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INTELLIGENCE, REACTION TIME AND THE EFFECTS OF SMOKING

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Summary—A group of 113 smokers of normally distributed IQ was tested on two occasions on a choice reaction time task and the newly introduced 'odd-man-out' task. Performance on these two tasks was found to correlate significantly with IQ and personality variables as measured by the WAIS-R intelligence test and the EPQ and IVE. The effect of smoking on these tasks was also measured giving significant improvement in performance on both the reaction time tasks. Reliabilities were found for the reaction time parameters, and the effects of using reliabilities to 'correct' correlations is demonstrated. The validity of the commonly used correction for attenuation due to restricted IQ range on the performance × IQ correlation was also investigated. The effect of smoking on reaction times is discussed in relation to Knott's "gate theory".

SMOKING AND REACTION TIME

The question of why habitual smokers continue to smoke in the face of social pressure to stop is typically answered in terms of either addiction or arousal modulation (Eysenck, 1973, 1980). Physiological addiction theories (e.g. Schachter, Silverstein, Kozlowski, Perlick, Herman and Leibling, 1977) typically postulate that somewhere within the CNS there are receptors which in a way analagous to opiate receptors' response to heroin in the addict, signal punishment when the circulating level of nicotine falls below a certain level. Such a model would predict that habitual smokers would make an effort to maintain their 'normal' nicotine levels even when attempts are made experimentally to alter levels of nicotine within the smoker.

Schachter *et al.* (1977) report that manipulating smokers' urinary pH and hence the rate of secretion of nicotine causes smokers to alter the amount of nicotine they take in through smoking. Mangan and Golding (1978), however, found that over a period of several days smokers given cigarettes of radically different nicotine content nonetheless smoked the same number. It should be noted that such experiments involving overt smoking will be confounded both by the secondarly reinforcing properties of the act of smoking itself, and that smokers, by altering their smoking characteristics, can extract far more or far less nicotine from each cigarette than figures derived from a standard smoking machine would suggest (Wesnes and Warburton, 1983).

Arousal modulation theories postulate that smokers are able to use nicotine to control their level of general arousal to perform optimally in a variety of situations (Eysenck, 1985a). The known biphasic effect of nicotine in animals, arousing in small doses, tranquilising in higher doses (Armitage, Hall and Sellers, 1969) has also been demonstrated in EEG (contingent negative variation CNV) studies in man (Ashton, Millman, Telford and Thompson, 1974), though evidence for the arousing effect of nicotine in man is stronger than for the depressant (Ulett and Itil, 1969; Knott and Venables, 1977).

Manipulation of arousal by cigarette smoking has been shown to facilitate performance in a variety of tasks. Frankenhaeuser, Myrsten, Post and Johansson (1971) showed that smoking counteracted the decrease in performance of a vigilance task over time; Myrsten, Post, Frankenhaeuser and Johansson (1972) showed that smoking improved reaction time performance in smokers when compared to a non-smoking condition, as have Smith, Tong and Leigh (1977) in a similar task. Similarly Wesnes and Warburton (1983) report improvements in both reaction time and accuracy in a digit detection task following smoking by habitual smokers, and oral nicotine doses given to non-smokers (Wesnes and Warburton, 1984). However, various authors have reported finding no significant improvement in reaction times after smoking (e.g. Knott, 1985), or even worsening of performance (Cotten, Thomas and Stewart, 1971). Knott (1978) suggested that nicotine allowed smokers to filter incoming sensory signals more efficiently. Knott (1980) reported smokers as better able to deal with the distracting effects of loud noise on reaction time; he also found reduction of P2 amplitude in response to aversive noise (Knott, 1985) indicative of a lowered arousal level which would result in better orientation to relevant stimuli. O'Connor (1980, 1982) found similar changes the magnitude of which were related to extraversion as measured by the Eysenck Personality Inventory (Eysenck and Eysenck, 1964). Ashton *et al.* (1974) reported the effect on the CNV of smoking, finding a biphasic effect with extraverts taking nicotine less rapidly than introverts, leading to stimulation in the extraverts and sedation in the introverts, results consistent with Eysenck's theory of individual differences in background levels of excitary/inhibitory activity in introverts and extraverts (Eysenck, 1967, 1980, 1985a).

The effect of smoking on performance is also dependent upon the complexity of the task; Elgerot (1976) reported an improvement in performance on complex tasks and a decrement on simple tasks following smoking deprivation. Such results are suggestive of an inverted-U relationship between arousal and performance. Evidence for the involvement of the catecholamines in the effect of nicotine on the CNS (as proposed by Burn and Rand, 1959) comes from human and animal studies. Frankenhaeuser *et al.* (1971) found increased levels of adrenaline in the urine of smokers following a reaction time task concurrent with smoking. Schechter and Rosecrans (1972) found that behaviour trained to be triggered in rats by injection of nicotine was reduced by depletion of brain levels of 5-HT.

The present study was designed to investigate the immmediate effect of smoking on two reaction time tasks which have been shown to be related to psychometric IQ. These tasks are assumed to involve some of the same processes that underlife performance on more complex 'real world' tasks. The two tasks, the 'Jensen' choice RT task and the odd-man-out paradigm are introduced below.

INTELLIGENCE AND RT

The relationship between intelligence as measured by psychometric tests and performance on very simple tasks has been the subject of inquiry since the end of the last century when Galton (1883) first suggested that reaction times might be a good index of mental ability. Interest in the theory was revived when Roth (1964) found a significant correlation between the slope of choice reaction time against bits of information and psychometric g. Roth's work led to the investigations of the 'Erlangen' school in Germany reviewed by Eysenck (1985b) and of Jensen and others in the U.S.A. reviewed by Jensen (1987).

In addition to measures derived from simple and choice reaction time paradigms, investigation has focussed on the brief presentation of displays requiring a discrimination as a response from the subject ('inspection time'). Typically such displays are of a number of lines of differing length with the subject indicating the shortest/longest. (Nettlebeck and Lally, 1976; Lally and Nettlebeck, 1980; Nettlebeck and Kirby, 1983; Eysenck, 1986a; Vickers and Smith, 1986: reviewed by Brand and Deary, 1982; Brebner and Nettlebeck, 1986).

The correlation of these simple tasks of rapid information processing with psychometric intelligence has led to theories seeking to explain individual differences in mental ability in terms of either a single information channel of limited capacity (Lehrl and Franks, 1982); or a network of information processing nodes of varying efficiency (Jensen, 1982) or neural pathways of limited signal-to-noise ratio (Eysenck, 1986b).

The chief results of the research using the 'Jensen' choice RT paradigm are:

1. Significant correlations between median RT and IQ at all different numbers of decision bits;
2. Significant correlations between median movement times (MT) and IQ at all different numbers of decision bits;
3. Significant correlations between variance of RTs and IQ at all different numbers of decision bits;
4. Significant correlations between slope of median RT on bits of decision information and IQ;
5. An increase in the correlation between RT and IQ with increasing number of bits of decision information.

Of these results those relating to parameters defined by Hick's law, i.e. the slope, appear to be the most uncertain. Barrett, Eysenck and Lucking (1986) and Frearson and Eysenck (1986) both report finding no relationship between slope and IQ. Both these also report some of their subjects not conforming to Hick's Law, nor do they find any increase in correlation between IQ and median RT with increasing bits of decision information.

A consensus view on the size of the relationship between reaction time parameters and psychometric IQ has been found difficult to come to. Experimental investigations have given widely different results, particularly for the parameters of low reliability ('slope' measures and variability of reaction time in particular), and differences in analysis and in the application of statistical corrections for attenuated range and reliability have further obscured consistencies in the field.

Jensen (1987) gives estimates, derived from a heterogenous group of studies, of correlations between IQ and mean RT of -0.32, between IQ and RT variability of -0.48 and between IQ and mean MT of -0.30. These estimates are based upon an assumption that different studies can be legitimately compared, even if they use different IQ measures, and that corrections can be made for attenuations in range of IQ and for unreliability of RT measures.

Recently a more complex reaction/inspection time task has been developed: the odd-man-out pradigm. Frearson and Eysenck (1986) report a high correlation between measures of median reaction time and of variability in reaction time on this task, and scores on Raven's Advanced Progressive Matrices.

The present study sets out to replicate the results of Frearson and Eysenck (1986) on the odd-man-out paradigm, using a more comprehensive measure of intelligence viz. the WAIS-R, to establish test–retest reliabilities for both the odd-man-out and the 'Jensen' choice RT using a large sample of normally distributed adults, and to investigate some of the issues that affect interpretation of the relationship between choice reaction time and IQ.

In detail, the aims of the present study are:

1. To replicate Frearson and Eysenck's (1986) odd-man-out findings using the WAIS-R as the criterion IQ test.
2. To replicate the relationships between various choice RT parameters and WAIS-R IQ.
3. To obtain test–retest reliabilities for both choice reaction time and odd-man-out parameters.
4. To investigate the effect of practise on performance on the choice reaction time and odd-man-out parameters.
5. To investigate whether scores on different psychometric instruments (in this case WAIS-R and Raven's Advanced Progressive Matrices) are sufficiently closely related to enable studies using different IQ measures to be combined.
6. To investigate the effect of using samples of attenuated range of IQ.
7. To investigate the meaningfulness of corrections for restriction of range and for unreliability.

METHOD

Subjects

A sample of 113 subjects was recruited from the local Job Centre, advertisements in local newspapers and in the London Mensa Newsletter. Efforts were made to ensure an approximately normal spread of IQ in particular by the purposeful recruitment of Mensa members and a brief pre-testing of some subjects at the Job Centre to ensure adequate sampling of both high and low IQ's. Of these 113 subjects a total of four were dropped from any analysis for a variety of reasons unrelated to the experiment viz.

Subject 34 had previously done the WISC test.

Subject 91 was extremely uncooperative and refused to do some of the tasks.

Subjects 97 and 105 only came to the first of the two testing sessions.

This left 109 subjects (70 male, 39 female). The age range of the males was from 17 to 60 years with a mean of 28.21 and an SD of 9.53. The age range of the females was from 18 to 44 with a mean of 26.49 and an SD of 7.21.

