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INTELLIGENCE, REACTION TIME (RT) AND A NEW 'ODD-MAN-OUT' RT PARADIGM

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Summary—A sample of adult *S*s of reasonably normal intelligence were given an 'IQ' test, a series of RT tests using 0, 1, 2, 3 bits of information in a Hick paradigm and an RT task requiring choice of 1 of 3 lights as an 'odd-man-out' on the basis of its relative position. Negative correlations were found between both RT and measures of variation in RT and 'IQ' for both of the two tasks. Recent results showing no correlation between Hick slope and 'IQ' and no increase in correlation between 'IQ' and RT with increasing number of bits, are confirmed. An explanation for findings of *S*s whose RT data do not conform to Hick's law is tested and found inadequate. The 'odd-man-out' task is found to show an effect of 'learning' across the period of the task, the size of the learning effect was found also to correlate with 'IQ', but no evidence for learning was found with the choice RT task.

INTRODUCTION

Research into the relationship between performance on simple cognitive tasks and 'complex' IQ tests was revived, after a gap of 30 years, by Roth's (1964) finding of a relationship between IQ and choice reaction time (RT). Specifically he found a correlation between psychometric '*g*' and the slope resulting in logarithmic increase in RT with increase in the number of choices in a choice RT paradigm (Hick, 1952). Roth's work led to the investigations of the 'Erlangen' school in Germany surveyed by Eysenck (1985), and of Jensen and his co-workers in the U.S.A. (Jensen and Munro, 1979; Jensen, Schafer and Crinella, 1981; Vernon, 1981, 1983).

In addition to the Hick RT paradigm, several other measures of timed performance and their relationship with IQ have been studied. The inspection time paradigm founded on the theorizing of Vickers, Nettlebeck and Wilson (1972) has been found to correlate with a variety of ability measures (Lally and Nettlebeck, 1980; Nettlebeck, 1982; Nettlebeck and Kirby, 1983; Nettlebeck and Lally, 1976; reviewed by Brand and Deary, 1982). Short-term memory scanning (Sternberg, 1966) and retrieval of over-learned semantic codes (Posner, Boies, Eichelman and Taylor, 1969) have also been found to correlate with IQ (Jensen, 1982a); as have a variety of still more complex tasks such as picture identification (French, Ekstrom and Price, 1963) and sentence–picture comparison (Clark and Chase, 1972).

Jensen's work on choice RT has been criticized both theoretically and for its methodology. Jensen is criticized for use of unrepresentative sample groups, his statistical manipulations and interpretations and non-systematic presentation of results. The task itself has been criticized for confounding number of choices with both order and retinal displacement and its possible elicitation of high-order response strategies (Carroll, 1985; Longstreth, 1984). Some of these criticisms are not really relevant to the issue of individual differences research, although they may affect the interpretation of results.

Jensen's theory of individual differences in choice RT is based upon a supposed oscillation in endogenous excitation of 'nodes' (synapses or groups of synapses) through which pass neuronal impulses. Each node will only 'fire' when external plus internal excitation exceed some threshold. Impulses are thus 'held up' at each node whilst its internal excitation 'cycles round'. Individual differences in rate of oscillation lead to differences in rate of information transmission and hence, choice RT.

Slowness of neural transmission also leads to limits on information processing and restrictions in retrieval from short- and long-term memory; hence to accumulating cognitive handicap (Eysenck, 1967, 1985; Jensen, 1982a). Jensen's theory both predicts and requires negative RT × *g* correlations and negative RT 'slope' × g correlations, and, since RT is logically linked to RT variability (Carroll, 1985), negative RT variability × g correlations.

Jensen (1982a) suggests that IQ correlates with (1) simple RT, (2) choice RT, (3) movement time (MT), (4) Hick slope, (5) variability of RT, (6) inspection time (IT), (7) Sternberg STM RT and (8) Posner LTM RT. However, not all experiments have given positive results. Irwin (1984) failed to find a significant correlation between IT and IQ. Barrett, Eysenck and Lucking (1985) and Carlson, Jensen and Widaman (1983) found only an insignificant correlation between Hick slope and IQ measures; Schmidtke (1961), Ameland (1985) and Barrett *et al.* (1985) failed to discover increases in RT × IQ correlations with increasing number of bits. Furthermore, Barrett *et al.* (1985) found 20% of their *S*s gave choice RT data that did not conform to Hick's law and that only on removal of these *S*s did their data conform to Jensen's published results. Smith and Stanley (1983), using a choice RT task requiring a different response from Jensen's, similarly report that 10% of their *S*s poorly fitted Hick's law.

