Research Article

SEX DIFFERENCES IN MATHEMATICAL REASONING ABILITY AT AGE 13: Their Status 20 Years Later

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Abstract—*Reported is the 20-year follow-up of 1,975 mathematically gifted adolescents (top 1%) whose assessments at age 12 to 14 revealed robust gender differences in mathematical reasoning ability. Both sexes became exceptional achievers and perceived themselves as such; they reported uniformly high levels of degree attainment and satisfaction with both their career direction and their overall success. The earlier sex differences in mathematical reasoning ability did predict differential educational and occupational outcomes. The observed differences also appeared to be a function of sex differences in preferences for (a) inorganic versus organic disciplines and (b) a career-focused versus more-balanced life. Because profile differences in abilities and preferences are longitudinally stable, males probably will remain more represented in some disciplines, whereas females are likely to remain more represented in others. These data have policy implications for higher education and the world of work.*

Benbow and Stanley's (1980) *Science* publication sparked a major controversy concerning sex differences in mathematical reasoning ability and their origins, eventuating in a media field day. Pronounced sex differences in mathematical reasoning ability were observed among 9,927 intellectually talented 12- to 14-year-olds. These students had taken the College Board Scholastic Aptitude Test, Mathematics (SAT-M) and Verbal (SAT-V), several years before the typical age. The SAT-M sex differences, favoring the boys, averaged 0.40 standard deviations.

Subsequently, Benbow and Stanley (1983) reported additional SAT data on 40,000 young adolescents. As discovered earlier, there was little difference between males and females in SAT-V scores, but SAT-M differences remained. When graphed (Benbow, 1988), the male and female SAT-V distributions were found to be essentially equivalent, but the male SAT-M distribution manifested a higher mean and larger variance than was observed for the females. Consequently, an exponential intensification of the male:female ratio occurred in the upper tail of the combined distribution: The ratio was 2:1 for adolescents with SAT-M scores of at least 500, 4:1 for those with scores of at least 600, and 13:1 for those with scores of at least 700. Although various theories purport to explain these differences (Geary, 1996; Halpern, 1992, 1997), they are far from confirmed. Yet the differences themselves have been affirmed and noted in an American Psychological Association task force report, "Intelligence: Knowns and Unknowns" (Neisser et al., 1996).

Since Benbow and Stanley's (1980) article, well over a million seventh and eighth graders have taken the SAT (or American College Test, ACT) through annual talent searches (Benbow & Stanley, 1996; Van Tassel-Baska, 1996). Sex differences in SAT-M scores among intellectually talented 12- to 14-year-olds have persisted and are mirrored by those observed with the ACT-Math (Benbow & Stanley, 1996; Stanley, 1994). In addition, Mills, Ablard, and Stumpf (1993) presented data documenting sex differences in mathematical reasoning as early as the second grade (among intellectually gifted students), and Robinson, Abbott, Berninger, and Busse (1996) reported sex differences in mathematical precocity before kindergarten. Moreover, these latter differences were maintained following mathematical enrichment opportunities. Indeed, boys gained more than girls did on quantitative and visual-spatial measures after an average of 28 (biweekly) intervention sessions (Robinson, Abbott, Berninger, Busse, & Mukhopadhyah, 1997).

Given these robust and early-emerging gender differences in mathematical reasoning ability, it is critical to understand their long-term implications. Large-scale studies have revealed that sex differences in mathematical reasoning ability persist throughout high school (Hedges & Nowell, 1995) and predict sex differences in math and science achievement at the end of high school and college (Benbow, 1992; Benbow & Minor, 1986; Benbow & Stanley, 1982). In one large intellectually gifted sample, there were twice as many males as females pursuing math and science degrees and four times as many males as females pursuing engineering and physical science doctorates (Lubinski & Benbow, 1992). In general and irrespective of gender, students with tilted intellectual profiles tend to gravitate toward their area of strength. Those with exceptional mathematical abilities relative to verbal abilities tend to gravitate toward mathematics, engineering, and the physical sciences, while those with the inverse pattern are more attracted to the humanities, law, and social sciences. The tilt in the math-physical sciences direction is especially pronounced for males, whereas the tilt toward humanities is stronger for females (Achter, Lubinski, Benbow, & Eftekhari-Sanjani, 1999; Humphreys, Lubinski, & Yao, 1993).

