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USING THE SAT-M TO IDENTIFY THE MATHEMATICALLY TALENTED IN SINGAPORE[1]

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Abstract

Experiences by the Study of Mathematically Precocious Youth (SMPY) at Johns Hopkins University indicated that the mathematical section of the College Board's Scholastic Aptitude Test (SAT-M) is an excellent measure of mathematical ability for youths below 13 years of age. In an attempt to search out the mathematically talented in Singapore, the SAT-M was administered to 2361 Secondary 1 students (equivalent to Grade 7) from 8 good schools. STEPWISE regression identified performance in primary level Mathematics as the major predictor of the SAT-M. The other significant predictors were stream, primary level English grade, gender and language spoken at home. Seven boys and a girl scored above a standard score of 700M (proportion of 1:4600 in the Secondary 1 cohort). These students were interviewed to explore their family background, educational level of parents, interests and career aspirations.

INTRODUCTION

Experiences by the Study of Mathematically Precocious Youth (SMPY) at Johns Hopkins indicated that the mathematical section of the College Board's Scholastic Aptitude Test (SAT-M) is an excellent measure of mathematical reasoning ability (Benbow &

[1] Paper presented at the International Test Commission's conference on Test Use with Children and Youths: International Pathways to Progress, Oxford, June 27 - 30, 1993. I would like to thank Julian Stanley of Johns Hopkins University for encouraging me to do this study and ETS for giving me permission to use a SAT-M test in Singapore for research purposes.

Stanley, 1983; Stanley, 1986a; Stanley & Benbow, 1986). In the United States, the average college-bound male students scored 500 on the SAT-M while the average female students scored 453 (College Board, 1987). About 6% of college-bound males and 2% of college-bound females scored 700 or more on the SAT-M. The SMPY, in systematic national searches in the United States since 1972, using both the SAT-M and SAT-V, found boys below 13 years of age scoring at least 700 on the SAT-M. Benbow and Stanley (1983) found that most of these grade 7 students had not received formal training in algebra or abstract mathematics. As they had not been exposed to the content of the test, they had to figure out by themselves how to solve the problem. Stanley (1988) estimated that these boys comprised the top one hundredth of 1% in terms of their age group for mathematical reasoning ability.

The SMPY was designed to identify gifted youths who reasoned exceptionally well mathematically and to provide them with better opportunities to develop their already exceptional skills. It was guided by a four-D model: a discovery phase to identify the mathematical talent; a description phase to test the identified students further, affectively and cognitively; a development phase to encourage the students to select special educational opportunities provided for them; a dissemination phase to publicise the principles, practices, programs and techniques of SMPY (Stanley & Benbow, 1986; Benbow, 1986).

SMPY had also been examining the characteristics of the talent search participants. Moore and Stanley (1988) found that Asian Americans had 22% representation in their sample of 292 mathematically precocious youths, despite 1.6% representation in the population (Stanley, Huang and Zu, 1986). As the largest percentage of the Asian Americans were of Chinese origin, Stanley (1986b) and Stanley, Huang and Zu extended the search of mathematically talented students to China. They found 15 boys and 6 girls under the age of 13 (out of 160 boys and 119 girls in the most outstanding schools in Shanghai) scoring at least 700M. The proportion of Chinese students who scored above 700M appeared to be higher than that of the talent searches in the United States.

As Singapore has a large ethnic population of Chinese (about 75% of its population), this study extended the use of the SAT-M in Singapore to study the mathematical ability of a sample of top students and to identify mathematically talented pupils, particularly those under 13 years of age. The mathematical ability of the sample will be examined in terms of differences in gender, age, stream, socio-economic status, language spoken at home and performance in primary level Mathematics and English. In addition, the group of mathematically precocious students (under 13 years of age with standard scores of at least 700M) would be interviewed to explore their family background, educational level of parents, interests and career aspirations.

METHOD

Instrument and Sample

The SAT-M, a test of mathematical reasoning, is designed as part of the SAT taken mainly by twelfth-grade students in the United States for admission to colleges. A candidate needs some knowledge of algebra and geometry to take the test effectively. For this study, the SAT-M was administered in May and June 1992 to Secondary 1 (equivalent to Grade 7) students in 8 schools in Singapore. These schools take in the top 10% of the students in the cohort, based on results from the Primary School Leaving Examination (PSLE). They are among the top 25 secondary schools in Singapore as listed by ST Schools 100, the Straits Times Guide to Secondary Schools (The Straits Times, August 1992).

