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Cortical Evoked Potential, Personality, and Intelligence

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The averaged cortical evoked potential (CEP) was measured from 296 male subjects in two studies and was correlated with scores on intelligence and personality tests. For both studies, auditory stimuli were used with bipolar electrode placement to the Cz and T3 scalp positions. In the first study, with 84 subjects, stimulus intensity was 95 dB (all dB readings re 20 $\mu N/m^2$). Intelligence was measured with the Mill Hill Vocabulary Scale and personality with H. J. Eysenck's PEN questionnaire. The second study, with 212 subjects, used additional stimuli at 75 dB and 55 dB. Intelligence was measured with the Ravens Progressive Matrices. State anxiety and other state measures at the time of testing were also taken. Neither study found any relation between the CEP and IQ or personality. However, more bored subjects showed larger CEP amplitudes. The results are discussed in terms of Ertl's neural efficiency hypothesis and Eysenck's arousal theory of personality.

In the last decade some interest has been expressed in the possibility of a relationship of personality and intelligence with individual differences in the cortical evoked potential (CEP). It has been suggested that neural efficiency (Ertl, Note 1) or speed of neural information processing (A. Hendrickson, 1972) may be related to intelligence and that these processes may be determined by the latency of the CEP components.

In support of this, Barry and Ertl (1965), Ertl and Schaffer (1969), and Chalke and Ertl (1965) all reported work that shows a negative correlation between CEP latencies and intelligence. This evidence is supported by Plum (1968), Osborne (1969), Weinberg (1969), and Gucker (1973). These experiments covered approximately 800 subjects, and mean correlations ranged between −.3 and −.8. Shucard and Horn (1972), with 108 subjects, found marginal support for these results. Although none of their correlations were less than −.3, about two thirds were significant at the .05 level. Callaway (1973), with 191 subjects, found 14 correlations out of 120 that were significant at the .01 level. In all these experiments a similar design was used. Stimuli were visual flashes with a random interstimulus interval of approximately 2 sec. Electrode placement was generally bipolar to the F4 and P4 scalp positions (10–20 International System). A large number of different IQ tests were used. The effect did not appear to be particular to any one type of test. In the auditory modality D. E. Hendrickson (1973), with about 90 subjects, found significant correlations of −.35. She used a Cz to T3 electrode placement with a random interstimulus interval between 4 and 9 sec.

There are, however, several studies that contradict these findings. Davis (1971) reported an attempt by Ertl to replicate the Ertl and Schaffer (1969) study. With several hundred subjects and an apparently identical design, he failed to find any significant effect. Griesel (1973), with 109 subjects, also found no significant correlations. Rhodes, Dustman, and Beck (1969), with 40 subjects, found correlations of IQ with CEP amplitude, but not with latency. This amplitude correlation was dependent on electrode placement. Engle and Fay (1972) measured the visual CEP of 828 neonates and found no correlation with the IQ at the age of four. In the auditory modality Callaway (Note 2) found that shorter latencies were associated with mental deficit.

It has been suggested that individual differences in arousal or in reaction to

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arousal-producing stimuli may be a causative factor for personality differences (H. J. Eysenck, 1967). Such a relation may be demonstrated through the CEP, as this is certainly related to some extrinsically arousing variables such as stimulus intensity. Shagass, Schwartz, and Krishnamoorti (1965) found a positive correlation of CEP latencies with extraversion and a negative correlation with neuroticism. D. E. Hendrickson (1973) also found a negative correlation with neuroticism in a moderate stimulus intensity condition but found that extraversion was negatively correlated with CEP amplitude. Shagass and Schwartz (1965) and Young (Note 3) found no direct relation between the CEP and extraversion or neuroticism. With the P scale (S. B. G. Eysenck & H. J. Eysenck, 1969), which is purported to measure personality dimensions of psychopathy, psychoticism, and tough-mindedness, D. E. Hendrickson found shorter latencies for high psychoticism scorers with medium intensity tones, but not for loud or quiet tones.