Here we report on the 20-year educational and career outcomes of gifted students identified at ages 12 to 14 who, at age 33, completed and returned follow-up questionnaires. Specifically, 2,752 participants from the Benbow and Stanley (1980) study were asked to participate in the Study of Mathematically Precocious Youth's (SMPY) longitudinal investigation (Lubinski & Benbow, 1994). The students were grouped into two cohorts. Cohort 1 comprised individuals identified during 1972–1974; Cohort 2 consisted of individuals identified during 1976–1979. Although different score criteria were used across time to select students for the longitudinal study, all participants examined here had SAT-M scores of at least 390 before age 13. This cutting score represents the top 1% in mathematical reasoning ability for this age group. Of participants not lost or deceased, we secured question-

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Table 1. *Secured educational credentials at age 33*

	Cohort 1 (840 males, 543 females)						Cohort 2 (403 males, 189 females)					
	Bachelor's		Master's		Doctorate		Bachelor's		Master's		Doctorate	
Major	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
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
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
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
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
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
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
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
Law					7.9	6.5					6.7	11.6
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
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
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
Math, inorganic sciences	**43.7**	21.6	**16.2**	7.7	**5.5**	1.3	**63.5**	34.4	**25.3**	9.5	**13.2**	2.1
Life sciences, humanities	33.7	**52.6**	5.6	**10.5**	12.4	**12.7**	27.0	**53.7**	7.2	**15.9**	11.2	**18.0**
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

Note. Numbers shown are percentages. The numbers do not reflect postsecondary studies under way at the time of the follow-up (Cohort 1: 2.3% of males, 4.1% of females; Cohort 2: 5.5% of males, 9.5% of females). In the summary statistics, the boldface 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.

naires from 840 males and 543 females from Cohort 1 (response rate: 77.1%), and 403 males and 189 females from Cohort 2 (response rate: 81.5%). Respondents' SAT-M means and standard deviations at age 13 were as follows: Cohort 1 males, $M = 537$, $SD = 77$; Cohort 1 females, $M = 505$, $SD = 59$; Cohort 2 males, $M = 567$, $SD = 65$; Cohort 2 females, $M = 519$, $SD = 54$.[1]

SECURED EDUCATIONAL CREDENTIALS

Both sexes demonstrated high achievement. Males and females, respectively, achieved baccalaureates (90%, 92%), master's degrees (39%, 37%), and doctorates (28%, 24%) well beyond base-rate expectations of 23%, 7%, and 1%, respectively, for these successive degrees (National Center for Educational Statistics, 1998). The picture is more impressive for Cohort 2 than Cohort 1 (Table 1), as would have been anticipated given their slightly higher ability level.

Overall, males' and females' attainment of advanced educational credentials was comparable with one exception: Males in Cohort 1, but not in Cohort 2, were more likely than females to secure doctorates, $\chi^2(1, N = 1{,}382) = 5.29$, $p = .02$. Both cohorts obtained extraordinary numbers of degrees in mathematics, engineering, and natural, medical, and physical sciences. Indeed, 48% of Cohort 1 and 64% of Cohort 2 secured at least one postsecondary math or science degree. These statistics speak to the predictive value of early SAT-M assessments for identifying students with promise for math and science careers.

Irrespective of cohort and degree level, however, males were much more likely to earn degrees in the inorganic sciences and engineering than females: Cohort 1, $\chi^2(1, N = 1{,}383) = 63.92$, $p < .001$; Cohort 2, $\chi^2(1, N = 592) = 45.64$, $p < .001$. In contrast, more females than males received degrees in biology and health-medicine: Cohort 1, $\chi^2(1, N = 1{,}383) = 25.34$, $p < .001$; Cohort 2, $\chi^2(1, N = 592) = 4.74$, $p = .03$. Moreover, the large number of terminal baccalaureate degrees in engineering should be noted: 31% of males and 13% of females. Relatively few individuals of either sex pursued doctorates in engineering, presumably because of the favorable job market for people with 4-year and master's degrees in engineering.

