Some Characteristics of SMPY's "700-800 on SAT-M Before Age 13 Group": Youths Who Reason *Extremely* Well Mathematically[1]

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Abstract

Statistics concerning background characteristics of a remarkable group of 292 youths who *reason* extremely well mathematically are presented. Identified initially at age 12 or less, they reside all over the United States and in two foreign countries. The sex ratio is 12 boys per 1 girl. The group tends to be quite able verbally, but much more so mathematically. Most of their parents are well educated. Some of these young students are vastly more accelerated in school grade placement than are the majority of the group. Other relevant characteristics are also discussed.

Since 1971 the staff of the Study of Mathematically Precocious Youth (SMPY) at Johns Hopkins University has been examining the characteristics of boys and girls who, in annual talent searches, at age 12 or younger score well on the mathematical sections of the College Board's Scholastic Aptitude Test (SAT-M). Most of these students are in the middle of the seventh grade when they take all three parts of the SAT: mathematical, verbal, and Test of Standard Written English (TSWE assesses proficiency in the mechanics of English expression). Experience by SMPY and others with many thousands of young examinees has shown that SAT-M is an excellent measure of mathematical reasoning ability, rather than primarily of computational facility or ability to learn concepts and algorithms taught systematically (e.g., Angoff, 1971; Benbow & Stanley, 1983a; Minor & Benbow, 1985). This ability seems to be crucial for learning readily and well precalculus mathematics, first-year college calculus, physics, and a number of other quantitatively oriented subjects.

Students eligible for the 14 annual talent searches thus far have usually been seventh graders of any age who on an in-school achievement test battery have scored in the top 3 percent of national norms on the mathematical or verbal part, or overall. Before 1980, SMPY conducted the annual Johns Hopkins talent search and used only the mathematical criterion. Eligibility via verbal, mathematical, *or* total scores began in 1980, after the Center for the Advancement of Academically Talented Youth (CTY) was formed at Johns Hopkins to conduct talent searches and special educational programs. Though instrumental in getting CTY started, SMPY has always been wholly independent of it. The number of students reporting SAT scores in the Johns Hopkins talent search rose from its low of 396 in 1972 to approximately 27,000 in 1987 (CTY, 1987).

500-800 or 700-800 on SAT-M Before Age 13

About 19 percent of the boys and 8 percent of the girls in CTY's annual talent search score 500 or more on SAT-M before age 13 (CTY, 1987). From several converging lines of evidence over the years, we estimate that they are the top 1 percent of their age group with respect to mathematical reasoning ability. The average college-bound male high school senior scores 500, the average such female 453 (College Board, 1987).

We consider a youth as being exceptionally talented quantitatively if he or she scores at least 500 on SAT-M before age 13, but the SAT score scale runs much higher, to 800. About 6 percent of college-bound male twelfth-graders score 700 or more, and 2 percent of college-bound female twelfth-graders score in that range. To score 700 or more on SAT-M before age 13 seems a phenomenal feat, rarely accomplished because such a pupil is not likely to have studied much mathematics in school. Yet, even in SMPY's small first talent search in 1972, two of the students scored above 700. There were some 700-800M scorers in each subsequent talent search, about 12 times as many males as females (Benbow & Stanley, 1983b).

These observations led SMPY to a systematic national three-year search to create a special "700-800 on SAT-M Before Age 13 Group" to be helped educationally and studied. It used the November 1980 through October 1983 administrations of the SAT across the country by the Educational Testing Service as the time frame in which to search for $\geq$700M boys and girls born not earlier than 1968. About half of the qualifying youths located came through CTY's annual Tal-

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ent search conducted by William G. Durden, the Midwest talent Search conducted by Joyce VanTassel-Baska from Northwestern University, searches in Illinois conducted by Sandra Schmulbach, the Project for the Study of Academic Precocity search of the West conducted by Sanford J. Cohn from Arizona State University, and the Talent Identification Project conducted by Robert N. Sawyer from Duke University. The other half came directly to our attention via various types of publicity the search attracted—in newspapers, magazines, and by word-of-mouth.

Two hundred sixty-nine boys and 23 girls were identified, a sex ratio of 12:1 (see Benbow & Stanley, 1983b). They reside in 30 states, the District of Columbia, Canada, and Guatemala, as follows: California (44); Maryland (42); New Jersey (37); New York (26); Michigan and Pennsylvania (20 each); Virginia (16); Illinois (15); Ohio (12); Arizona and Massachusetts (7 each); Connecticut and Washington (5 each); Delaware and Kansas (4 each); Indiana, North Carolina, Tennessee, and Wisconsin (3 each); Oregon and Texas (2 each); and 1 each from Alabama, Alaska, Canada, D.C., Florida, Georgia, Guatemala, Hawaii, Iowa, Maine, Missouri, and New Hampshire.

