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Relationship of Personality Measures to the Alpha Rhythm of the Electroencephalogram

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Introduction

The relationship of electroencephalographic (EEG) differences to personality measures aroused early interest (see Hill, 1963). For example, Adrian (1935) considered that EEG variations between subjects might correspond to differences in emotional constitution, and contrasts have been found in the personalities of patients with high and those with low alpha indices (McAdam and Orme, 1954).

Recently, the problem has been re-opened. Shagass and Naiman (1956), Shagass (1957) and Savage (1964) attempted to link electrographic and personality measures through Eysenck's (1957) typological postulate, which suggested that extraverts and hysterics (neurotic extraverts) have high cortical inhibition, whereas introverts and dysthymics (neurotic introverts) have low cortical inhibition. The former workers believed that their electrographic measure—sedation threshold—measured a factor closely allied to introversion–extraversion, through a cortical excitability cycle. High cortical inhibition is thus equated with low activity of the reticular formation and hence with low EEG arousal and high alpha activity. Extraverts, with high cortical inhibition would be expected to show more elevated amplitude and increased prevalence of alpha activity than introverts, low in cortical inhibition. Evidence that stimulus-provoked alpha activity (Morrell, 1966) may be a sign of central inhibition supports this concept. Savage's findings were consistent with his prediction in respect of extraversion but did not bear out his further prediction of an inverse relationship between neuroticism and alpha amplitude. However, the criticism may be made that alpha abundance —the output between 8–13 Hertz (Hz) of a low frequency analyser over a standard epoch of EEG input—which Savage used as a measure of EEG activity, suffers from ambiguity due to confounding of amplitude and prevalance components. Fenton and Scotton (1967) were unable to find any correlation between extraversion and alpha measures, and this inconsistency is taken up in the discussion.

Still more recently, attention has been drawn (Gray, 1967) to the possible identification by means of EEG correlates of the introversion–extraversion dimension with one of two possible dimensions of personality developed by Russian workers (Nebylitsyn, 1966).

In the present experiments (*see* Glass and Broadhurst (1966) for preliminary report), these hypotheses were re-investigated using other parameters of alpha activity, and mental arithmetic (Glass, 1964, 1967) as a stimulus.

Method

Subjects

The total of 51 subjects available for personality assessment was drawn from a larger group of 61 subjects, in whom the influence of mental arithmetic on the EEG was studied (Glass, 1965, 1966 and 1967). The 43 males and eight females included undergraduates and academic and technical staff of the University of Birmingham Medical School. Their mean age was 23·6 years (s.d. ±6·9).

Procedure

Each subject reclined in a partially sound-isolated room, with eyes closed. Thirty minutes of EEG recording were made in an adjacent room while a series of 20 arithmetical tasks were posed by a male voice through a loudspeaker (Glass, 1967). Two to six months later the subjects completed the Maudsley Personality Inventory (MPI) (Eysenck, 1959), which Savage (1964) has used as a measure of extraversion and neuroticism.

EEG Recording

Conventional saline pad electrodes were held to the scalp by a standard rubber head-cap. Bipolar recordings were made from electrode pairs C3–O1, O2–C4, O1–O2

(International Ten Twenty System, 1958) from which one channel was selected for assessment.

Recordings on a six-channel EEG machine were taken at paper speeds of 6 cm./sec. with time-constants set at 0·3 sec. and filters at 75 Hz. One channel indicated time of question presentation and moment of answer. A second channel recorded the presence of alpha rhythm by the appearance of "blips" and a third, the "raw" trace under analysis.

EEG Measurements

The following electrographic parameters were measured; per cent. time alpha; rate of change of potential (r.c.p.) —derived from ratio of length of "raw" trace to its duration (Glass, 1964); amplitude; and frequency of alpha rhythm.

Per cent. time alpha activity (Davis and Davis, 1936; Martinson, 1939; Lorens and Darrow, 1962; Matousek, 1967) was automatically assessed by a per cent. time alpha logger (Glass and Gurney, 1964). Alpha activity was registered on separate counters in, first, the 10-second resting period prior to task presentation (alpha 1), second, during calculation (alpha 2), together with, third, the duration of each calculation. These counters were controlled by a twin-headed tape-recorder. The first counter yielded alpha 1, and the ratio of the second to the third counter reading gave alpha 2. The ratio of each alpha 2 to each alpha 1 (Index III) was averaged for each subject.

Rate of change of potential (r.c.p.) (in microvolts per second) was measured opisometrically from the "raw" trace, in the ten seconds before task-presentation (r.c.p. 1) and during (r.c.p. 2) the initial five calculations of the series of twenty. The mean of the ratio r.c.p. 2/r.c.p. 1 was found.