OCCUPATIONS

Occupational information for males and females in the two cohorts is displayed in Figure 1. Overall, somewhat more than a quarter of the Cohort 1 males and females became executives or administrators, constituting the largest occupational category for both sexes at age 33. For Cohort 1 males, the next most frequent occupations were engineering, math and computer science, medicine, and law. For Cohort 1 females, physician and other health-related professions were the next most popular, followed by engineering and law. In terms of academe, more males (5%) than females (2%) were employed in faculty positions, $\chi^2(1, N = 1{,}214) = 4.04$, $p = .04$. Females were more eclectic than males in their career choice. A similar pattern was revealed for Cohort 2. For Cohort 2 males, math and computer science constituted

1. SAT-V scores at age 13 were available for a representative subset of Cohort 1 participants (257 males, 170 females) and all of the Cohort 2 participants. SAT-V means and standard deviations were as follows: Cohort 1 males, $M = 426$, $SD = 82$; Cohort 1 females, $M = 455$, $SD = 86$; Cohort 2 males, $M = 455$, $SD = 75$; and Cohort 2 females, $M = 467$, $SD = 67$.

the largest occupational category, followed by management, engineering, postsecondary teaching, and medicine. For Cohort 2 females, the largest occupational categories were management, math and computer science, law, medicine, and postsecondary teaching. The percentage of women who were homemakers at age 33 did not differ significantly between the two cohorts.

Among participants employed full-time, the median income for males was higher than that for females—$60,000 versus $50,000 in each cohort: Cohort 1, $\chi^2(1, N = 960) = 47.1$, $p < .001$; Cohort 2, $\chi^2(1, N = 439) = 14.1$, $p < .001$. These sex differences in median income remained in an analysis controlling for differential representation across occupational categories: Cohort 1, $F(1, 947) = 24.31$, $p < .001$; Cohort 2, $F(1, 402) = 16.13$, $p < .001$. However, sex differences in income within occupational categories failed to emerge in an analysis controlling for hours worked and removing (mostly male) outliers (incomes greater than 4 interquartile range intervals above the median within categories).[2]

The sexes did not differ significantly in satisfaction with the direction of their careers, whether or not career as a homemaker was included (63–67% were "satisfied" or "very satisfied" in both cohorts). Participants also saw themselves as successful in their chosen profession, again with no significant sex differences emerging; most described themselves as "successful" or "very successful" (Cohort 1 males: 68%, Cohort 1 females: 70%, Cohort 2 males: 62%, Cohort 2 females: 70%).

