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Reaction Time, Movement Time, and Intelligence

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Speed of information processing is measured in terms of reaction time (RT) and movement time (MT) to five stimulus displays which differ in the amount of information transmitted, over a range from 0 to 3 *bits* of information. RT, but not MT, increases as a linear function of the number of *bits* in the stimulus display. RT and MT show reliable individual differences which are significantly correlated with intelligence as measured by Raven's Standard Progressive Matrices.

The use of reaction time (RT) as a measure of intelligence dates back to Sir Francis Galton (1883) and James McKeen Cattell (1890). These early attempts were prematurely considered unsuccessful, and investigation of the relation between RT and intelligence was abandoned early in the history of differential psychology. In recent years there has been a revival of interest in RT in connection with theories of information processing. It has been shown that RT to stimuli of varying complexity bears a direct linear relationship to the amount of information conveyed, when the amount of information is scaled in *bits,* i.e., number of binary choices required to reduce the uncertainty to zero (Hick, 1952; Hyman, 1953). Information is varied by changing the number of alternatives among which a choice is to be made.

A central concept in the definition of intelligence is capacity for information processing. Following this lead, Roth (1964) demonstrated that although simple RT, i.e., zero *bits* of information conveyed by the stimulus, shows no significant correlation with intelligence, the upward slope of the RT function with increasing informational input is negatively correlated with IQ. Roth's subjects were required to turn off a light as fast as possible after it went "on" by pressing a button directly adjacent to the light. The amount of information was varied by presenting a different number of light/button alternatives. The number of *bits* of information equals the logarithm, to the base 2, of the number of alternatives. On each trial only one light in the whole array goes "on", and the subject must turn it off as quickly as he can by pressing the button adjacent to the light. Roth's RT measure actually included not only the RT to the stimulus, but also the movement time (MT) involved in reaching out and pressing the button. This raises the question of whether RT and MT measure the same ability (and if so may be treated additively) or measure different abilities which may have different correlations with intelligence.

METHOD

The present experiment obtains experimentally independent measures of RT and MT, and correlates these with scores on a standard test of intelligence.

The apparatus for measuring the subject's RT and MT consists of a panel, 13 in. × 17 in., painted flat black, and tilted at a 30° angle. At the lower center of the panel is a red pushbutton, ½ in. in diameter, called the "home" button. Arranged in a semicircle above the "home" button are eight red pushbuttons, all equidistant (6 in.) from the "home" button. Half an inch above each button (except the "home" button) is a ½ in. faceted green light. Different flat black panels can be fastened over the whole array so as to expose arrays having either 1, 2, 4, 6 or 8 light/button combinations.

The subject is instructed to place the index finger on the "home" button; then an auditory warning signal is sounded (a high-pitched tone of 1 sec. duration), followed (after a continuous random interval of from 1 to 4 sec.) by one of the green lights going "on," which the subject must turn off as quickly as possible by touching the microswitch button directly below it. RT is the time the subject takes to remove his finger from the "home" button after the green light goes on. MT is the interval between removing the finger from the "home" button and touching the button which turns off the green light. RT and MT are thus experimentally independent. On each trial they were registered in milliseconds by two electronic timers.

Every subject was given a total of 30 trials on each of the five arrays, i.e., 1, 2, 4, 6 or 8 light/button alternatives, corresponding to 0, 1, 2, 2.58, and 3 *bits* of information, respectively. The particular light that went on in each trial was random and hence unpredictable by the subject. All tests were administered by the second author.

Intelligence was measured by Raven's Standard Progressive Matrices (Raven, 1947), a 60-item nonverbal test of reasoning ability which many studies have shown to correlate highly (about .8) with *g*, the general factor common to most tests of intelligence. It was group administered, with a one-hour time limit. All subjects attempted all of the items within the hour.

The subjects were all of the 39 girls (33 whites and 6 blacks) in one physical education class in the 9th grade of junior high school. (In this sample, race is not significantly correlated with RT, MT, or Raven scores.) Their average age was 14.7 yr., *SD* 0.76.

RESULTS AND DISCUSSION

RT increases with amount of information, while MT varies only slightly, as shown in Figure 1. RT and MT are plotted separately for the high, middle and low one-thirds of the sample in terms of Raven scores. With the exception of a few subjects, the relationship of RT to *bits* for individuals is quite linear. This is evident from the Pearson correlation between RT (mean of 30 trials) and number of *bits* for each subject. The mean r (via Fisher's Z transformation) is .97. A correlation this high indicates nearly perfect linear regression of RT on *bits* of information for individuals. MT shows a less systematic relation to amount of information; the mean r between MT and number of *bits* is .54.