Amplitude of the alpha rhythm was measured by the envelope method (Walter and Yeager, 1956) over a one-second interval selected at random in the ten-second period prior to the initial five tasks. Upper and lower peaks were joined by continuous lines over the period, and these were intersected at eight equally spaced points by lines vertical to the time axis of the trace. Lengths in millimetres between upper and lower intersections were measured, and means were found for each sample and subject and these were converted to microvolts.

Alpha frequency was measured by a standard cursor. Waves within the alpha frequency band were counted over a two-second period, which always included the same portion of trace as that selected from the pre-calculation period for amplitude measurement.

Results

Mean per cent. time alpha activity prior to task solution (alpha 1) was 66·9 per cent. and mean per cent. time alpha during calculation (alpha 2) was 49·0 per cent. Mean r.c.p. 1 of all subjects was 544·6 microvolts (μV) and the mean frequency of the alpha rhythm 9·57 Hz. Mean amplitude of the alpha rhythm was 28·7 μV.

The results were first subjected to analysis of variance. Using the MPI scores as criteria precisely as Savage (1964) did, a fourfold differentiation of subjects into E, e, N and n groups yielded four unequal groups from our 51 subjects. These were: high extraversion—E—taken as MPI E-score greater than 29, low extraversion, i.e. introversion—e—score 29 or less, and high neuroticism—N—taken as MPI N-score greater than 27, and low neuroticism—n—score 27 or less. As Table I shows, analysing the alpha 1 and amplitude measures, differences significant at the 5 per cent. level between high and low scorers (E/e) on the extraversion scale were found. In alpha 1, high and low scorers for neuroticism (N/n) also differed significantly. Mean values for alpha 1 were 58·3 per cent. for

Table I

Analyses of variance—electrographic parameters

Source of variation		Electrographic measures					
		Alpha 1		Amplitude		Alpha 1 × amplitude	
	d.f.	MS	F	MS	F	MS	F
E/e	1	3283·1	5·6*	884·3	4·9*	12905228	6·2*
N/n	1	2878·9	4·9*	237·3	1·3	5627143	2·7
E×N	1	427·1	<1	11·7	<1	302373	<1
Residual	47	584·8		180·0		2096195	
Total	50						

* = significant at the 5 per cent. level.

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the E group and 73·9 per cent. for e, and for amplitude were 23·8 μV for E and 32·4 μV for e. For neuroticism, the mean values were 58·4 per cent. alpha 1 for the N group and 73·9 per cent. for n. As would be expected, the multiplicative score of alpha 1 × amplitude also showed a significant difference at the 5 per cent. level (Table I), the E group scoring 1572 and e 2487 on this compound measure.

No significant differences between E and e, nor between N and n emerged from analyses of variance of r.c.p., alpha frequency or during calculation (mental arithmetic) either in alpha 2 or in Index III (ratio of alpha 2 to alpha 1).

While interaction between personality dimensions and sex in no case reached statistical significance, it should be noted that the differences found were more marked in females than in males.

Correlations between extraversion and r.c.p. 2 were negative for the total group and for the sub-group of males (−0·32 and −0·30 respectively); and were significant at the 5 per cent. level. The correlation of neuroticism with frequency was highly significant (1 per cent. level), both for the total group and for males (−0·38 and −0·48 respectively). All other correlations calculated differed insignificantly from zero, though correlations of alpha 1 and 2 with neuroticism were systematically negative.

Discussion

From the Eysenckian typological postulate, Savage predicted that introverts with lower cortical inhibition would show lower alpha levels as a postulated consequence of high activity in the reticular formation. Our findings show agreement with those of Savage in that analyses of alpha prevalence and amplitude produced a significant difference between extraverts and introverts, but our results are in the opposite direction. This cannot be explained by the different measures of alpha activity used, because an increase in the complex measure of a low frequency analyser must be positively related to both alpha amplitude and alpha prevalence during the epoch. Our multiplicative analysis of per cent. time alpha 1 × alpha amplitude showed a significant change in the same direction as would be expected from its component factors, and of all our measures this bears the closest similarity to that used by Savage. Neither can the sex composition of the samples explain the differences. Although females constituted the earlier sample studied, the personality differences were if anything more pronounced among our small female group. It is interesting that our finding of a significantly low amplitude in the EEGs of high neuroticism scorers confirms Savage's (1964) prediction that neuroticism depresses alpha amplitude. These findings may also explain why Fenton and Scotton (1967) found no correlation between alpha index and personality scores. Possibly they examined population samples which differed in some significant respect from ours. All their subjects had alpha indices above 50 per cent. (mean 83 per cent.), thus excluding the low alpha indices or "m" types of Golla, Hutton and Walter (1943) which were, of course, included in our sample, in which no selection on the basis of EEG or alpha index was made (our mean, 64 per cent.). Comparison of the mean alpha amplitudes (29·0 μV as against 28·7 μV for our sample) shows good agreement. Thus some subjects with low alpha prevalence and high extraversion scores, who were found in our study, would not have been included in theirs. Furthermore, since it was only in our analysis of variance of prevalence measures that significant findings emerged, it is hardly surprising that Fenton and Scotton, using a correlation analysis, failed to find significance.