Eysenck (1986) has attempted to review the literature on RT × g experiments, and to integrate the findings into a general theory of intelligence as a function of speed of information processing. He has also (Eysenck and Barrett, 1985) reviewed the literature on the psychophysiological measurement of intelligence to extend the range of that theory and to provide a more directly biological foundation for it. The theory in question bears a close resemblance to that of the 'Erlangen' school (Lehrl and Franks, 1982) and of Jensen (1982a) but differs in important ways from both.

The present study seeks to replicate the results of Barrett *et al.*, and by repeating the first condition of the choice RT task, investigate whether the 'non-fitting' can be accounted for by the 'trivial' explanation of insufficient practice on the early trials. A new elementary cognitive task is introduced, the 'odd-man-out'. The odd-man-out is presented as a more complex task than choice RT without recourse to using materials requiring the S to use high-order processes (such as semantic encoding, picture recognition etc) as are needed in other of the more difficult elementary cognitive tasks (e.g. Jenkinson, 1983). The results of these experiments may throw some light on the various theories of RT × g relationship surveyed by Eysenck (1986).

METHOD

Subjects

A sample of 37 *S*s (23 male, 14 female) were recruited from the local government employment bureau and through various advertisements posted in colleges of the University of London. The age range of the males was from 16 to 32 yr, with a mean of 23 and an SD of 3.77. The age range of the females was from 16 to 46 yr, with a mean of 23.57 and an SD of 6.96.

Each S performed both RT tasks and a 20 min version of Raven's Advanced Progressive Matrices (APM).

Apparatus

All equipment control, stimulus presentation and data acquisition was controlled by an ACT Sirius I microcomputer. Signal priming, detection and timing were implemented via a Biodata Microlink unit, which for the Jensen paradigm encompassed modules RR8 (8-channel reed relays), CC8 (8-channel digital inputs) and 2 TIM modules (timing/clock module, providing msec units). A further CC8 was later added to the Microlink allowing monitoring of the 'home button'. For the odd-man-out paradigm modules RR8, CC8 and TIM were used. The Jensen arrangement of lights and buttons was copied exactly from the measurements and description given in Jensen and Munro (1979).

Procedure

Reaction time (RT) and movement time (MT). Following the details of the Jensen paradigm RTs and MTs were assessed over four conditions of 0, 1, 2, and 3 bits of decision information (corresponding to 1, 2, 4 and 8 lights on show, respectively). The 0-bit condition was given twice, once at the beginning of the task and once at the end, the order of conditions then being 0, 1, 2, 3, 0 bits. Twenty trials were given on each condition with a short (1 min) rest between conditions. Covers were placed over lights not required on any one condition.

The *S* was seated in front of the response box, using the preferred hand for button-pressing. The computer monitor was not visible to the *S* and since all switching and timing was electronic, no auditory or visual cues were available to the *S* prior to any stimulus. The *S* was given as many practice trials as required until confidence in the task was expressed. The *S* began the experiment with the index finger depressing the home button. [After the first 25 *S*s, analysis of their results revealed that some *S*s on some trials were failing to have the home button depressed at the start of the trial (leading to an MT of 0). The apparatus was altered to automatically suspend the task, to be re-started by the experimenter after an admonishment, if this should occur—all data on *S*s who had returned a 0 MT were discarded.]

The following sequence describes the acquisition procedure:

(1) A warning tone of 1000 Hz frequency and 54 msec duration is presented at approx. 70 dB SPL by the Sirius. The tone is followed by a random delay of 1–4 sec.

(2) Following the warning tone and delay, a light is illuminated in one of the possible positions of the operative condition. Simultaneously the RT clock is started. The *S* responds by moving the index finger from the home button to press the button underneath the light, turning it off. Releasing the home button stops the RT clock and starts the MT clock, the MT clock being stopped by the *S* pressing the target button.

(3) The *S* returns the finger to the home button and the sequence is repeated.

(4) RT, MT and light position are recorded by the Sirius, which then resets the two clocks.

Odd-man-out. The odd-man-out paradigm used the same response box as the Jensen. Here, though, each trial consists of the simultaneous onset of 3 of the 8 lights. The 3 lights are so arranged that the distance (the number of intervening light positions) between the left light and the centre light is different to the distance between the centre and the right light. Such displays were explained to the *S* as consisting of a pair of lights (the two closest together) with an 'odd-man-out'. With the 8 light positions of the Jensen box these are 44 such possible displays, the present study used the 24 shown in Fig. 1.

