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The experimental study of the relation between the Alpha rhythm of the electroencephalogram and intelligence

David Gordon Shacter
University of Nebraska at Omaha

AN EXPERIMENTAL STUDY OF THE RELATION BETWEEN THE ALPHA RHYTHM OF THE ELECTROENCEPHALOGRAM AND INTELLIGENCE

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DAVID GORDON SHACTER

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D. G. S.

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CHAPTER I

THE PROBLEM AND DEFINITIONS OF TERMS USED

During the year 1808, Gall was assessing a person's intellectual attributes by means of bumps on their heads.[1] He held the opinion that an intellectual trait, as well as any other trait, would show the degree of its development by exerting a local pressure, pressing outward and finally appearing as a bump.

In the year 1882, Francis Galton initiated his "testing center."[2] Upon the payment of a small fee, anyone could have their intellect appraised. Here in his office at the South Kensington Museum, he measured what he considered "higher" and "lower" mental functions. Galton believed that intelligence could be measured by means of sensory acuity tests as well as tests of perception.[3] In order to measure the "threshold for linear visual comparison", he designed an apparatus referred to in this age as the Galton Bar. Using this equipment, the person being tested matches a movable line to a standard line.

In the early Twentieth century, Binet appeared on the horizon with his intelligence test, which has since undergone many revisions. Binet's first scale (1905) was composed of a series of thirty tests. These tests were arranged in order of increasing difficulty. Finding that he had used

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[1] Murphy, Gardner, Historical Introduction to Modern Psychology (Harcourt, Brace, and Co. New York) 1940. pp. 56-7.

[2] Philip L. Harriman, Modern Psychology. Ames Iowa. (Littlefield Adams and Co.) 1956. pp. 158-61.

[3] Ibid., p. 158.

too many tests of rote memory and sensory acuity, he revised it in 1908. In this revision, he expanded the scale to a total of fifty-eight items. The last revision in which Binet took part occured in 1911. This version started at a mental age of three years. There were a total of eighty-one items in this scale.

In 1939, D. Wechsler made available an individual intelligence test known as the Wechsler-Bellevue Intelligence Scale. This test, composed of eleven tests, is divided into two divisions. One is known as the Verbal scale, and the other is referred to as the Performance scale. The combination of the Verbal and Performance score is called the Full Scale score.

During the past twenty years, the search for a reliable and accurate method of ascertaining man's intellectual prowess has continued. A search for a method which would be more free from cultural influence than existing tests or methods. One that would be able to be given to the mentally ill, whether or not they were capable of, or interested in, performing an "intelligence test."

In 1957, Mundy-Castle found that intelligence, as was measured by the revised South-African Wechsler-Bellevue Adult Intelligence Scale, was correlated with the Alpha rhythm of the EEG.[4] In this study, the procedure was such that a considerable amount of time elapsed between the administration of these two items.[5] The data which Mundy-Castle used was compiled originally for various other reasons than that of his study.[6] For example, the subjects were given the Wechsler test as

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[4]Mundy-Castle, A.C. "Electrophysiological Correlates of Intelligence." Journal of Personality. June 1958. Vol. 26. No. II. p. 184.

[5]Ibid., p. 187. [6]Ibid., p. 186.

part of the procedure involved in standardizing the test for use in the Union of South Africa. Previous to Mundy-Castle's study there had been no attempt to correlate intelligence as determined by the Wechsler-Bellevue with EEG phenomena for a normal population.[7] For the reasons outlined, it seemed as though an answer to the question of whether there exists a correlation between intelligence and EEG phenomena could not be given, due to inadequate experimentation.

The purpose of this study was to test Mundy-Castle's hypothesis that Alpha index and Alpha frequency are correlated with intelligence as measured by the Wechsler-Bellevue scale. For this purpose the EEG technique, as reported by Mundy-Castle was used. In addition a new measure which accounted for more of the EEG record was utilized.

Among the limitations of study are the following. The group of subjects were composed of University students from the University of Omaha. The greater part of this group of students were freshmen in Psychology. The age of the subjects were also limited for purposes explained in the chapter on Method. Finally, the part that personality plays in intelligence was regarded as being outside the scope of this study.

TERMS USED

In the year 1929, Hans Berger, a German neuropsychiatrist published the results of his five years experimentation of the recording of electrical activity in the human brain. He called the recording an Electrenkephalogramm from which

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[7] A.C. Mundy Castle, Electrophysiological Correlates of Intelligence, Journal of Personality. Vol. 26. No. 2. June 1958. p. 186

we derive the English term, electroencephalogram. It is abbreviated EEG. The EEG is to be differentiated from the electrogram. The latter is a recording obtained with the electrodes touching a part of the brain, whereas the EEG is a recording where the electrodes are affixed to the surface of the scalp.