Design

All subjects performed each of the two reaction time tasks three times over a period of 2 'working days' (i.e. about a fifth of all subjects were tested on a Friday and then next on the following Monday). Half the subjects performed the choice reaction time task twice on day 1 with the smoking of a single cigarette between, the other half performed the odd-man-out twice on day 1, again with the two performances separated by a cigarette. On day 2 the second task was repeated twice, again with a cigarette smoked between the two performances.

	Day 1	Day 2
Group 1	Odd-man out 1	Odd-man-out 2 Smoke Odd-man-out 3
	Choice RT 2 Smoke Choice RT 3	Choice RT 1
Group 2	Odd-man-out 2 Smoke Odd-man-out 3	Odd-man-out 1
	Choice RT 1	Choice RT 2 Smoke Choice RT 3

Such a design allows for a direct measurement of day to day reliability by the comparison of RT task 1 and 2. By comparison of tasks 2 and 3 the effect of smoking on RT performance could be measured, though confounded with any effect of practise on the task.

To measure directly the effect of practise on the RT tasks as many as possible of the original sample were retested a variable time later (from 2 weeks to 9 months depending on when they were originally tested). The retest sample consisted of 39 subjects (24 male, 15 female). The age range of the males was from 19 to 56 yr with a mean of 28.58 and an SD of 10.38. The age range of the females was from 20 to 44 yr with a mean of 25.73 and an SD of 6.46. All of the retest sample performed each of the two RT tasks twice, the two tasks separated by a rest period of about 5 min to simulate the time taken up previously by smoking. Half the sample performed on the choice RT task first, the other half on the odd-man-out task.

	Day 1
Re-test Group 1	Odd-man-out 4 Break Odd-man-out 5 Choice RT 4 Break Choice RT 5
Re-test Group 2	Choice RT 4 Break Choice RT 5 Odd-man-out 4 Break Odd-man-out 5

Subjects' smoking throughout the experiment was intended to be as natural as possible. Subjects were not asked to use a prescribed puff-pattern or to leave a standard length of butt. Subjects were given one of four test cigarettes closest in nicotine delivery to their own preferred brand and were instructed to smoke it in their normal way (in line with the suggestions of Morgan and Pickens, 1982).

In addition to the RT tasks each subject was given the WAIS-R intelligence test, the sub-tests being split over the 2 days of testing, and a computer administered version of the Eysenck

Personality Questionnaire (Eysenck and Eysenck, 1975) and the I_7 [IVE] (Impulsivity, Venturesomeness, Empathy) (Eysenck, Person, Easting and Allsopp, 1985) questionnaire. All the subjects except numbers 1–7 and 9–22 (i.e. 88 out of the 109 subjects analysed) were also given a 20-min version of the Raven's Advanced Progressive Matrices both to ensure compatibility with Frearson and Eysenck (1986) and to examine the relationship between the Raven and WAIS-R.

Apparatus

All experimental control, stimulus presentation and data acquisition were controlled by an ACT Sirius 1 microcomputer. Signal priming, detection and timing were implemented via a Biodata Microlink unit comprising modules RR8 (8 channel reed relays), two CC8 (8 channel digital inputs) and two TIM (clock module timing in msec units). Timing of reaction times was implemented purely by hardware enabling millisecond accuracy, timing of movement times required software intervention and hence movement times are accurate only to hundredths of seconds. The arrangement of stimulus lights and response buttons was copied exactly from measurements and description given in Jensen and Munro (1979).

Procedure for choice reaction time task

Reaction times and movement times were assessed over conditions of 1 and 2 bits of decision information, corresponding to two and four lights on show respectively. Four sets of 10 trials were given, the order of conditions being fixed for all subjects. The first set of trials was at 1-bit, then 2-bits, then a second set at 2-bits and a second set at 1-bit. This order was used to ensure that on the after smoking task the 1-bit and 2-bit conditions were on average equally distant from the smoking. Covers were placed over the lights not used in any condition.

The subjects were seated in front of the response box and used their preferred hand for all button-pressing. The subjects were given as many practise trials on the 1-bit condition as were required before the subject expressed confidence in the task. The practise trials were given on all the tasks except those that immediately followed the cigarette smoking or the non-smoking break in the retest sample (i.e. Choice RT 3 and Choice RT 5).

Each trial is started by a warning tone of 1000 Hz frequency and 54 msec duration given at approximately 70 dB by the Sirius. The tone is followed by a random delay of 1–4 sec. If the subject's finger is on the home button the target light is illuminated. (If the subject is not on the home button the experimenter receives a warning message from the Sirius and can restart the trial after having ensured the subject is holding down the home button.) The sequence of positions for the target light are randomized for each subject. The RT clock is started at the onset of the light and is stopped by the subject releasing the home button which also starts the MT clock which is stopped by the subject's pressing the target button. The RT, MT and light position are recorded by the Sirius.

Procedure for odd-man-out task

The odd-man-out paradigm uses the same response box as the choice RT task. Each stimulus in the odd-man-out task consists of 3 out of the possible 8 lights being lit. 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 from the distance between the centre and right lights. Such displays are explained to the subject as consisting of a pair of lights (the two closest together) with an 'odd-man-out'. With 8 light positions there are 44 such possible displays. The present study uses 12 different displays of which 6 are left–right mirror images of the other 6 (Fig. 1). These 12 were chosen as those which were found to have the best correlation with Raven's matrices score by Frearson and Eysenck (1986).

The subjects were instructed, starting with their finger on the home button, to press the button corresponding to the odd-man-out light. Each display was presented to the subject five times, making a total of 60 separate trials. The 60 trials were assigned to two groups (three of any display in one group, two in the other). The order of presentation of displays was randomized within each group. After every 15 trials the task was suspended, to allow the subject to rest, the task being restarted by the experimenter at the subject's instigation.

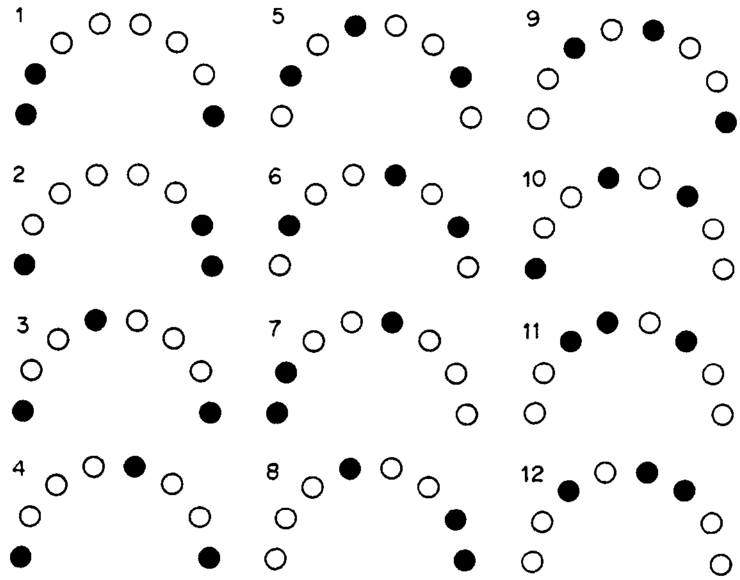

Fig. 1

Trials where the subject produced an error (pressed a button other than that corresponding to the odd-man-out) were repeated at the end of each block. (If errors occurred in these repetitions the trial was given 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 to allow for more practise. (Although in fact only one of the 113 subjects tested had any problems with the task and produced more than 10 errors in a block. Her data were discarded from the analysis when she refused to carry on with the task.)

Subjects were instructed in the task and then given a batch of 8–18 practise trials consisting of displays of varying complexity until they expressed confidence in the task. Subjects were told to be as quick as possible in all button-pressing but not to be overly concerned about the possibility of making an error as all errors would be repeated.

The odd-man-out task is implemented in a similar way to the choice RT task. Reaction times, movement times, type of response (right or wrong) and the chronological sequence of the trial are logged by the Sirius.

STATISTICAL ANALYSIS

Choice reaction time

Because each condition is given twice (two sets of 10 trials) within each task, data from each condition can be analysed either by taking each set of 10 trials separately or by treating all 20 trials as a single condition. Each parameter is computed for each task in these three ways.

Both RT and MT data were 'corrected' by replacing the largest value within any condition with the mean value of the other RT/MT in that condition, as suggested by Barrett *et al.* (1986). This constitutes an objective method of dealing with excessively long RTs and MTs such as might be caused by momentary lapses of concentration (for the RT) or by 'missing' the target button (for the MTs).

Data were also passed through a validity check, such that if an RT was less than 140 msec or longer than 999 msec or an MT was less than 90 msec or greater than 999 msec, the RT/MT would be replaced by the mean RT/MT for that condition.

The choice reaction time data were then analysed to give a median RT and MT for each condition and the SD of RT and MT for each condition. In addition a 'slope' measure was obtained by subtracting the median RT obtained from all 20 1-bit trials from the median RT obtained from the 20 2-bit trials.

Odd-man-out

The median RT and MT of the five correct responses for each display were calculated. Two measures of dispersion were calculated: the 'range', which is simply the largest minus the smallest RT/MT, and the 'inter-quintile range', which is the second largest minus the second smallest RT/MT. It was hoped that the inter-quintile range might be more reliable a measure than the simple range. These measures were chosen over the mean and standard deviation because of skewness in the RT/MT data as has been suggested for other RT measures by Brownlee (1975) and Winer (1971); and because of the small number of observations respectively. Also the number of errors made during the task was calculated.

RESULTS

Factor structure of odd-man-out

The parameters derived from the odd-man-out paradigm are 6 sets of 12 repetitions of a single parameter computed for each of the 12 displays in turn (i.e. median RT 1–12, median MT 1–12 etc.). To ascertain whether the 12 values for each statistic could be legitimately combined to give a composite score a set of six factor analyses was performed, one on each set of 12 values. All six factor analyses gave results compatible with a general factor model. Values of Kaiser factor alpha criterion (Kaiser, 1960, 1965) for the first two (or three) eigenvalues and the value of coefficient alpha derived when the 12 scores are designated as a scale are given in Table 1.