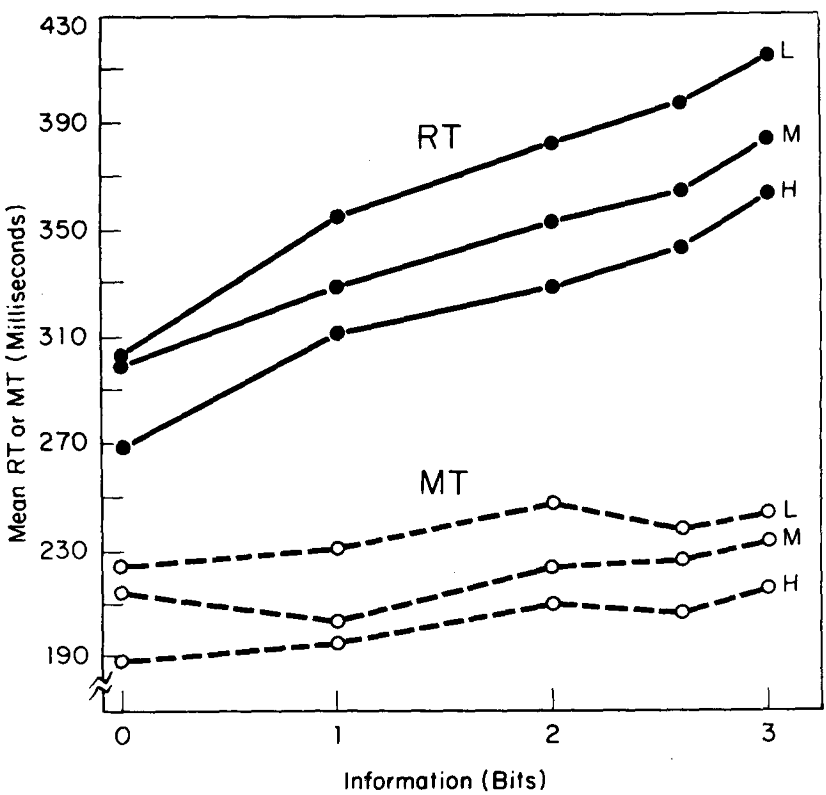

FIG. 1. Mean reaction time and movement time (in milliseconds) as a function of *bits* of information in the stimulus display, plotted separately for the high (H), middle (M), and low (L) one-third of the sample on Raven's Progressive Matrices scores.

The reliabilities of RT and MT were determined by the split-half method, i.e., the subjects' means for the first set of 15 trials were correlated with the means of the second set of 15 trials, and the correlation was boosted by the Spearman–Brown formula to give the reliability for the mean of all 30 trials. The reliability coefficients do not differ significantly for the various amounts of information. The average reliability for RT is .90, for MT, .89.

The fact that RT and MT do not reflect entirely the same source of individual differences is seen in the relatively low correlation of .37 between total RT and total MT. The average of the correlations among each of the five RT measures (for 0, 1, 2, 2.58, and 3 *bits*) and each of the others is .85. The corresponding average correlation among MTs is .77. But the average of all the correlations between RT and MT is only .31.

The Raven Progressive Matrices mean raw score is 46.1 (SD = 8.45), which is above the norm for this age group. The internal consistency reliability (K–R 20) of the Raven scores is .90. In this sample, the correlation between Raven scores and age in months is zero.

The relationship of RT and MT to psychometric intelligence was examined by computing Pearson correlations between the Raven total score and the following variables obtained on each subject: Total RT and Total MT (the sum of RTs [or MTs] over 30 trials on all five light/button tasks); *SD* RT and *SD* MT (the standard deviations of the RTs [or MTs] over 30 trials on each of the light/button tasks); RT and MT measured over 30 trials on each of the five tasks separately; the slope of the regression of each subject's mean RT on *bits*. The correlations are as follows:

Raven × Total RT: $r = -.39$ ($p < .02$).
Raven × *SD* RT: $r = -.31$ ($p < .05$).
Total RT × *SD* RT: $r = +.48$ ($p < .01$).
Total RT and *SD* RT × Raven: multiple $R = .42$ ($p < .01$), shrunken $R = .36$.