A prominent type of brain wave is called Alpha. It consists of a series of rhythmical cycles of electrical energy occuring with a frequency of from eight to twelve cycles per second.[8] It normally occurs in an adult with a frequency of ten cycles per second. While recordings may be made of Alpha from any area of the scalp, it appears to be concentrated for the most part in the occipital and parietal areas.[9] During the recording of Alpha waves the subject must keep his eyes closed, for the Alpha activity vanishes when the eyes are opened.

By the term Alpha frequency is meant the number of Alpha waves per second. The period of time Alpha activity is present during a unit of time is referred to as Alpha index. For example, if Alpha activity is present for ninety seconds over a hundred-second intervals then the Alpha index is said to be ninety. Alpha index is also referred to as Alpha percent time present.

Kappa waves are waves of a frequency of eight to twelve cycles per second. They are said to differ from Alpha waves in that they are not affected by various stimuli as Alpha waves are.[10] Their existence has not been confirmed or denied. More will be said about them in the chapter on related research.

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[8] D.B. Lindsley, Electroencephalography. McV. Hunt (Ed.), Personality and Behavior Disorders. New York. Ronald, 1944. Vol. II, Ch. 33, p. 1039.

[9] Ibid., p. 1038

[10] J. L. Kennedy, R. M. Gottsdanker, J. C. Armington, and Florence E. Gray. "A New Electroencephalogram Associated with Thinking." Science, 1948, p. 528.

For the purposes of this study, the term intelligence is defined as the scores obtained from the Wechsler-Bellevue Scales. "The common procedure for validating a new intelligence test is to correlate it with other accepted tests."[11]

A correlation of .89 was found between the Wechsler-Bellevue I.Q's and the Stanford-Binet 1937 Form L I.Q. The N was 227 and the subjects ages ranged from 10 to 69 years. The subject population consisted of male and female Mental hospital patients.[12]

The validity of the Wechsler-Bellevue, has also been measured using another criterion. This other criterion being the correlation between the Wechsler-Bellevue I.Q.'s and teachers judgment. The correlation's here were found to be .43 and .52. The N was not given.[13]

The purpose of psychology may be said to consist of the scientific study of man's behavior. Intellect is one aspect of man's behavior, and is thus studied. The ultimate aim or goal of any science is prediction. Intelligence tests are of value in that they are valid predictors of selected aspects of man's behavior.

Before a science can make a prediction, it must make measurements. From these measurements it discovers the fundamental characteristics of the natural

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[11] C.H. Patterson, The Wechsler-Bellevue Scales: A Guide for Counselors. Charles C. Thomas, Springfield, 1953, p. 20.

[12] David Wechsler, The Measurement of Adult Intelligence. Third Edition. Baltimore, Williams & Wilkins, 1941, p. 130.

[13] M.B. Mitchell, Performance of mental hospital patients on the Wechsler-Bellevue and the Revised Stanford-Binet, Form L. J. Educ. Psychol., 33:538-544, 1942., p. 541.

phenomena being studied, and the relations which exist between these measures. One group of these relations may be termed, natural constants. If Psychology be regarded as a biological science, few of these natural constants are found, as compared to the physical sciences which abound with them. An example of a natural constant would be the speed of light (186,283 miles per second). It seems that in order for Psychology to become more of a science, the psychologist must seek out these constants and gather them together. Intelligence tests are of use here, because they are measures of mental potential, and as mentioned previously, measurements may be thought of as a preliminary step in the scientific process.

CHAPTER II

PREVIOUS RELATED RESEARCH

In 1942, Knott, et al., found a correlation of 0.5 between intelligence as measured by the Stanford-Binet 1937 Revision, and Alpha frequency. The test population consisted of forty-eight 8 year old children. The correlation of Alpha percent time present, and intelligence was not found to be significant. No significant correlation was found between the above measures and intelligence for a group of forty-two 12 year olds.[14]

Kreezer and Smith did not find a significant relationship between the Mental age and the Alpha rhythms.[15] They used as their intelligence test the 1916 Stanford-Binet. The correlations obtained were small and were not significant at the five percent level. One of the larger correlations obtained was 0.323, this being the correlation between Alpha frequency and the M.A. The number of subjects was forty-six.

