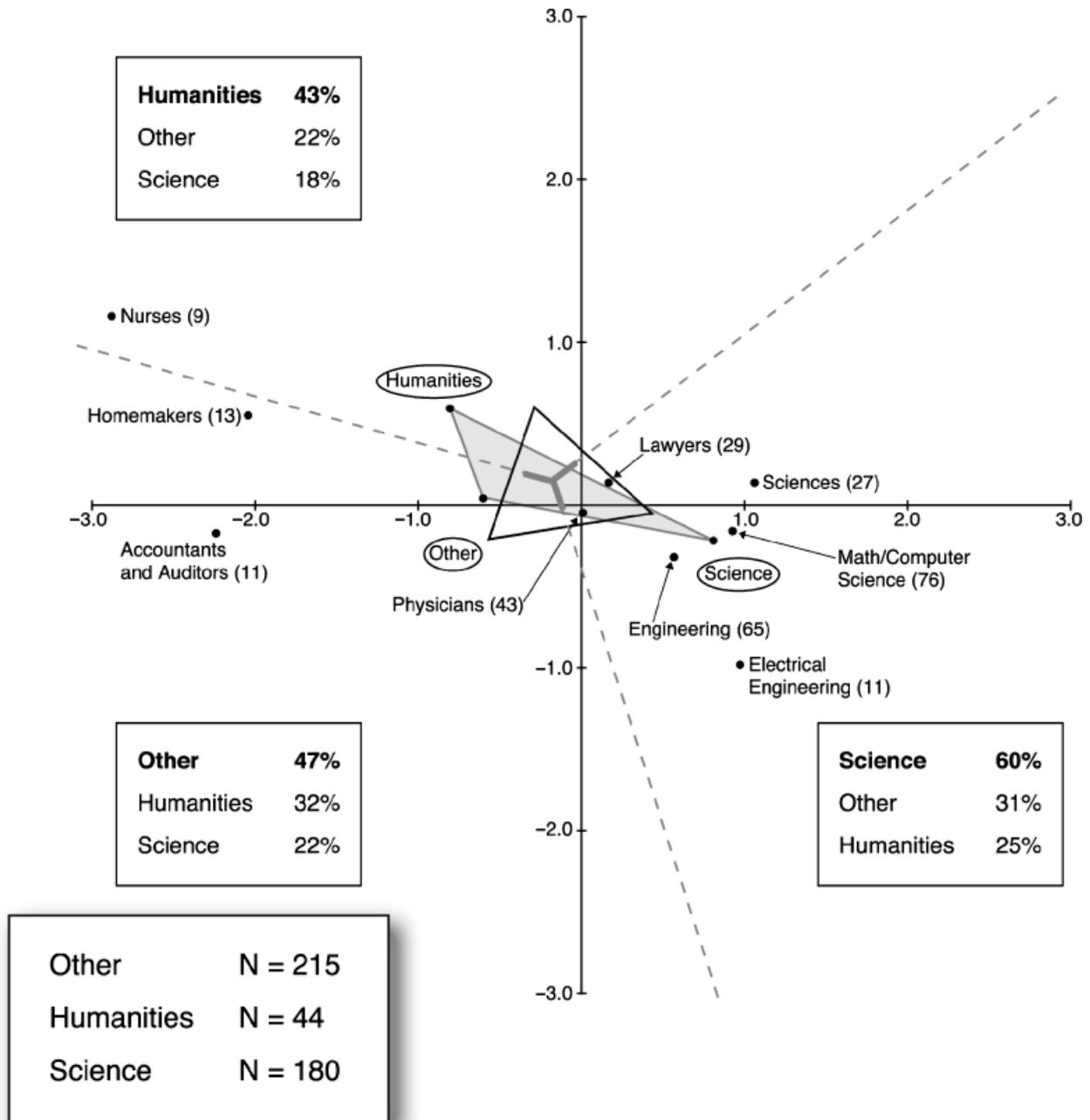
In a study conducted a decade later (Wai et al., 2005), these ability-preference findings (Achter et al., 1999) predicting educational outcomes were evaluated for their generalizability to occupational outcomes. Specifically, we were interested in ascertaining whether the functions were robust enough to maintain their validity over another decade by predicting occupational-group membership at age 33. If age-33 occupational data could be shown to occupy regions drawn with discriminant functions based on age-13 assessments and calibrated on age-23 educational criteria, the psychological significance of these functions would accrue additional validity. Across Cohorts 1, 2, and 3, there were 323 men and 188 women who had taken both the SAT and the SOV at age 13 and who had 20-year longitudinal data listing an occupation. These participants' occupations were classified as in the humanities, math or science, or another area, and their discriminant function scores were plotted in the space derived in the previous study (Achter et al., 1999). Figure 6 shows the three occupational groups' bivariate means on the two discriminant functions. Lines connecting these three bivariate

means form the shaded triangle. (Bivariate means for some individual occupational groups are also plotted.) For each of the three major categories, the percentage of hits (participants predicted to be in the category and actually in the category) and misses (participants predicted to be in the category but in one of the other two categories) is provided in each region. Clearly, the preponderance of each group is classified correctly, which suggests that teaming abilities and preferences is useful for predicting qualitative differences in occupational choice. Indeed, a salient people-versus-things dimension (or, as we prefer, an organic-inorganic dimension), not illustrated in the figure, runs between nurses and homemakers along the dashed-line boundary between the "Humanities" and "Other" regions and extends through the bivariate point for math-science occupations, continuing on under the positive  $x$ -axis between engineers and computer scientists.

Function 1, the math-science function, accounted for the majority of variance among the three groups, inasmuch as in both studies, the math-science group was more readily distinguished from the other two groups than those two groups were from each other. Nevertheless, both functions provide powerful analytic tools for conceptualizing educational and career choices. Moreover, these findings also suggest how learning and work environments can be adjusted to match the differential proclivities of students and professionals who differ markedly on these functions, although a discussion of such implications is beyond the scope of this article. These functions afford insight into how members of different professions (manifesting significant group differences on these two functions) approach intellectual problems and create contrasting but dispositionally congruent organizational climates (Bouchard, 1997; Lubinski, 1996, 2000). In essence, these functions tell an important story about the intellectual character of intellectually talented populations and the environments they are motivated to seek out, avoid, and even create (Bouchard, 1997; Scarr, 1996). They are also helpful in conceptualizing sex differences: In the occupational study (Wai et al., 2005), for example, the differences between males and females (males minus females) on Function 1 and Function 2, measured in standard deviation units, were 1.54 and  $-1.05$ , respectively.