The general failure to replicate results in both these areas suggests that the production of significant correlations may be dependent on unknown intervening variables. It may be that there is an interaction between IQ and personality or that different types of subject react differently to the testing situation, producing intervening variables, such as anxiety, which may affect the CEP directly. In the two studies reported below, an attempt was made to replicate the effects while additionally measuring the state of the subject at the time of testing.

Method

Subjects

In Study 1, subjects were 84 male twins from a twin register compiled at the Institute of Psychiatry. The mean age was 24.2 yr, ranging between 17 and 44 yr. For Study 2, 149 male prisoners and 63 miscellaneous subjects were tested. The mean ages of these two groups were 29 yr (SD = 4.7) and 27 years (SD = 5.2), respectively.

Apparatus

The electroencephalograms (EEG) were recorded by a Mingograf EEG polygraph (Elema-Schonander, Sweden) and recorded on a Thermionic tape recorder for subsequent analysis. One channel of EEG was measured from bipolar electrode placement to the Cz and T3 scalp positions. The time constant was .3 sec with a frequency filter of 70 Hz. Tonal stimuli were generated by an audio oscillator (SG65A Advance) and were presented binaurally through stereophonic headphones. All stimuli were sinusoidal, of 1 sec duration and at a frequency of 1,000 Hz.

Procedure

For both studies the experiments were carried out in a dark room. Subjects were informed of the stimulus conditions and were asked to keep their eyes closed during testing. For the first study, subjects received 20 stimuli at an intensity of 95 dB (all dB readings re 20 μN/m^2) with a regular interstimulus interval of 33 sec. The Mill Hill Vocabulary Scale and the PEN personality questionnaire (Eysenck & Eysenck, 1969) were administered. The latter gives scores on the personality measures of extraversion, neuroticism and psychoticism.

In the second study, the stimulus conditions of the first study were replicated. In addition, the subjects received 50 stimuli at 55 dB and 50 at 75 dB; interstimulus interval for these two conditions was random between 4 and 9 sec. The subjects filled in the Spielberger State Anxiety Questionnaire (Spielberger, 1972) as well as the Ravens Progressive Matrices and the PQ (a later version of the PEN) just before the experiment and afterward answered some questions about their state during testing.

Analysis

The EEG was sampled for 500 msec after each stimulus and was averaged, using a Linc-8 computer. A typical averaged response is shown in Figure 1. For scoring, the large negative deflection at about 100 msec and the large positive deflection at about 200 msec were defined as N2 and P3 respectively. The largest positive deflection prior to N2 was then defined as P2, and the largest negative deflection after P3 as N3. The scores used were the latencies in milliseconds and the amplitudes in microvolts of these maximum and minimum points. In all cases amplitudes were

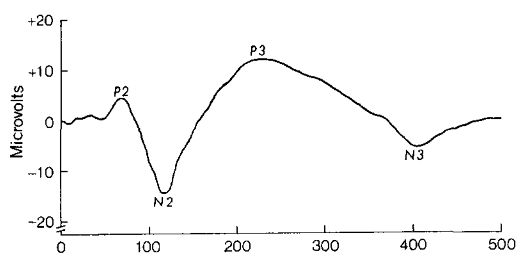

FIGURE 1. Cortical evoked potential response from one subject in the 95-dB re 20 μN/m^2 tone condition.

TABLE 1
MEANS AND STANDARD DEVIATIONS OF THE CORTICAL EVOKED POTENTIAL VARIABLES

Variable	Stimulus intensity					
	95 dB		75 dB		55 dB	
	M	SD	M	SD	M	SD
Latency						
P2	50.0	13.4	40.6	12.8	44.1	15.5
N2	112.	15.5	101.	15.8	108.	16.8
P3	215.	37.6	201.	38.7	212.	37.9
N3	399.	39.9	376.	53.4	386.	56.0
Amplitude						
P2–N2	20.5	9.60	9.87	4.03	8.79	3.93
N2–P3	30.5	12.0	14.7	5.52	12.5	4.86
P3–N3	28.3	9.60	12.3	4.78	9.96	4.02

Note. All dB readings are re 20 μN/m^2. For the loud-tone condition, the two studies have been combined. Latencies are in milliseconds; amplitudes in microvolts. Abbreviations: P = positive; N = negative.

converted into differences between successive positive and negative points. There were, therefore, seven CEP variables for each average, these being P2, N2, P3, and N3 latencies and P2–N2, N2–P3, and P3–N3 amplitudes.

