Reaction Times and Intelligence

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A total of 205-nine-year-olds were tested on reaction times providing 12 reaction time (RT) parameters consisting of: movement times, decision times in simple, choice, and odd-man-out tasks, variabilities, and also on a number of intelligence tests measuring the major primary abilities. Virtually all the reaction time parameters were significantly correlated with psychometric intelligence at a magnitude of around 0.2. Factor analysis showed the existence of a general factor on which reaction time and psychometric tests were correlated. In addition, there were four primary factors of psychometric intelligence, movement time, reaction time, and the odd-man-out task. Broad similarities, and some differences, were found between the present results and those of a similar study by Buckhalt and Jensen (1989).

INTRODUCTION

The discovery by Roth (1964) of a positive correlation between intelligence and the speed of reaction in choice reaction time tasks has generated considerable research exploring this relationship. In general, subsequent work has confirmed that a significant association of the kind found by Roth does exist (Jensen and Munro, 1979; Jensen, 1982, 1987; Vernon, 1983; Frearson & Eysenck, 1986) although there have also been criticisms of the claim (Longstreth, 1984).

One of the significant developments in this field has been the breakdown of reaction times into four components which are generally designated: movement time (MT); simple reaction time (SRT); choice reaction time (CRT); and the variability of reaction times as measured by the standard deviation of the mean or median on a number of trials (RT-SD). It has generally been found among adults that more complex reaction times (e.g., choice RTs as compared with simple RTs) and variability are more highly correlated with intelligence than are movement times and simple reaction times, but, among children, these differences have not been so clearly established (Jensen & Munro, 1979; Buckhalt & Jensen, 1989). The findings in several studies that variability of reaction times has the highest correlation with intelligence has led some commentators to propose that the capacity for sustained attention is the underlying variable responsible for the association between reaction times and intelligence (Mackintosh, 1986).

A recent study by Buckhalt and Jensen (1989) makes an important contribution in this area by factor analyzing twelve parameters of reaction times and showing that three independent factors are present. They identify these as movement time, reaction time (i.e., speed of apprehension or decision time) and variability of reaction times. The isolation of a variability factor supports the contention that variability is a distinct component of performance on reaction time tasks independent of reaction time as

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such and movement time. It was considered that the Buckhalt and Jensen result is sufficiently important to justify an attempt at replication and this was the first objective of the study to be reported in this paper.

The second objective of the study was to examine the relationship between reaction times and the six major primary abilities originally identified by Thurstone (1938), consisting of reasoning; verbal comprehension; spatial, numerical, and perceptual speed; and fluency abilities. Hitherto, studies of the relationship between intelligence and reaction times have mainly employed only a general reasoning test, of which Raven's Progressive Matrices has been the most commonly used. It is possible that some of the components of reaction times might be a function of one or more of the established primary mental abilities rather than of general intelligence (Spearman's *g*). The most obvious hypothesis is that perceptual speed primarily is involved in reaction time tasks. We do not believe that this question has been investigated as yet.

Method

The subjects were 205 children (93 boys and 112 girls) attending primary schools in small country towns and villages in Northern Ireland. All the nine-year-olds in the schools were tested. The mean age was 112.4 months, standard deviation 4.1.

The Primary Mental Abilities Test For grades 4–6 (Thurstone, 1963) was administered. This consists of five subtests that measure reasoning, verbal, numerical, spatial and perceptual speed abilities. The test does not contain Thurstone's sixth major primary of fluency. Hence, two fluency tests were given. These were to write down as many animals and round objects as possible. Two minutes were allowed for each test and were scored for the number of acceptable words given (incorrect spellings were accepted).

Raven's Standard Progressive Matrices and Cattell's Culture Fair Test, Scale 2, Form A, were also given to provide generally recognized tests of general intelligence or Spearman's g. In Cattell's terminology, the Culture Fair Test is a measure of fluid intelligence.