#### *Modeling Talent Development More Comprehensively*

One important dimension missing in the aforementioned studies is spatial ability. The model depicted in Figure 1 has three cognitive abilities, and many investigators have made a compelling case for assessing all three in educational practice and research (Gohm, Humphreys, & Yao, 1998; Gottfredson, 2003; Humphreys et al., 1993; Snow, 1994, 1999). But the studies that we have summarized involved only mathematical and verbal reasoning measures. Recently, we conducted a 5-year study in which we examined mathematical, verbal, and spatial abilities, along with two broad preference inventories, the SOV and the Strong Interest Inventory (RIASEC dimensions), as predictors



**Fig. 6.** Location of college-degree and occupational categories (humanities, math-science, or other) in a two-dimensional space defined by the discriminant functions in Table 6 ( $x = \text{Function 1}$ ,  $y = \text{Function 2}$ ). Lines connecting the bivariate means of these two functions for college majors form the unshaded triangle, whereas lines connecting the bivariate means for occupations form the shaded triangle. A number of specific occupations are plotted within this two-dimensional space (with sample sizes in parentheses). (Two occupations, physician and lawyer, were not classified in one of the three criterion groups, but their bivariate points are plotted to show where they fall in this space.) This space was partitioned into three exhaustive regions by drawing a line from each college major's bivariate mean through the midpoint of the other two college majors' bivariate means (see the dashed lines). Then, the percentage of participants with occupations corresponding to the area that their bivariate points fell in was calculated. The boldface entry in the box in each region indicates the percentage of participants predicted to be in that category who were in fact in that category (i.e., hits); the remaining percentages indicate the percentage of people predicted to be in the category who were in each of the other categories (i.e., misses). From Wai, Lubinski, and Benbow (2005).

of educational outcomes and occupational intentions (Webb, Lubinski, & Benbow, in press). This study constitutes the most comprehensive mapping of our talent-development model to date.

Our outcome variables were based on information collected from SMPY's Cohort 4 at their age-18 follow-up (i.e., after high school). The five criterion variables were favorite high school course, least-favorite high school course, preferred leisure

activity, college major, and planned occupation. Two sets of discriminant function analyses were performed—one for each preference inventory. For all five criterion variables, the incremental validity of spatial ability was evaluated, following the entry of the SAT and either the SOV or RIASEC themes. These analyses are too extensive to be reviewed thoroughly here, but, on average, spatial ability added 2.4% incremental validity to the prediction of these criteria. As before, the first discriminant function to emerge in these analyses was a math-science function, and Table 7 presents the results for this function, averaged across all five criterion variables, for each preference inventory. For both the SOV and the RIASEC themes, a salient math-science ability pattern emerges in Function 1. For example, salient positive math and space loadings and negative verbal loadings are found in this structure matrix, coupled with positive theoretical and negative social, aesthetic, and religious preferences. In interpreting these functions and those from the discriminant function studies discussed in the previous section (Achter et al., 1999; Wai et al., 2005), however, one should not surmise that the negative weights for verbal ability mean that development of math-science expertise does not involve verbal ability. Rather, it would be more precise to say that individuals with extraordinary verbal ability, especially when it is accompanied by somewhat lower math and space abilities, are more inclined to pursue other areas (as discussed earlier).

**TABLE 7**  
*Loadings for Two Sets of First Discriminant Functions Predicting Three Criterion Groups in Cohort 4: Math-Science, Humanities, and Other*

		Analysis	
Study of Values		RIASEC dimensions	
Variable	Loading	Variable	Loading
		Realistic	.11
Theoretical	.57	Investigative	-.04
Aesthetic	-.42	Artistic	-.69
Social	-.36	Social	-.51
Economic	.47	Enterprising	-.42
Religious	-.17	Conventional	.02
SAT-V	-.19	SAT-V	-.24
SAT-M	.39	SAT-M	.30
Spatial ability	.70	Spatial ability	.64

**Note.** Interest and value themes designed to measure conceptually similar constructs have been aligned as much as possible. Each loading in the structure matrix is the mean correlation taken over five criterion variables for Function 1: favorite high school course, least favorite high school course (reverse-scored), preferred leisure activity, undergraduate major, and expected occupation. Two sets of five discriminant functions were run. Both included three abilities: SAT verbal score (SAT-V), SAT math score (SAT-M), and a spatial-ability composite of two Differential Aptitude Tests (Mechanical Reasoning and Space Relations). One of the functions utilized the scales from the Study of Values (SOV), and the other utilized the RIASEC interests. Because the SOV is an ipsative measure (all profiles sum to 240), all the information is contained in any five scales, and the sixth is completely redundant; the Political scale was arbitrarily omitted from our analyses. Adapted from Webb, Lubinski, and Benbow (in press).

Naturally, the findings involving spatial ability must be interpreted with caution, because they reflect only 5-year longitudinal data and intentions as opposed to actual outcomes for 4-year college degrees and occupations. Nevertheless, other researchers have observed the same pattern in more mature samples (Austin & Hanisch, 1990; Gohm et al., 1998; Humphreys & Lubinski, 1996; Humphreys et al., 1993; Smith, 1964). Moreover, given that the psychometric properties of the SAT, RIASEC dimensions, and SOV, when applied to intellectually precocious young adolescents who are then followed for 20 years, have consistently mirrored findings on more mature populations, these results hold promise. At the very least, all of these findings combine to suggest that modern talent searches should be augmented to include measures of spatial visualization in the selection process, and doing so is likely to uncover some STEM talent currently being lost. Indeed, it is estimated that contemporary talent searches miss approximately half of the top 1% in spatial ability (Shea et al., 2001; Webb et al., in press), by exclusively restricting talent identification to mathematical and verbal abilities.

Finally, although exploring sex differences is not a primary thrust of our work, they are hard to ignore. Sex differences on the two functions in Table 8 are especially revealing. The average effect size for sex (males minus females) across the series of five discriminant functions based on the SOV was 1.04, and the average effect size across the series of five discriminant functions based on the RIASEC dimensions was 1.04 as well. Thus, rather large differences between the sexes are uncovered when models aggregate different classes of relevant variables (abilities and preferences), and these variables all display sex differences in the same direction when calibrated for STEM pursuits. The perplexities encountered when focusing on one class of relevant variables are, to a certain extent, resolved when more complete models are considered. Moreover, personal attributes beyond abilities and preferences are germane to STEM pursuits; these attributes manifest large individual differences as well and are helpful in further clarifying individual and group differences in occupational outcomes (especially in STEM areas).

### Conative Factors

It takes more than the right mix of specific abilities, interests, values, and opportunities to be attracted to and excel in STEM areas (Lubinski & Benbow, 2000; Lubinski, Benbow, et al., 2001; Tyler, 1974; Williamson, 1965). Conative variables are highly important for mastering these intellectually demanding and time-intensive disciplines, and they are underappreciated relative to abilities and interests. Regardless of the domain of distinction (securing tenure at a top university, making partner at a prestigious law firm, or becoming chief executive officer of a major organization), notable accomplishments are rarely achieved by people who work 40 hr per week or less (Campbell,

**TABLE 8**  
*Rank Order of Preferences for Cohort 5*

Rank order	Interest/Value theme											
	Investigative/Theoretical		Artistic/Aesthetic		Enterprising/Economic		Social/Social		Realistic/Political		Conventional/Religious	
	M	F	M	F	M	F	M	F	M	F	M	F
1	64/43	52/44	16/21	23/20	2/9	2/12	10/14	9/13	11/7	13/6	3/12	5/10
2	25/30	33/26	24/21	23/19	1/14	2/20	12/16	12/12	29/10	21/12	7/9	10/10
3	7/14	11/13	25/16	19/25	4/16	5/17	20/23	19/21	26/20	27/21	17/8	17/5
4	3/8	2/9	12/20	13/15	12/16	15/18	32/20	28/21	18/26	23/23	21/9	19/10
5	0/4	1/7	11/14	12/12	28/25	28/20	15/20	17/24	10/23	8/22	36/13	32/13
6	1/1	1/2	11/8	10/8	53/19	47/14	11/8	15/8	6/15	8/15	16/48	16/52

**Note.** The table presents the percentage of male (M) and female (F) participants for whom each preference had the indicated rank. Themes designed to measure conceptually similar constructs were aligned as much as possible. In each cell, results for the Strong-Campbell Interest Inventory (RIASEC dimensions) are given first, followed by results from the aligned dimension from the Study of Values (SOV). For the SOV,  $n = 362$  for males and 342 for females; for the Strong-Campbell inventory,  $n = 362$  for males and 340 for females.