The *S*'s task, starting with the finger depressing the home button was to press the button corresponding to the odd-man-out light. Each display was given to the *S* for 5 trials, making 120 separate trials on the task. The 120 trials were allocated to 4 blocks of 30 so that in each block, no display was repeated more than twice and each block contained at least one of each display. The 30 trials within each block were given in random order. After every 15 trials the task was suspended, to allow *S*s a rest, the task being re-started by the experimenter on the instigation of the *S*.

Trials leading to errors (where the *S* pressed a button other than that corresponding to the odd-man-out) were repeated at the end of each block. (If errors recurred on the repetition the trial was repeated again after all the other errors from that block had been repeated.) If on any one block more than 10 errors occurred, the program was halted and returned to the start to allow for re-education of the *S*.

Subjects were instructed in the task and then given a batch of 8–18 practice trials consisting of displays of varying complexity, until they expressed confidence in the task. *S*s were exhorted to be as quick as possible in their button-pressing, being told not to be over-concerned about errors as any trial they got wrong would be repeated. Only 1 *S* had difficulty understanding the task, scoring more than 10 errors in the first block, and he had also experienced difficulties when first presented with the Jensen task.

The 'odd-man-out' task is in essence an IT (inspection time) type of paradigm, but is much shorter and more reliable than the usual IT type of task, and avoids many of the difficulties and inefficiencies of the latter.

The following sequence describes the acquisition process.

(1) A warning tone of 1000 Hz frequency, duration 54 msec, is presented at approx. 70 dB by the Sirius followed by a random delay of 1–4 sec.

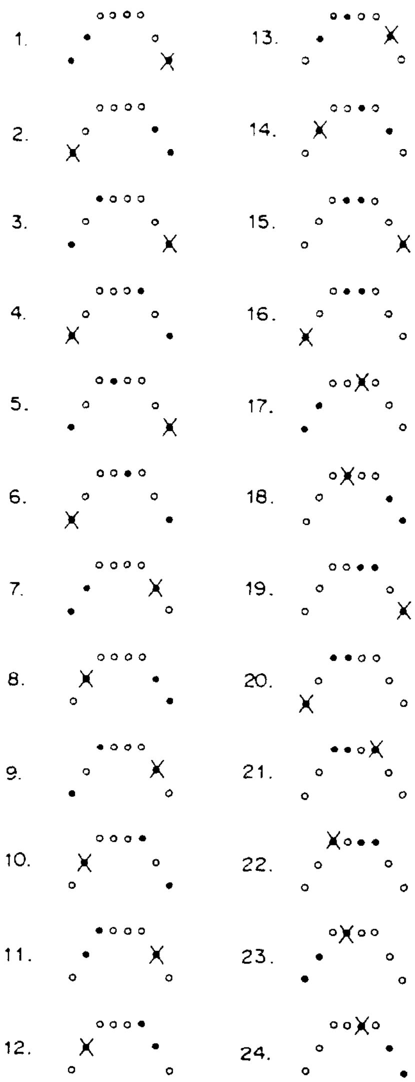

Fig. 1. The 24 patterns used in the odd-man-out paradigm, the 'target' is marked with a cross.

(2) Following the warning tone and delay, a pattern of 3 lights is illuminated, and simultaneously the clock is started. The *S* responds by releasing the home button, stopping the clock and pressing the odd-man-out button. The *S*'s response is checked.

(3) The *S* returns his finger to the home button and the sequence is repeated.

(4) The RT, and the chronological position of the trial in the sequence are recorded; if the response was an error the trial is marked as such, and the trial is repeated until a correct response is made.

Subjects were first given the Jensen task, then a 5 min break during which they were asked for various personal details required for administrative purposes, and then given the odd-man-out task. During both tasks experimenter and *S* remained in the same room. The *S* was then taken to a second test room to be administered Raven's Matrices.

Subjects were given Set I of the APM to accustom them to the test, and then allowed 20 min to perform on Set II. *S*s were instructed not to guess and were reassured that they were not expected to do all the items in the time limit. The *S* was left alone for the 20 min test time.*

*During the war H. J. Eysenck and J. C. Raven carried out many unpublished studies for the U.K. army on different methods of administering the APM test, using 20, 40 min and untimed procedures. All correlations were well into the 0.90 s averaging around 0.95, suggesting that time limitations have little influence on relative standing as far as the APM test is concerned.