Given the adoption of a general factor solution the arithmetic mean of the 12 individual scores could be taken as a reasonable measure of performance on all 12 different displays. The 'factor' scores' were computed by applying unit weights to all variables. The six factor scores are then ORT.FS for the 12 median reaction times, OMT.FS for the 12 movement times, ORRNG.FS for the 12 ranges of reaction times and OMRNG.FS for the ranges of the movement times, and ORQUI.FS and OMQUI.FS for the inter-quintile ranges of reaction times and movement times.

Table 1. Eigenvalues with their Kaiser factor alpha and percentage of variance accounted for and values of coefficient alpha for 12 item scales

Reaction times (ORT1–ORT12)		
Eigenvalue	Kaiser-alpha	Percentage variance
10.024	0.982	83.533
0.626	−0.651	5.217
		Alpha = 0.982
Movement times (OMT1–OMT12)		
Eigenvalue	Kaiser-alpha	Percentage variance
9.506	0.976	79.215
0.543	−0.917	4.528
		Alpha = 0.976
Reaction time ranges (ORRNG1–ORRNG12)		
Eigenvalue	Kaiser-alpha	Percentage variance
6.678	0.928	55.650
0.996	−0.005	8.298
		Alpha = 0.927
Movement time ranges (OMRNG1–OMRNG12)		
Eigenvalue	Kaiser-alpha	Percentage variance
2.413	0.639	20.111
1.362	0.290	11.351
1.267	0.230	10.561
		Alpha = 0.607
Reaction time inter-quintile ranges (ORQUI1–ORQUI12)		
Eigenvalue	Kaiser-alpha	Percentage variance
6.412	0.921	53.434
1.210	0.189	10.084
0.768	−0.330	6.400
		Alpha = 0.920
Movement time inter-quintile ranges (ORQUI1–ORQUI12)		
Eigenvalue	Kaiser-alpha	Percentage variance
2.798	0.701	23.320
1.552	0.388	12.932
1.186	0.171	9.884
		Alpha = 0.693

Reliability

The day-to-day retest reliability of all parameters derived from either the choice RT or odd-man-out were calculated by computing the correlation between each parameter from Choice RT 1/odd-man-out 1 with the parameter from Choice RT 2/odd-man-out 2. This gives a measure for half the sample in which the two tasks being compared are in fact separated by a third performance of the task (i.e. those subjects who performed Task 2 followed by Task 3 on day 1). To determine whether the inclusion of this third task affects test–retest reliability, the reliabilities for the two halves of the subject set were calculated. The results of this comparison are given in Table 2 for the choice reaction time and Table 3 for the odd-man-out. Clearly the two halves have similar test–retest reliabilities; to obtain a single figure for all subjects the two halves could apparently be simply recombined and the test–retest reliability calculated over all 109 subjects. However, if this is done, the reliabilities for the group as a whole tend to be lower than the reliability for either half particularly in the odd-man-out results (e.g. for ORT.FS reliabilities for the two groups are 0.859 and 0.820; for the whole group 0.696). Whilst individually these differences between reliabilities do not reach significance, the existence of any result where the merging of two apparently equivalent groups leads to a lowering of reliability requires explanation. In this case it is suspected that the intervening task in the odd-man-out paradigm for one-half of the subjects has led to their performing better on OMO 1 than the half who did not have the advantage of this extra practise. The improvement in performance has apparently had a similar effect on all subjects, so the monotonic relationship between day 1 and day 2 performance has been preserved, and consequently the reliabilities of the two groups do not differ. Mixing the two groups will however depress the correlation between day 1 and day 2 performance due to the addition of this 'practise effect'. A simple numerical example will illustrate the effect of such an increment: if Group 1 has 4 data points (1, 1), (2, 2), (3, 3), (4, 4) and Group 2 has the 4 data points (1, 11), (2, 12), (3, 13), (4, 14), both groups taken separately have a correlation between x and y of 1.0, but if the 8 points are just treated as a single group the correlation will clearly drop (in this case to 0.22).

It appears then that whilst the odd-man-out paradigm has extremely good reliability for many of its parameters the magnitude of parameters derived from it depends upon the extent to which subjects have become accustomed to it.

Table 2. Day-to-day retest reliabilities for 25 parameters from the choice reaction time task computed either just for subjects who did CRT 1 on day 1 (i.e. not confounded with an intervening task) and just for subjects who did CRT 1 on day 2 (i.e. confounded with an intervening task)

Variable	Test–retest reliability: Based on subjects doing CRT 1 on day 1	Test–retest reliability: Based on subjects doing CRT 1 on day 2
RT1A	0.714	0.639
RT2A	0.746	0.593
RT2B	0.772	0.619
RT1B	0.843	0.678
RT1	0.805	0.691
RT_2	0.759	0.609
SLOPE	−0.066	0.066
RV1A	0.243	0.351
RV2A	0.132	0.560
TV2B	0.333	0.218
RV1B	0.428	0.390
RV1	0.459	0.368
RV2	0.478	0.323
MT1A	0.567	0.593
MT2A	0.699	0.695
MT2B	0.781	0.796
MT1B	0.823	0.567
MT1	0.774	0.561
MT2	0.774	0.797
MV1A	0.766	0.556
MV2A	0.425	0.338
MV2B	0.706	0.266
MV1B	0.717	0.395
MV1	0.825	0.566
MV2	0.583	0.291

Table 3. Reliabilities of the six factor scores from the odd-man-out paradigm computed either just for subjects who did OMO 1 on day 1 (i.e. not confounded with an intervening task) and just for subjects who did OMO 1 on day 2 (i.e. confounded with an intervening task)

Variable	Test–retest reliability: Based on subjects doing OMO 1 on day 1 $N = 55$	Based on subjects doing OMO 1 on day 2 $N = 54$
ORT.FS	0.859	0.820
OMT.FS	0.793	0.891
ORRNG.FS	0.766	0.604
OMRNG.FS	0.243	0.367
ORQUI.FS	0.755	0.598
OMQUI.FS	0.384	0.390

Choice RT and intelligence and personality

The results of the two non-smoking conditions were amalgamated by simply taking the mean for each parameter for each subject over the two occasions. The means and standard deviations for all choice RT parameters are presented in Table 4. RT results are broadly similar to those reported elsewhere, MTs, as expected, were smaller than RTs, though SDs were similar.

Comparisons with the results of Frearson and Eysenck (1986) and Barrett *et al.* (1986) that were calculated over the same number of trials show that results in the present study are compatible with studies done in the orthodox style (i.e. with a mixed group of smokers and non-smokers and all 20-trials on one condition presented in a single block rather than the two blocks of the present study). The correlation (uncorrected for reliability) between RT variables and Full scale, Performance and Verbal IQ derived from the WAIS-R are given in Table 5. These results are in line with similar published results from this laboratory (Barrett *et al.*, 1986; Frearson and Eysenck, 1986). The correlation between a sub-set of the RT parameters (just those derived from the full sets of 20 trials) and the 11 sub-tests of the WAIS-R are given in Table 6. Comparison of these correlations and the correlation of the sub-tests with Full scale IQ show no consistent relationship between the size of correlation and the sub-tests 'g' loading. This is an unexpected result in view of Hemmelgarn and Kehle's (1984) finding of a large relationship between the 'g' loading of WISC-R sub-tests and correlation to RT slope.

Table 4. Means and standard deviations of the means of each choice RT parameter from CRT 1 and CRT 2

Variable	Mean	Standard deviation
RT1A	326.752	53.136
RT2A	333.844	49.654
RT2B	329.096	48.956
RT1B	312.569	46.757
RT1	321.330	48.099
RT2	333.404	49.317
SLOPE	12.073	13.242
RV1A	32.760	12.541
RV2A	29.521	11.293
RV2B	28.932	9.523
RV1B	28.789	11.227
RV1	37.282	13.237
RV2	33.902	11.110
MT1A	283.413	69.099
MT2A	275.514	62.650
MT2B	271.151	64.765
MT1B	268.284	67.540
MT1	277.220	67.217
MT2	274.936	63.230
MV1A	38.212	38.903
MV2A	33.166	27.869
MV2B	28.697	22.222
MV1B	31.824	36.093
MV1	44.996	41.222
MV2	41.338	29.156

$N = 109$.

Table 5. Correlations between the mean of 25 parameters derived from task one and task two on the choice reaction time task and Verbal, Performance and Full scale WAIS IQs

Variable	Correlation with Verbal IQ	Correlation with Performance IQ	Correlation with Full scale IQ
RT1A	−0.270**	−0.214*	−0.268**
RT2A	−0.177*	−0.156	−0.186*
RT2B	−0.156	−0.154	−0.170*
RT1B	−0.165*	−0.192*	−0.197*
RT1	−0.220**	−0.210*	−0.238**
RT2	−0.172*	−0.164*	−0.185*
SLOPE	0.157	0.151	0.175
RV1A	−0.310**	−0.333**	−0.350**
RV2A	−0.159	−0.155	−0.173*
RV2B	−0.138	−0.186*	−0.174*
RV1B	−0.246**	−0.341**	−0.308**
RV1	−0.346**	−0.384**	−0.390**
RV2	−0.168*	−0.193*	−0.198*
MT1A	−0.370**	−0.358**	−0.392**
MT2A	−0.349**	−0.318**	−0.364**
MT2B	−0.320**	−0.301**	−0.335**
MT1B	−0.340**	−0.344**	−0.363**
MT1	−0.361**	−0.367**	−0.389**
MT2	−0.330**	−0.303**	−0.344**
MV1A	−0.246**	−0.384**	−0.320**
MV2A	−0.123	−0.265**	−0.190*
MV2B	−0.289**	−0.368**	−0.332**
MV1B	−0.269**	−0.409**	−0.344**
MV1	−0.287**	−0.399**	−0.351**
MV2	−0.292**	−0.421**	−0.362**

Significant correlations marked with * ($P < 0.05$ 1-tailed) or ** ($P < 0.01$ 1-tailed).
$N = 109$.