The reaction times were recorded with an apparatus described by Jensen and Munro (1979). It consists of a black metal box with the top side pitched at a 20° angle. On the top surface of the box is a 15 cm. radius semicircle of eight plastic, 3/4-inch, microswitch pushbuttons which are lit from underneath. At the center of the semicircle, nearest the subject, is a black "home" button. Pressing the home button activates each trial which is programmed and timed by an Apricot microcomputer. Subject's data are recorded automatically on the working disk immediately after each trial. The apparatus measures reaction time (time between the onset of a stimulus light and release of the home button) and movement time (time between the release of the home button and depression of the response button). The consistency of response for reaction time and movement time is also measured as the standard deviation of responses across trials. Three conditions were employed in the reaction time experiment. In the first condition, simple reaction time was measured. Only one of the lights was employed and the others were masked. Sixteen trials were given, preceded by three practice trials (further practice may be given if necessary). In the second condition, choice reaction time was measured. All eight lights were employed. At each of the 16 trials (three practice trials) one of the lights came on at random. The third condition involved the use of the "odd-man-out" paradigm which was introduced by Frearson and Eysenck (1986). Thirty odd-man-out trials (six practice trials) were presented in two blocks of 15 trials with a rest of approximately one minute between them. In each of the trials, three of the eight buttons illuminated simultaneously and the subjects were asked to press the button which was farthest away from the other two (i.e., the odd-man-out). After the third condition, another 16 trials of the second condition were given. When errors occurred due to subjects pressing the wrong button, the trials were repeated at the end of the block of trials in that condition. If errors recurred on repetition, the trial was repeated until the correct response was made. In the first and second conditions, trials were logged as errors where the RT was less than 170 msec or greater than 999 msec or where the MT was less than 40 msec and greater than 999 msec. In the third condition, trials were logged as errors where the RT was less than 170 msec or greater than 1999 msec, and where the MT was less than 40 msec and greater than 999 msec.

The following five measures were obtained from the reaction time trials: movement times; simple reaction time; complex (3-bit) reaction time; odd-man-out reaction time; and the variability as measured by the standard deviations. Median times were taken, rather than means, to reduce distorting effects of exceptionally fast or slow times.

Results

Descriptive statistics giving means and standard deviations for all the reaction time measures are given in Table 1. The first six variables are the mean medians (mm). Each subject's median was obtained and the figure entered in the table is the mean of the medians. The second six variables are the intra-individual variations (IV) and consist of the standard deviations of the medians. The effect size is the sex difference expressed in standard deviation units, using the standard deviations for the entire sample. Thus, the largest sex difference is in movement time in the simple reaction time task: The figure 0.36 D indicates that the mean of boys is faster than that of girls by 0.36 of a standard deviation. This is the only statistically significant sex difference. We believe that a difference of this kind has not hitherto been obtained; most studies have not reported sex differences in reaction times.

The means and and standard deviations for the intelligence tests are set out in Table 2. It will be seen that there are no statistically significant sex differences in the three reasoning tests, i.e., the Progressive Matrices, and Cattell Culture Fair and the PMA reasoning. However, the girls obtained significantly higher means on fluency and the PMA verbal, numerical and perceptual speed tests, and on the total PMA IQ.

One of the main objectives of the study was to compare the relation of reaction time parameters to intelligence among children in Ireland with those found in the United States, and, in particular, with those in the Buckhalt and Jensen (1989) study.

TABLE 1
Mean Medians (MM) and Intra-individual Variation (SD) for Reaction Times and Movement Times by Sex

