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SPEED OF INFORMATION PROCESSING IN ACADEMICALLY GIFTED YOUTHS AND THEIR SIBLINGS

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Summary—Academically gifted children and their full siblings were compared on the Raven Matrices, and reaction time (RT) on an elementary cognitive task—the Semantic Verification Test (SVT). Significant differences between the gifted and their intellectually less gifted siblings and the significant correlation between RT and Raven scores *within* as well as *between* sibships indicate that the correlation of RT with psychometric *g* is not entirely attributable to shared environmental influences.

INTRODUCTION

A correlation between speed of information processing, as measured by reaction time (RT) on various elementary cognitive tasks (ECTs), and conventional tests of intelligence, or psychometric *g*, is now well established (Eysenck, 1987; Jensen, 1982; Vernon, 1987). A strong item of evidence for the relationship between RT and *g* is the mean difference in RT between groups that differ, on average, in *g* or its educational or occupational correlates. For example, Cohn, Carlson and Jensen (1985) found large mean differences in RT on a variety of ECTs between academically gifted children and unselected children of the same age, and Jensen, Larsen and Paul (1988) found marked differences in RT on a Semantic Verification Test (SVT) between U.S. Navy recruits and university students. Because the contrasted groups in these studies were not matched on socioeconomic status (SES) and cultural background, the question is raised whether the observed group differences in RT, and consequently the correlation between RT and *g*, are chiefly attributable to environmental effects associated with SES and cultural differences in family background.

Jensen (1980) has proposed that the main effects of environmental differences between families can be controlled almost completely by obtaining data on full siblings who have been reared together. The advantage of using siblings in correlational research rests in the capacity for analyzing correlations into *within*- and *between*-family components. The between-families (BF) correlation reflects genetic and environmental factors that differ *between* families but not among siblings *within* families. The within-family (WF) correlation reflects genetic and environmental factors that differ among siblings. The WF variance cannot reflect main effects of cultural and SES differences in the case of siblings reared together in the same family, as siblings share those aspects of family background that define social and cultural environment. As has been explicated in greater detail elsewhere (Jensen, 1980), the population correlation between two variables, x and y, is theoretically composed of two components, a BF component and a WF component. The BF correlation and the WF correlation can each be empirically calculated separately. WF correlation refers to r_{xy} obtained *within* a family, that is, a WF r_{xy} is the correlation between traits x and y in the n siblings in the family. Calculation of a BF correlation is achieved by correlating the mean of n siblings on trait x with their mean on trait y over N families. This is best done using the one pair of siblings nearest in age from each family. The WF correlation, obtained from the same sample of sibling pairs, is calculated as the correlation between the signed difference between the siblings (older minus younger) on trait x and on trait y. If the BF correlation is not appreciably larger than the WF correlation (allowing for the statistically inevitable difference in their reliabilities), it means that

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the main effects of social class and cultural factors do not account for the correlation and that these aspects of family background are negligible source of variance in one or both of the correlated variables.

The purpose of the present study is to determine whether academically gifted children and their less gifted full siblings differ in the speed of information processing variables derived from the SVT, and to compare the WF and BF correlations between the SVT variables and psychometric *g* as measured by the Raven Matrices.

METHOD

Subjects

Along with their siblings closest in age, 36 academically gifted students were recruited as volunteers from participants in the Center for Talented Youth's (CTY) 1983 and 1984 Talent Searches. Of the 36 sibling-pairs, 12 were brothers, 9 were sisters, and 15 were brother–sister.

Gifted (*G*). The Gifted (G) group had a mean age of 14 years, 10 months (SD = 6 months). Qualifying for the CTY Talent Search required that students be in the top 3% of their age group with respect to psychometrically assessed reasoning abilities. Participating in the Talent Search meant taking the College Board's Scholastic Aptitude Test (SAT) as seventh graders (or in higher grades, but of seventh-grade age). The SAT is a test of mathematical and verbal reasoning abilities and writing skills normally given to college-bound high school juniors and seniors. At junior-high age (about 14 years), students in the G group significantly outperformed the norm group of able students 5 years older than those on SAT-M. By virtue of their performance on the SAT, the members of the G group can be considered among the top 1% of their age group in academic aptitude. This is roughly equivalent to IQs >135.