Correlations between parameters derived from the choice reaction time task and the score on the 20-min version of Raven's Advanced Progressive Matrices are given in Table 7.

Comparison of these results with Frearson and Eysenck (1986) shows a general lowering of correlations, though the pattern of significant results stays similar. This effect is paralleled in the results of the odd-man-out paradigm and will be discussed further below.

Generally correlations between Choice RT parameters and intelligence measures are of the same magnitude as reported by Jensen, 1987, for a variety of studies. Only the high correlation between parameters of variability in movement time and Raven's score, Verbal, Performance and Full scale IQ are unexpected, Jensen (1987) reporting no relationship between MT variability and IQ.

Correlations between Choice RT parameters and personality variables obtained from the EPQ and the IVE are presented in Tables 8 and 9 respectively. Correlations between personality variables

Table 6. Correlations between Choice RT parameters that were calculated over 20 trials and WAIS-R sub-test scores

	Correlation with							
	RT1	RT2	RV1	RV2	MT1	MT2	MV1	MV2
Information	−0.149	−0.125	−0.261	−0.158	−0.304	−0.255	−0.250	−0.339
Digit span	−0.223	−0.195	−0.254	−0.127	−0.387	−0.378	−0.172	−0.095
Vocabulary	−0.167	−0.124	−0.311	−0.214	−0.279	−0.227	−0.283	−0.268
Arithmetic	−0.109	−0.071	−0.217	−0.649	−0.166	−0.140	−0.169	−0.220
Comprehension	−0.182	−0.153	−0.324	−0.110	−0.315	−0.277	−0.256	−0.262
Similarities	−0.185	−0.146	−0.258	−0.078	−0.302	−0.297	−0.182	−0.202
Verbal IQ	−0.220	−0.172	−0.346	−0.168	−0.361	−0.330	−0.287	−0.292
Pict. completion	−0.221	−0.169	−0.358	−0.208	−0.363	−0.312	−0.370	−0.399
Pict. arranging	−0.165	−0.109	−0.322	−0.085	−0.276	−0.208	−0.307	−0.283
Block designs	−0.225	−0.181	−0.399	−0.167	−0.377	−0.326	−0.387	−0.406
Object assembly	−0.172	−0.118	−0.298	−0.140	−0.259	−0.188	−0.389	−0.461
Digit symbol	−0.329	−0.324	−0.433	−0.318	−0.361	−0.306	−0.385	−0.310
Performance IQ	−0.210	−0.164	−0.384	−0.193	−0.367	−0.303	−0.399	−0.421
Full scale IQ	−0.238	−0.185	−0.390	−0.198	−0.389	−0.344	−0.351	−0.362

Correlations over −0.16 are significant beyond 0.05 (1-tailed), over −0.22 beyond 0.01 (1-tailed).
$N = 109$.

Table 7. Correlation between average of 25 parameters from task one and task two on choice reaction time task and score on Advanced Progressive Matrices

Variable	Correlation with APM
RT1A	−0.164
RT2A	−0.125
RT2B	−0.114
RT1B	−0.181*
RT1	−0.170*
RT2	−0.126
SLOPE	0.133
RV1A	−0.304**
RV2A	−0.026
RV2B	0.001
RV1B	−0.344**
RV1	−0.356**
RV2	−0.036
MT1A	−0.217*
MT2A	−0.245*
MT2B	−0.207*
MT1B	−0.214*
MT1	−0.220*
MT2	−0.224*
MV1A	−0.152
MV2A	−0.270**
MV2B	−0.192*
MV1B	−0.073
MV1	−0.203*
MV2	−0.310**

Significant scores marked by * ($P < 0.05$ 1-tailed) or ** ($P < 0.01$ 1-tailed).
$N = 89$.

and movement time parameters are generally higher than those between personality and reaction time parameters. The relationship between extraversion and Choice RT variables is as has been found elsewhere (e.g. Buckalew, 1973); and is as expected from a model of central inhibition in extraverts allowing for greater reactivity to external events (Eysenck, 1967). The relationship

Table 8. Correlations between average of 25 parameters from task one and task two on the choice reaction time task and personality scores from the EPQ

Variable	Correlation with Psychoticism	Correlation with Extraversion	Correlation with Neuroticism	Correlation with Social Desirability
RT1A	−0.003	−0.234*	0.032	0.220*
RT2A	0.026	−0.236*	0.018	0.149
RT2B	−0.002	−0.179	0.007	0.141
RT1B	−0.014	−0.199*	0.007	0.172
RT1	−0.018	−0.213*	0.015	0.200*
RT2	0.010	−0.213*	0.020	0.143
SLOPE	0.101	−0.019	0.020	−0.193*
RV1A	−0.084	−0.237*	0.196*	0.154
RV2A	0.117	−0.160	0.074	0.116
RV2B	0.094	−0.066	0.088	0.072
RV1B	−0.030	−0.248*	0.039	0.126
RV1	−0.065	−0.261**	0.103	0.180
RV2	0.133	−0.163	0.124	0.124
MT1A	0.024	−0.274**	0.043	0.232*
MT2A	−0.004	−0.284**	0.068	0.194*
MT2B	−0.016	−0.303**	0.068	0.196*
MT1B	0.015	−0.354**	0.048	0.220*
MT1	0.027	−0.340**	0.054	0.237*
MT2	−0.012	−0.298**	0.078	0.176
MV1A	0.111	−0.223*	0.047	0.311**
MV2A	0.098	−0.252**	0.135	0.158
MV2B	0.155	−0.252**	−0.085	0.340**
MV1B	0.142	−0.152	0.028	0.236*
MV1	0.103	−0.184	0.042	0.292**
MV2	0.129	−0.231	0.042	0.303**

Significant results marked with * ($P < 0.05$ 2-tailed) or ** ($P < 0.01$ 2-tailed).
$N = 109$.

Table 9. Correlations between average of 25 parameters from task one and task two on the choice reaction time task and personality scores from the IVE

Variable	Correlation with Impulsivity	Correlation with Venturesomeness	Correlation with Empathy
RT1A	−0.154	−0.221*	−0.152
RT2A	−0.120	−0.205*	−0.118
RT2B	−0.100	−0.155	−0.106
RT1B	−0.109	−0.207*	−0.120
RT1	−0.138	−0.211*	−0.136
RT2	−0.108	−0.191*	−0.110
SLOPE	0.096	0.056	0.085
RV1A	−0.159	−0.272**	−0.020
RV2A	−0.058	−0.158	−0.056
RV2B	0.049	−0.058	0.013
RV1B	−0.200*	−0.182	−0.099
RV1	−0.199*	−0.279**	−0.115
RV2	−0.005	−0.152	0.004
MT1A	−0.146	−0.418**	−0.241*
MT2A	−0.064	−0.377**	−0.136
MT2B	−0.081	−0.408**	−0.145
MT1B	−0.128	−0.434**	−0.224*
MT1	−0.152	−0.425**	−0.244*
MT2	−0.058	−0.386**	−0.122
MV1A	−0.201*	−0.316**	−0.145
MV2A	−0.049	−0.162	0.036
MV2B	−0.146	−0.188	−0.202*
MV1B	−0.167	−0.227*	−0.169
MV1	−0.194*	−0.280**	−0.127
MV2	−0.096	−0.264**	−0.085

Significant scores marked with * ($P < 0.05$ 2-tailed) or ** ($P < 0.01$ 2-tailed).
$N = 109$.

between impulsivity and reaction time again would be predicted from the known relationship between extraversion and impulsivity.

Odd-man-out

The results of the two non-smoking conditions were amalgamated by taking the mean of each parameter over the two performances, as for the Choice reaction time data. The means and standard deviations for all parameters are given in Table 10.

The present results for reaction times and ranges of reaction times and the results of Frearson and Eysenck (1986) are closely comparable. Data on movement times and inter-quintile ranges are new. Interestingly the movement times in the odd-man-out paradigm are longer than those from the choice reaction time though the movement is identical. This could be an artifact due to the removal of abnormally long CRT movement times and not those from the odd-man-out. Alternatively it could be inferred that processing is being carried out during the movement time, this processing being more complex in the odd-man-out leading to longer movement times. The conclusion that there is some processing going on in the movement time would mean a reinterpretation of results from the choice reaction time, where it has been assumed that movement time was only a function of the peripheral nervous system. The correlation (uncorrected for reliability) between reaction and movement times and ranges and inter-quintile ranges for reaction

Table 10. Means and standard deviations of the mean of the 12 'factor scores' from performance 1 and 2 of the odd-man-out paradigm

	Mean	Standard deviation
ORT.FS	626.164	180.515
OMT.FS	336.182	77.713
ORRNG.FS	375.138	198.602
OMRNG.FS	252.833	78.755
ORQUI.FS	145.204	82.972
OMQUI.FS	78.247	32.689

$N = 109$.

Table 11. Correlations between six factor scores from the odd-man-out paradigm and Verbal, Performance and Full scale WAIS-R IQs and score on Advanced Progressive Matrices

Variable	Correlation with Verbal IQ $N = 109$	Correlation with Performance IQ $N = 109$	Correlation with Full scale IQ $N = 109$	Correlation with APM score $N = 88$
ORT.FS	−0.189*	−0.391**	−0.297**	−0.483**
OMT.FS	−0.195*	−0.288**	−0.254**	−0.154
ORRNG.FS	−0.319**	−0.534**	−0.436**	−0.516**
OMRNG.FS	−0.197*	−0.406**	−0.298**	−0.182*
ORQUI.FS	−0.300**	−0.528**	−0.424**	−0.501**
OMQUI.FS	−0.129	−0.378**	−0.255**	0.011

Significant scores marked by * ($P < 0.05$ 1-tailed) or ** ($P < 0.01$ 1-tailed).

and movement times and Raven's score WAIS-R Verbal, Performance and Full scale IQ are given in Table 11; and the correlations to individual sub-tests in Table 12.