The sample of 2361 students, comprising 6.5% of the Secondary 1 cohort of 36500 students, was made up of 48.4% males and 51.6% females. Half of the sample (50.2%) were 12 years old, 2.9% of the sample were 11 years old, and the rest (46.9%) were 13 years old. In terms of socio-economic (SES) groupings, using housing as a proxy, 12.1% were from the low SES group, 57.9% from the middle SES group, and 30.0% from the high SES group. All subjects used English as a first language in schools and their mother tongue mainly as a second language. At home, 52.1% speak mainly English,

45.7% speak mainly Mandarin or chinese dialects, while 7.6% speak either Malay or an Indian language.

After the PSLE, students are selected into the Gifted, Special, Express and Normal streams of the secondary school (Ministry of Education, 1986). Students in the top 10% of the cohort can opt to be in the Special stream and study both English and Chinese at the first language level. Students in the top 40% of the cohort are channelled in the Express stream while the rest of the students are placed in the Normal stream. Students in the top 2% of the cohort can be selected into the Gifted stream through additional tests (Phua, 1983). In the sample, 10.0% were from the Gifted stream, 34.3% were from the Special stream and 55.7% were from the Express stream.

FINDINGS AND DISCUSSION

Data

The summary statistics of the sample, by gender, stream and schools, are shown in Table 1. The boys had significantly higher mean scores than the females, $F(1, 2359) = 110.6$, $p < .001$. Students from the Gifted stream had significantly higher mean scores than students from the Special and Express streams, $F(2, 2358) = 342.23$, $p < .001$. There were significant differences between the mean scores of the different schools, $F(7, 2353) = 342.23$, $p < .001$. The mean of the SAT-M students in the 8 schools ranged from 425.42 to 550.48.

Insert Table 1 about here

Table 2 displays the proportion of male and female students in the Singapore sample at various cutting scores of the SAT-M by age groups. Generally the 12-year-olds performed as well as the 13-year-olds. According to Stanley (1988), 12-year-olds and

under, scoring at least 500M, were considered as talented quantitatively. Focusing on this sample of 12-year-olds and under, the male-female ratio of the Singapore sample was compared with a similar sample of American students in the same age group from Lubinski and Benbow (1992). Table 2 shows that 422 Singapore students (0.012% of the cohort) scored at least 500M; the gender ratio was 1.45:1, compared with 2:1 for the American sample. For scores of at least 600M, there were 69 Singapore students (0.0019% of cohort). This indicated a gender ratio of 2.63:1 compared with the American ratio of 4:1. Eight Singapore students (0.00019% of cohort) scored at least 700M; the male- female ratio was 7:1 versus 13:1 for the American youths. The gender ratio for a similar group of students from China was 4.2:1 (Stanley, Feng and Zu, 1989). These findings will be discussed below.

Insert Table 2 about here

Characteristics of the Sample

The characteristics of the Singapore sample as a whole was then examined. STEPWISE multiple regression analysis was carried out to explore the extent to which gender, age group, stream, primary level Mathematics grade, primary level English Grade, SES and language spoken at home were predictive of SAT-M scores. In this procedure, STEPWISE in SAS (SAS Institute Inc., 1985), variables were added one by one to the model, as in the forward selection method, with the F statistic for the added variable to be significant at a certain level. After a variable was added, the stepwise procedure then looked at all the variables already included in the model and deleted any variable that did not satisfy the identified significant level. The stepwise procedure continued until no more variables could be entered or removed (Kleinbaum and Kupper, 1978).

The results of the STEPWISE procedure, presented in Table 3, established that primary level Mathematics grade, stream, primary level English grade, gender and langauge

spoken at home were significant predictors of the independent variable, SAT-M. The Mathematics grade, as expected, was the major predictor of SAT-M, contributing 24.0% to the total variance. Stream contributed another 10.7%; students in the Gifted stream had significantly higher mean scores than students in the Special and Express streams. Seven out of the eight students, scoring at least 700M, were from the gifted stream.