RESULTS

The means and standard deviations of the seven CEP variables for the three stimulus intensities are given in Table 1. For the loud tone condition, the means from the two studies have been combined. It can be seen that the amplitude of the CEP is clearly related to stimulus intensity, the amplitudes of the CEPs from the loud stimuli being over twice as big as those from the more quiet tone conditions. For the latencies there seems to be a U-shaped relationship with stimulus intensity. This may, however, reflect the difference in interstimulus interval between the conditions.

TABLE 2
CORRELATIONS OF THE CORTICAL EVOKED POTENTIAL (CEP) WITH IQ, PERSONALITY, AND AGE IN STUDY 1

Variable	P	E	N	IQ	Age
Latency					
P2	−.05	−.08	−.03	−.09	.02
N2	.17	−.06	−.17	−.01	.26*
P3	−.06	.C7	.02	.18	.04
N3	.04	−.02	.04	.13	.23
Amplitude					
P2–N2	−.10	−.08	−.03	.06	−.04
N2–P3	−.08	−.05	−.03	.06	−.04
P3–N3	.00	−.03	−.06	.04	−.16

Note. Personality is measured on the PEN questionnaire which gives scores on P (psychoticism), E (extraversion), and N (neuroticism). Intelligence is measured by the Mill Hill Vocabulary Scale. Abbreviations for variable: P = positive; N = negative.
* $p < .02$.

For the first study the reliabilities of the measures were calculated by averaging the 20 trials over two successive blocks of 10 trials and using the Spearman formula to calculate the reliability of the combined average (r_{nn}) from the correlation between these (r_{tt}). This is given by $r_{nn} = 2r_{tt}/(1 + r_{tt})$. The reliabilities averaged .74 for the latencies and .84 for the amplitudes.

For Study 1, the mean scores on the PEN personality scale were 3.3 for psychoticism, 10.9 for extroversion, and 9.6 for neuroticism. The standard deviations were 2.0, 4.1, and 4.2, respectively. The mean Mill Hill Vocabulary Score (Part A) was 22.4 with a standard deviation of 4.0. All of these scores correspond fairly closely with the population parameters. Correlations of all these measures and age with the CEP variables are given in Table 2. It can be seen that the only significant correlation in this table is between N2 latency and age. No relationship at all between personality and CEP is suggested. For intelligence, the one latency measure that approaches significance does so in the opposite direction to that suggested by the prevailing hypothesis.

In the second study there were several differences in personality and intelligence between the two groups. The means and

TABLE 3

MEANS AND STANDARD DEVIATIONS OF IQ AND PERSONALITY SCORES IN THE TWO GROUPS IN STUDY 2

Variable	Group				t test ($p<$)
	Prisoners		Nonprisoners		
	M	SD	M	SD	
Psychoticism	5.83	3.68	4.18	3.51	.01
Extraversion	14.08	4.58	12.92	5.22	*ns*
Neuroticism	12.72	5.45	8.62	4.22	.0001
IQ (Ravens)	42.38	6.19	50.06	5.99	.0001
State Anxiety	43.54	10.97	31.08	6.12	.0001
Age (in yr)	29.29	4.70	27.64	5.16	.05

standard deviations for these are given in Table 3, together with the significance level of the t test for comparison between the means. For personality, the differences are those that would be expected in any comparison between prisoners and nonprisoners. The age difference is significant but not very large. The large difference for intelligence presumably reflects sampling bias in the nonprisoner group in which the Ravens score is somewhat above the population mean. Because of these differences between groups, the correlations (Table 4) were calculated from the within-groups variance-covariance matrix of the multivariate T. These correlations are, therefore, in effect, adjusted for differences between the groups. The suitability of this adjustment was checked by comparing this matrix with those from the two groups separately. These