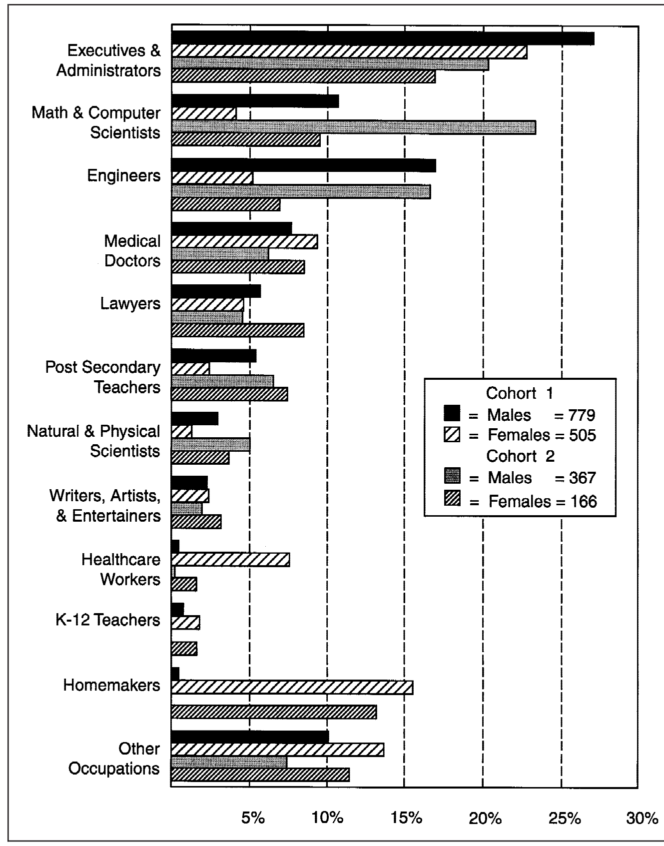

Fig. 1. Percentages of participants employed within 12 occupational categories. The denominator used to compute these percentages contained participants for whom occupational information was not volunteered (Cohort 1: 4.8% of males, 3.1% of females; Cohort 2: 1.2% of males, 0.0% of females), unemployed participants (Cohort 1: 2.1% of males, 2.4% of females; Cohort 2: 1.2% of males, 1.1% of females), and students (see Table 1 footnote for percentages).

LIFE PRIORITIES

Figure 2 displays males' and females' mean responses for a number of lifestyle items, responded to in terms of personal importance, along with effect-size differences (d). The most striking differences are those for the importance placed on having a full-time career ($d = .71$, males > females) and the importance of having a part-time career for a limited period of time ($d = .76$, females > males). This pattern motivated us to examine some independent work-related questions in more detail.

When asked how many hours they would be willing to work, at most, if given their job of first choice, more females than males endorsed less than a 40-hr workweek: Cohort 1, 25% versus 4%, $\chi^2(1, N = 1{,}296) = 136.71$, $p < .001$; Cohort 2, 32% versus 10%, $\chi^2(1, N = 547) = 42.47$, $p < .001$. Interestingly, the actual number of hours typically worked showed the same pattern, with more females than males in the workforce working less than 40 hr per week: Cohort 1, 25% versus 7%, $\chi^2(1, N = 1{,}186) = 70.28$, $p < .001$; Cohort 2, 21% versus 6%, $\chi^2(1, N = 475) = 25.42$, $p < .001$. Excluding homemakers, males reported working outside the home 4 to 7 hr more per week than did females: Cohort 1, $t(1230) = 9.21$, $p < .001$; Cohort 2, $t(511) = 2.74$, $p = .006$. This finding did not vary for those with or without doctorates. Single women with no children also reported working less than males by 2 to 3 hr in Cohorts 1 and 2.

When these gender differences regarding work behavior are combined with other gender differences observed in Figure 2, their collective impact may tell an important story. For example, with the cohorts combined, males placed greater importance than females (at $p < .001$) on "being successful in my line of work," "inventing or creating something that will have an impact," and "having lots of money." Females considered the following more important than males did: "having strong friendships," "maintaining a close personal relationship with parents," "living close to parents and relatives," and "having a meaningful spiritual life," at $p < .001$; and "having a good education" and "having children," at $p < .01$. There were, however, insignificant sex differences in the importance of "continuing to develop my intellectual interests," "continuing to develop my skills/

2. Separate multiple regression analyses were performed for each of nine occupational categories, combining cohorts. These categories, along with the percentages of male and female outliers removed prior to analyses, were as follows: medical doctors (excluding interns and residents and including professors of medicine), 8.6, 0.0; postsecondary teachers, 0.0, 0.0; engineers, 0.6, 0.0; lawyers, 5.4, 0.0; math and computer scientists, 4.0, 0.0; natural and physical scientists, 2.4, 0.0; executives and administrators, 7.0, 2.0. The remaining full-time employed participants were divided into two additional generic categories based on Stevens and Hoisington's (1987) occupational prestige ratings: other-high prestige, 2.7, 3.6; and other-lower prestige, 0.0, 0.0. Male and female Ns used in the analyses were as follows: medical doctors, 91, 66; postsecondary teachers, 44, 18; engineers, 178, 31; lawyers, 53, 34; math and computer scientists, 144, 34; natural and physical scientists, 41, 13; executives and administrators, 252, 131; other-high prestige, 107, 108; and other-lower prestige, 27, 28. In every analysis, main effects and interactions for sex failed to reach significance (alpha = .05) after controlling for hours worked per week.