This type of search, which is continuing,[2] does not uncover nearly all the persons who would have qualified if they had taken the SAT-M young enough. Our best estimate from results of the annual regional talent searches is that about 1 in 10,000 12-year-olds could qualify. At this rate, fewer than 400 are born each year in the United States. Thus, with respect to mathematical reasoning ability, these are the top one-hundredth of 1 percent of that age group, undoubtedly the most quantitatively apt set of youngsters ever identified. If other abilities and their environmental influences are favorable, these young students seem to have the potential to become the nation's superstars in pure and applied mathematics, computer science, electrical engineering, physics, and other fields that depend heavily on great quantitative aptitude. Quite a few of the 292 appear well on the way toward excellence in such fields.

Also, we know the accomplishments thus far of some 700M scorers from earlier talent searching. For example, the very first two, from the 1972 talent search, received Ph.D. degrees at age 24, one in computer science from Cornell University and the other in mathematics from the Massachusetts Institute of Technology. Two from that first search who had scored a little below 700 also received Ph.D. degrees at age 24, in computer science and theoretical plasma physics, respectively, from two of the country's greatest universities.

Other Characteristics of the 700-800M Group

After that general background, let us go to certain statistics that describe the group better. All of the qualifiers scored at least 700 on SAT-M before age 13, or had to earn an additional 10 points for each month or fraction of a month he or she was beyond the 13th birthday when tested. The average age of the boys when they qualified on SAT-M was 12.5 (s.d. 0.59). For the girls these statistics were about the same, 12.7 and 0.64.

It is clear that these students are more precocious mathematically than verbally. The means and standard deviations of the two sexes on SAT-M, SAT-V, and TSWE are shown in Table 1. Even on SAT-V and TSWE, however, they scored far beyond the average college-bound high-school senior of their sex, being for both sexes on both tests in about the upper fourth or fifth of that norm group. The girls scored higher than the boys on each of the three parts: 5 points on SAT-M, 15 points on SAT-V, and the equivalent of 31 points on TSWE.

The two sexes had equally variable SAT-M and SAT-V scores, but the boys were far more variable on TSWE; the ratio of those variances was almost 2 to 1. No girl scored less than 40 on TSWE, whereas 8 percent of the boys did. Similarly, 30 percent of the girls but only 16 percent of the boys earned the highest possible score, 60, on TSWE. Clearly, these girls tend to be appreciably more knowledgeable than the boys about the use of commas, capitalization, tense and number of verbs, and other aspects of grammar and syntax. Educational Testing Service finds a similar sex difference among college-bound twelfth-graders (e.g., College Board, 1985). Also, see Lupkowski (1987).

Mediation of M Via V or RPM?

Variability of test scores can have more important consequences than their central tendency. The large standard deviations of the SAT-V scores, 94 for the boys and 93 for the girls, suggest that explicit selection on SAT-M restricts the *range* of verbal ability little or none. For these 292 students, all of whom scored 700-800 on SAT-M, it is 280-760. For

Table 1.
SAT Scores of the 700-800M Group

Gender	SAT-M			SAT-V			TSWE		
	Mean	%ile*	S.D.	Mean	%ile*	S.D.	Mean	%ile*	S.D.
Male	730	96	26	514	74	94	51.5	74	7.9
Female	735	99+	26	529	81	93	54.6	81	5.8

* Percentile rank of mean for same-sex college-bound high-school seniors (College Board, 1987)

[2] Please see the Appendix for an explanation of eligibility rules.

comparison, in CTY's annual talent search the typical standard deviation of SAT-V scores is approximately 75 (CTY, 1987). Even the variance of the College Board's SAT population for the entire country over several forms of SAT-V during a given year is only 42 percent greater for males and 37 percent greater for females than the variances of the SAT-V scores of these high-SAT-M youths.

A major consequence of this huge range of SAT-V scores is that the discrepancy for a given individual can be large. One of SMPY's best mathematics students scored 760M and 310V at age 12 the second time he took the SAT, a 3.5-standard-deviation discrepancy. The eight-year-old in Australia scored 760M and 290V. A year later his V-score had risen to 380, still 134 points less than the mean for boys shown in Table 1. At that rate of increase, however, he would approach Harvard's average at age 12 and score 800 by age 14 (Gross, 1986).

A 12-year-old scored 720M and 750V. He was a much slower learner of mathematics than the 760M 310V 12-year-old. It seems likely that there is a "hidden variable" essential for learning mathematics from algebra through elementary calculus fast and comfortably at an early age. Sheer high IQ alone is not sufficient. SMPY has observed repeatedly that non-verbal reasoning ability of the sort measured by the advanced (36-item) form of the Raven Progressive Matrices (R) also seems important.