For all odd-man-out variables, correlations are generally larger with Raven score than with WAIS-R scores and correlations with Performance IQ are generally larger than with Verbal IQ. This is a marked difference with Choice reaction time data, where correlations with Raven are typically smaller than with WAIS-R, and Verbal IQ and Performance IQ do not differ. Probably these results are indicative of a greater role for spatial ability in the odd-man-out task.

As with the Choice reaction time data, the present study shows smaller correlations between Raven score and odd-man-out variables than did Frearson and Eysenck (1986). It was suspected that the higher correlations in the previous study were due to the abnormal distribution of Raven score (see Fig. 2) with two peaks and a lack of subjects scoring around the mean score. A sub-set

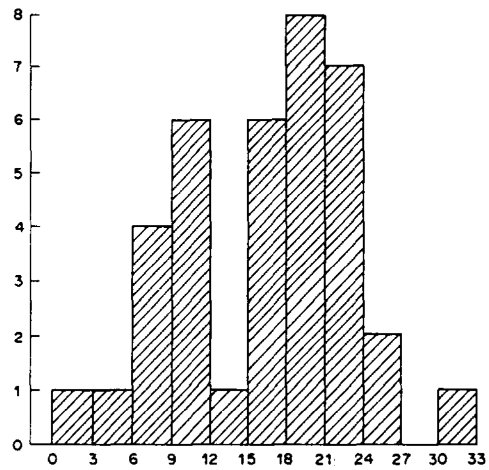

Fig. 2

Table 12. Correlations between the factor scores derived from the means of parameters from OMO 1 and OMO 2 and WAIS-R sub-test scores

	Correlation with					
	ORT.FS	OMT.FS	ORRNG.FS	OMRNG.FS	ORQUI.FS	OMQUI.FS
Information	−0.148	−0.159	−0.285	−0.290	−0.258	−0.214
Digit span	−0.060	−0.253	−0.172	−0.042	−0.149	−0.036
Vocabulary	−0.165	−0.112	−0.287	−0.251	−0.289	−0.139
Arithmetic	−0.124	−0.099	−0.232	−0.173	−0.225	−0.116
Comprehension	−0.184	−0.166	−0.282	−0.222	−0.264	−0.136
Similarities	−0.153	−0.212	−0.224	−0.259	−0.204	−0.173
Verbal IQ	−0.188	−0.195	−0.319	−0.197	−0.300	−0.129
PICT. completion	−0.300	−0.254	−0.431	−0.370	−0.436	−0.435
PICT. arranging	−0.306	−0.272	−0.433	−0.371	−0.416	−0.297
Block designs	−0.404	−0.357	−0.491	−0.410	−0.503	−0.374
Object assembly	−0.375	−0.214	−0.477	−0.382	−0.480	−0.350
Digit symbol	−0.456	−0.284	−0.482	−0.336	−0.460	−0.274
Performance IQ	−0.391	−0.288	−0.534	−0.406	−0.528	−0.378
Full scale IQ	−0.297	−0.254	−0.436	−0.298	−0.424	−0.255

Correlations greater than −0.16 are significant beyond 0.05 (1-tailed) and those greater than −0.22 are significant beyond 0.01 (1-tailed).

Table 13. Correlations between six factor scores from the odd-man-out paradigm and personality variables from the EPQ

Variable	Correlation with Psychoticism	Correlation with Extraversion	Correlation with Neuroticism	Correlation with Social Desirability
ORT.FS	−0.064	−0.155	0.058	0.254**
OMT.FS	0.029	−0.350**	0.105	0.179*
ORRNG.FS	−0.012	−0.123	0.004	0.278**
OMRNG.FS	0.037	−0.083	0.023	0.157
ORQUI.FS	−0.037	−0.138	0.048	0.273**
OMQUI.FS	0.089	−0.076	0.060	0.079

Significant scores marked by * ($P < 0.05$ 1-tailed) or ** ($P < 0.01$ 1-tailed).

of the present sample was created by removing all subjects with a Raven score between 12 and 15. This left a sample of 69 subjects. The correlations between Ravens score and odd-man-out parameters for this sub-group were as expected boosted to levels comparable to the previous study.

Correlations between odd-man-out parameters and personality scores from the EPQ are given in Table 13 and between odd-man-out parameters and scores from the IVE in Table 14. As with the choice RT data relationships with personality are mainly between median movement times and extraversion and venturesomeness, and to a lesser extent with the social desirability scale. Given that the movement time parameters of the choice RT and odd-man-out are basically measuring the same thing, relationships between odd-man-out measures and personality can be explained by the same processes as between choice RT and personality.

Smoking

The effect of smoking on each of the parameters from either the choice reaction time task or the odd-man-out paradigm was assessed by subtracting, for each subject the value of each parameter in the pre-smoking and post-smoking task (i.e. CRT 2 and CRT 3 and OMO 2 and OMO 3) to give a set of difference scores. These difference scores are given in Table 15 for the choice reaction time and Table 16 for the odd-man-out. Each difference score was then checked to see if it differed significantly from zero, in effect doing a matched pairs t-test between pre- and post-smoking conditions (significances shown in Tables 15 and 16).

These results show significant improvements in choice reaction times for both 1 and 2 bits. Also of interest is the much smaller effect smoking appears to have on the second sets of 10 reaction times compared to the first sets of 10 (i.e. RT1A vs RT1B and RT2A vs RT2B). Also significant are the decrements in performance on the movement times for 1 bit (both computed over all 20 trials and just the second 10).

To investigate the effect of doing two identical tasks back-to-back, irrespective of the smoking, the data from the 39 subjects who were retested were analysed in the same way to give sets of difference scores due to practise alone. These difference scores are given in Table 17 for the choice reaction time and Table 18 for the odd-man-out.

Two alternative approaches are now possible to determine whether changes in performance apparently due to smoking differ significantly from what would be expected from practise alone. Either the difference scores due to smoking for the 39 subjects retested can be computed and compared with the differences due to practise alone by a matched pairs t-test, or the difference due to practise alone can be compared to the difference due to smoking for the whole group who were

Table 14. Correlations between six factor scores from the odd-man-out paradigm and personality variables from the IVE

Variable	Correlation with Impulsivity	Correlation with Venturesomeness	Correlation with Empathy
ORT.FS	−0.175*	−0.176*	−0.121
OMT.FS	−0.080	−0.474**	−0.136
ORRNG.FS	−0.163*	−0.251**	−0.237**
OMRNG.FS	0.016	−0.173*	−0.167*
ORQUI.FS	−0.177*	−0.208*	−0.195*
OMQUI.FS	0.048	−0.070	−0.073

Significant scores marked by * ($P < 0.05$ 1-tailed) or ** ($P < 0.01$ 1-tailed).

Table 15. Means and standard deviations of the differences between CRT 2 and CRT 3 for all subjects (i.e. the effect of smoking)

Variable	Mean	Standard deviation
RT1A	14.495	42.164**
RT2A	11.624	37.886**
RT2B	5.147	32.921
RT1B	1.789	27.136
RT1	7.982	28.257**
RT2	7.752	32.301*
SLOPE	−0.229	23.757
RV1A	2.804	18.644
RV2A	2.122	15.432
RV2B	−0.723	17.316
RV1B	−0.046	12.114
RV1	2.290	13.768
RV2	0.416	14.426
MT1A	−3.028	36.393
MT2A	−5.248	39.767
MT2B	−5.606	29.972
MT1B	−12.523	46.927**
MT1	−7.138	37.502*
MT2	−5.606	32.892
MV1A	4.819	31.936
MV2A	1.225	39.431
MV2B	−6.046	36.063
MV1B	−3.305	30.236
MV1	−0.144	24.531
MV2	−2.380	27.902

Significant differences from zero marked with * ($P < 0.05$ 2-tailed) or ** ($P < 0.01$ 2-tailed).
$N = 109$.

Table 16. Means and standard deviations of the differences between six factor scores from the odd-man-out on OMO 2 and OMO 3 (i.e. the effect of smoking) for all subjects

Variable	Mean	Standard deviation
ORT.FS	87.043	91.308**
OMT.FS	−3.558	36.498
ORRNG.FS	127.614	126.118**
OMRNG.FS	17.143	115.465
ORQUI.FS	47.971	54.025**
OMQUI.FS	8.443	41.170*

Significant differences from zero marked with * ($P < 0.05$ 2-tailed) or ** ($P < 0.01$ 2-tailed).
$N = 109$.

Table 17. Means and standard deviations of the difference on each of 25 parameters from the choice reaction time task between task four and task five i.e. the magnitude of the 'practise effect'

Variable	Mean	Standard deviation
RT1A	−3.820	27.426
RT2A	−0.308	24.448
RT2B	−5.385	25.520
RT1B	3.692	25.854
RT1	0.256	19.390
RT2	−2.718	21.467
SLOPE	−2.974	26.558
RV1A	1.854	12.865
RV2A	0.450	13.623
RV2B	−0.979	13.430
RV1B	−1.444	9.915
RV1	−0.611	9.590
RV2	0.160	10.478
MT1A	−2.769	27.199
MR2A	1.103	27.191
MT2B	−7.359	35.623
MT1B	−2.974	33.715
MT1	−2.205	24.810
MT2	−3.846	28.808
MV1A	−5.783	24.294
MV2A	3.180	26.528
MV2B	−0.774	30.849
MV1B	7.576	28.249
MV1	2.215	31.648
MV2	−0.544	32.730

Significant differences from zero marked with * ($P < 0.05$ 2-tailed) or ** ($P < 0.01$ 2-tailed).
$N = 39$.

Table 18. Means and standard deviations of the differences between six factor scores from the odd-man-out on OMO 4 and OMO 5 (i.e. the effect of practise) for subjects who were retested.

Variable	Mean	Standard deviation
ORT.FS	20.494	77.800
OMT.FS	4.356	20.192
ORRNG.FS	40.170	99.204
OMRNG.FS	1.854	69.215
ORQUI-FS	17.515	38.319
OMQUI.FS	3.645	29.727

Significance differences from zero marked with * ($P < 0.05$ 2-tailed) or ** ($P < 0.01$ 2-tailed).
$N = 39$.

not retested (removal of the 39 retested subjects allows a t-test between two unrelated samples of size 39 and 70).