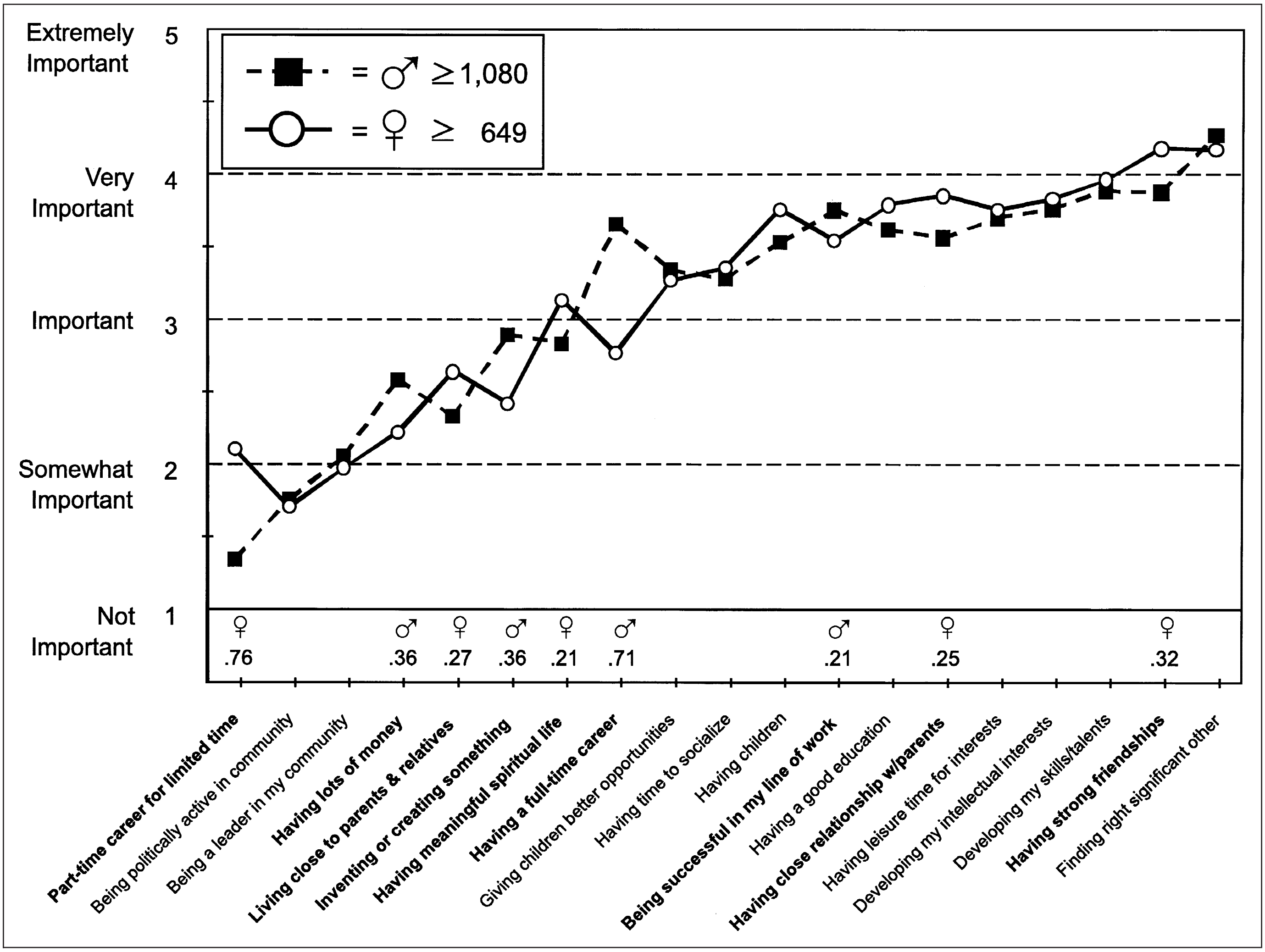

Fig. 2. Mean responses and significant effect-size differences (*ds*; $p < .001$) for the personal-importance items. The presented effect sizes are the unweighted means of separately calculated cohort effect sizes. Items with significant effect-size differences are listed in boldface, and the sex with the higher mean is indicated. According to Cohen (1988), effect-size magnitudes are as follows: .20 = small, .50 = medium, .80 = large.

talents," "having leisure time to enjoy avocational interests," "finding the right person with whom to spend my life," "being a leader in my community," "being politically active in my community," "being able to give my children better opportunities than I've had," and "having time to socialize."