	Boys	Girls	Effect Size (D)	t
MM Simple RT	366.6 (65.8)	366.5 (53.4)	-0.00	0.01
MM Choice RT	466.7 (66.7)	472.3 (68.5)	-0.08	-0.59
MM Odd-man-out RT	882.2 (170.3)	920.8 (186.9)	-0.21	-1.55
MM Simple MT	206.4 (58.1)	227.2 (54.3)	-0.36	-2.63*
MM Choice MT	231.5 (65.0)	244.2 (56.0)	-0.21	-1.48
MM Odd-man-out MT	262.5 (97.0)	282.4 (91.2)	-0.19	-1.35
SD Simple RT	118.7 (34.3)	111.6 (30.3)	0.22	1.55
SD Choice RT	137.2 (23.2)	139.6 (24.5)	-0.10	-0.71
SD Odd-man-out RT	318.9 (79.2)	336.1 (84.0)	-0.21	-1.50
SD Simple MT	60.9 (22.9)	60.1 (21.7)	0.04	0.26
SD Choice MT	71.0 (25.0)	66.7 (19.1)	0.20	1.36
SD Odd-man-out MT	114.7 (51.4)	118.8 (46.5)	-0.08	-0.59

* Significant $p < 0.05$.

To facilitate the comparison, the correlations of the 12 reaction time parameters with the Progressive Matrices in the Buckhalt and Jensen study and in the present study are set out in Table 3 in columns 1 and 2, respectively. It will be seen that the results of the two studies are broadly similar, but the correlations in the present study are marginally more favorable to the existence of a positive association between reaction times and intelligence (the preponderantly negative signs in the correlations arise because fast reaction times are represented by low scores and these correlate negatively with high scores on the intelligence tests).

The principal features of interest in the comparison of the Buckhalt-Jensen results with those obtained in the present study are that in both studies the trend of the correlations is predominantly negative, indicating an association between fast reaction times, low variability and higher psychometric intelligence. This is the case with nine out of 12 correlations in the present study. Only three of the correlations are statistically significant in the Buckhalt-Jensen study as compared with 10 of the correlations in the present study, but this difference is largely due to the difference in the number of subjects (78 in the Buckhalt-Jensen study as compared with 205 in the present study). Taken as a whole, the magnitude of the correlations is approximately similar, five of the correlations being greater in the Buckhalt-Jensen study and seven in the present study. There are some differences of detail in the magnitude of the correlations

TABLE 2
Means (and SDs) for Intelligence Tests by Sex

	Boys	Girls	Effect Size (D)	t
Raven SPM Percentile	44.1 (29.3)	38.2 (25.3)	0.22	1.56
Catell culture fair IQ	93.9 (19.6)	94.2 (17.6)	-0.02	-0.13
Verbal fluency-animals	10.9 (4.3)	13.7 (4.6)	-0.60	-4.44*
Verbal fluency-things	5.9 (2.8)	7.0 (2.7)	-0.39	-2.98*
PMA Verbal IQ	98.6 (18.4)	103.3 (15.3)	-0.28	-1.99*
PMA Numerical IQ	97.1 (15.9)	101.5 (10.4)	-0.33	-2.38*
PMA Space Relations IQ	97.1 (18.6)	97.4 (15.5)	-0.02	-0.14
PMA Reasoning IQ	96.0 (14.3)	99.5 (12.6)	-0.26	-1.85
PMA Perceptual Speed IQ	93.1 (17.1)	98.2 (15.1)	-0.32	-2.26*
PMA Total IQ	5.5 (17.1)	100.4 (12.7)	-0.33	-2.34*

* Significant $p < 0.05$.

for individual reaction time parameters between the two studies, for example, in the Buckhalt-Jensen study the odd-man-out movement time has the highest correlation with the Progressive Matrices ($r = .33$) whereas in the present study this correlation is low. We are not able to detect any meaningful patterns in these differences and prefer to attribute them sampling errors.

Also shown in Table 3 (Column 3) are the correlations between the reaction time parameters and Thurstone's perceptual speed primary ability. It will be seen that the correlations are quite low and no greater than those of the reaction times with the Progressive Matrices. This shows that none of the reaction time parameters are measures of Thurstone's perceptual speed.

The complete correlation matrix for all of the reaction time parameters and intelligence tests is shown in Table 4. The negative correlations between reaction times and intelligence test measures have been reflected to avoid a large number of negative signs. It will be seen that virtually all the correlations are positive.