The matched pairs t-test for the retest group of 39 subjects gives the following results: in the choice reaction time data, the median RT to 2-bits computed either over all 20-trials or over only the first 10 or the second 10 gives a significantly ($P < 0.05$ 2-tailed) larger improvement after smoking than could be attributed solely to practise. Also significantly different is the reaction time to the first set of 10 trials to 1-bit. In the odd-man-out data the factor scores for median reaction times, the ranges for both reaction times and movement times and the inter-quintile range for reaction times show improvement after smoking that is significantly greater than could be attributed solely to practise ($P < 0.01$ 2-tailed).

The t-test between the two unrelated samples of 39 and 70 gave the following results. For the choice reaction time the improvement due to smoking on the median reaction time of the first 10 trials for 1-bit significantly differed from what could be attributed to practise alone ($P < 0.01$ 2-tailed). The changes in variability in movement time on 1-bit for both the first set of 10 trials and the second set differed significantly from the practise effect ($P < 0.05$ 2-tailed). However, as in the first set of 10 trials, the change was a lessening of variability but in the second an increase. There was no significantly change in variability calculated over all 20 trials.

The odd-man-out paradigm showed that the changes due to smoking differed significantly from what could be assigned to practise for factor scores on median reaction times, and range and inter-quintile range of reaction times.

The overall effect of smoking on the choice reaction time task is mixed, although there appears to be evidence of an effect on median reaction times, the magnitude of this diminishes quite rapidly with time after smoking. On the odd-man-out paradigm, smoking has a large effect on reaction time parameters, both the magnitude of median reaction times and their variability being reliably decreased more than could be attributed to practise.

The improvement in the three reaction time parameters from the odd-man-out paradigm due to smoking (for all 109 subjects), are all significantly negatively correlated with WAIS-R Verbal, performance and Full scale IQ and Raven's score, i.e. the dull improve more. The improvement in range and inter-quintile range are significantly negatively correlated with venturesomeness.

Practise

The effect on the reliability of an intervening task in the odd-man-out paradigm indicates that there is an effect of practise on performance of the odd-man-out. The means and standard deviations of the difference between OMO 4 and OMO 5 for the 39 retested subjects are given in Table 18. Only the ranges and interquintile ranges of reaction times show a difference that differs significantly from zero ($P < 0.05$ and $P < 0.01$ 2-tailed respectively). The size of the practise effect on these two variables is correlated with Raven's score -0.284 and -0.168 respectively, though neither are significantly correlated with Full scale, verbal or performance WAIS-R IQ. None of the choice reaction time parameters showed a significant practise effect.

Multiple regressions

The six factor scores from the odd-man-out paradigm were used as independent variables to predict Full scale, Performance and Verbal IQ. The shrunken values for these three multiple Rs were 0.472, 0.602 and 0.343 respectively. The use of multiple regression with the odd-man-out parameters adds relatively little to the prediction value of the individual parameters because of their universally high inter-correlation.

A similar multiple regression was performed using the eight choice reaction time parameters that had been derived from 20 trials (median RT/MT for 1 and 2-bits, and variability in RT/MT for 1 and 2-bits). The shrunken multiple Rs with Full scale, Performance and Verbal IQ's were 0.478, 0.493 and 0.410, the smaller inter-correlations between choice reaction time parameters leading to greater increases in prediction ability with more variables than in the odd-man-out case. Using the parameters from both odd-man-out and choice reaction time paradigms give shrunken multiple Rs of 0.582, 0.658 and 0.500 with Full scale, Performance and Verbal IQs.

The inclusion of the seven personality scores from the EPQ and IVE further enhance the predictive power of the performance variables. The shrunken multiple R for the odd-man-out parameters with Full scale IQ becomes 0.601; for the choice reaction time parameters 0.644, and for both sets together 0.683. The role of the personality variables is not however merely that of 'suppressor' variables as the personality variables are correlated to Full scale IQ in their own right, giving a shrunken multiple R of 0.519. The correlations between personality scores and intelligence measures are given in Table 19 from which it can be seen that whilst the three personality

Table 19. Correlations between seven personality scores from the EPQ and the IVE and Verbal, Performance and Full scale WAIS-R IQs and score on Advanced Progressive Matrices

Variable	Correlation with Verbal IQ $N = 109$	Correlation with Performance IQ $N = 109$	Correlation with Full scale IQ $N = 109$	Correlation with APM score $N = 88$
Psychotisism	0.022	−0.006	0.017	0.028
Extraversion	0.013	0.026	0.018	0.047
Neuroticism	0.013	−0.022	−0.007	−0.027
Social Desirability	−0.372**	−0.330**	−0.382**	−0.152
Impulsivity	−0.041	−0.056	−0.054	−0.051
Venturesomeness	0.231**	0.199*	0.230**	0.253**
Empathy	0.308**	0.277**	0.315**	0.246*

Significant scores marked by * ($P < 0.05$ 1-tailed) or ** ($P < 0.01$ 1-tailed).

dimensions of the EPQ are unrelated to IQ, the desire for social conformation scale is strongly related to intelligence as are the venturesomeness and empathy scales from the IVE. It appears then that the relationship between performance variables and IQ might be partially mediated by personality factors and the inclusion of measures of personality in future studies would therefore be advisable.

Correlation between WAIS-R and Raven's matrices

The correlations between the score on the 20-min version of Raven's advanced progressive matrices used in the present study and full scale WAIS-R IQ is 0.708, between Raven's score and verbal IQ 0.639 and between Raven's and performance IQ 0.684. These correlations, whilst high, do not support the notion that Raven's score and WAIS-R score can be used interchangeably, and in particular they indicate that RT studies that use different criterion IQ tests should not be combined.

DISCUSSION

The effects of smoking on the two reaction time tests are of considerable importance in that the relationship between at least the odd-man-out paradigm and IQ ensures that the measures are representative of the sorts of real-world cognitive tasks that will typically elicit smoking from smokers.

On the choice reaction time the picture of changes due to smoking is unclear. The single most reliable result is the improvement in median reaction time on the first set of 10 1-bit trials which is always more than could be attributed to practise alone. The results on the 2-bit condition are significantly different from practise only when a matched pairs t-test is used: here the improvement is significant for both first and second sets of 10 trials. Results for median movement times and variability in movement times, though in 2 cases, significant are hard to interpret as their direction changes and significance is not maintained over different tests.

The effects of smoking on the odd-man-out paradigm are much clearer. In both the paired and unpaired t-test, performance on median reaction time and range and inter-quintile range of reaction time is significantly improved over what could be attributed to practise. Improvements on median movement time were significant only in the paired t-test.

The effect of smoking appears to be confined to the reaction time phase of the performance tasks, movement time being only unreliably effected as would be predicted by a model of central rather than peripheral nicotine effect. The pattern of results for the choice reaction time task is indicative of the effect of smoking being extremely short-lived in that effects are larger for the first 20 trials (i.e. the first 10 1-bit, and first 10 2-bit) than for the second 20; the whole period of testing on the choice reaction-time task was less than 10-min.

The results of Elgerot (1976) are not replicated in that the performance on the more complex of the tasks is more improved than that on the simpler. The finding of relationships between the size of the improvement following smoking and venturesomeness is however indicative of an interaction between endogenous arousal levels and smoking effects. The finding of performance improvements after smoking a normal cigarette normally is in contrast to Morgan and Pickens' (1982) finding that only abnormal cigarettes or prescribed smoking patterns produce performance changes.

Overall the results of the present study on the effect of smoking tend to support a 'gate' theory (Knott, 1978) rather than a theory of changes in general arousal which would predict improvements in peripheral as much as central nervous system performance. The finding of large, immediate improvements in performance on a task like the odd-man-out, which is strongly related to psychometric IQ and hence to a wide variety of 'real-world' tasks is strong support for a model of smoking maintenance based upon psychological reinforcement rather than physiological addiction.

Correleations in the present study between performance measures derived from the odd-man-out task and Raven's Advanced Progressive Matrices and those published elsewhere are broadly in agreement once the effect of aberrant samples is accounted for. The new measures introduced in this study—inter-quintile range of reaction times and median movement times, range of movement times and inter-quantile range of movement times—are also found to be related to IQ measures. For reaction time parameters correlations are generally stronger with performance and Raven's score than with Verbal and Full scale IQ: for movement time parameters again performance gives better correlations than verbal and full scale IQ though the correlations between movement time parameters and Raven's score are unexpectedly low. (In general correlations for odd-man-out movement time scores and IQ measures are lower than would be expected in comparison to movement time parameters from the choice RT. This is even more surprising given that the odd-man-out movement times have equally good test–retest reliabilities as the choice reaction time movement time parameters. The low correlations between OMO movement time parameters and IQ measures might be attributable to the apparent 'carry-over' of some processing into the movement time phase as alluded to previously.)

The effect on odd-man-out parameters of previous exposures to the test both in terms of a practise effect lasting through the period of the test and an apparent 'priming' effect lasting from day to day are disturbing from the viewpoint of the tests's use as a practical IQ measure. Clearly these issues must be pursued further.

The results from the choice reaction time task are similar to those of other studies carried out in this laboratory (Barrett *et al.*, 1986; Frearson and Eysenck, 1986) and also comparable to the results from studies reviewed by Jensen (1987). The principal difference in the results relating to correlations between IQ measures and reaction time parameters is the consistent finding of a relationship between variables relating to variability in movement time and a range of IQ measures (Verbal, Performance, Full scale WAIS-R IQ and Raven's score).

Reliability measures are similar to those given by Jensen (1987) for test–retest reliability of groups of University students tested in Jensen's laboratory. The finding of no significant practise effects on the choice reaction time task is again as has been found elsewhere.

CONCLUSION

The main conclusions of the present study are:

(1) Concerning the effect of smoking on performance:

a. Smoking of a cigarette by a smoker under naturalistic conditions improves the performance of the smoker on an IQ related task.

b. The locus of smoking's effect on performance appears to be in the central rather than the peripheral nervous system.