Statistical analysis

Jensen. Both RT and MT data were 'corrected' by replacing the largest value with the mean value of the other RT/MT in that condition, as suggested by Barrett *et al.* (1985). This constitutes an objective method for correcting excessively long RTs/MTs due to loss of concentration (RT) or 'missing' the button (MT), as sometimes occurs.

Data were also passed through a validity check, such that if an RT was < 140 msec or > 999 msec or an MT was < 120 msec or > 999 msec, the RT/MT would be replaced by the mean RT/MT for that condition. Data for the two 0-bit conditions were analysed separately.

The Jensen analysis programme provided the median RT and MT for each condition, the SD of RT and MT for each condition and the mean intra-individual variability (σ_{RT}) defined as the mean of the SDs of RTs computed over each condition.

The intercept slope and percentage fit (squared value of the correlation coefficient) of the regression (least squares) of median RT/MT against bits of information, i.e. $\log_2$ (number of lights) was also calculated using the data for both the 0-bits condition in turn.

Odd-man-out. The median RT of the five correct RTs for each display, and the range between the largest and smallest of the RTs were calculated, these statistics being chosen in preference to the mean and SD because of suspected skewness of data and, as has been suggested for other RT measures by Brownlee (1975) and Winer (1971), the limited number of observations.

RESULTS

Raven's scores varied from 1 to 30, with a mean of 15.9 and an SD of 6.7. Foulds and Raven (1950) give a test–retest reliability of 0.91 for adults using a 40 min version of the APM; this would represent an upper limit for reliability for the 20 min version of the APM used in the present study.

Jensen

Table 1 presents means and standard deviations for all RT/MT parameters. RT results are broadly similar to other published data, though comparisons with Barrett *et al.* (1985) reveals less intra-individual variability, particularly the 3-bit SD.

Table 1. Means, standard deviations and correlations with Raven's score for the unedited sample ($N = 37$)

Variable	Mean	SD	Correlation with Raven's APM
0A Bits RT	303.27	54.39	−0.31*
0B Bits RT	304.41	44.00	−0.25
1 Bits RT	328.08	54.39	−0.33*
2 Bits RT	341.65	51.06	−0.36*
3 Bits RT	364.65	50.09	−0.31*
Slope	20.52	10.44	−0.01
Intercept	303.00	48.06	−0.35*
% Fit	79.92	21.70	0.36* (two-tailed)
0A Bits SD	38.74	19.23	−0.26
0B Bits SD	32.61	12.00	−0.23
1 Bits SD	38.08	14.26	−0.25
2 Bits SD	35.96	12.98	−0.28*
3 Bits SD	43.52	17.54	−0.17
σ_{RT}	37.78	11.56	−0.31*
0A Bits MT	264.38	55.31	−0.46**
0B Bits MT	262.05	64.26	−0.47**
1 Bits MT	257.35	56.81	−0.53**
2 Bits MT	266.49	61.70	−0.47**
3 Bits MT	281.49	65.76	−0.48**
Slope	5.62	11.46	−0.15
Intercept	259.36	53.76	−0.49**
% Fit	57.97	30.23	−0.03
0A Bits SD	37.06	21.78	0.11
0B Bits SD	25.78	16.38	0.03
1 Bits SD	25.94	17.40	0.01
2 Bits SD	26.77	15.38	−0.06
3 Bits SD	41.55	27.37	−0.15
Raven's	15.84	6.67	

Significance levels (one-tailed): $P < 0.05$; $^{**}P < 0.01$.

MTs, as expected, were smaller than RTs, though SDs were similar. As reported in Jensen (1982a, b) there appeared to be no increase in MT with increasing number of bits nor any systematic increase in SD.

Results of the two 0-bit conditions were similar, though for both RT and MT the first 0-bit condition showed greater intra-individual variability than the second [a matched-pairs t-test gives: for RT, $t = 2.65$ ($P < 0.01$); for MT, $t = 3.18$ ($P < 0.01$); both one-tailed tests with 36 df]—as might be expected given the Ss' increasing confidence with the testing apparatus. Table 2 gives relevant correlations between the first and second 0-bit conditions.