For example, the 380V Australian 9-year-old scored 32 points on R in about 45 minutes; the average British university student scores 21. Also, the boy did not miss any of the 4 most difficult items, and quickly corrected his four errors when told which of the 8-option items he had marked incorrectly (Stanley, 1986).

Thus, in assessing the cognitive abilities of a mathematically highly precocious youth one needs to know at least his or her M, V, and R scores. All three may be high, or M and V may be high and Raven fairly low. It is unlikely that M will be extremely high but *both* V and R extremely low. Either good verbal or good Raven ability appears needed to produce a high-M scorer at an early age.

This triadic relationship, which seems to imply differential influences of crystallized vs. fluid intelligence (e.g., Horn, 1976) at age 12, is chiefly conjecture at present. SMPY's researchers have not yet administered the advanced form of the Raven Progressive Matrices to enough high-M high-V vs. high-M low-V scorers to be sure the hypothesis holds up. It warrants further study.

The 292 vary greatly in ethnicity and national origin. Two are black males. Twenty-two percent are of Asian parentage, chiefly Chinese and mostly first-generation Americans, compared with the 1.6 percent of Asian Americans of their background in the U.S. (Moore & Stanley, unpublished). Parents of the group are well educated (see Table 2), averaging about a master's degree for the fathers and a bachelor's degree for the mothers. The fathers have nearly 3½ times as many doctorates as the mothers. The girls' parents have 75 percent more doctorates than the boys', which may help explain the already-noted somewhat higher SAT-V and TSWE scores of the girls, compared with the boys.

Table 2.
Educational Level of Parents of the 700-800M Group (Percentages)

	Father of		Mother of	
Level	**Boys**	**Girls**	**Boys**	**Girls**
Doctorate or equivalent	43	74	12	22
Master's degree	19	17	24	43
Bachelor's degree	25	4	40	22
Two-year degree	1	0	5	4
Some college	5	0	9	4
Technical school	1-	4	3	0
High School graduate	3	0	5	4
Less than high school	1-	0	1	0
Not ascertainable	3	0	2	0
N	269	23	269	23

The fathers' occupational status runs the gamut from quite low to extremely high, but is consistent with their average educational level. Neither the fathers' nor the mothers' occupational status differs much according to the sex of their child.

Parents had married rather assortatively; the educational level of the boys' parents correlated .58, exactly the same figure that Benbow and Stanley (1980) found for the 873 participants in SMPY's 1976 talent search. It was .50 for the parents of a comparison group of 92 participants in the talent searches who had scored at virtually the chance level on both M and V (personal communication from Camilla P. Benbow of Iowa State University). For the 23 700M girls of the present study, parents' education correlated .77, not significantly different statistically from the boys' .58.

Of the six possible correlation coefficients among the three SAT scores for the two sexes, only the two for V with TSWE were of appreciable magnitude: .61 for boys and .83 for girls. The explicit restriction of range on M kept *its* correlation with V and TSWE, and probably almost anything else, low.

None of the three SAT scores related substantially to father's or mother's education level or occupational status. Because they had qualified for the "700-800 on SAT-M Before Age 13 Group," all 292 youths had extremely high mathematical reasoning ability, no matter what their parents' education and occupation might be. Nevertheless, the lack of correlation of education and occupation with V and TSWE is surprising. For the 507 boys and 366 girls in the 1976 talent search, Benbow & Stanley (1980) found 12 $\underline{r}$s ranging from .14 to .34 (median, .25) for the 2 x 2 x 3 matrix of correlations of SAT-M and SAT-V scores with the father's education, mother's education, and father's occupational status. They had no TSWE scores.

Older boys tended to score a bit better than the younger ones; age at time of the boys' qualifying on SAT-M correlated modestly but beyond the .05 level of statistical significance with SAT-M score (.14), SAT-V score (.21), and TSWE score (.14). Their age correlated non-significantly, however, with their fathers' education (-.08) and mothers' education (-.08). Because of the small number of girls, their respective rs (.20, .09, .00, -.11, and -.04) were not statistically significant.

Siblings

No sizable sex differences in sibling order were found. The girls averaged 1.2 siblings; 17 percent of them were only children. Seventy percent were the oldest. The boys averaged 1.4 siblings; 11 percent were only children. Sixty-three percent were the oldest.

Educational Acceleration

Over the years we have learned that youths who score extremely high on SAT-M tend to accelerate their grade placement in school considerably by the end of high school and college. In this study of the background of these students who qualified for the 700-800M group it is natural to wonder whether or not they were already appreciably accelerated when first identified. Although they were then the age of not more than seventh graders, we found that 48 percent of the boys and 65 percent of the girls were above that grade level, either by grade skipping or starting school young. The *mode* for the boys was seventh grade; for the girls it was eighth grade. It is not clear to what extent high test ability caused the acceleration. Instead, acceleration into higher subject matter may have increased the score. This is the familiar confounding of cause and effect.