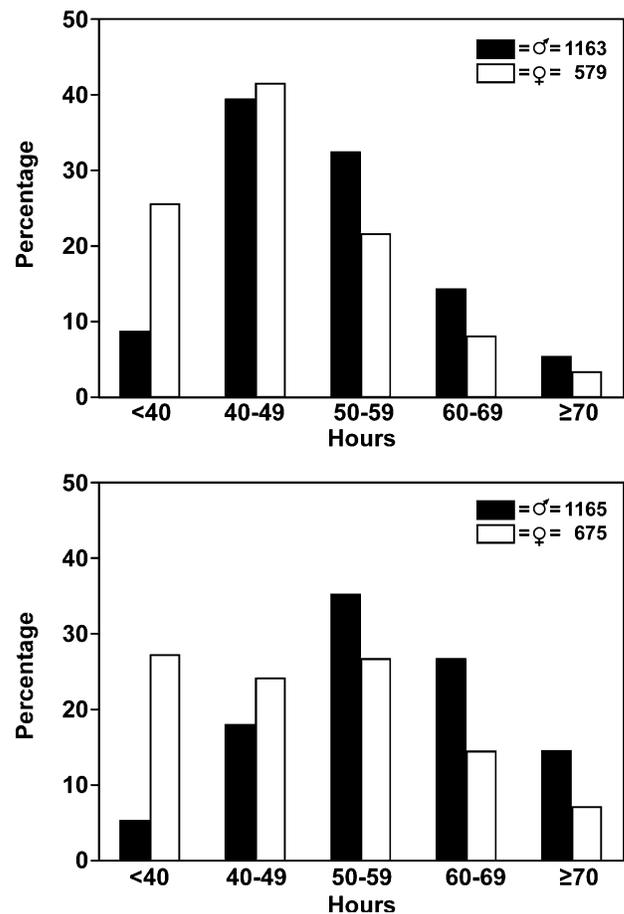
1977; Ericsson, 1996; Eysenck, 1995; Gardner, 1993; Jackson & Rushton, 1985; Simonton, 1988; Zuckerman, 1977). World-class performers work on average 60 to 80 hr per week with commitment and passion. Galton's (1869) observations about the capacity for work, will, and zeal exhibited by extraordinary performers are as true today as when he made them.

Consider the following remarks by a leading authority on the development of eminence and a distinguished biologist:

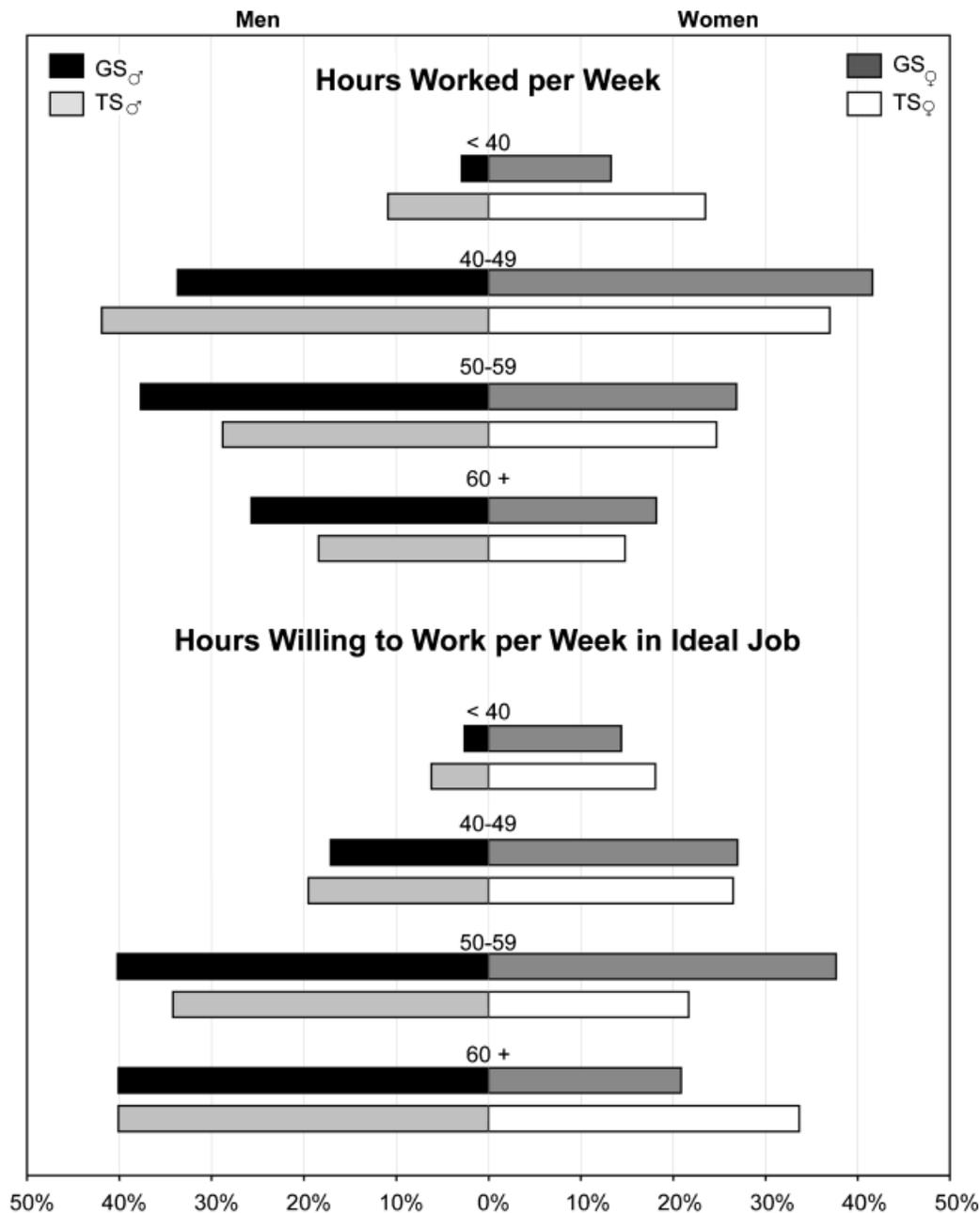
Making it big [becoming a star] is a career. People who wish to do so must organize their whole lives around a single enterprise. They must be monomaniacs, even megalomaniacs, about their pursuits. They must start early, labor continuously, and never give up the cause. Success is not for the lazy, procrastinating, or mercurial. (Simonton, 1994, p. 181)