(2) Concerning the correlation between performance measures and IQ:

a. In the choice reaction time paradigm both median reaction times and movement times are significantly correlated with IQ; as are variabilities for both reaction and movement times.

b. In the odd-man-out paradigm ranges and median reaction time and movement times are significantly correlated with IQ.

c. The inter-correlations between different psychometric tests are not high enough to justify combining RT studies which use different criterion IQ tests.

d. Corrections due to attenuation of IQ range in a sample are unjustified (see Appendix).

e. Corrections due to unreliability of a performance measure are likely to be subject to such large sample error as to make them of no value unless the reliability is high (see Appendix).

APPENDIX

Corrections for Unreliability and Restriction of Range

Restriction of range. It had previously been assumed by workers in this field that it is possible to correct the correlation between IQ and a parameter derived from a performance task for any restriction in the sample's range of IQ. Equations for doing so are given by various authors (Guilford and Fruchter, 1973; Gullikson, 1950). The assumption underlying such a 'correction' is that the relationship observed for the sample of restricted range exists equally across the whole range.

For the relationship between reaction time variables and IQ these corrections have been routinely used, though no evidence to support the underlying assumption has yet been brought forward.

To investigate the effect of the use of subject groups with IQ ranges that differ from the normal distribution, a series of subgroups having specific IQ distributions were taken. First a sub-set of 97 subjects was taken from the original sample of 109. This sub-group was so chosen as to given an approximately symmetrical distribution. [This involved the removal of all 4 subjects of Full scale IQ less than 75, and the removal of half the subjects of IQ between 115 and 120 (8 subjects)].

Table 20. Correlations between Full scale WAIS-R IQ and parameters from the choice reaction time task for each of the five sub-groups of specified IQ range

	Correlation to Full scale WAIS-R Group of IQ range 75–135 $N = 97$	Group of IQ range 75–105 $N = 51$	Group of IQ range 105–135 $N = 46$	Group of IQ range 75–95 and 115–135 $N = 54$	Group of IQ range 95–115 $N = 43$
RT1	−0.274	−0.212 (−0.351)	−0.344 (−0.542*)	−0.407 (−0.316)	0.065 (0.178)
RT2	−0.211	−0.208 (−0.345)	−0.284 (−0.462*)	−0.338 (−0.260)	0.059 (0.162)
RV1	−0.411	−0.370 (−0.567)	−0.405 (−0.615)	−0.513 (−0.408)	0.015 (0.042*)
RV2	−0.172	−0.087 (−0.149)	−0.283 (−0.461*)	−0.289 (−0.220)	−0.142 (−0.370*)
MT1	−0.361	−0.368 (−0.565*)	−0.361 (−0.563*)	−0.477 (−0.376)	0.124 (0.328)
MT2	−0.352	−0.407 (−0.610*)	−0.375 (−0.580*)	−0.476 (−0.375)	0.289 (0.642*)
MV1	−0.299	−0.265 (−0.429)	0.101 (0.176)	−0.308 (−0.235)	−0.326 (−0.691*)
MV2	−0.325	−0.184 (−0.308)	0.041 (0.072*)	−0.338 (−0.260)	−0.357 (−0.728*)

Values in brackets are the 'corrected' correlations. Corrected correlations marked with * lie outside the 0.95 confidence limits on the true value (i.e. the correlation for the full group).

Table 21. Correlations with Full scale WAIS-R IQ for each of the five sub-groups of specified IQ range

	Correlation to Full scale WAIS-R Group of IQ range 75–135 $N = 97$	Group of IQ range 75–105 $N = 51$	Group of IQ range 105–135 $N = 46$	Group of IQ range 75–95 and 115–135 $N = 54$	Group of IQ range 95–115 $N = 43$
ORT.FS	−0.268	−0.091 (−0.156)	−0.183 (−0.311)	−0.356 (−0.274)	−0.238 (−0.562*)
OMT.FS	−0.247	−0.359 (−0.554*)	−0.197 (−0.334)	−0.326 (−0.250)	0.180 (0.453*)
ORRNG.FS	−0.370	−0.230 (−0.378)	−0.104 (−0.181*)	−0.435 (−0.340)	−0.285 (−0.636*)
OMRNG.FS	−0.276	−0.477 (−0.684*)	0.001 (0.002*)	−0.340 (−0.261)	−0.061 (0.167)
ORQUI.FS	−0.382	−0.268 (−0.434)	−0.114 (−0.198)	−0.464 (−0.365)	−0.314 (−0.676*)
OMQUI.FS	−0.292	−0.349 (−0.542*)	−0.179 (−0.305)	−0.334 (−0.256)	−0.132 (−0.347)

Values in brackets are the 'corrected' correlations. Corrected values marked with * lie outside the 0.95 confidence limits on the true value (i.e. correlation for the full group).

The Full scale WAIS-R IQ's of the sub-set were distributed with a mean of 103.63 and a standard deviation of 15.33. The correlation between the eight parameters from the choice reaction time task that were calculated over 20 trials and Full scale IQ for this group are shown in Table 20. The correlations between this group's six odd-man-out factor scores and Full scale IQ are in Table 21. These correlations will be taken as the reference values in that they are 'uncorrectable' with reference to restricted range. This group of 97 subjects was then split into 4 sub-groups according to subjects IQ:

1. Subjects of Full scale WAIS IQ between 75 and 105 ($N = 48$).
2. Subjects of Full scale WAIS IQ between 105 and 135 ($N = 49$).
3. Subjects of Full scale WAIS IQ between 75 and 95 or between 115 and 135 ($N = 48$).
4. Subjects of Full scale WAIS IQ between 95 and 115 ($N = 49$).

A direct test of the assumption that correlations from a group of limited IQ range can be used to infer the true correlation is possible by studying the changes in correlation with IQ for the 5 groups created above. Table 20 gives the pattern of correlations for the choice reaction time task and Table 21 for the odd-man-out.

The results for the choice reaction time task are of particular interest as it is here that previous work has been concentrated. By taking only the subjects of below average IQ the standard deviation of Full scale IQ falls to 8.670. The correlations with IQ in this low IQ group tend to be lower than in the full group (though note that two have actually risen); however the correction for restriction of range in IQ boosts the 'corrected' correlations to above the reference correlation in all but two cases. (The standard value of 15 is used for the population standard deviation of WAIS IQ rather than the 15.331 that actually occurs in this sample. Using the higher value will have the effect of making the corrected values even larger).

For the high IQ group the effect of using the correction is even more significant; again the effect is to boost correlations to above their 'true' value. It should also be noted that for this group the finding of a negative correlation between movement time variability and IQ scores for the whole sample of 109 is not repeated. This is in line with the majority of other studies which have generally been done using undergraduate samples who might be expected to have approximately this IQ range.

The group composed of a mixture of high and low IQ subjects has as expected an inflated standard deviation for IQ (20.041) and again all the correlations have been boosted over the reference values for the whole group. Correcting for the over large range now reduces the size of correlations, though again in six out of the eight cases the corrected correlation is in excess of the reference value.

In the final sub-group (the set of subjects with IQs close to the mean) the correlations with IQ have fallen substantially, many now having changed sign (again it is the movement time variabilities that appear to behave differently from the other parameters). The effect of applying the correction for restricted range to these values is to push the values even more positive and hence away from their reference values.

The results from the odd-man-out task are less clear. Certainly the corrected correlations from the low IQ group have been generally increased over the reference value. In the high IQ half, equal numbers of corrected correlations are over-estimates as under-estimates. The group of high and low IQs generally show corrected correlations below the reference values, whilst the group of middling IQs give corrected correlations above the reference values.

It is important to note that these four sub-groups whilst having been purposefully created to differ from normally distributed IQs are in fact quite representative of the groups other workers have studied. Jensen (1987) states that his estimate of the average restriction of range in the studies he reviews of one-half is 'conservative', further, almost all the studies are on groups of either relatively high (i.e. undergraduate) or relatively low (i.e. border-line retarded) IQ. The absence of a middling IQ group will, on the basis of evidence from the present study, serve to boost correlations with IQ not, as has been previously assumed, to diminish them by virtue of the restriction of IQ range.

Reliability

It has commonly been the practise of workers in the field of performance correlates to IQ to 'correct' obtained correlations to account for the unreliability of the performance measures. The correlations so produced are then taken as indicators of the degree of 'true' correlation between two hypothesized traits of the individual which have been imperfectly measured by the IQ and performance tests. Formulae for making such corrections are given by various authors (e.g. Guilford and Fruchter, 1973). The formulae are generally used in the fields of questionnaire research and psychometric test construction where typical sample sizes are large enough to make errors due to sampling insignificant. In the field of performance measures where samples are routinely smaller than 100, while the formulae remain valid, their use should be accompanied by estimates of the confidence limits that can be placed around the 'corrected' correlations.

Confidence limits should be set around both the correlation between the performance measure and the test–retest reliability and the corrected correlation derived from the two. As an example two of the variables from the present sample will be corrected for unreliability. The variability in choice reaction time to 1-bit for the first 10 trials (RV1A in the tables) has a high correlation to Full scale IQ (−0.350) and a low reliability (0.243); it is the sort of variable which has typically been 'corrected' for unreliability. The factor score on the median reaction time on odd-man-out paradigm (ORT.FS in the tables) also has a smaller correlation with Full scale IQ (−0.297) but it has a much better reliability (0.859). The 95% confidence limits around the correlations to IQ for RV1A are −0.172 and −0.505 and for ORT.FS they are −0.117 to −0.462; note that the limits around the correlations to IQ are approximately similar for the two variables. The 95% confidence limits for the reliabilities are for RV1A from −0.024 and 0.480 and for ORT.FS they are 0.765 and 0.918. Aside from the limits on the RV1A having slipped below zero, it is clear that the confidence limits on the reliability of the RV1A are very much wider than the ORT.FS; this is a consequence of the non-normal distribution of correlation coefficients.

The confidence limits to be set around the corrected value of the correlation will be a function of the confidence limits around both the correlation to IQ and the reliability. To compute precisely the value of these confidence limits it is necessary to construct a frequency distribution for the corrected value as a function of the values of reliability and correlation to IQ. Alternatively an approximation to the confidence limits can be made by constructing a computer model of the two distributions and then sampling randomly from them to produce a distribution of the corrected values from which can be obtained the required confidence limits.