The next step was to factor analyze the correlations in order to determine which factors are present. Buckhalt and Jensen (1989) obtained a general factor which they identified as "general speed," and four primary factors identified as psychometric ability, consistency of performance (the reciprocal of variability) in the RT and MT tasks, movement time, and reaction time. The problem was whether our data would yield the same set of factors.

TABLE 3
Correlations of 12 Reaction Time Parameters with Raven's Standard Progressive Matrices in the Buckhalt-Jensen Study and in the Present Study, and Correlations with Thurstone's Perceptual Speed Primary Ability

	Progressive Matrices		Perceptual Speed
Reaction Time measures	Buckhalt & Jensen Study	Present Study	Present Study
Simple reaction time - RT	.01	-.23***	-.15*
Choice reaction time - RT	-.16	-.22***	-.21***
OMO reaction time - RT	-.17	-.33***	-.34***
Simple reaction time - SD	-.09	-.13*	-.19**
Choice reaction time - SD	-.22*	-.14*	-.13*
OMO reaction time - SD	-.15	-.30***	-.30***
Simple reaction time - MT	-.17	-.22***	-.11
Choice reaction time - MT	-.24*	-.15*	-.12*
OMO reaction time - MT	-.33*	-.05	-.03
Simple reaction time MT SD	.11	-.17**	-.08
Choice reaction time MT SD	.15	-.14*	-.18**
OMO reaction time MT SD	-.07	-.02	.00

TABLE 4
Correlation Matrix for All Variables

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1. Simple RT-MM	-																			
2. Simple MT-MM	53																			
3. Simple RT-SD	75	36																		
4. Simple MT-SD	45	81	38																	
5. Choice RT-MM	69	43	59	36																
6. Choice MT-MM	40	83	28	69	34															
7. Choice RT-SD	51	30	45	28	79	26														
8. Choice MT-SD	-29	55	23	52	29	70	27													
9. OMO RT-MM	31	15	28	14	47	09	43	03												
10. OMO MT-MM	22	62	19	53	16	80	15	59	-06											
11. OMO RT-SD	21	06	14	05	32	06	31	01	84	-01										
12. OMO MT-SD	-04	26	01	27	12	36	-05	32	-18	61	07									
13. Progressive Matrices	23	22	13	17	22	15	14	14	33	05	30	02								
14. Culture Fair	18	09	15	04	14	11	06	09	28	07	30	08	65							
15. PMA-Verbal	10	04	16	06	14	06	07	10	22	01	20	07	44	61						
16. PMA-Number	16	07	17	06	17	07	10	07	28	04	21	02	52	62	60					
17. PMA-Space	09	11	04	08	05	08	02	12	26	03	24	05	52	55	37	42				
18. PMA-Reasoning	17	14	15	14	18	13	11	16	23	05	20	04	60	66	60	54	47			
19. PMA-Perc. Speed	14	11	19	07	20	12	12	18	32	05	27	00	56	61	58	65	45	63		
20. Verbal Fluency-A	16	-01	12	02	10	02	05	06	02	02	00	00	28	36	56	49	29	40	41	
21. Verbal Fluency-T	14	-07	10	05	03	11	08	12	07	04	06	08	24	35	48	38	32	33	42	56

Decimal points omitted and correlations between reaction times and intelligence tests inflected to remove minus signs. Correlations of 12 and above are statistically significant at the 5 per cent level.

The method of factor analysis most usually employed on data of this kind is principal component analysis to obtain a general factor identified as Spearman's g, followed by varimax rotation to obtain the primary factors. However, Jensen prefers to use the Schmid-Leiman (1957) method of factor analysis on the grounds that the first principal component in a principal components analysis can produce a spurious general factor from two independent clusters of correlations. In view of these technical problems, we considered it would be useful to present both methods of analysis.

The principal components analysis produced four factors with eigenvalues greater than unity. These were varimaxed to distribute the variance over four independent factors. The results of the principal components analysis and varimax rotation are shown in Table 5.