In Kreezer's, et al., study, the age range was broad being from sixteen to fifty-four years of age. Alpha frequency is dependent to some extent upon age, so this factor would probably lower any correlation that existed. Kreezer, et al., did try to some extent to limit the effect of chronological age on the Alpha rhythm by excluding subjects under sixteen years of age. But, he did not

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[14] J. R. Knott, H. Friedman, and R. Bardsley, "Some Electroencephalographic Correlates of Intelligence in Eight Year Old, and Twelve Year Old Children." Journal of Experimental Psychology. Vol. 30., p. 390.

[15] G. L. Kreezer, and F. W. Smith, "The Relation of the Alpha Rhythm of the Electroencephalogram, and Intelligence Level in the Non-Differentiated Familial Type of Mental Deficiency." Journal of Psychology. 1950. p. 29, 49.

correct this factor at the upper end of the age scale. Lindsley and others have found that in normal children the Alpha frequency increases as the chronological age increases.[16]

On the basis of the results of an earlier study on Mongoloids, Kreezer reported a correlation of 0.316 between Alpha index and mental age. This was significant at the three percent level. Kreezer, giving the reasons he used mental age in place of intelligence, stated:

> "In the computation of the I.Q. for adults, it is customary to take as the value for chronological age a standard value not greater than 16 years. Consequently the restriction of our experimental group to subjects older than 16 years means that the I.Q.'s of different subjects will be proportional to their mental age, and independent of differences in their chronological age. The classification of our subjects in terms of absolute mental age-level will, therefore, correctly represent their distribution in terms of intelligence quotient as well." [17]

Kreezer however, did not find any significant correlation between Alpha frequency and mental age. Again he used the 1916 Stanford-Binet. Kreezer tested this result to see if this correlation could be caused by extraneous factors such as variations in the electrode resistance, location of electrodes or sex. The correlations he found were exceedingly small and well below the five percent level of significance.[18]

Kennedy, et al., claim to have found what they term Kappa waves to be associated with mental processes. Kappa waves are said to be spindle shaped waves with a frequency of 8 to 12 cycles per second. Kappa activity, the report

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[16] D. B. Lindsley, Electroencephalography. McV. Hunt (ed.) Personality and Behavior Disorders. New York., Ronald, 1944, Vol. II, Ch. 33., p. 1053.

[17] G. Kreezer, "Intelligence Level and Occipital Alpha Rhythm in the Mongolian Type of Mental Deficiency." American Journal of Psychology. 1952. p. 505.

[18] Ibid., p. 527.

continues, were found during the performance of various mental tasks, such as reading, problem solving, etc. Kennedy claims that Kappa waves are not a form of Alpha waves because they are not affected by various stimuli as are Alpha waves. Kennedy's results "have neither been confirmed, or refuted by other workers."[19]

Ellingson states "that the weight of evidence indicates that the Alpha rhythm is unrelated to test intelligence."[20] Ellingson made this comment after reviewing the work done in this field to 1956. At that time there was no published study between the Wechsler-Bellevue test and Alpha rhythm.

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[19] R. J. Ellingson. "Brain Waves and Problems of Psychology." Psychological Bulletin. 1956. Vol. 53. p. 19.

[20] Ibid., p. 18.

CHAPTER III

METHOD AND PROCEDURE

Thirty subjects were given the Wechsler-Bellevue Adult Intelligence Scale, and an EEG was recorded for a period of fifteen minutes. The age of the subjects ranged from 18 to 32 years. There were 19 women and 11 men. All of the subjects were students at the University of Omaha, with the greater number of them being freshmen in Psychology. In order to make the experiment as compatible as possible to Mundy-Castles, and in order to facilitate comparison between them, the raw scores of the Wechsler-Bellevue scale were used in the statistical analysis.

EEG procedure—Five electrodes, circular shaped and composed of solder, were attached to the subject's scalp by means of hydrogen chloride paste. The insulated leads of these electrodes were inserted into a connecting box, and by means of an insulated cable the in-put of electrical impulses were transferred to an ink-writing oscillograph of the electromagnetic type. The electroencephalograph used was the Offner Type D.

Because the Alpha rhythm appears to be stronger over the occipital and parietal areas, the electrodes were affixed to these areas. Recordings from both sides of the head were taken. One of the electrodes was used as a ground and attached to the forehead by means of the hydrogen chloride paste.

The subject then reclined on a bed with his eyes closed in a darkened room. The room was insulated from both sound and stray electrical impulses.