Two normal distributions are constructed, one for the reliability of the variable, one for its correlation with IQ, with the measured value of the correlation (z-transformed) as the mean and the standard error as the standard deviation. From these two distributions are then taken 5000 pairs of values at random, and from each pair is computed the 'corrected' correlation. The resulting set of 5000 values gives the distribution of corrected values from which can be taken the confidence limits required. Results from this procedure are: for ORT.FS a corrected correlation of −0.338 with 95% confidence limits of −0.13 and −0.54; for RV1A a corrected correlation of −0.748 with 90% confidence limits of −0.41 and −3.58. The enormous range of the confidence limits foir RV1A (note that these are the 90% confidence limits, the 95% confidence limits are actually incalculable as more than 2.5% of the possible values of the corrected correlation are obtained from negative reliabilities which make the formula for correction unusable) would appear to invalidate corrections for reliability where reliabilities are low and/or the sample is small.

The effect of making corrections for unreliability in small samples is bipolar. For unreliable variables the effect is large but leads to very large estimates of error, for reliable measures the effect is small but the resultant answer more certain. What level of error is acceptable in a quoted value for a corrected correlation is clearly dependent on what use is to be made of such a value; however, as the above example shows the confidence limits for these corrected correlations can easily become so large as to make the value meaningless.

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REFERENCES

Armitage A. K., Hall G. H. and Sellers C. M. (1969) Effects of nicotine on electrocortical activity and acetylcholine release from the cat cerebral cortex. *Br. J. Pharmac.* **35**, 152–160.

Ashton H., Millman J. E., Telford R. and Thompson J. W. (1974) The effect of caffeine, nitrazepam and cigarette smoking on the contingent negative variation in man. *Electroenceph. Clin. Neurophysiol.* **37**, 59–71.

Barrett P., Eysenck H. J. and Lucking S. (1986) Reaction time and intelligence: a replicated study. *Intelligence* **10**, 9–40.

Brand C. R. and Deary I. J. (1982) Intelligence and 'inspection time'. In *A Model for Intelligence* (Edited by Eysenck H. J.). Springer, New York.

Brebner J. and Nettlebeck T. (Eds) (1986) Inspection time. *Person. individ. Diff.* **7**, 603–730.

Brownlee K. T. (1975) *Statistical Theory ad Methodology in Science and Engineering*. John Wiley, New York.

Buckalew L. W. (1973) Relationship between a physiological and personality index of excitability. *Physiol. Psychol.* **2**, 158–160.

Burn J. H. and Rand M. J. (1959) Sympathetic postganglionic mechanism. *Nature* **184**, 163–165.

Cotten D. J., Thomas J. R. and Stewart D. (1971) Immediate effects of cigarette smoking on simple reaction time of college male smokers. *Percept. Mot. Skills* **33**, 336.

Elgerot A. (1976) Note on selective effects of short-timer tobacco-abstinence on complex versus simple mental tasks. *Percept. Mot. Skills* **42**, 413–414.

Eysenck H. J. (1967) *The Biological Basis of Personality*. Thomas, Springfield, Ill.

Eysenck H. J. (1973) Personality and the maintenance of the smoking habit. In *Smoking Behaviour: Motives and Incentives* (Edited by Dunn W. L.). John Wiley, New York.

Eysenck H. J. (1980) *The Causes and Effects of Smoking*. Maurice Temple Smith, London.

Eysenck H. J. (1985a) Smoking and health. In *Smoking and Society* (Edited by Tallisman). Lexington Books, Toronto.

Eysenck H. J. (1985b) The theory of intelligence and the psychophysiology of cognition. In *Advances in Research in Intelligence* (Edited by Sternberg R. J.), Vol. 3. Erlbaum, Hillsdale, N.J.

Eysenck H. J. (1986a) Inspection time and intelligence: an historical introduction. *Person. individ. Diff.* **7,** 603–609.

Eysenck H. J. (1986b) Speed of information processing, reaction time and the theory of intelligence. In *Speed of Information Processing and Intelligence* (Edited by Vernon P. A.). Ablex, Harvard, N.J.

Eysenck H. J. and Eysenck S. B. G. (1964) *Manual of the Eysenck Personality Inventory.* University of London Press.

Eysenck H. J. and Eysenck S. B. G. (1975) *Manual of the Eysenck Personality Questionnaire.* Hodder & Stoughton, London.

Eysenck S. B. G., Pearson P. R., Easting G. and Allsopp J. (1985) Age norms for impulsiveness, venturesomeness and empathy in adults. *Person. individ. Diff.* **6,** 613–620.

Frankenhaeuser M., Myrsten A. and Post B. and Johansson G. (1971) Behavioral and physiological effects of cigarette smoking in a monotonous situation. *Psychopharmacologia* **22,** 1–7.

Frearson W. M. and Eysenck H. J. (1986) Intelligence, reaction time (RT) and a new 'odd-man-out' RT paradigm. *Person. individ. Diff.* **7,** 807–817.

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

Guilford J. and Fruchter B. (1973) *Fundamental Statistics in Psychology and Education.* McGraw-Hill, New York.

Gullikson H. (1950) *The Theory of Mental Tests.* John Wiley, New York. Hemmelgarn T. E. and Kehle T. J. (1984) The relationship between reaction time and intelligence in children. *School Psychol. Int.* **5,** 77–84.

Jensen A. R. (1982) Reaction time and psychometric '*g*'. In *A Model for Intelligence* (Edited by Eysenck H. J.), pp. 93–132. Springer, New York.

Jensen A. R. (1987) Individual differences in the hick paradigm. In *Speed of Information Processing and Intelligence* (Edited by Vernon P. A.). Ablex, Harvard, N.J.

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

Kaiser H. F. (1960) The application of electronic computers to factor analysis. *Educ. Psychol. Measur.* **20,** 141–151.

Kaiser H. F. (1965) Psychometric approaches to factor analysis. *Proceedings of the 1964 Invitational Conference on Testing Problems.* Educational Testing Service, Princeton, N.J.

Knott V. J. (1978) Smoking, EEG and input regulation in smokers and non-smokers. In *Smoking Behaviour: Physiological and Psychological Influences* (Edited by Thornton R. E.), pp. 115–130. Churchill Lilvingstone, Edinburgh.

Knott V. J. (1980) Reaction time, noise distraction and autonomic responsivity in smokers and non-smokers. *Percept. Mot. Skills* **50,** 1271–1280.

Knott V. J. (1985) Effects of tobacco and distraction on sensory and slow cortical evoked potentials during task performance. *Neuropsychobiology* **13,** 136–140.

Knott V. and Venables P. (1977) EEG alpha correlates of non-smokers, smoking and smoking deprivation. *Psychophysiology* **14,** 150–156.

Lally M. and Nettlebeck T. (1980) Inspection time, intelligence and response strategy. *Am. J. men. Defic.* **89,** 553–560.

Lehrl S. and Franks H. G. (1982) Zur humangenetischen Erklarung der Kurzspeicher-Kapazitat als der Zentrale individuelle Determinante von Spearman's Generalfaktor der Intelligenz. *Grundl. kybernet. Geisteswissenschaft.* **23,** 177–186.

Mangan G. L. and Golding J. (1978) An enhancement model of smoking maintenance. In *Smoking Behaviour: Physiological and Psychological Influences* (Edited by Thornton R. E.), pp. 87–114. Churchill Livingstone, Edinburgh.

Morgan S. F. and Pickens R. W. (1982) Reaction time performance as a function of cigarette smoking procedure. *Psychopharmacology* **77,** 383–386.

Myrsten A., Post B., Frankenhaeuser M. and Johansson G. (1972) Changes in behavioral and physiological activation induced by cigarette smoking in habitual smokers. *Psychopharmacologia* **27,** 305–312.

Nettlebeck T. and Kirby N. H. (1983) Measures of timed performance and intelligence. *Intelligence* **7,** 39–52.

Nettlebeck T. and Lally M. (1976) Inspection time and measured intelligence. *Br. J. Psychol.* **67,** 17–22.

Nunally J. C. (1978) *Psychometric Theory.* McGraw-Hill, New York.

O'Connor K. (1980) The CNV and individual differences in smoking behaviour. *Person. individ. Diff.* **1,** 271–285.

O'Connor K. (1982) Individual differences in the effect of smoking on frontal-central distribution of the CNV: observations on smokers control of attentional behaviour. *Person. individ. Diff.* **3,** 271–285.

Roth E. (1964) Die Geschwindigkeit der Verabeitung von Informationen und ihr Zusammenhang mit Intelligenz. *Z. exp. angew. Psychol.* **11,** 616–623.

Schachter S., Silverstein B., Kozlowski L. T., Perlick D., Herman C. P. and Leibling B. (1977) Studies of the interaction of psychological and pharmacological determinants of smoking. *J. exp. Psychol. General* **106,** 5–40.

Schechter M. D. and Rosecrans J. A. (1972) Nicotine as a discriminative stimulus in rats depleted norepinephrine or 5-hydroxytryptamine. *Psychopharmacologia* **24,** 417–429.

Smith D. L., Tong J. E. and Leigh G. (1977) Combined effects of tobacco and caffeine on the components of choice reaction time, heart rate and hand steadiness. *Percept. Mot. Skills* **45,** 635–639.

Ulett J. A. and Itil T. M. (1969) Quantitative electroencephalogram in smoking and smoking deprivation. *Science* **164,** 969–970.

Vickers D. and Smith P. (1986) The rationale for the inspection time index. *Person. individ. Diff.* **7,** 609–625.

Wesnes K. and Warburton D. M. (1983) Effects of smoking on rapid information processing performance. *Neuropsychobiology* **9,** 223–229.

Wesnes K. and Warburton D. M. (1984) Effects of scopolamine and nicotine on human rapid information processing performance. *Psychopharmacology* **82,** 147–150.

Winer B. J. (1971) *Statistical Principles in Experimental Design.* McGraw-Hill, New York.