The first principal component accounts for 29% of the variance. All the variables, except OMO MT-SD, have high loadings on the first principal component and has the appearance of a g factor (signs of the reaction time measures are positive and those of the intelligence test negative because fast speeds on the reaction time measures are represented by low scores and these correlate with high scores on the intelligence tests).

The varimax rotation breaks the general factor up into independent primary factors. The first of these is psychometric intelligence with high loadings for all intelligence tests and no loadings on the reaction times. The second factor is movement time with high loadings for all six movement times. The third factor consists of simple and choice reaction time medians and variability. The fourth factor is the odd-man-out factor with high loadings for OMO median and variability. It is curious that there are also negative loadings of verbal fluency on this factor. Verbal fluency is generally considered to be a measure of long-term memory capacity, and there seems no apparent explanation for its negative loading on the odd-man-out factor.

While principal components analysis followed by varimax rotation has become the standard method of factorial analysis, Jensen prefers to use the Schmid-Leiman (1957) method and employs this in the Buckhalt and Jensen (1989) paper. A Schmid-Leiman analysis begins with a principal factor analysis, obtains the significant factors, and from these, extracts a second-order general factor. This is partialed out of the primary factors, rendering them orthogonal. We considered it useful to carry out a Schmid-Leiman analysis so that our results could be compared with those of Buckhalt and Jensen (1989), and also to afford a comparison between Schmid-Leiman analysis and the more familiar principal components-varimax.

The procedure for carrying out the Schmid-Leiman analysis was as follows. The signs of the 12 reaction time parameters were reversed. The 21 reaction time, movement time and psychometric variables were then intercorrelated, and this matrix factor was analyzed by the maximum likelihood technique (Jereskog, 1967). The Kaiser-Guttman test (Kaiser & Rice, 1974; Guttman, 1956), and the MAP test (Velicer, 1976), on an initial principal components solution, both indicated that four factors should be extracted. These four factors were rotated to simple structure by direct oblimin (Jenrich & Sampson, 1966), the free parameter delta which controls the obliqueness of the solution being swept over the range of −30.0 to 0.6 in steps of

TABLE 5
Factor Loadings on the First Principal Component Showing a General Factor and Varimax Rotation Showing Four Primary Factors

	General Factor	Psychomotor IQ	Movement Time	Simple Choice RT	OMO RT
Simple RT-Mean	.60	-.13	.24	.84	.02
Simple MT-Mean	.58	-.04	.79	.38	.06
Simple RT-SD	.52	-.12	.15	.79	-.04
Simple MT-SD	.52	-.03	.73	.36	.03
Choice RT-Mean	.59	-.09	.14	.85	.24
Choice MT-Mean	.56	-.06	.89	.24	.04
Choice RT-SD	.46	.02	.12	.71	.34
Choice MT-SD	.49	-.10	.73	.19	-.03
OMO RT-Mean	.50	-.24	-.07	.36	.80
OMO MT-SD	.39	.01	.89	.01	-.02
OMO RT-SD	.42	-.22	-.04	.18	.81
OMO MT-SD	.17	-.06	.64	-.28	-.08
Prog. Matrices	-.66	.69	-.13	-.06	-.32
Verbal	-.60	.79	.01	-.09	.04
Number	-.62	.78	.02	-.10	-.08
Space Relations	-.51	.64	-.10	.10	-.25
Reasoning	-.66	.78	-.09	-.06	-.11
Percept. Speed	-.67	.79	-.05	-.09	-.15
Culture Fair	-.66	.81	-.07	.01	-.23
Fluency-A	-.43	.67	.08	-.17	.41
Fluency-T	-.43	.62	-.04	-.08	.31

0.1. The optimal solution was taken to be that in which the number of variables in the 0.1 hyperlane was maximized. This procedure (which has been advocated implicitly by Harman, 1976, p. 322, and used in a number of previous studies) increases the chances that direct oblimin reaches simple structure by removing the need for an arbitrary prior specification of factor obliqueness.