I have been presumptuous enough to counsel new Ph.D.'s in biology as follows: If you choose an academic career you will need forty hours a week to perform teaching and administrative duties, another twenty hours on top of that to conduct respectable research, and still another twenty hours to accomplish really important research. This formula is not boot-camp rhetoric. (Wilson, 1998, pp. 55–56)

In all of our age-33 follow-ups, we have examined how much time our participants devote to their careers and how much time they are willing to devote to their careers. Figure 7 summarizes responses to two questions from SMPY's 20-year follow-up of Cohorts 1 and 2 (Benbow et al., 2000; Lubinski & Benbow, 2000). At age 33, participants were asked how much they would be willing to work in their "ideal job" and how much they actually did work. Figure 8 summarizes answers to the same two questions from SMPY's Cohorts 3 and 5 (the top-1-in-10,000 group and the top math-science graduate students, respectively), when both samples were in their mid-30s (Lubinski et al., 2006). These data, taken from four extraordinarily able cohorts



**Fig. 7.** Number of hours participants in Cohorts 1 and 2 worked per week and were willing to work per week in the ideal job, by sex. Participants were surveyed when they were in their mid 30s; they were asked how many hours per week they typically worked (top panel; homemakers were excluded from this question) and how many hours per week they were willing to work, given their job of first choice (bottom panel). Adapted from Lubinski and Benbow (2000).



**Fig. 8.** Number of hours graduate-student (GS) and talent-search (TS; Cohort 3—top 1 in 10,000) participants worked per week and were willing to work per week in the ideal job, by sex (cf. Fig. 7). Participants were surveyed when they were in their mid-30s. The data for hours worked are based on *ns* of 276 and 264 for male and female GS participants, respectively, and 217 and 54 for male and female TS participants, respectively. The data for hours participants were willing to work are based on *ns* of 269 and 263 for male and female GS participants, respectively, and 206 and 57 for male and female TS participants, respectively. From Lubinski, Benbow, Webb, and Bleske-Rechek (2006).

and assimilated over multiple time points, reveal considerable variation in the noncognitive factor of willingness to work long hours. To understand the possible impact of this factor, one need only imagine the differences in research productivity likely to accrue over a 5- to 10-year interval between faculty members, research scientists, or lawyers who work 45-hr weeks and those who work 65-hr weeks (other things being equal). The same

pattern would emerge for advancing knowledge or achieving distinction in other occupational pursuits (see especially Campbell, 1977, p. 58).

These figures also reveal another interesting sex difference that is difficult to ignore: The percentage of individuals who were working and preferred to work less than 40 hr per week was appreciably greater among the women than the men. These data

fit with a number of reports in the popular press indicating that many women graduating from elite colleges are opting out of career tracks, preferring to become stay-at-home mothers (cf. Story, 2005), as well as with reports on middle-aged women voluntarily leaving highly successful careers to pursue other interests (cf. Kuczynski, 2002). These findings align with gender differences uncovered in other studies of occupational aspirations and time devoted to work (Bhargava, 1986; Browne, 2002; V.R. Fuchs, 1988; Hoffman & Reed, 1982; Shye, 1991; Wood, Corcoran, & Courant, 1993). That these findings are observed in highly talented men and women who are similarly able, similarly aware of their abilities, and similarly satisfied with their current careers and life in general at age 33 (Benbow et al., 2000; Lubinski et al., 2006) indicates that sex differences in occupational outcomes cannot be fully understood by examining only levels and patterns of abilities, interests, values, and opportunity. Conative factors also need to be incorporated when modeling sex differences in outcomes.

If sex differences in time devoted to work persist, large sex differences in creativity, occupational accomplishments, and work-related outcomes will remain over time. Indeed, we (Benbow et al., 2000) found that controlling for number of hours worked eliminated the commonly observed statistically significant sex differences in income. How much time individuals are willing to devote to their careers also engenders different professional opportunities, particularly in STEM areas. Staying up to date in these areas requires assimilating a continuous stream of not only substantive but also technical knowledge: One way in which STEM careers are more challenging than careers in other disciplines is the extent to which they are technologically rich and ever-changing (almost continuous technical updating is required). Many disciplines are, of course, experiencing great technological changes, but they are undoubtedly more intense in STEM areas. In these disciplines, taking a leave of absence or working part time for a number of years is possible, but doing so reduces significantly the likelihood of reentering where one left off or of keeping up to date and subsequently achieving a high-impact leadership role. Albert Einstein noted that one of the more powerful forces of nature is the compounding of interest. The same holds for productivity. It too compounds, and thus, it is hard to catch up if earlier contributions are missing or unimpressive. Perhaps this is why it is often found that eminent individuals began to develop their talent early. The sooner a person manifests exceptional performances, the sooner he or she is likely to be recognized by others and to stimulate the provision of opportunities for further development, which if seized upon will make that person stand out even more and increase, in turn, the likelihood of even more opportunity, and so on—this is the multiplicative effect of taking advantage of opportunity (Zuckerman, 1977), or simply compounding.

For many individuals, however, balancing work and family becomes a true challenge when pursuing a highly competitive career (Browne, 2002; Rhoads, 2004), and it is not clear how to

best meet this challenge. What is clear is that individual differences will likely factor into ultimate life choices (Tyler, 1974); people vary in how they choose to allocate their time, because what some may consider a minor inconvenience, others may view as totally unacceptable (cf. Lubinski & Benbow, 2001). What SMPY findings suggest, however, and what decades of individual differences research have revealed for all of the personal attributes examined here (Lubinski, 2000; Tyler, 1965), is that there is much more variation within groups than between groups. Therefore, for a long time, the best science has suggested that opportunities should be open and readily available to members of all groups on the basis of their individual characteristics (Dawis, 1992; Tyler, 1974, 1992; Williamson, 1965).

### Educational Factors

The talent-development process in science, as in other areas (e.g., athletics, arts), typically begins early (e.g., in special math or science programs), as early as fifth grade, and is then sustained (Lubinski, Benbow, et al., 2001). We (Lubinski, Benbow, et al., 2001) have concluded that developing exceptional scientific expertise requires both special educational opportunities and particular personal characteristics and that this attribute-plus-opportunity tandem operates similarly for males and females. Bloom (1985) also found that early intervention and stimulation clearly stood out in the lives of talented and excelling adults.

From the start, SMPY has emphasized both talent identification and development. Its approach has been to tailor educational opportunities to be responsive to students' individuality and to build on their strengths (Benbow & Stanley, 1996; Lubinski & Benbow, 2000). Literally hundreds of studies have shown that advancing talented students in their studies so that they are working with curricula designed for older students (i.e., acceleration) is effective in enhancing achievement (Benbow, 1991; Benbow & Stanley, 1996; Colangelo et al., 2004; Swiatek & Benbow, 1991a); positive effects are detectable up to 50 years later (Cronbach, 1996). Because of SMPY's initial and short-term success with acceleration, and because the educational efficacy of acceleration has been documented repeatedly by other investigators (Colangelo et al., 2004), we focus here on the long-term evidence emerging from SMPY.