A few of each sex were in the highest category, "Beyond 11th grade." For example, one boy received his bachelor's degree in mathematics, with high honors, at age 12 years 42 days. Another received his baccalaureate in mathematics before his 14th birthday.

When found, no girl was enrolled below the seventh grade, whereas 6 percent of the boys were in Grade 6 and one boy was in Grade 5. Imagine how an elementary school teacher must feel to have in his or her fifth-grade class a youngster who scores as high on SAT-M as the average Harvard freshman did at age 17 or 18! How could anyone expect such a teacher to be able to individualize instruction in mathematics sufficiently for such a mathematically gifted student?

The record score SMPY has found is 760 on SAT-M at age 8 the first time the SAT was taken by a Chinese-background boy, Terry Tao, in Australia (Gross, 1986; Stanley, 1986). A 7-year-old in California, also of Chinese ancestry, scored 670 his first try. Fortunately, both of these boys were allowed to move ahead much faster in mathematics than their agemates. Terry, born in 1975, is in mathematics and physics at a university near his home while remaining in high school for other subjects. He was a member of Australia's six-person high-school team for the International Mathematical Olympiad in 1986, winning a bronze medal in Warsaw a few days before his 11th birthday. A year later he won a silver medal.

Conclusion

Much can, and should, be done for youths this able. For 15 years SMPY has devised various educational procedures that vastly improve curricular flexibility and articulation of one level of a subject with the next. For example, highly able young students can learn much mathematics, biology, chemistry, physics, computer science, or other subjects in three or six summer weeks (see Benbow & Stanley, 1983a, and Stanley & Stanley, 1986). SMPY is cheered by its successes, and spurred on to greater efforts by the many obstacles that the age-in-grade Carnegie Unit lock step puts in the way of individualizing instruction of most intellectually highly talented youths, not just those who reason extremely well mathematically.[3]

Appendix

Search Under Way For Youths Exceptionally Talented Mathematically

SMPY conducts nationwide searches for the tiny fraction of youngsters 12 and under who demonstrate extraordinary mathematical reasoning ability.

The talent search—"700-800 on SAT-M Before Age 13" on the mathematical (M) part of the College Board's Scholastic Aptitude Test (SAT)—is designed to identify mathematically highly talented students and to help them enrich their educations. SMPY sends members of the group materials, especially including a long quarterly newsletter, suggesting how they can proceed faster and better in mathematics and related subjects. Also, from time to time SMPY obtains scholarships for pre-college summer experiences.

Julian C. Stanley, professor of psychology and director of the Study of Mathematically Precocious Youth (SMPY) at Johns Hopkins, and Camilla P. Benbow, now an associate professor of psychology at Iowa State University, instituted "700-800 on SAT-M Before Age 13" in the fall of 1980. During its first three years the search located nearly 300 boys and girls throughout the United States who scored at least 700 (attained by only the upper 6 percent of college-bound 12th grade males) on the mathematics portion of the College Board's Scholastic Aptitude Test (SAT-M) before the age of 13.

A graduated scoring system permits students to be eligible beyond their 13th birthday. After his or her 13th birthday,

[3] For details about the rationale of SMPY, see Stanley and Benbow (1986). For an extension to the People's Republic of China, see Stanley, Huang, & Zu (1986). On 24 October 1986, Mrs. Stanley and I met at the Shanghai Teachers University with 19 of the 21 People's Republic of China members of SMPY's "700-800 on SAT-M Before Age 13 Group." Further SAT-M testings is planned for Beijing, Shanghai, Tianjin, and Taipei (Taiwan), and perhaps for Cost Rica, Hong Kong, Japan, and Spain.

a student participating in "700-800M Before Age 13" must earn ten points above 700 for each month or fraction of a month, up to the maximum attainable score of 800 the day he or she becomes 13 years 10 months old.

Boys and girls who want to qualify for the 700M group should take the entire SAT—that is, the mathematics and verbal portions as well as the Test of Standard Written English—in their communities on a regularly scheduled testing date. A free practice booklet ("Taking the SAT") and SAT registration materials may be secured from the college counselor in any senior high school or by writing the Educational Testing Service, Princeton, New Jersey 08541. Those intending to take the SAT examination should study the first half of the practice booklet thoroughly and then take its practice test under timed conditions. For more practice, send $8.95 to ETS for a 300-page book entitled *Ten SATs*.

Students who qualify should send a copy of their SAT score report to Professor Julian C. Stanley, SMPY, 30 Shriver Hall, Johns Hopkins University, Baltimore, MD 21218.

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