The correlations between the four factors were then similarly subjected to a maximum likelihood factor analysis; one general factor being extracted as indicated by the Kaiser-Guttman and MAP tests. The hierarchical structure of the first- and second-order factor loadings was then analyzed by the Schmid-Leiman procedure (Schmid & Leiman, 1957). This procedure effectively partials out the influence of the second-order factor from each of the primaries, allowing the second-order factor to be related directly to the original variables rather than to the first-order factors. Loadings of the variables on the second-order factor and the four primary factors are shown in Table 6.

The higher order factor is a general reaction time factor on which all the reaction time measures have appreciable loadings except for odd-man-out movement time medians and variability (replicating the results on the first principle components). However, the cognitive tests have only low positive loadings on the factor. The results are closely similar to those in the Buckhalt-Jensen (1989) study which also obtained a higher order reaction time factor which they identify as "general speed." There is a remarkable concordance between the two studies in so far as in both the Progressive Matrices load .27 on the general factor.

The four primary factors obtained from the Schmid-Leiman (1957) analysis are very similar to those obtained from the varimax analysis given in Table 5. Factor 1 is cognitive ability on which all the psychometric tests have high loadings. Factor 2 is movement time. Factor 3 is simple and choice reaction time and factor 4 is odd-man-out reaction time. Both the varimax and the Schmid-Leiman analyses suggest that performance on the reaction time tasks can be broken down into three independent processes, namely; movement time; reaction time and variability on the simple and choice task; and reaction time and variability on the odd-man-out task.

It is possible to consider these movement and reaction time factors as micro-cognitive processes and to consider whether these combine to determine performance on the complex reasoning problems presented in intelligence tests. To answer this question, multiple correlations have been calculated between all the reaction time measures, Progressive Matrices, and the Culture Fair Test. The multiple correlations are .41 and .38 respectively. These multiple correlations are substantially higher than any of the correlations between the individual reaction time measures and intelligence shown in Tables 3 and 4, and suggest that the reaction time tasks consist of several micro-processes which come together to determine intelligence test performance.

DISCUSSION

One of the principal aims of the investigation was to determine how far the Buckhalt and Jensen (1989) results on the correlations between reaction times and intelligence

TABLE 6
Schmid-Leiman Factor Analysis Showing the General Factor and Four Primary Factors

	General Factor	Psychomotor IQ	Movement Time	Simple Choice RT	OMO RT
Simple RT-Mean	.69	.05	.13	.39	-.04
Simple MT-Mean	.47	-.04	.73	.14	.04
Simple RT-SD	.60	.07	.04	.36	-.07
Simple MT-SD	.42	-.04	.63	.13	.03
Choice RT-Mean	.79	.01	-.01	.45	.07
Choice MT-Mean	.38	-.02	.88	.05	.06
Choice RT-SD	.66	-.09	-.01	.38	.12
Choice MT-SD	.31	.05	.63	.06	-.04
OMO RT-Mean	.48	.08	-.05	.08	.82
OMO MT-SD	.19	-.06	.82	-.03	.00
OMO RT-SD	.33	.08	-.01	-.01	.80
OMO MT-SD	.07	.05	.50	-.13	-.07
Progressive Matrices	.26	.63	.05	.02	.13
Verbal	.18	.74	-.05	.01	-.01
Number	.22	.73	-.06	.02	.04
Space Relations	.11	.56	.05	-.07	.14
Reasoning	.22	.75	.02	.01	-.00
Perceptual Speed.	.24	.73	.00	.01	.09
Culture Fair	.19	.78	.01	-.03	.08
Fluency-A	.11	.60	-.09	.05	-.23
Fluency-T	.08	.52	.04	-.02	-.07