Swiatek and Benbow (1991b) conducted a 10-year follow-up of 13-year-old participants in SMPY's fast-paced mathematics classes, which began with the expressed intent of challenging students in mathematics and sparking or maintaining their interest in math and sciences until they reached college. Indeed, relative to equally able comparison groups, SMPY participants were twice as likely to be in math-science career tracks in their mid-20s and in their mid-30s (Benbow, 2006). Other math-science interventions conducted by SMPY revealed the same trend (Benbow & Lubinski, 1996). Thus, being challenged by intellectually rigorous math-science educational opportunities

that are responsive to one's learning needs increases the likelihood of being in a STEM career 20 years later.

The Advanced Placement (AP) program is becoming extremely popular in today's schools as a means for challenging the most capable students in high school. When asked to look back, gifted students often cite AP courses as their favorite courses (Bleske-Rechek, Lubinski, & Benbow, 2004). At age 33, moreover, 70% of participants in Cohorts 1 and 2 who had taken one or more AP courses or exams had obtained an advanced degree (master's or beyond), compared with 43% of those who had not taken an AP course or exam. Participation in an AP course accounted for between 5 and 7% of additional variance in advanced-degree attainment after SAT-M scores were controlled. Thus, through self-selection or something intrinsic to the AP program itself, AP involvement is a positive predictor of educational success and satisfaction for intellectually talented youth (Bleske-Rechek et al., 2004).

### Top STEM Graduate Students: A Generalization Probe

As noted earlier, SMPY's Cohort 5 was selected to conduct a generalization probe to ascertain the fidelity of the TS model for identifying math-science talent. In 1992, first- and second-year graduate students attending the top 15 math-science training programs in the United States were surveyed (Lubinski, Benbow, et al., 2001). This cohort consisted of 368 male and 346 female participants (the universities and disciplines included are listed in Lubinski, Benbow, et al., 2001). To our knowledge, a large group of approximately equal numbers of male and female nascent scientists of this caliber has never been psychologically profiled so comprehensively. Some of the information secured included SAT scores for those who participated in talent searches, high school SAT scores, Graduate Record Examination (GRE) scores, and scores on the Strong Interest Inventory, the SOV, and the Adjective Check List (Gough & Heilburn, 1983). In addition, much background information was collected. One question in the initial survey, for example, asked the students if they felt they would have qualified for a talent search when they were in seventh grade (and they were provided with an extensive description of the qualification criteria): Only 8% felt that they would not have qualified.

Overall, this study confirmed that the salient attributes uncovered by SMPY's longitudinal research were also prominent psychological features among these graduate students, regardless of their sex. Talent searches were not as well known back when these students were in seventh grade, but 13 to 15% had age-13 SAT scores. These assessments placed them just above the top 1 in 200 in quantitative reasoning ability. The high school SAT scores of Cohort 5 were analyzed for ability tilt (viz., SAT-M minus SAT-V), and the mean difference was 92 ( $Mdn = 90$ ) for males and 79 ( $Mdn = 70$ ) for females (Lubinski, Benbow, et al., 2001). Throughout the 1980s, the maximum mean difference between math and verbal SAT scores was 66 points for

males and 33 points for females (College Entrance Examination Board, 1992). Thus, these math-science graduate students did appear to display marked tilts. To evaluate the psychological significance of these tilts more concretely, we calculated the percentages of math-science degrees among SMPY Cohort 2 participants, comparing those who did and did not have tilts equivalent to the tilts found among the graduate students (i.e., tilts  $\geq 70$  vs.  $< 70$  for female participants and tilts  $\geq 90$  vs.  $< 90$  for male participants (Lubinski, Benbow, et al., 2001). This analysis showed that 75% of TS males and 51% of TS females with SAT difference scores at or beyond the median of their gender-equivalent graduate-student counterparts secured undergraduate math-science degrees. For TS participants with difference scores below these medians, the percentages receiving such degrees dropped significantly to 57% for males and 28% for females.

The male and female graduate students in Cohort 5 displayed the preference pattern (high investigative-theoretical preference and lower social and religious preferences) typically found for scientists, and were remarkably similar in other personal attributes, especially when the sex differences uncovered among the TS participants are considered. For example, males and females in Cohort 5 displayed congruent rank orderings in interests and values (Table 8); the lack of sex differences in these profiles is striking, and hard to ignore given the conspicuous sex differences in rank orderings for these dimensions among SMPY's TS participants (see Table 5). For each instrument, summing the percentages of graduate students who ranked each theme first or second reveals sex differences of only a few percentage points. For example, 73% of males and 70% of females ranked Theoretical as one of their top two SOV themes, as would be expected of individuals pursuing scientific career tracks. The male-female similarity in Cohort 5 was further supported by more general personological assessments. The first- and last-ranked scales among the 36 standard Adjective Check List scales were the same for the two sexes: *creative personality* and *succorance*, respectively. This pattern is indicative of independently minded creative innovators and illustrates another way in which male and female top math-science graduate students are psychologically similar.

Tables 9 and 10 reveal additional similarities between top male and female math-science graduate students, not only in their educational experiences and accomplishments (e.g., seeking out advanced learning opportunities and special programs in math-science and excelling in them), but also in their commitment to studying and doing research. In addition, a majority of the graduate students reported math or science as their favorite high school class, and graduate students of both sexes reported early participation in special programs and contests for the gifted, such as math and science competitions (Table 9). (Sex differences had emerged on these items for TS participants.) These findings reflect an early commitment to math-science endeavors among the graduate students of both

**TABLE 9**  
*Percentage of Participants With Various Educational Experiences*

Experience	Graduate students		TS participants	
	M	F	M	F
Interest in math-science stimulated by a special person	61	69	68	73
<b>Math-science contest or special program before college</b>	<b>58</b>	<b>54</b>	<b>54</b>	<b>37</b>
Accelerated primary or secondary education . . .				
via advanced subject-matter placement	58	62	68	60
via Advance Placement or other exams for college credit	66	67	92	88
via college courses during high school	33	33	37	29
via grade skipping	11	13	23	28
by any means	88	91	92	92
Reported influence of acceleration experience				
Positive	78	80	70	70
Negative	2	1	10	8
Took biology, chemistry, physics, and calculus during high school	68	66	65	60
<b>Favorite high school class was in math or science</b>	<b>79</b>	<b>74</b>	<b>64</b>	<b>39</b>
Selected for the National Honor Society	70	79	63	70
Was National Merit finalist	23	21	42	38
Awarded National Merit scholarship	15	17	23	21
Was Presidential Scholar	13	13	3	5
Experienced mentoring relationship before college	28	28	33	34
Positive influence on educational-career plans	96	97	95	89
Negative influence on educational-career plans	3	0	2	2
<b>Math-science contest or special program during college</b>	<b>20</b>	<b>21</b>	<b>25</b>	<b>11</b>

**Note.** Items with important differences between groups are displayed in boldface. Group *ns* vary by item. Graduate students are the participants in Cohort 5. TS participants are talent-search participants in Cohort 2. M = males; F = females. From Lubinski, Benbow, Shea, Eftekhari-Sanjani, and Halvorson (2001).

sexes. As graduate students, they devoted much of their time to their educational-vocational development, spending a median of 50 hr per week on studying and research (Table 10). Overall, the psychological profile and educational experiences and accomplishments of the graduate students, both in and outside of school, paralleled those of TS participants who went on to secure STEM degrees (Lubinski, Benbow, et al., 2001; Wai et al., 2005; Webb, Lubinski, & Benbow, 2002). The findings converged. Collectively, these data indicate that regardless of sex, an individual's abilities, preferences, and commitment to work combine to promote the active pursuit of scientific excellence in the scientific community as now constructed.