Siblings (S). The Sibling (S) group included the full siblings who were closest in age to their respective gifted (G) brothers or sisters. The S group had a mean age of 13 years 4 months (SD = 2 years, 9 months).

Because the members of the G group were all seventh-grade students, their siblings unavoidably varied more in age, and averaged 18 months younger than the G group.

Psychometric tests

The Raven Standard Progressive Matrices (SPM) and Advanced Progressive Matrices (APM) were individually administered without time limit to *S*s in groups G and S.

Speed-of-information-processing

*S*s in groups G and S took the three-letter version of the SVT (Jensen *et al.*, 1987), a reaction time task in which a single statement describing a permutation of ABC (e.g. "A before C," or "A not before C") is followed by a sequence of letters (e.g. "BCA"). The *S* indicates, by pressing one of two buttons, whether or not the sequence of letters is true or false relative to the description of the letter pairs preceding it.

The apparatus consists of a response console with a alphanumeric display screen; the response console has a 'home' button (black) and two response buttons (one red, one green). The microswitch buttons are 1 inch in dia, and form a triangle, with the centers of the buttons 3–3/4 inches apart; the 'home' button is nearest the *S*. The response console is pictured elsewhere (Jensen, 1985, p. 87). The console was interfaced with an Apple II+ microcomputer (48 K), and the entire test was programmed on a diskette and administered automatically, paced by the *S*'s pressing the 'home' button.

The sequence of events is as follows. The *S* presses the 'home' button and holds it down. A 'sentence' (e.g. "C before A") appears on the display screen for 2 sec. After a random interval of between 0.5–1.5 sec, a sequence of three letters appears, and the *S* responds by moving his or her finger from a 'home' button to one of two pushbuttons designated *True* or *False* according to whether or not the letter positions correspond to the descriptive statement. The RT is the interval, measured in msec, between onset of the letter-pair and the *S*'s releasing the 'home' button in order to touch the *True* or *False* button. The movement time (MT) is the interval between releasing the 'home' button and touching either the True or False response button. The task is *S*-paced, each

Table 1. Differences between G and S on psychometric and chronometric variables age-standardized scores are scaled as raw scores

Variable	G Mean (SD)	S Mean (SD)	Correlated t test	Effect size
SPM	55.5 (1.5)	51.1 (4.6)	4.49**	1.06
APM	28.2 (2.6)	23.0 (6.0)	4.63**	1.09
MSVT RT (msec)	1050.7 (187.1)	1355.2 (436.7)	−3.86**	−0.91
SDSVT RT (msec)	414.9 (127.6)	609.3 (368.5)	−3.17**	−0.75
MSVT MT (msec)[a]	447.7 (121.8)	517.5 (178.8)	−1.81	−0.43
SDSVT MT (msec)[b]	202.7 (77.4)	353.6 (310.7)	−2.77**	−0.65
SVT% correct[c]	91.7 (6.1)	91.3 (4.8)	0.32	0.08

*$P < 0.05$, **$P < 0.01$.
[a]MSVT MT = Mean movement time on SVT.
[b]SDSVT MT = Standard deviation of MT on SVT.
[c]SVT % Correct = Percentage of correct responses on SVT.

trial initiated by the *S*'s depressing the 'home' button. There are six practice trials and 84 test trials, with every possible permutation of true 'sentence' types appearing an equal number of times in the same random order for all *S*s. (Full details of the SVT program will be provided on request.)

RESULTS

Differences between groups

In selecting academically talented students (G) and their siblings (S), we anticipated that the S group would be more intellectually able than average but less able than the G group. Table 1 summarizes the mean differences.

Because the G and S groups differ significantly in age, age-standardized scores* are used in all comparisons.

Psychometric variables. On the 60-item Raven SPM test, G outscores S significantly ($t = 4.49$, $P < 0.01$). The effect size is equivalent to $1.06s$, where s is the SD of the pooled G and S groups within each study. The G group scores slightly above the mean for undergraduates at the University of California, Berkeley (UCB), even though the members of the G group are about 6 years younger than the university students.

On the more difficult 36-item APM test, there is a similar significant difference ($t = 4.63$, $P < 0.01$), equivalent to $1.06s$.