TABLE 4

CORRELATIONS OF THE CORTICAL EVOKED POTENTIAL WITH AGE, IQ, PERSONALITY, AND STATE VARIABLES IN STUDY 2

Variable	Cortical evoked potential						
	Latency				Amplitude		
	P2	N2	P3	N3	P2-N2	N2-P3	P3-N3
95-dB stimulus intensity							
Psychoticism	−.04	.01	.04	.02	.05	.00	−.02
Extraversion	.00	−.08	−.01	−.12	.08	.03	.00
Neuroticism	−.01	.00	.03	−.03	.04	−.03	−.05
Ravens (IQ)	.14	−.09	−.13	−.10	.07	.04	.06
Age	.01	.09	.03	.01	−.11	−.02	−.03
State anxiety	.11	.02	.12	−.04	.13	.12	.05
Boredom	.11	−.04	−.03	.00	.09	.15*	.20**
75-dB stimulus intensity							
Psychoticism	.02	.06	−.06	.10	.05	.01	−.03
Extraversion	−.08	.00	.04	.16*	.16*	.05	−.06
Neuroticism	.02	−.08	.09	−.05	.01	−.01	−.04
Ravens (IQ)	−.03	.00	−.06	.05	.05	.04	.09
Age	.03	−.03	.02	−.06	−.11	−.08	−.08
State anxiety	.00	.01	.02	.09	.09	.05	.00
Boredom	.01	.01	−.11	.00	.11	.17*	.13
5-dB stimulus intensity							
Psychoticism	.07	.12	−.01	.02	.00	.02	−.03
Extraversion	−.03	−.08	.01	−.13	.00	−.01	−.10
Neuroticism	−.09	.03	−.04	−.03	.01	.00	−.01
Ravens (IQ)	−.03	−.13	−.03	.01	.06	.06	.07
Age	−.13	−.02	.00	.05	−.05	−.05	−.09
State anxiety	.03	.07	.09	.11	.09	.03	.00
Boredom	−.07	−.05	−.03	.04	.12	.15*	.18**

Note. All dB readings are re 20 $\mu N/m^2$.

* p < .05.

** p < .01.

showed good agreement. As in Study 1, no relationship was found between personality or intelligence and the CEP. The few significant results show no consistent pattern, are not replicable across conditions, and probably represent the few significant effects we would expect by chance from this number of correlations.

At the end of the experiment in this second study, subjects were asked whether they had become sleepy, anxious, or bored during the testing. Answers were scored on a 4-point scale ranging from "definitely" to "not at all." Sleepiness and anxiety showed no significant effects, but (as Table 4 shows) there was a consistent significant positive correlation of boredom with CEP amplitude.

Discussion

From the two studies there is no evidence for a relationship between IQ and the CEP. In the literature the only other experiment to use the auditory modality is that of D. E. Hendrickson (1973), who also used the same electrode placement and stimulus paradigm. She found the effect with a large number of different IQ subtests. Different IQ tests were used in the present research, but it is unlikely that this accounts for the difference in results. The Mill Hill Vocabulary Scale and Ravens Progressive Matrices used in the present studies are of known reliability and validity. They give measures of verbal and nonverbal IQ, respectively, and in the general population have a correlation with each other of about .5.

Another explanation for the difference from Hendrickson could be that the loud tone condition used here produced arousal that failed to dissipate. However, this seems unlikely, as no significant correlations between the CEP and subjective estimates of arousal were found. In view of the large number of subjects in the present studies, it is believed that the case for a relationship between IQ and auditory CEP remains unproven.

Much more of the available evidence is from experiments using the visual modality. According to Ertl's neural efficiency hypothesis, there is no reason why the effect should be restricted to any particular modality. The present results, therefore, do not support Ertl's hypothesis. Indeed, this hypothesis seems too general and raises more questions than it solves. The generalization from information processing of simple light flashes at 2-sec intervals to complex problem-solving behavior seems rather strained, as does that from neuronal to gross brain behavior. In general, correlations are not found between IQ and simple reaction times.