### Entering and Exiting STEM Areas

Although it is well known that men are more frequently involved in math-science domains than women are, analyses of individual differences attributes among people who choose to pursue advanced training in math-science domains reveal that these attributes are more important than group membership (e.g., sex) for understanding this educational choice. Findings from Webb et al. (2002) support this idea.

We tracked 1,110 Cohort 1 and 2 participants who reported plans to major in math or science at the onset of their undergraduate studies and then compared those who eventually

completed a degree in math or science with those who completed a degree outside these areas. More women than men eventually chose to pursue degrees in areas outside of math and science, a finding that was not surprising given current statistics. This pattern is often interpreted as negative because of a focus on demographic parity. But in-depth analyses of the participants' educational, vocational, and life outcomes affords a different and more positive interpretation.

First, individual differences in ability pattern and interests, not biological sex, surfaced as the central predictors of who actually completed a degree in math or science and who completed a degree outside these areas. Thus, it appears that group status is a frail proxy variable for specific individual differences attributes (Lubinski & Humphreys, 1997), such as ability and preference patterns. The latter more centrally guide educational-vocational choices.

Second, students who completed degrees in math or science and those who completed degrees outside these areas showed similar levels of success, career satisfaction, and life satisfaction. For example, participants who completed their undergraduate degrees outside of math and science, regardless of sex, were as likely to earn graduate degrees as participants who majored in math or science; they merely secured their graduate degrees in different areas. This finding mirrors other research demonstrating that SMPY women earn baccalaureate and

**TABLE 10**  
*Educational Experiences of the Graduate Students in Cohort 5*

Experience	Males	Females
Participated in a talent search during junior high school	15	13
Believe would have been eligible for a talent search	63	62
Believe would not have been eligible for a talent search	7	8
Would have enrolled in a talent search	65	72
Gifted programs were available at some point	74	78
Participated in gifted program (given program was available)	86	84
Average number of years participated in a gifted program ( <i>SD</i> )	5.2 (2.9)	5.4 (2.9)
Participated in a summer program for the gifted	26	23
Positive experience from gifted programs	67	71
Negative experience from gifted programs	3	3
Worked on an independent research project during high school	25	23
Took honors course during high school in		
Humanities	52	59
Social studies	42	45
Languages	30	38
Science	66	68
Changed undergraduate major	29	35
Changed from a program outside math-sciences	12	11
Age decided on undergraduate major ( <i>SD</i> )	17.7 (2.1)	18.1 (1.8)
Participated in an undergraduate research program	83	83
Positive influence on educational-career plans	88	88
Negative influence on educational-career plans	5	4
Experienced mentoring relationship as undergraduate	57	61
Positive influence on educational-career plans	96	94
Negative influence on educational-career plans	1	3
Member of undergraduate honor society (e.g., Phi Beta Kappa)	71	76
Median number of hours per week spent on		
Studying	20	20
Research	30	30

**Note.** No significant differences between the sexes were found ( $\alpha = .01$ ). Statistics represent percentages, except where specified otherwise. From Lubinski, Benbow, Shea, Eftekhari-Sanjani, and Halvorson (2001).

postbaccalaureate degrees at the same rates as SMPY men, but that the women are more likely than the men to pursue their credentials in organic fields, such as the social sciences, biology, and medicine, and the men are more likely than the women to pursue their credentials in inorganic fields, such as engineering and the physical sciences (Achter et al., 1999; Benbow et al., 2000; Lubinski, Webb, et al., 2001). To achieve parity, should society try to push women away from organic sciences into inorganic disciplines? If so, how much social engineering would be appropriate? What is the appropriate way to produce greater parity in engineering? How much parity is acceptable, and how much is ideal?

Third, many individuals who completed their degrees in non-math-science areas ultimately chose math-science occupations, and vice versa. Among mathematically talented populations, the leaking pipeline is not an appropriate metaphor. Upon reflection, this fluidity is not surprising for mathematically precocious females. In samples of males and females selected for mathematical talent, females display higher levels of verbal ability

than males, and also more uniform levels of mathematical and verbal ability (Lubinski, Benbow, et al., 2001). Thus, mathematically precocious females more often than mathematically talented males are endowed with talents that enable them to excel with distinction in domains that require highly developed verbal-linguistic skills (these skills and the flexibility they lend could perhaps propel these individuals in varied directions, in part because verbal-linguistic skills tend to co-occur with social, or organic, interests and values—Ackerman, 1996; Schmidt et al., 1998). This versatility is useful in navigating today's multidimensional work environments, which are becoming increasingly scientific and technical. Scientific and quantitative reasoning skills, for example, are essential not only in physics, but also in environmental law or scientific journalism. Given the ever-changing nature of the modern world of work, it is not surprising that talented women are attracted to environments that capitalize on both their quantitative and their verbal reasoning abilities (as well as their personal preferences) and that they may move in and out of careers formally labeled as

STEM careers more frequently than men do. They are working in the interface areas that form connections with multiple disciplines and that they are particularly well suited for. Are such career choices or shifts really a representation of a loss of talent? Is saving a large segment of precious Alaskan land through expertise in environmental law less of a contribution to society than publishing a discovery about the physical universe in *Nature*? What is the right balance?

### CONCLUDING PERSPECTIVES ON PSYCHOLOGICAL SCIENCE

Our model for talent development (TWA) emphasizes the importance of tailoring educational opportunities in accordance with each student's individuality (Lubinski & Benbow, 2000). It is predicated on the importance of accurately assessing individual differences and anticipating future individuality. Psychological knowledge about individual differences and the effective use of above-level assessments do help in identifying extraordinary human potential. Appropriate psychometric measures of specific abilities do have the potential to uncover a wide range of talent among diverse groups and, along with information on interests and values, can facilitate a more precise tailoring of educational opportunities (Corno et al., 2002). Teaming assessments of individual differences with differential opportunities harnesses both components of the "two disciplines of scientific psychology" (Cronbach, 1957): aptitude (or personal readiness) and treatment (or environmental opportunity). Moreover, to the extent that educators do not respond to the individuality of intellectually precocious students and align learning opportunities accordingly, academic underachievement becomes much more likely (Benbow & Stanley, 1996; Bleske-Rechek et al., 2004; Colangelo et al., 2004; Lubinski & Humphreys, 1997; Stanley, 2000).