Chronometric variables. Previous studies (Cohn *et al.*, 1985; Wade, 1984) have shown that gifted students perform faster on chronometric tasks, and demonstrate less trial-to-trial intraindividual variability in RT, than more typical youths. Intraindividual variability is measured as the SD of a *S*'s RT (or MT) over all trials; it is symbolized as SDSVT in Table 1 and Fig. 1. Corroborating past findings, the 36 G *S*s show significantly faster mean RT than their siblings, with an effect size of $0.91s$, and also show significantly less intraindividual variability in RT, with an effect size of $0.75s$. On MT, the G and S groups differ significantly (effect size $= -0.65s$) on the SD (intraindividual variability), but not in means, although the latter's effect size is $-0.43s$.

The G and S groups are compared with university students on the Raven APM and on the SVT in Fig. 1. Even though younger by about 6 years, the G group resembles U.C. Berkeley undergraduates on the more difficult APM. Two groups of UCB students are shown in Fig. 1, one composed of the 50 UCB undergraduates used to investigate the SVT (Jensen *et al.*, 1987), and another (totally independent) group of 300 UCB students (Paul, 1986). The S group scores lower than the G group and the UCB students, but nearly the same as the normative group of university students used by Raven (1965) to norm the APM. The S group must therefore be considered well above average in intelligence. On the RT variables, the G group resembles the 50 UCB students used in the Jensen *et al.* (1988) study more closely than the S group on both the mean differences

*All variables listed in Table 1 show a linear (first order) correlation with age. No significant higher (second or third) order correlations were found. Age standardization removes the linear component of the regression of a given dependent variable on age, leaving the variable uncorrelated with age. Age standardization was accomplished by calculating age-regressed scores, i.e. based on the regression of test score on age (in months), an expected score was calculated for each of the 72 *S*s, and the deviation of the observed from the expected score was transformed via Z scores to a scale having the same mean and SD as the original raw scores.

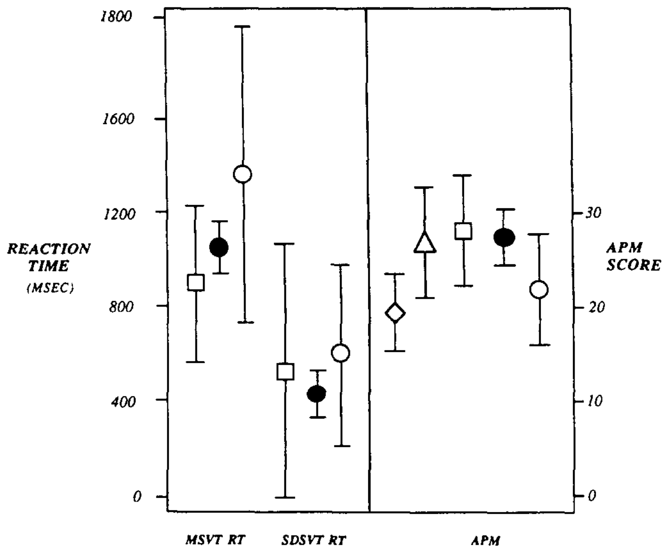

Fig. 1. Comparison of G and S groups with university students on chronometric variables, MSVT RT and SDSVT RT, and on Raven's APM. Age-standardized scores are shown for the G and S groups. SDs are depicted as whiskers on the dot-and-whisker plots. ●, 36 gifted (G) students; ○, 36 siblings (S); □, 50 VC Berkeley students (Jensen et al., 1987); △ 300 UC Berekeley students (Paul, 1986); ◇, 170 university students (norm group; Raven, 1965).

(mean reaction time, on the SVT; MSVT RT), and intraindividual variability (standard deviation of reaction time on the SVT, SDSVT RT).