would be replicated on children in Ireland. It was found that the correlations were quite similar and confirm the existence of modest but statistically significant associations between all reaction time parameters and psychometric intelligence. Factor analysis showed that the factors obtained in the two data sets were similar but not identical. Both studies find a general reaction time factor on which intelligence tests have low positive loadings. Both studies obtained four primary factors of which two were clearly identifiable as psychometric intelligence and movement times. The remaining two factors show some differences in the two studies. The Buckhalt-Jensen (1989) analysis obtained a choice and odd-man-out reaction time factor and a variability factor, whereas the present study produces a reaction time median and variability factor, and an odd-man-out median and variability factor. Theoretically, the Buckhalt-Jensen result may seem more satisfying because an independent variability factor suggests some kind of attention mechanism which intermittently breaks down, producing high variability on all tasks. Nevertheless, the results in the present study do not confirm the existence of such a factor. Rather, the appearance of the odd-man-out median and variability on a single factor suggests that the odd-man-out task calls on some cognitive component not present in simple and choice reaction times.

Taken together, the Buckhalt-Jensen and the present results suggest the following conclusions. First, there is some neural process which brings all cognitive performances into positive correlation, as Spearman originally proposed, and which can be identified as Spearman's *g*. This process includes movement times, and may plausibly be considered to be the speed of neural transmission, as Jensen (1982) suggests. In addition to this factor, both the varimax and the Schmid-Leiman analyses suggest that performance on reaction time tasks entails three primary factors. Two of these can be identified with some confidence as they appear in the Buckhalt-Jensen (1989) results and in the present study. These are movement times and decision timies. There remains some doubt about the third factor which appeared as the odd-man-out task in the present study and as variability in the Buckhalt-Jensen study.

NOTE

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REFERENCES

Buckhalt, J.A. & Jensen, A.R. (1989). The British Ability Scales speed of information processing subtest: What does it measure? British Journal of Educational Psychology, 59, 100–107.

Frearson, W. & Eysenck, H.J. (1986). Intelligence, reaction time and the "odd man out" R.T. paradigm. *Personality and Individual Differences, 7*, 6, 807–818.

Guttman, L. (1956). Best possible systematic estimates of commonalities. *Psychometrika, 21*, 273–285.

Harman, H.H. (1976). *Modern factor analysis (3rd ed.).* Chicago: University of Chicago Press.

Jennrich, R.I., & Sampson, P.F. (1966). Rotation for simple loadings. *Psychometrika, 31*, 313–323.

Jensen, A.R. (1982). Reaction time and psychometric g. In H.J. Eysenck (Ed.), *A model for intelligence.* Springer.

Jensen, A.R. (1987). Process differences and individual differences in some cognitive tasks. *Intelligence, 11*, 107–136.

Jensen, A.R. & Munro, E. (1979). Reaction time, movement time and intelligence. *Intelligence, 3*, 121–126.

Jereskog, K.G. (1967). Some contributions to maximum likelihood factor analysis. *Psychometrika, 32*, 443–482.

Kaiser, H.F. & Rice, J. (1974). Little Jiffy Mk IV. *Educational and Psychological Measurement, 34,* 111–117.
Longstreth, L.E. (1984). Jensen's reaction time investigations of intelligence: A critique. *Intelligence, 8,* 139–160.
Mackintosh, N.J. (1986). A biology of intelligence? *British Journal of Psychology, 77,* 1–18.
Roth, E. (1964). Die geschwindigkeit der verarbeitung von information und ihr zusammenhang mit intelligenz. *Zeitschrift fur Experimentale Angew Psychologie, 11,* 616–622.
Schmid, J. & Leiman, J.M. (1957). The development of hierarchical factor solutions. *Psychometrika, 22,* 53–61.
Thurstone, L.L. (1938). Primary Mental Abilities [Monograph]. *Psychometrica Monograph,* 1, Introduction—121. Chicago: University of Chicago Press.
Thurstone, T.G. (1963). *The primary mental abilities test.* Chicago: Science Research Associates.
Velicer, W.F. (1976). Determining the number of loadings from the matrix of partial correlations. *Psychometrika, 41,* 321–327.
Vernon, P.A. (1983). Speed of information processing and general intelligence. *Intelligence, 7,* 53–70.