Overall, both sexes saw education and developing one's talents as important for personal success. In general, however, males seemingly placed somewhat greater weight on career success, whereas females were more balanced in their life priorities (career, family, and friends). The fact that males reported working longer hours than females did is consistent with this pattern. Yet, as Figure 3 reveals, no significant sex differences emerged in either self-esteem (e.g., "I take a positive attitude toward myself," "I am a person of worth," "On the whole, I am satisfied with myself") or internal locus of control (e.g., "When I make plans, I am almost certain I can make them work"). Indeed, on all self-concept indicators examined in our 20-year follow-up, across both cohorts, the sexes were indistinguishable in terms of feeling good about themselves on educational, occupational, and interpersonal fronts. Both sexes felt that they were "pretty special," were "first rate," and possessed "outstanding qualities," and that it takes a lot of hard work to develop talent. They simply differed somewhat in how they preferred to allocate their time.

INTERPERSONAL RELATIONSHIPS AND CHILDREN

In Cohort 1, 81% of both males and females were in long-term relationships. This statistic was lower in Cohort 2, but also equal for both sexes (72%). Overall, 92% of the participants were at least "satisfied" with this relationship, and, again, there were no significant sex differences. Significant others were well educated: 78% (Cohort 1) and 88% (Cohort 2) had earned at least a bachelor's degree. In Cohort 1, 60% of both males and females had children; this figure was 45% for Cohort 2.

Excluding homemakers and students, females with children worked fewer hours per week outside the home compared with fe-