Three EEG measures were used. First, the two measures that Mundy-Castle utilized—EEG Alpha frequency, and percent time present. In determining the

value for Alpha percent time present, Mundy-Castle used one 100-second portion of the record. Besides doing this, a third measure was added. This additional measure consisted of the mean of the Alpha percent time present of three separate determinations of the Alpha index. One determination of Alpha index was taken for every five minutes of the recording.

STATISTICAL PROCEDURE

Determination of Alpha frequency—The Arithmetic mean of 20, one-second periods was used. The twenty periods chosen were those with the greatest amplitude over the entire EEG recording.

Determination of Alpha index—Alpha index measurement #1—is when the record was split into three 5-minute segments. Alpha index was taken for a 100-second interval following the initial 30 seconds of each segment. The value of the Alpha index for the first of these 100-second periods constitute Alpha Measurement #1.

Determination of Alpha index—Alpha index measurement #2—is composed of the mean of the value of Alpha index for all three Alpha index evaluations.

The correlations between the three EEG measures and the Wechsler test scores were computed using the product moment correlation formula, which is used to measure association in the linear sense.[21]

$$r = \frac{\frac{\Sigma XY}{N} - \left(\frac{\Sigma X}{N}\right)\left(\frac{\Sigma Y}{N}\right)}{\sqrt{\frac{\Sigma X^2}{N} - \left(\frac{\Sigma X}{N}\right)^2}\ \sqrt{\frac{\Sigma Y^2}{N} - \left(\frac{\Sigma Y}{N}\right)^2}}$$

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[21] Y.H.E. Yuker. A Guide to Statistical Calculations. G.P. Putnam's Sons. New York, 1958., p. 40.

CHAPTER IV

RESULTS

INTRODUCTION TO TABLES

The following three tables are a compilation of the results. Table I contains the product moment correlations between the raw test scores and Alpha frequency. The second table contains the product moment correlations between the first measure of Alpha index (for one 100-second portion of the EEG record), and the raw test scores. The third and final table gives the product moment correlation between the second measure of Alpha index (the mean of three 100-second intervals of the EEG record), and the raw test scores. Sub-tests, number one to six inclusive, constitute the verbal part, and sub-tests, seven to eleven compose the performance part of the Wechsler-Bellevue scale. The Verbal score is a sum of all the Verbal test scores, while the Performance test scores are added together to form the performance score. The addition of the Verbal score to the Performance score equals the Full Scale Score.

RESULTS

TABLE I

The product moment correlations between the raw test scores and Alpha frequency.

	Wechsler Sub-test	Correlation Coefficient		Wechsler Sub-test	Correlation Coefficient
1.	Information	.003	8.	Picture Completion	.111
2.	Comprehension	.201	9.	Block Design	.195
3.	Arithmetic	.112	10.	Picture Arrangement	.077
4.	Similarities	.057	11.	Object Assembly	.137
5.	Digit Span	.190	12.	Verbal Score	.315
6.	Vocabulary	.005	13.	Performance Score	.014
7.	Digit Symbol	.127	14.	Full Score	.078

No significant correlation at the 1% or at the 5% level was found. The correlation for the Verbal score was significant at the 10% level.

RESULTS

TABLE II

Product moment correlations of test scores with Alpha index measurement #1—an analysis of 100-second stretch.

	Wechsler Sub-test	Correlation Coefficient		Wechsler Sub-test	Correlation Coefficient
1.	Information	.104	8.	Picture Completion	.040
2.	Comprehension	.270	9.	Block Design	.124
3.	Arithmetic	.041	10.	Picture Arrangement	.093
4.	Similarities	.111	11.	Object Assembly	.109
5.	Digit Span	.121	12.	Verbal Score	.298
6.	Vocabulary	.300	13.	Performance Score	.694
7.	Digit Symbol	.421	14.	Full Score	.146

The findings in Table II are not sufficient at the 1% and 5% level, but are positive in a direction which tends to support the hypothesis. Two correlation coefficients were noteworthy: the picture completion at .421, which is significant at 5%, and the full performance score at .694, which is in turn significant at the 1% level. Both the Vocabulary and the Verbal score would be very close to being significant at the 10% level as their values are .300 and .298 respectively. A correlation of .306 would be needed for significance at the 10% level.

RESULTS

TABLE III

Product moment correlations between raw test scores and the Alpha index measure #2--an analysis of three 100-second periods.