Correlations between psychometric tests and processing variables

Correlations between RT (and intraindividual RT variability) on the SVT task and scores on the psychometric tests are shown in Table 2. The overall and within-group correlations are generally near the top of the range of correlations found in a previous study of the gifted (Cohn *et al.*, 1985). The only correlations that deviate markedly below prior findings are those between the Raven SPM test and the RT within the G group (Table 2). The unusually low correlations (−0.16 and −0.15) are undoubtedly due to the fact that the SPM is too easy a test for the G group, and the resultant severe restriction of range on SPM scores severely limits the correlation coefficient. Both the BF and WF correlations between the psychometric test scores (SPM and APM) and the chronometric variables [mean response latencies (MSVT RT) and intraindividual

Table 2. Correlations between performance on Raven's SPM and APM, and chronometric variables for G group, S group, and combined (G + S) groups. Calculations based on age-standardized scores

	Combined ($N = 72$)	Gifted ($N = 36$)	Sibling ($N = 36$)	WF[a]	BF[a]
Correlation of SPM with:					
MSVT RT[b]	−0.50**	−0.16	−0.42*	−0.37* (−0.44**)	−0.41* (−0.49**)
SDSVT RT	−0.49**	−0.15	−0.41*	−0.35* (−0.44**)	−0.43* (−0.54**)
MSVT MT	−0.18	0.03	−0.11	−0.00 (−0.00)	−0.19 (−0.21)
SDSVT MT	−0.40**	0.04	−0.32	−0.29 (−0.32)	−0.30 (−0.34)
Correlation of APM with:					
MSVT RT[b]	−0.53**	−0.43*	−0.42*	−0.29 (−0.34*)	−0.54* (−0.63**)
SDSVT RT	−0.57**	−0.60**	−0.47**	−0.39* (−0.48**)	−0.58* (−0.71**)
MSVT MT	−0.20	−0.16	−0.10	−0.6 (−0.07)	−0.29 (−0.32)
SDSVT MT	−0.43**	−0.18	−0.37*	−0.22 (−0.24)	−0.46** (−0.51**)

*$P < 0.05$, **$P < 0.01$.

[a]The WF and BF correlation coefficients were corrected for attenuation (based on KR-20 reliability coefficients), because the reliability of the difference scores required for the calculation of the WF r is lower than the reliability of the sibling mean used in the calculation of the BF r. The disattenuated correlations are shown beside them in parentheses.

[b]See Table 1 for the explanation of variables.

variability (SDSVT RT)] are significant and substantial. Correlations for mean MT are consistently small and nonsignificant, except for SDSVT MT (intraindividual variability of MT), which shows a significant BF correlation with the APM.

The sibling correlations themselves are not worth reporting. Because the highly selected gifted members of the sibling pairs represent the top 1% of the general population in intellectual ability, the coefficient of correlation between the gifted and their siblings would not be an estimate of any population parameter, and would have no genetical or general theoretical significance.

DISCUSSION

The SVT is so simple and virtually without any intellectual content except knowledge of the letters A, B, C, and of the relational words 'before', 'after', 'first', 'last', and 'between', that even the majority of average children in the third and fourth grades can do all the items without error (Jensen *et al.*, 1987). Hence, RT and the variability of RT over trials are the only reliable measures of individual differences yielded by the SVT in groups of older children or among gifted children. The fact that the average RTs to the SVT items are scarcely > 1 sec, attests to the extreme simplicity of the task. Yet, despite the quite highly restricted range of ability in the present samples, the correlations between the SVT and the Raven Matrices are all substantial and significant beyond the 0.01 level, averaging about −0.46 for mean RT and about −0.55 for the SD of RT (i.e. intraindividual variablility of RT over trials). The latter measure of RT in many different studies measuring RT in various elementary cognitive tasks has rather consistently shown higher correlations with psychometric *g* than does the mean or median RT itself. This suggests that the SD of RT is, in some way, a more fundamental measure of individual differences than is the average RT itself (Jensen, 1982, 1987).

The unique finding of the present study is that the mean RT and SDRT are both correlated with Raven Matrices scores *within* as well as *between* families, and the WF and BF correlations do not differ appreciably. This suggests that performance on both the SVT and the Raven Matrices is influenced little, if at all, by cultural and socioeconomic sources of variance that exist between families, at least within the range of interfamilial variation in the present sample. The gifted and their siblings differ almost as much as the SVT RT as in Raven scores. The average speed of information processing on the SVT is about 30% greater in the gifted than in their siblings, who show almost 50% greater intertrial variability in RT than the gifted probands.

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