The other significant predictors, the English grade, gender and language spoken at home accounted for an additional 4.7% of the total variance. The English grade and home language proved to be significant predictors as students who were weak in English or did not speak English at home, might have difficulties comprehending the mathematical problems. As for gender, boys had significantly higher mean scores than girls. Similar gender differences had been found in Stanley (1988), Benbow (1992) and Lubinski and Benbow (1992). However, as shown above, the Singapore sample had a smaller gender ratio for students under 13 years of age at each of the cutting scores of SAT-M ($\geq$ 500M, $\geq$ 600M, $\geq$ 700M). Currently, in Singapore, both boys and girls have equal opportunities to take mathematics and advanced mathematics courses at the secondary level. The better schools are single sex schools; 4 schools in the sample are all-boys schools while the other 4 are all-girls schools. As indicated in Riordan's (1990) review of single-sex schooling, single sex education is advantageous for females. She found, from analysis of data collected as part of a longitudinal study, that there was little difference in short-term outcomes for boys in single-sex schools. However, girls in single-sex schools showed an average test score advantage of one-half grade equivalent over girls in mixed-sex schools.

Insert Table 3 about here

Characteristics of the 700M-800M Group

Group interviews were carried out with students, under the age of 13, identified as mathematically precocious: 6 of the 7 boys who scored at least 700M (one boy was not available for interview) and a girl who scored 720M. The youngest boy was eleven years of age. The interviews focused on family background, educational level of parents, their own interests and career aspirations.

Generally the students were enthusiastic, spoke well and were very forthcoming with their ideas. All were confident and well adjusted and has always done well in mathematics. The boys' strong interest in Mathematics arose from primary school days; some started on their own while others were motivated by their parents or teachers. One boy was motivated by his sister ("my sister gave me mathematics puzzles to solve during kindergarten"). The boys were also interested in science, science-related subjects and computers.

All the students felt they were better in the science subjects. They were all very high achievers and preoccupied with marks and grades. The subjects that they expressed non-confidence in correlated with the marks that they got e.g. geography and literature. They felt that it was difficult to study geography in Singapore because it was such a small place with few illustrations of geographical phenomena. They felt that marking schemes for geography and literature were strict and they were not too sure what the teachers were looking out for. Despite their interests in Maths, the boys had other interests as well: one boy was interested in Music and the choir, two other boys were interested in chess and soccer.

All the boys interviewed (except for one) were in training for mathematics competition. Although the girl liked 'challenge' problems in Mathematics, she was not interested in being 'groomed' for mathematics competitions. There are several mathematics competitions in Singapore organised by secondary schools, junior colleges,

the local university as well as an Australian university. The best students identified through these competitions will then attend training for the Mathematics Olympiad.

The boys were interested in doing science projects; currently, most of them were participating in an INNOVATION Programme set up for gifted pupils. Under the mentorship of lecturers from a local university, the boys were doing practical-based projects such as robotics, rotary wardrobe (designs that are of practical use). The boys were excited with the projects. The girl did not join the INNOVATION Programme, despite given the opportunity. She was doing a project on churches. The boys have done projects on non-science related subjects as well. Last year one of the boys did a project on what was then known as the Soviet Union: a write-up on the history of soviet union, a survey on what people thought of the soviet union and an interview with a political science professor and an ambassador.

The parents of these 7 students were not all highly educated. The fathers' average educational level was a bachelor's degree (3 with secondary education, 3 with bachelor's degrees and 1 with PhD) and the mothers' average educational level, about secondary education (2 with primary education, 2 with secondary education, 3 with bachelor's degrees). Possibly the mothers were less educated than the fathers, because at that time in Singapore, girls had less opportunities for college education. Currently both boys and girls have equal opportunities for education in both schools and colleges.

A study by Lupkowski and Stanley (1988), extension of a study by Moore and Stanley (1986), revealed that the parents of a similar sample of mathematically precocious American students were very highly educated. About half of the sample had fathers with PhD (75% for Asian Americans) and mothers with either bachelor's or master's degrees. More than 80% of the sample, both Asian Americans and others, had parents with at least a bachelor's degrees. Similarly, Stanley, Huang and Zhu (1986) reported that about 80% of their Chinese sample (80 boys and girls from Shanghai in this mathematically precocious group) had parents with college education. The results of the American and Chinese

groups were not really reported for comparison with the Singapore group, but mainly for interests. The Singapore group was far too small (N = 8); the study was constrained by the small size of the Singapore population, a total of 3 million people, about the population of a city elsewhere in the world.