Wechsler Sub-test	Correlation Coefficient	Wechsler Sub-test	Correlation Coefficient
1. Information	.143	8. Picture Completion	.021
2. Comprehension	.276	9. Block Design	.019
3. Arithmetic	.133	10. Picture Arrangement	.070
4. Similarities	.105	11. Object Assembly	.107
5. Digit Span	.197	12. Verbal Score	.238
6. Vocabulary	.188	13. Performance Score	.195
7. Digit Symbol	.254	14. Full Score	.278

There were no statistically significant correlations to be found in Table III.

CHAPTER V

DISCUSSION

The results do not substantiate the findings in Mundy-Castles study. Mundy-Castle found significant correlations between the Verbal, Performance and Full scores, and the EEG measures. Only two significant correlations were found here and both of these were from the performance part of the scale.

The second Alpha measure (which was the mean of three 100-second periods), had no statistical correlation at all with any of the test scores. The reason for this may be that the factor in Alpha index which is related to intelligence, assuming that there be such a relation, is present to a greater extent during the beginning of the recording. The frequency, for instance, of the Alpha rhythm decreases in the cases where long recordings are taken.

However, the results do suggest some connection between the Verbal score, and the EEG measures used here. If consistency is accepted for a criterion, the correlation between the Alpha index measures and the Verbal scores were essentially in agreement with the findings reported by Mundy-Castle. These correlations were also exceedingly close to being statistically significant at the 10% level. Then too, it should be remembered, that the "n" or population consisted of thirty persons, and sample size does influence the power of tests of significance.

Due to the contrasting correlations between the performance score and the first measurement of Alpha index as it was found in this and Mundy-Castle's study, it is questionable as to whether there exists any correlation in this area.

CHAPTER VI

SUMMARY

Results of previous studies on the relation between Intelligence and Alpha measures of the EEG suggested that there exists no significant correlation between these two. These studies all utilized the Stanford-Binet Test.

In 1957, Mundy-Castle found a significant relation between the vocabulary, the verbal performance, the general I.Q. and the Alpha measures of the EEG.

This study of Mundy-Castle was now repeated but more concise controls were employed and a greater portion of the EEG recording was analyzed. No correlation significant beyond the 5% level was discovered between the Alpha frequency and any score of the Wechsler-Bellevue Test. However, the Alpha index derived from a portion of the EEG recording, covering one 100-seconds resulted in two statistically significant correlations. This was the same Alpha index measure used by Mundy-Castle. There was no important relation found between Alpha index and any scores on the scale when three 100-second recordings were used to derive the Alpha index.

Nevertheless, it was noted that a small but consistent relation seemed to exist between the Verbal score and the Alpha index.

At its present stage of development, the EEG and similar neurophysiological techniques are still inadequate to present a satisfactory explanation of the processes underlying the higher mental functions.

CHAPTER VII

CONCLUSIONS

Considering the results of this study, the following conclusions were reached:

1. There exists no significant correlation at the 1% or 5% level between Alpha frequency, and the raw scores of the Wechsler-Bellevue Adult Intelligence Scale.

2. There exists no significant correlation at the 1% or 5% level between Alpha index measure over a period of fifteen minutes, and the raw test scores from the Wechsler-Bellevue Adult Intelligence Scale.

3. There was found a significant correlation at the 1% and 5% level respectively, between Alpha index when measured at the start of an EEG recording, and the Performance score and Digit Symbol sub-test of the Wechsler-Bellevue Adult Intelligence Scale.

BIBLIOGRAPHY

BIBLIOGRAPHY

A. BOOKS

Harriman, Philip L. Modern Psychology. Ames Iowa: Littlefield, Adams & Co. 1956.

Lindsley, D.B. "Electroencephalography." McV. Hunt (Ed.) Personality and Behavior Disorders. Ronald. 1944. New York: Vol. II, Ch. 33.

Murphy, Gardner, Historical Introduction to Modern Psychology. Harcourt, Brace, and Co. New York: 1940.

Patterson, C.H. The Wechsler-Bellevue Scales: A Guide for Counselors. Charles C. Thomas, Springfield. 1953.

Walter, W.G. "The Living Brain" Norton. New York: 1953.

Wechsler, David. The Measurement of Adult Intelligence. Third Edition. Baltimore, Williams & Wilkins. 1941.

Wechsler, David. Wechsler-Bellevue Adult Intelligence Scale. "Test Manual" Psychological Corporation. New York. 1955.