Fifty years ago, Donald G. Paterson (1957), a dominant force in the applied psychological sciences, anticipated the importance the Association for Psychological Science is currently placing on the scientific study of human capital. Paterson's famous Bingham lecture, delivered at Ohio State University in 1956 and published in the *American Psychologist* the following year, is full of wisdom and is still important reading. TWA was developed by two of his students (Dawis & Lofquist, 1984; Lofquist & Dawis, 1969, 1991), and we conclude with contributions from two others to underscore its contemporary relevance in the context of findings from SMPY. The first quotation is from James J. Jenkins. Jenkins was selected by Paterson to carry on his applied psychological studies (Jenkins & Lykken, 1957; Jenkins & Paterson, 1961), but Jenkins's (1981) passion and readiness for psycholinguistics eventually propelled him toward other pursuits. The second quotation is from Leona E. Tyler, arguably the most distinguished counseling psychologist of the 20th century.

If you are concerned with improving the output of some complex system, you must study the component that produces the largest variance first. Adjusting or correcting smaller sources of variance has no appreciable effect on the output of the system as long as the major source of variance is uncontrolled. (Jenkins, 1981, p. 224)

In our haste to abolish the unjust and the obsolete, we cannot afford to ignore the psychological realities that generated such systems in the first place. There are highly significant psychological differences among individuals, and the soundness of our social institutions depends upon how successfully we take them into account. . . . A complex society cannot regard its members as identical interchangeable parts of a social machine. Its complex functioning depends upon the contributions of individuals specializing along different lines, equipped for carrying out different specialized tasks.

For this reason we must not be content with any system of universal education that provides identical treatment for all pupils. We must look for ways of diversifying education to make it fit the diverse individuals whose talents should be developed and utilized. (Tyler, 1974, pp. 6–7)

Psychology cannot afford to neglect the individuality found within intellectually talented populations—nor can the study and development of human capital initiatives.

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#### APPENDIX: SEX DIFFERENCES IN GENERAL AND IN SPECIFIC ABILITIES

Sex differences are routinely observed among intellectually talented young adolescents, and it is useful to have some benchmarks of the normative distributions that give rise to them. Although most investigators find essentially no sex differences in overall level of general intellectual ability (Jensen, 1998), sex

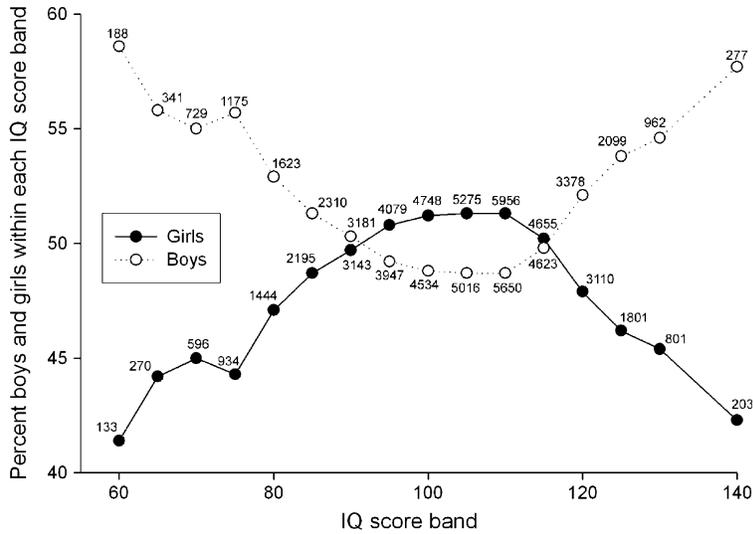


Fig. A1. Distribution of IQs among Scottish boys and girls who were born in 1921 and tested at age 11 in the 1932 Scottish Mental Survey. The graph shows the percentage of each sex in each 5-point band of IQ scores. The numbers beside the plotted points indicate the absolute number of boys and girls in each 5-point band. From Deary, Thorpe, Wilson, Starr, and Whalley (2003).