Our EEG findings on alpha index and amplitude have a bearing on the important attempt by Gray (1967) to identify the dimension of introversion–extraversion with either the dimension of strength of the nervous system or that of equilibrium in dynamism as understood by Russian workers (e.g. Nebylitsyn, 1966). There are difficulties in reconciling Savage's results with Gray's hypothesis of identification of weakness of the nervous system with introversion. Our results, being contrary to Savage's, are in accord with Gray's hypothesis; the dimension "strength of the nervous system" and the personality dimension of introversion–extraversion are congruent. They do not support Gray's (1967) alternative hypothesis that "the dimensions of introversion–extraversion and

equilibrium in dynamism are identical, the introverts corresponding to the individual with a predominance of excitation in dynamism". If excitation in dynamism were due to high activity in the reticular activating system, we would expect low amplitude of alpha activity and low prevalence to be associated with excitation, as shown by Nebylitsyn (1966). By contrast, in our introverted subjects, alpha amplitude and per cent. time alpha are high, suggesting predominance of inhibition.

If replicated, the significant negative correlation between r.c.p. and extraversion scores could be interpreted in two ways. First, that frequency of the alpha rhythm is not associated with extraversion in the population studied, in which case the association of high opisometric scores with introversion would imply a high amplitude of the alpha rhythm (Glass, 1964; Volavka, Matoušek and Roubíček, 1967) which was in fact the case in these experiments. This is consistent with Savage's finding that alpha abundance correlated positively with extraversion only if it is remembered that high amplitude alpha rhythm of constant prevalence cannot be distinguished from a constant amplitude alpha rhythm of high prevalence by low frequency analysis. The second interpretation of the correlation takes frequency changes into account as components of the r.c.p. As an overall measure of both frequency and amplitude, r.c.p. is a direct assessment of individual differences in cortical activity (zero activity being the equipotential state of zero r.c.p. (Glass, 1964)). High r.c.p. will, therefore, be associated with increased cortical activity. Thus extraverts will have increased cortical inhibition (Eysenck, 1957) and decreased cortical electrical activity. Consequently, r.c.p. can be regarded as an overall measure of cortical activity which may be directly related to personality measures as an electrographic manifestation of cortical inhibition, and because r.c.p. is related to energy, this latter hypothesis may be more directly tested by measurement of power spectral densities, a form of analysis which will be used in future experiments.

The positive correlation of alpha frequency and neuroticism was highly significant but unexpected. By contrast, Gastaut, Dongier and Dongier (1960) found an alpha frequency below normal in a group of neurotics. Possibly both the elevated frequency of the alpha rhythm and the neurophysiological determinants of the behavioural characteristics of neurotics have an underlying elevation in metabolic rate or body temperature (Bertrand, Delay and Guillain, 1938; Blake, 1967) in common, perhaps due to an increase in circulating thyroxine. The importance of thyroxine in rats selectively bred for reactivity has been demonstrated (Eayrs, Glass and Broadhurst, 1962; Feuer and Broadhurst, 1962), and Eysenck (1963) has drawn the analogy between behavioural reactivity in animals and neuroticism in humans.

Sex difference is another major consideration. Some of the discrepancies between past and present findings may be explicable in these terms alone. Because the EEG is affected by different phases of the menstrual cycle (Margerison *et al.*, 1964) and the degree of alpha suppression to mental arithmetic differs in the two sexes (Glass, 1968), the relationship of personality to EEG measures was calculated separately for male and female subgroups. Apart from a significant association of extraversion with calculation time, female subjects gave no significant correlations. This, however, may reflect the relatively small size of the female sample.

Our EEG results, in other respects, agree with those of earlier workers. Resting per cent. time alpha of 66·9 per cent. corresponds well with the value of 61 per cent. in normal adults (Brazier and Finesinger, 1944), suggesting that our selection of subjects was not unduly biased. It is perhaps also noteworthy that the significant relationships of EEG to personality dimensions were detected with eyes closed during relaxation and not during mental activity, also in agreement with earlier findings (Werre, 1957).

Summary

In this combined behavioural and electrophysiological study of 51 normal young subjects, introverts and extraverts differed in per cent. time alpha and alpha amplitude. In contrast to earlier findings, introverts were higher in both. High and low scorers on neuroticism also differed in per cent. time alpha. Statistically significant associations were demonstrated between rate of

change of potential (r.c.p) of the EEG and extraversion, and also between the frequency of the alpha rhythm and neuroticism. Thus relationships have been found between EEG parameters and behavioural measures of personality. The conflict with other findings and the relevance of this work to attempts to identity introversion–extraversion with "strength of the nervous system" or with "equilibrium in dynamism" are discussed.

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