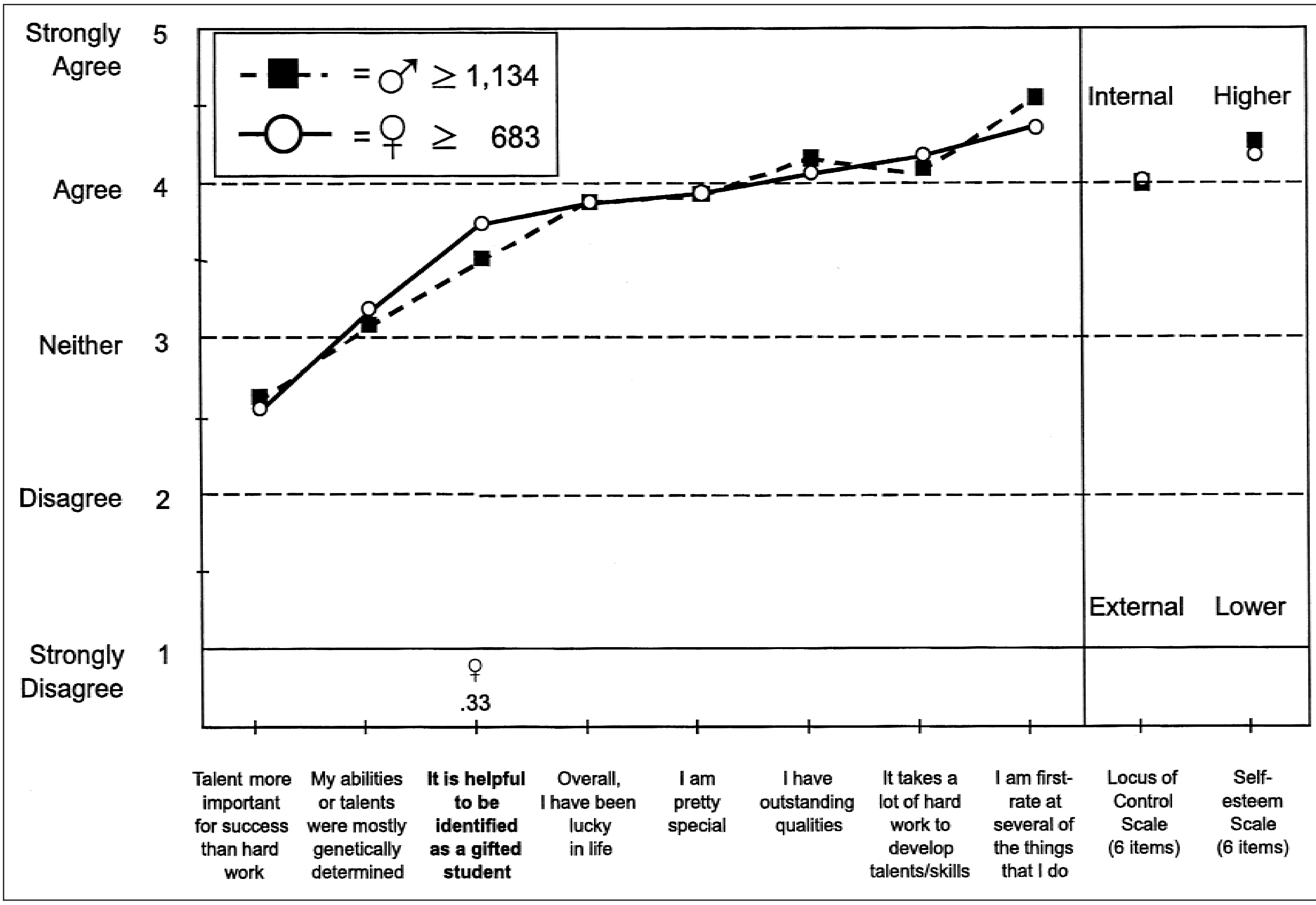

Fig. 3. Mean responses to items measuring self-concept, personal views of talent development, locus of control, and self-esteem. The item in boldface had a significant ($p < .001$) effect-size difference (d), when effect size was calculated as the unweighted mean of separately calculated cohort effect sizes. According to Cohen (1988), the magnitude of this effect size is between small (.20) and medium (50).

males without children: Cohort 1, 39 versus 47 hours, $t(391) = 7.21$, $p < .001$; Cohort 2, 40 versus 47 hours, $t(129) = 2.74$, $p = .007$. This was not the case for the males. The interaction between sex (male vs. female) and children (with children vs. without children) was statistically significant in both cohorts: Cohort 1, $F(1, 1145) = 39.83$, $p < .001$; Cohort 2, $F(1, 471) = 9.11$, $p = .003$. In addition, when we analyzed the data for females in more detail, those with children rated having a full-time career as somewhat less important than did those without children: Cohort 1, $t(489) = 6.80$, $p < .001$, $d = .63$; Cohort 2, $t(173) = 3.41$, $p < .001$, $d = .52$. Excluding homemakers from this analysis, a significant difference remained for Cohort 1, $t(415) = 4.19$, $p < .001$, $d = .41$, but not for Cohort 2. When only females who were in the workforce and had doctorates were included, a significant difference remained for Cohort 1 only, $t(95) = 2.68$, $p < .009$, $d = .54$. Despite these differences in work patterns, satisfaction with career direction and perceived success in chosen profession did not differ significantly between women who did and did not have children.

PERCEPTIONS OF EDUCATIONAL INTERVENTIONS

SMPY is a proponent for appropriate developmental placement (Lubinski & Benbow, 2000), that is, tailoring the level and rate of the curriculum (e.g., fast-paced classes, Advanced Placement exams) to meet the needs of intellectually advanced students (Benbow & Stanley, 1996). On average, accelerated males and females in both cohorts saw this experience as helpful for educational and career planning, but having little impact on the ability to form friendships (Fig. 4).

Homogeneous ability grouping for instruction is another effective means of meeting the needs of intellectually talented students with multiple developmental and social benefits (Benbow & Stanley, 1996; Kulik & Kulik, 1992). The subjective appraisal of the two cohorts combined (Fig. 5) affirms these positive findings—with most participants (80%) being “somewhat” to “very” unsupportive of eliminating homogeneous ability grouping across the board.