Both the Singapore boys and girls were inclined towards careers in Mathematics and Science; two of the boys want to teach mathematics (one at university level), two wanted to do medicine, two, engineering. One of the boys who wanted to be an engineer would like to be a professional chess player as he was very interested in chess. The girl wanted to do something in Science. In Lupkowski and Stanley's study, nearly two-thirds of the boys and one-third of the girls selected the natural sciences. More girls selected medicine (37% of the Asian American girls and 22% of the other American girls). More of the non-Asian American girls selected law, humanities or business. With the small Singapore sample, it is not possible to compare. However, generally in Singapore, girls do select careers in mathematics and science because of the emphasis of technology and innovation in the industrial growth of Singapore. Furthermore Singapore aims to be an "intelligent" island where diverse transactions can be effected instantaneously and efficiently (Singapore, 1991).

CONCLUSION

Experiences in Singapore, just as those in China, showed that the SAT-M is not culture-bound and does not necessarily favour "the sort of Americans who construct it and a type of mind especially familiar with multiple-choice items" (Stanley, Feng and Zhu, 1989, p. 33). Students, below 13 years of age, scored as well in the SAT-M as a similar group of students in the U.S. Zak, Benbow and Stanley (1983) found that, besides general intelligence, mathematical reasoning is an important cognitive aptitude associated with success in learning mathematics and science-related subjects. As recommended by Stanley, Huang Zu (1986), there is a need to help high scorers in the SAT-M move ahead in mathematics and science-related subjects at levels commensurate with their

mathematical abilities.

There appeared to be proportionately less mathematically precocious students in Singapore or the U.S., compared with China. Stanley pointed out that this could be because the criteria to select student to sit for the SAT was "tough" (Johns Hopkins Magazine, 1987). Chinese investigators had selected the best students in the best schools. In Singapore, the study might not have identified all students who could have qualified for the 700M score as the study was carried in only 6 of the top 10 schools; the other 2 schools were ranked in the 20th and 21st positions by the ST Schools 100, the Straits Times Guide to secondary schools (The Straits Times, August 1992). There is a need to extend the study to more schools in Singapore so that more definitive comparisons can be carried out with the U.S. and China.

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TABLE 1. Summary Statistics of the SAT-M by Gender, Stream and School.

Group	Subgroup	N	Mean	SD	Maximum	Minimum
Sample		2361	478.51	77.32	750.00	200.00
Gender	Males	1142	495.03	79.93	750.00	250.00
	Females	1219	463.04	71.43	720.00	200.00
Stream	Gifted	236	589.63	72.44	750.00	240.00
	Special	810	482.50	58.54	680.00	370.00
	Express	1315	455.75	70.22	700.00	200.00
Schools	School A	422	493.94	77.64	720.00	200.00
	School B	315	550.48	75.20	750.00	340.00
	School C	145	510.28	79.65	690.00	350.00
	School D	325	425.42	63.26	610.00	230.00
	School E	208	443.85	54.35	600.00	290.00
	School F	384	491.85	59.08	680.00	330.00
	School G	298	433.09	62.90	660.00	250.00
	School H	264	476.02	55.14	610.00	320.00

TABLE 2. Students with SAT of 500M - 800M by Gender and Age

SAT-M	GENDER	AGE			TOTAL
		11 years	12 years	13 years	
≥ 500M	Male	9	241	213	463
	Female	4	168	151	323
≥ 600M	Male	3	47	57	107
	Female	-	19	27	46
≥ 700M	Male	1	6	4	11
	Female	-	1	-	1

TABLE 3. Stepwise Regression on the SAT-M Test

	MODEL				
Dependent Variable	Independent Variable	Regression Coefficient	Partial R^2	F Test	Model R^2
SAT-M	P6 Mathematics Grade	-33.79	0.2398	679.90***	0.3937
	Stream	-35.65	0.1070	352.77***	
	P6 English Grade	-24.01	0.0310	107.39***	
	Gender	-20.93	0.0144	50.81***	
	Home Language	-5.36	0.0015	5.33*	

* $p < 0.05$
** $p < 0.01$
*** $p < 0.001$