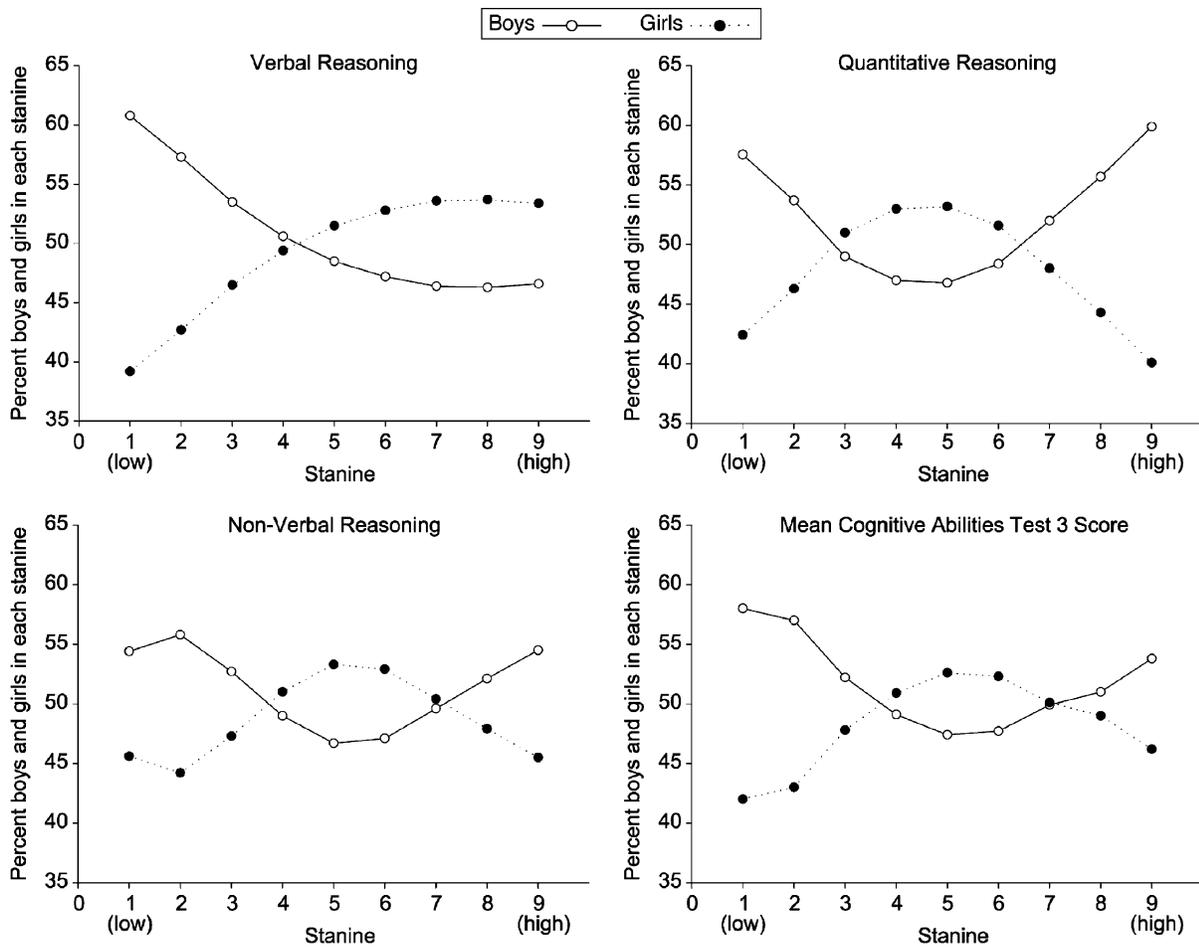
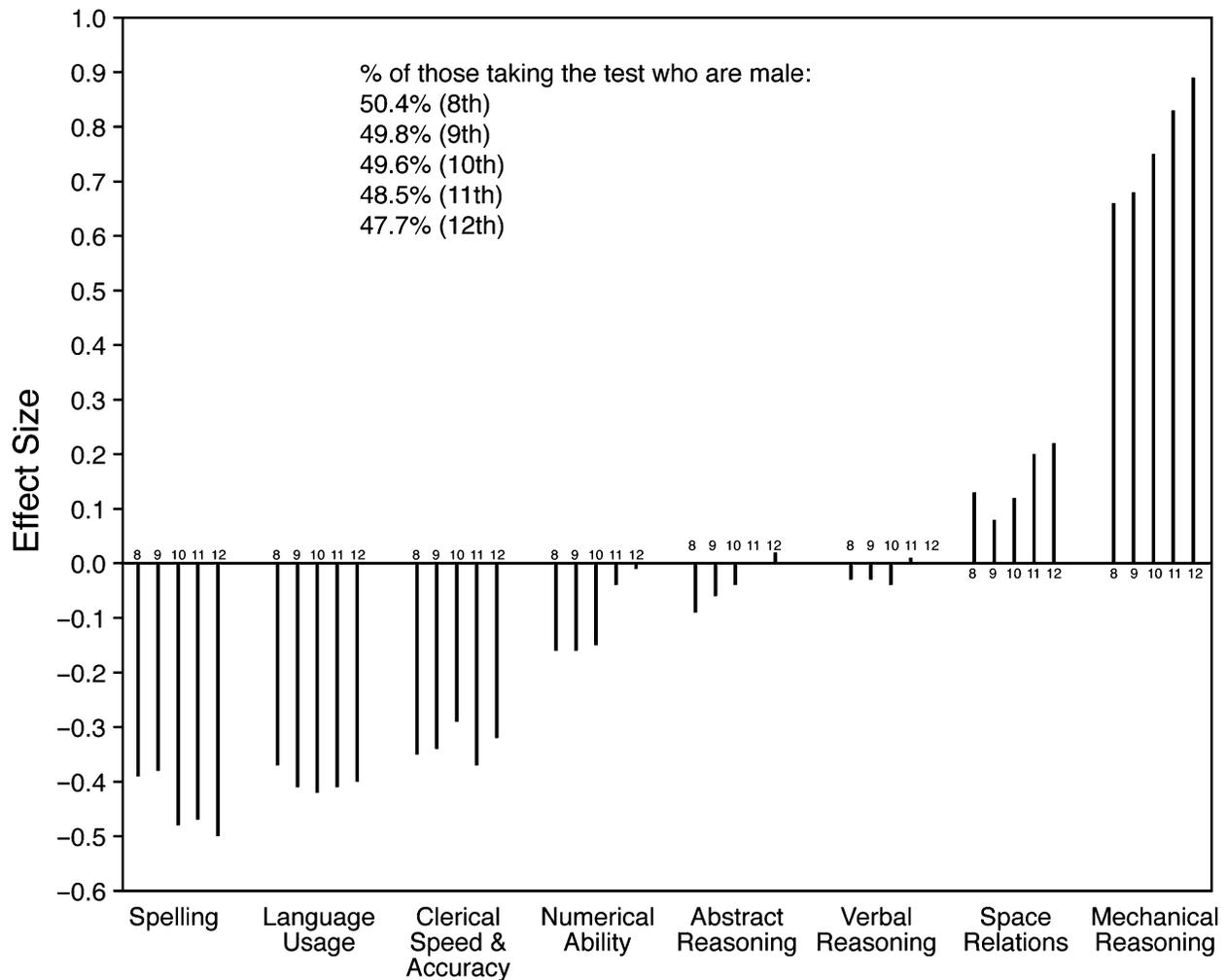


Fig. A2. Scores on four subtests of the Cognitive Abilities Test among a large and representative sample of pupils in the United Kingdom (Strand, Deary, & Smith, 2006). The sample constituted more than 320,000 students, ages 11 and 12 years (between September 2001 and August 2003). Results are shown for the nationally standardized tests of verbal reasoning, quantitative reasoning, and nonverbal reasoning, as well as for a composite of these three measures.



**Fig. A3.** Sex differences (males minus females, in standard deviation or effect-size units) for eight Differential Aptitude Tests (DAT), which were developed to provide a standardized procedure for measuring abilities in grades 8 through 12 (Bennett, Seashore, & Wesman, 1982). These norms for the DAT were based on a representative sample of more than 61,000 students in grades 8 through 12 (approximately 6,000 students per grade per sex). For each test, the effect size for each grade is shown separately. From Stanley, Benbow, Brody, Dauber, and Lupkowski (1992).

differences in variability of general intellectual ability are routinely observed, as are sex differences in both level and variability of specific abilities. For example, Deary, Thorpe, Wilson, Starr, and Whalley (2003) recently illustrated the group differences in ability dispersion using a Scottish sample of more than 80,000 children who were born in 1921 and assessed at age 11 in the 1932 Scottish Mental Survey (see Fig. A1).

More recently, Strand, Deary, and Smith (2006) analyzed a representative sample of 320,000 students in the United Kingdom. The students were assessed at ages 11 and 12, between September 2001 and August 2003. The distributions in this sample, shown in Figure A2, highlight male-female differences among extreme scorers on measures of verbal reasoning, quantitative reasoning, and nonverbal reasoning. The fourth panel is a composite measure of these three measures that, like the earlier study of Deary et al. (2003), illustrates an inordinate

number of males relative to females at both extremes in general ability. The effect-size difference favoring the females over the males on the verbal test was 0.15, whereas the effect-size difference favoring the males on the other two tests was less than this value. However, for all three tests, there were substantial sex differences in the standard deviation of scores, with greater variance among boys. Boys were overrepresented relative to girls at both the top and the bottom extremes for all tests, with the exception of the top extreme in verbal reasoning. On some verbal tests, more girls than boys were found at the extremes (as Strand et al., and other investigators, have found); but other findings on variability were mixed for this specific ability (cf. Lubinski & Dawis, 1992, p. 47, Table 7).

Finally, Stanley, Benbow, Brody, Dauber, and Lupkowski (1992) published an extensive analysis of the sex differences (males minus females in standard deviation or effect size units)

on a variety of aptitude tests (see Fig. A3). These benchmarks are useful to keep in mind when analyzing group differences at the extreme tails of ability distributions (Arden & Plomin, 2006;

Feingold, 1995). For further reading on this topic, see Hedges and Nowell (1995), as well as Geary (1998), Halpern (2000), Kimura (1999), and Lubinski and Humphreys (1990a).