Correlating median RT scores with Raven's scores produces four correlations significant at $P < 0.05$ (Table 1). Correlating the SD of conditions to Raven's scores produces only one correlation significant at $P < 0.05$, with a further three just below significance. Mean intra-individual variability also correlates significantly with Raven's score. RT 'slope' shows a near-zero correlation with Raven's, whilst 'intercept' is significantly correlated to Raven's.

These results conform to those obtained by Barrett *et al.* (1985) using the WAIS [either the full WAIS or the shortened version provided by Silverstein (1982)] as an 'IQ' measure rather than the Raven's. Like Barrett *et al.* (1985) these results differ from Jensen's summary of his own RT work (Jensen, 1982a, b). In particular Jensen cites RT slope as one of the best correlates with IQ, and an increase in RT × IQ correlations with an increase in the number of bits; neither of these results was replicated.

Correlating median MT with Raven's produced five correlations significant at $P < 0.05$; the 'intercept' score also correlated at $P < 0.05$ with Raven's. However given that there is no apparent function relating MT to number of bits, the 'intercept' has little meaning other than as an average of the MT medians. MT standard deviations are unrelated to Raven's score, all correlating non-significantly, two negatively, three positively. This failure may be largely due to the unreliability of the score.

The correlation of Raven's with MT is surprising in the light of Jensen's (1982b) statement that only amongst the retarded is there a significant relationship between MT and IQ. However, Jensen and Munro (1979) report a correlation of -0.43 ($P < 0.01$) between total MT (the sum of median MTs on the 0-, 1-, 2- and 3-bit conditions) and Raven's score, compared with a correlation of -0.39 ($P < 0.02$) between total RT and Raven's, the sample being 37 females of mean age 14.7 yr and above average intelligence.

Barrett *et al.* (1985) report that some 20% of their Ss poorly fit Hick's law and that removal of these aberrant Ss both makes their data more like Jensen's published data and boosts nearly all their RT–IQ correlations.

Following Barrett *et al.* the percentage fit of individual Ss, using the first and second 0-bit conditions in the regression separately, were investigated. Seven of the 37 Ss were found to have a percentage fit of <60% in both cases, or negative slopes (2 of the 7 had a negative slope in one case and a low percentage fit in the other). A further 3 Ss had low percentage fits if the first 0-bit condition was used in the regression and high percentage fits when the second 0-bit condition was used; this was the pattern expected to be produced if the poor fit was a result of 'equipment shyness' or lack of sufficient practice.

The data from 37 Ss were then split into a fitting and a non-fitting group. The fitting group consisted of the data of 27 Ss using the first 0-bit condition (these being the 27 Ss who had a high percentage fit using either 0-bit condition) and 3 Ss using the second 0-bit condition, making a total of 30 Ss. The non-fitting group consisted of 7 Ss' data using the first 0-bit condition.

Table 2. Correlations between variables from the first and second 0-bit conditions ($N = 37$)

Variable	Correlation
RT	0.87
SD of RT	0.68
MT	0.86
SD of MT	0.39

Barrett *et al.* (1985) hypothesized that non-fitting might be due to inattention to the task. Such an hypothesis leads to three predictions.

(1) *S*s who do not fit Hick's law will have larger measures of variability than those who fit the model (SDs of RTs within each condition).

(2) Differences between samples are largely a result of differences between the proportion of *S*s who 'fail to attend' (an experimenter effect perhaps). Editing out these *S*s should lead to a greater homogeneity between different samples.

(3) The fit to Hick's law is independent of IQ.

Barrett *et al.*'s data support predictions (2) and (3), but are equivocal on prediction (1). The present sample supports the prediction of elevated variability amongst the non-fitters. The SDs of 0A, 0B 1-, 2- and 3-bit conditions for the fitters are provided in Table 3, for the non-fitters the relevant figures are 54.91, 44.00, 44.29, 42.25, 46.87; all greater than those for the fitters and giving respective F-ratios using a two-sample t-test, of 6.56 (sign. $P < 0.05$), 9.03 (sign. $P < 0.01$), 1.56, 2.01 and 0.29, all with 35 *df*.

The editing procedure (removal of *S*s with low percentage fit) makes the present sample conform slightly more closely to the two samples given in Barrett *et al.* However the improvement due to the editing is slight compared to the differences in published data between different samples. The present study does find a significant correlation between percentage fit and Raven's score. The correlation of 0.36 in the unedited data is significant at $P < 0.05$ (two-tailed), though the correlation in the edited data just fails to be significant (0.27), as it does amongst the non-fitters (0.20). Nonetheless, a relationship between percentage fit and Raven's must call into question the validity of editing the data to increase correlations to Raven's on the basis of percentage fit.