It is difficult, in fact, to see any consistent pattern in the literature. Contradictory results are found for both adults and children, within modalities, electrode placements, interstimulus intervals, and IQ tests. According to Ertl's hypothesis the effect should always be present. Failure to find it could be due only to lack of reliability or validity in the measures. There is no evidence that those who did not find the effect used less reliable IQ tests. For the CEP the only reliabilities reported are .75 in the present study and one of .9 found by Rhodes et al. (1969), who also found no effect. Apparently, reliability measures were taken by Ertl in the Davis (1971) study, but these have yet to be published. By comparing the stimulus paradigms, we would, in fact, expect the reliability of some of the experiments that found the effect to be smaller than some of those that did not. The size of some correlations reported in the literature (often greater than .7) seems much too large in view of the expected reliabilities of the variables and the number of intervening steps that presumably must operate between two such different types of measure.

The strongest evidence so far for the effect is from the Ertl and Schaffer (1969) study. In view of this, the failure of Ertl to replicate it, as reported by Davis (1971), is rather worrisome. It may be that, as Davis suggests, inadequate control for various experimenter effects was made in the original study. Pessimistically, one might disregard Ertl's unreplicated results and then account for the other reported effects, all of which give smaller correlations or use smaller samples, in terms of the well-known literature bias in favor of positive results.

Callaway (1973) suggested that the effect may be mediated by state variables at the time of testing. It may be, for example, that more intelligent subjects become bored during some experiments and that this boredom affects their CEP. However, although relationships between state variables and the CEP have been found, they are not generally very large. Nor would we expect any sizable relationship between these state variables and IQ. When this is considered in conjunction with the validity of most IQ tests (about .70), we would not expect much of a contribution to the effect from any such intervening variable. It seems unlikely that state variables could produce effects of the size reported in the literature. This is, however, an empirical matter. We shall have to wait for an experiment in which these possible intervening variables have been measured and a significant effect has been found.

For personality, the present results also find no evidence of a relationship with auditory CEP. As with IQ, the literature is conflicting. Test-retest reliabilities of the personality measures used are above .7 (Eysenck & Eysenck, 1969), which compare favorably with those of most personality tests. Theoretical backing for effects might seem more plausible here than in the case of IQ, as arousal can be incorporated as an intervening variable. However, although there is evidence that both extrinsic arousal (e.g., stimulus intensity) and intrinsic arousal (e.g., attention) affect the CEP (Haider, Spong, & Lindsley, 1964; Ritter, Vaughan, & Costa, 1968), there is no consistent evidence for a relationship between personality and physiological arousal (Rust, 1974). A more simple, although less impressive, hypothesis to explain any results in this field lies in the differential reactions of different personality types to the testing situation. Some personality types may be more likely to become anxious, sleepy, or bored during testing, and these secondary effects may relate to the CEP. As with the IQ, however, we should not expect any such effects to produce much of a relationship between personality and the CEP.

With the present studies the CEP amplitude was found to be related to the subject's boredom, although this latter variable was not correlated with personality or IQ. Although we might think it more likely that the CEP would relate with state anxiety or sleepiness rather than with boredom, no such effects were found. For sleepiness, it may be that the variation was not large enough, but for state anxiety, there was certainly a large variation in the sample. We cannot, therefore, interpret the boredom result in terms of arousal as measured by state anxiety scales or in terms of personality. Perhaps the explanation lies in differences in attention of bored and nonbored subjects.

In general it is felt that the case for a direct relationship of IQ and personality with the CEP is not proven. Before any strong case can be made for it, experiments showing significant correlations between the two sets of variables will have to show additionally that situational variables at the time of testing were not involved. Even if the effects exist, they cannot be general, in view of the inconsistencies in the literature and the negative findings of the present studies. Thus, we would not be justified in basing any theory of personality or IQ in terms of biological variables on generalized results from the evoked potential area.

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