CONCLUSION AND SUMMARY

Two cohorts of students, initially identified at age 12 to 14 as being in the top 1% in mathematical ability, were included in SMPY’s longitudinal study and tracked for 20 years. At age 33, these individuals exhibited exceptional educational achievement, with 90% earning bachelor’s degrees and 26% earning doctorates. Males as a group were heavily invested in the inorganic sciences and engineering, whereas greater female participation was observed in the medical

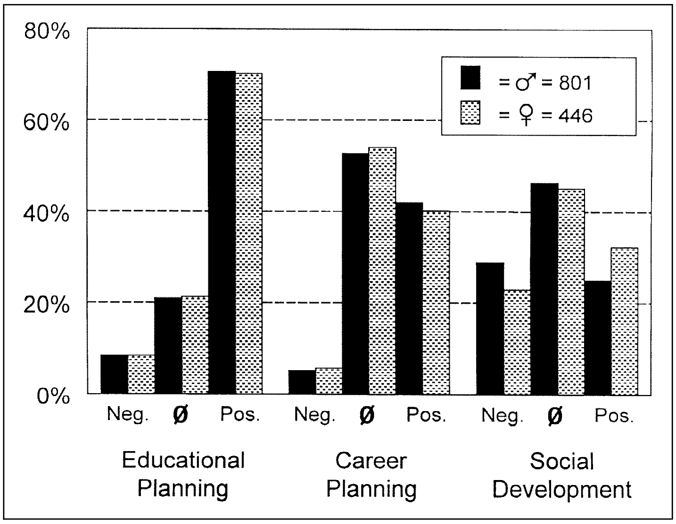

Fig. 4. Perceived influence of educational acceleration on educational planning, career planning, and ability to develop social contacts and friendships. Only those respondents who had participated in accelerated education were asked for their opinion on the effect of acceleration: Neg. = "strongly negative," "negative influence," or "somewhat negative influence"; Ø = "no influence"; Pos. = "somewhat positive influence," "positive influence," or "strongly positive influence."

arts and biological sciences, as well as in the social sciences, arts, and humanities.

On all indicators examined, the sexes reported feeling equally good about themselves and their success, even though the males, on average, earned higher incomes (but worked longer hours). This could be because the sexes differed somewhat in how they preferred to allocate their time: Males placed greater weight on securing career success, whereas females were more balanced in their priorities regarding career, family, and friends.

The differential gravitation across educational and vocational tracks is concordant with sex differences in ability and preference profiles among the gifted (Achter, Lubinski, & Benbow, 1996; Lubinski, Webb, Morelock, & Benbow, in press; Schmidt, Lubinski, & Benbow, 1998), as well as the general population (Hedges & Nowell, 1995; Lippa, 1998; Lubinski, 2000). Although equally achieving educationally, these men and women appear to have constructed satisfying and meaningful lives that took somewhat different forms. These findings have implications for higher education and expectations for equal representation of men and women across careers.

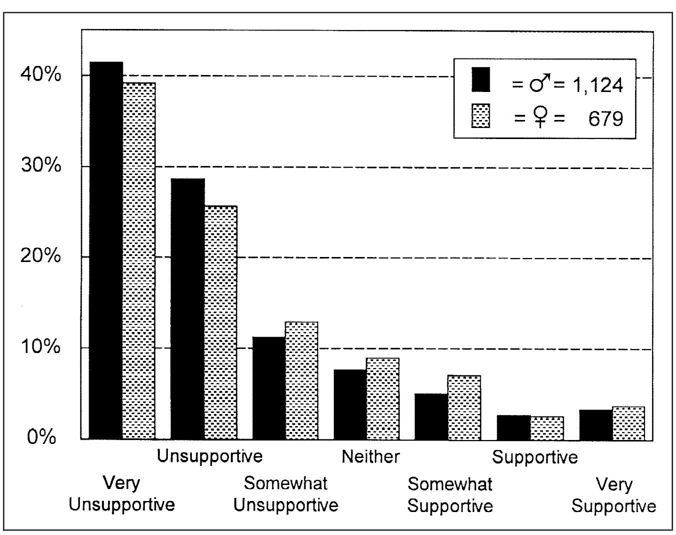

Fig. 5. Attitude toward eliminating homogeneous ability grouping for instruction. All participants in both cohorts were asked the following question: "A number of educational policymakers have proposed the following: eliminating homogeneous grouping for instruction (i.e., grouping students according to their abilities and skills, as in reading groups or honors classes) and, instead, teaching students of all ability levels in the same group. How supportive are you of this proposal?"

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