Correlating the edited RT parameters with Raven's has mixed results. RT × Raven's correlations fall, correlations between SDs of RTs and Raven's generally rise (of the six SD parameters, three increase, two decrease, one is unchanged). MT × Raven's correlations are also decreased. Table 3 provides the results from the fitting group. The removal of non-fitters in this sample is less successful than Barrett *et al.*'s editing, though the most notable result of Barrett *et al.*'s editing—the increase in SD × IQ correlations—is partially replicated.

Table 3. Means, standard deviations and correlations with Raven's score for the edited sample (N = 30)

Variable	Mean	SD	Correlation with Raven's APM
0A Bits RT	293.17	42.35	−0.17
0B Bits RT	293.03	35.92	−0.02
1 Bits RT	315.80	44.60	−0.20
2 Bits RT	333.66	48.58	−0.20
3 Bits RT	360.43	49.37	−0.20
Slope	22.90	9.12	−0.08
Intercept	290.65	38.81	−0.20
% Fit	87.23	9.12	0.27
0A Bits SD	34.97	14.97	−0.36*
0B Bits SD	29.95	10.22	−0.23
1 Bits SD	36.63	13.68	−0.26
2 Bits SD	34.50	13.70	−0.19
3 Bits SD	42.74	18.33	−0.15
σ_{RT}	35.75	10.65	−0.32
0A Bits MT	257.63	44.95	−0.29
0B Bits MT	252.07	50.41	−0.32*
1 Bits MT	250.60	44.70	−0.41*
2 Bits MT	258.50	51.43	−0.37*
3 Bits MT	274.43	58.22	−0.40*
Slope	5.30	10.89	−0.28
Intercept	252.78	41.36	−0.34*
% Fit	56.43	30.68	−0.07
0A Bits SD	35.64	21.16	0.36*
0B Bits SD	26.65	16.39	0.08
1 Bits SD	25.12	16.54	−0.06
2 Bits SD	26.41	15.70	0.46
3 Bits SD	40.96	28.07	0.35
Raven's	16.76	6.17	

Significance level (one-tailed): $^*P < 0.05$.

Odd-man-out

Table 4 shows the means and SDs of median RTs and of ranges for each of the 24 displays used in the odd-man-out paradigm. Correlating the medians and ranges with Raven's score shows all 48 scores to be negatively correlated with Raven's; the RT × Raven's correlations range from -0.64 to -0.38 with 23 significant at $P < 0.01$ and 1 at $P < 0.05$ (one-tailed); the range × Raven's correlations vary from a -0.62 to -0.04 [14 significant at $P < 0.01$, 7 significant at $P < 0.05$ (one-tailed)].

A principal-components analysis was undertaken on the results from both RTs and ranges. Three tests of factor extraction quantity were used, the Velicer MAP test (Velicer, 1976), the Kaiser factor α-criterion (Kaiser, 1960, 1965) and Autoscree [a computer implementation of Cattell's scree test (Barrett and Kline, 1982)]. For the median RTs the first two eigenvalues were 18.09 and 1.532 accounting for 75.36 and 6.38% of the variance, respectively, indicating a general factor solution.

For the ranges the first three eigenvalues were 12.06, 2.059 and 1.47 accounting for 50.25, 8.58 and 6.13% of the variance, respectively, and again a general factor solution was suspected. However, a hyperplane maximized direct oblimin (Jenrich and Sampson, 1966, 1979; Barrett and Kline, 1980; Barrett, 1985) rotation was implemented on both the first two and first three components. The δ-parameter was swept from 0.5 to -10.5 in steps of 1.0, the hyperplane bandwidth set at $+0.10$. In this way maximized simple structure solutions were obtained. The two-factor solution has only three variables loading more heavily on Factor 2 than Factor 1; the three-factor solution has only two variables loading preferentially on Factor 2, and only two on Factor 3.

Coefficient α was calculated for the RTs and the ranges by designating the 24 RTs and all 24 ranges each as a scale. The resulting αs are 0.99 for the RTs and 0.95 for the ranges. With such high values it was felt that the adoption of a general factor solution for both the RTs and the ranges was justified. Given the adoption of a general factor solution, rather than computing multiple *R*s for the RTs and ranges against Raven's the mean of the RTs and ranges was correlated with Raven's score. The mean RT × Raven's was -0.62, the correlation between mean range and Raven's was 0.52; both these correlations are significant at $P < 0.01$. The high correlation (0.87) between mean RT and mean range parameter makes computation of a multiple *R* from these of little value.