Raven × Total MT: $r = -.43$ ($p < .01$).
Raven × *SD* MT: $r = +.07$ n.s.
Total MT × *SD* MT: $r = .00$

Total RT × Total MT: $r = +.37$ ($p < .02$).
Total RT and Total MT × Raven: multiple $R = .50$ ($p < .01$), shrunken $R = .45$.

A measure of information processing capacity that is independent of absolute RT is the slope, b, of the regression of RT on *bits*. This measure, b, was determined for every subject. The correlation between Raven scores and b is $-.30$ ($p = .06$). Corrected for attenuation, based on the split-half reliability of .76 for *b* and the K-R 20 reliability of .90 for the Raven, the correlation is $-.36$ ($p < .05$). Our expectation, from the study of Roth (1964) suggesting that the slope of RT with increasing information is the best measure of information processing capacity, and from consideration of the linear relationship of RT to *bits* of information found in other studies (Hick, 1952; Hyman, 1953), was that the slope of regression of RT on *bits* would have the highest correlation with the Raven scores. Along the same lines, we expected RT to show higher correlations than MT with Raven scores. The fact that these specific expectations were not borne out seems somewhat puzzling; at present we can offer no explanation. The slope of the regression of MT on *bits* shows nearly zero correlation ($r = +.05$) with Raven scores.

The correlations between Raven scores and RT and MT on each of the five light/button tasks separately are shown in Table 1, along with the correlations corrected for attentuation. The correction for attenuation is based on the split-half reliabilities of RT and MT and the Raven reliability (K-R 20) of .90.

It should be noted that since the correlation betwen Raven scores and age is zero in this sample, age is in effect partialed out of all of the correlations of the Raven scores with the RT and MT measures. For comparison we may note the correlation (with age partialed out) of .35 between Raven scores and the Peabody Picture Vocabulary Test in a large ($N = 608$) sample of white school children (Jensen, 1974, p. 198). Also the Raven has a median correlation of .51 with the Wechsler Intelligence Scale for Children Full Scale IQ in various studies (Sattler, 1974, p. 155). Thus the Raven correlates much the same with the RT and MT measures in this study as with other standard tests of intelligence reported in the literature. When each of the five RT and MT measures are combined in a multiple regression equation, they predict Raven

TABLE 1
Correlation (Uncorrected and Corrected for Attenuation) Between Raven Scores and RT and MT as a Function of Bits of Information

Number of Bits	Uncorrected *r*		Corrected *r*	
	RT	MT	RT	MT
0	-.26	-.38*	-.30	-.47**
1	-.33*	-.43**	-.36*	-.49**
2	-.41**	-.36*	-.45**	-.45**
2.58	-.49**	-.40**	-.54**	-.48**
3	-.35*	-.36*	-.39*	-.41**
Mean	-.37*	-.39*	-.41**	-.46**

*$p < .05$
**$p < .01$

scores with a multiple correlation of $R = .66$, shrunken $R = .49$. These correlations seem most interesting when one considers that the RT and MT measures are not based on past learning or on any intellectual content whatsoever. The fact that RT is highly related to the task complexity as measured in *bits* while MT is not (see Figure 1), and that individual differences in RT and MT are not highly correlated ($r = .37$), yet each is correlated to about the same degree with Raven scores, suggests the hypothesis that RT and MT reflect different components of fluid intelligence or information processing capacity. It is the task of future research further to understand the nature of these components.

REFERENCES

Cattell, J. McK. Mental tests and measurements. *Mind,* 1890, *15,* 373–380.

Galton, F. *Inquiries into Human Faculty and its Development.* London: Macmillan, 1883.

Hick, W. On the rate of gain of information. *Quarterly Journal of Experimental Psychology,* 1952, *4,* 11–26.

Hyman, R. Stimulus information as a determinant of reaction time. *Journal of Experimental Psychology,* 1953, *45,* 188–196.

Jensen, A. R. How biased are culture-loaded tests? *Genetic Psychology monographs,* 1974, *90,* 185–244.

Raven, J. C. *Progressive Matrices.* London: H. K. Lewis, 1947.

Roth, E. Die Geschwindigkeit der Verabeitung von Information and ihr Zusammenhang mit Intelligenz. *Zeitschrift für Experimentelle und Angewante Psychologie,* 1964, *11,* 616, 622.

Sattler, J. M. *Assessment of Children's Intelligence.* Philadelphia: W. B. Saunders, 1974.