Table 5 shows the correlation between the two composite odd-man-out parameters with Jensen RT and MT parameters. The generally high correlations again make the computation of a multiple *R* of doubtful validity. However, it should be noted that correlations of the psychophysical parameters with Raven's are of the same magnitude as those amongst the psychophysical parameters.

Data from the odd-man-out paradigm were tested for 'learning' effects both across items and across *S*s. A regression of RT on position in chronological sequence (from 1 to 120) was done for each item, using data from all 37 *S*s. Of the 24 different patterns, 21 gave a negative slope indicating an improvement in performance with time (mean negative slope of -0.73, SD of 0.34). However, it should be noted that the percentage fits to the regression lines were small (mean percentage fit of 1.96%) as would be expected given the size of individual differences on the task.

The sum of the RTs of the second 60 trials was subtracted from the sum of the RTs on the first 60 to give each *S* an 'improvement' score. Of the 37 *S*s, 31 showed a positive improvement [mean improvement score of 3180, SD of 8400 (which represents an average improvement on each RT of 53.0 msec)]. The 'improvement' scores correlated 0.19 with Raven's score. However, removal of a single outlying *S* (who had an improvement score of $-39{,}600$, about three times the magnitude of the next largest score and over 10 SD from the mean using the results from the other 36 *S*s) increased the correlation to 0.37 (significant at $P < 0.05$, two-tailed). Removal of the outlier altered only the intercept of the regression line, the slope remaining unchanged.

DISCUSSION

Results from the present sample on the choice RT task are similar to both Jensen's published data and Barrett *et al.*'s (1985). The correspondence between average slope and intercept indicates that there is an enduring psychophysical phenomenon to be measured in the choice RT paradigm.

Table 4. Means, standard deviations and correlations with Raven's score for the RTs and ranges for each odd-man-out display ($N = 37$)

	Variable		Mean	SD	Correlation with Raven's APM
1	●●○○○○○●	RT	557.08	107.80	−0.64**
2	●○○○○○●●	RT	557.54	95.78	−0.60**
3	●○●○○○○●	RT	557.78	128.33	−0.54**
4	●○○○○●○●	RT	582.78	133.73	−0.49**
5	●○○●○○○●	RT	772.68	385.62	−0.38*
6	●○○○●○○●	RT	673.59	260.43	−0.56**
7	●●○○○○●○	RT	546.97	108.49	−0.59**
8	○●○○○○●●	RT	587.51	119.05	−0.55**
9	●○●○○○●○	RT	575.21	145.46	−0.54**
10	○●○○○●○●	RT	586.89	127.98	−0.49**
11	○●●○○○●○	RT	533.67	105.46	−0.58**
12	○●○○○●●○	RT	552.03	100.46	−0.54**
13	○●○●○○●○	RT	608.78	254.43	−0.50**
14	○●○○●○●○	RT	677.16	490.74	−0.51**
15	○○○●●○○●	RT	561.62	88.59	−0.48**
16	●○○●●○○○	RT	559.51	100.07	−0.56**
17	●●○○●○○○	RT	585.89	153.38	−0.60**
18	○○○●○○●●	RT	599.40	120.57	−0.46**
19	○○○○●●○●	RT	644.68	111.42	−0.50**
20	●○●●○○○●	RT	623.08	135.77	−0.55**
21	○○●●○●○○	RT	553.00	114.26	−0.63**
22	○○●○●●○○	RT	592.35	127.33	−0.55**
23	●●○●○○○○	RT	624.30	157.49	−0.63**
24	○○○○●○●●	RT	625.14	166.11	−0.54**
1	●●○○○○○●	RNG	221.62	179.68	−0.37*
2	●○○○○○●●	RNG	239.32	139.62	−0.41**
3	●○●○○○○●	RNG	277.51	207.71	−0.29*
4	●○○○○●○●	RNG	301.11	340.54	−0.47**
5	●○○●○○○●	RNG	834.54	1497.40	−0.39**
6	●○○○●○○●	RNG	744.43	1078.12	−0.45**
7	●●○○○○●○	RNG	265.32	227.75	−0.48**
8	○●○○○○●●	RNG	273.49	206.84	−0.33*
9	●○●○○○●○	RNG	353.54	436.19	−0.37*
10	○●○○○●○●	RNG	304.43	215.77	−0.31*
11	○●●○○○●○	RNG	179.54	122.56	−0.51**
12	○●○○○●●○	RNG	176.92	108.78	−0.45**
13	○●○●○○●○	RNG	626.97	707.63	−0.36*
14	○●○○●○●○	RNG	405.35	521.85	−0.48**
15	○○○●●○○●	RNG	203.03	85.08	−0.04
16	●○○●●○○○	RNG	204.43	143.44	−0.62**
17	●●○○●○○○	RNG	279.49	194.68	−0.44**
18	○○○●○○●●	RNG	273.51	172.97	−0.23
19	○○○○●●○●	RNG	276.24	156.13	−0.17
20	●○●●○○○○	RNG	258.81	154.63	−0.31*
21	○○●●○●○○	RNG	262.57	220.84	−0.57**
22	○○●○●●○○	RNG	235.24	192.89	−0.49**
23	●●○●○○○○	RNG	337.49	240.21	−0.42**
24	○○○○●○●●	RNG	294.41	184.59	−0.48**

Significance levels (one-tailed): $^{*}P < 0.05$; $^{**}P < 0.001$ (one-tailed).

Table 5. Correlation between the two composite scores from the odd-man-out paradigm and Jensen RT/MT parameters ($N = 37$)

Jensen variable	Mean odd-man-out RT	Mean odd-man-out range
0A Bits RT	0.52	0.36
0B Bits RT	0.51	0.34
1 Bits RT	0.67	0.53
2 Bits RT	0.74	0.57
3 Bits RT	0.68	0.48
σ_{RT}	0.53	0.32
0A Bits MT	0.54	0.57
0B Bits MT	0.41	0.38
1 Bits MT	0.54	0.57
2 Bits MT	0.45	0.43
3 Bits MT	0.41	0.38
Raven's	−0.62	−0.52

However, the parameters that define Hick's law slope and intercept appear to be uncorrelated with IQ (note that given the correlation between the 0-bit RT and IQ the intercept is forced to correlate with IQ); nor is there any increase in the RT × IQ correlation with an increase in the number of bits. The highest correlations with IQ are observed with MTs, a surprising result that has also been found elsewhere (Jensen and Munro, 1979). Overall, whilst the choice RT results support a general 'speed' theory of IQ, they counter-indicate Jensen's specific theory, as do the slope results.

The present study has failed to provide a complete explanation for the poor fit to Hick's law of some *S*s. The 'trivial' explanation of insufficient practice is only a partial answer as is excessive response variability. The discovery of a correlation between percentage fit and IQ, in direct opposition to Barrett *et al.*'s (1985) results, calls into question the legitimacy of editing on the basis of percentage fit. Clearly more data on the percentage fit of individual *S*s are required.

The odd-man-out paradigm has been shown to be capable of producing measures that are both reliable and correlate well with IQ. RTs and ranges for individual patterns vary widely, but differences between patterns appear not to have any psychometric significance, a general factor solution being optimal for both RTs and ranges. The high values for correlations between RT/range and IQ contradict Vickers *et al.*'s (1972) prediction that only the simplest of tasks will correlate highly to IQ. The low correlations between some of the other more difficult elementary cognitive tasks and IQ would appear to be attributable to the incorporation of irrelevant (or at least unrelated to IQ) high-level processes.

The relationship between RT and IQ in the odd-man-out paradigm could be explicable in our information theoretic framework, the task requiring simply more of Jensen's binary decision nodes than a choice RT. However, it should be noted that there are no differences in RT × IQ correlations between displays that would be difficult (e.g. ●○○○●○○●) and those that would be easy (e.g. ●○○○○○●●) on such a basis. Also differences such as the position of a pattern on the diaplay (e.g. ●●○●○○○○ and ○○●●○●○○) which would be immaterial in an information theory framework, produce differences in mean RT. Performance on the odd-man-out task appears not to conform to information theory expectations.

Evidence of learning through the period of the odd-man-out task is contrasted with Barrett *et al.*'s (1985) finding of no decrease in RT within each condition on the choice RT paradigm and the similarity between first and second 0-bit condition in the present study. A detailed examination of 'where' the learning effects took place would require more replications on each pattern than the five used here; investigation of the durability of the learnt decrement in RT would require repeated representations of the task. Both of these requirements are to be met in future studies.

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