B. PERIODICALS

Ellingson, R.J. "Brain Waves and Problems of Psychology." Psychological Bulletin. Vol. 53 (1956) pp. 1-34

Kennedy, J. L., R.M Gottsdanker, J.C. Armington, and Florence E. Gray. "A New Electroencephalogram Associated with Thinking." Science Vol. 108 (1948) pp 527-29

Knot, Jr. R., H. Friedman, and R. Bardsley. "Some Electroencephalographic Correlates of Intelligence in Eight Year Old, and Twelve Year Old Children." Journal of Experimental Psychology. Vol. 30 (n.d.) pp. 380-91

Kreezer, K.G. "Intelligence Level and Occipital Alpha Rhythm in the Mongolian Type of Mental Deficiency." American Journal of Psychology.(1952) pp. 503-32

Kreezer, G., and F.W. Smith. "The Relation of the Alpha Rhythm of the Electro-encephalogram, and Intelligence Level in the Non-differentiated Familial Type of Mental Deficiency." Journal of Psychology. Vol. 29 (1950) pp. 47-51

Mitchell, M.B. "Performance of mental hospital patients on the Wechsler-Bellevue and the Revised Standford-Binet, Form L. Journal of Educational Psychology. 33:(1942) p. 541

Mundy-Castle, A.C. "Electrophysiological Correlates of Intelligence." Journal of Personality. Vol. 26. No. II. (1958) pp. 184-99

APPENDIX

APPENDIX

TABLE IV

RAW DATA

Subject number	1	2	3	4	5	6	7	8	9	10
Information	19	18	26	16	26	20	25	19	29	23
Comprehension	23	20	19	19	23	13	23	21	28	21
Arithmetic	14	8	13	12	13	8	11	13	15	12
Similarities	20	15	20	16	22	10	21	14	20	15
Digit Span	13	11	13	10	12	8	12	10	13	11
Vocabulary	56	59	75	50	66	39	66	55	78	60
Digit Symbol	65	67	60	81	69	81	65	81	76	61
Picture Completion	15	11	17	15	15	13	16	15	20	14
Block Design	45	38	43	38	43	32	45	41	44	43
Picture Arrangement	28	28	30	33	31	29	30	22	25	28
Object Assembly	36	35	33	28	32	29	37	33	40	40
Verbal Score	77	64	77	63	85	49	79	68	94	72
Performance Score	61	55	59	63	61	60	62	59	72	60
Full Score	138	119	136	126	144	109	141	127	166	132
EEG Frequency	10.1	10.2	10.5	10.2	11.1	9.8	10.8	10.3	10.8	10
1st Measure Alpha Index	93.1	97.9	87.9	89.4	86.4	96.6	96.1	95.2	92.4	86
2nd Measure Alpha Index	94.6	94.5	79.5	78.7	94.4	78.7	84.3	66.8	87	89.2

TABLE IV CONTINUED

RAW DATA

Subject number	11	12	13	14	15	16	17	18	19	20
Information	15	21	25	14	22	20	23	23	13	16
Comprehension	19	25	26	16	22	27	25	21	25	27
Arithmetic	13	10	15	11	12	10	14	11	13	11
Similarities	11	22	21	11	15	20	15	20	19	16
Digit Span	10	14	14	10	13	16	11	10	14	13
Vocabulary	61	58	75	43	69	66	52	62	59	59
Digit Symbol	50	83	65	62	83	86	81	72	66	74
Picture Completion	14	17	17	12	18	15	17	16	17	14
Block Design	24	43	48	29	46	43	41	28	34	29
Picture Arrangement	19	30	30	22	29	24	29	16	23	31
Object Assembly	21	37	39	21	37	25	34	22	23	36
Verbal Score	64	80	94	60	76	83	76	72	78	73
Performance Score	40	68	67	45	70	60	64	49	52	59
Full Score	104	148	161	105	146	143	140	121	130	132
EEG Frequency	10.6	11.5	10.9	10	11.6	8.7	10.6	10	10.5	10.35
1st Measure Alpha Index	88	97.5	90	59.4	83.2	93.2	89.2	82.8	96.8	89.5
2nd Measure Alpha Index	84.3	89.9	88.7	74	82.4	95.0	89.1	93.0	94.3	86.4

TABLE IV CONTINUED

RAW DATA

Subject number	21	22	23	24	25	26	27	28	29	30
Information	25	22	16	21	19	24	29	17	20	24
Comprehension	25	19	13	22	22	25	24	16	22	20
Arithmetic	13	13	10	16	16	11	12	8	12	17
Similarities	20	22	13	21	18	23	20	15	18	22
Digit Span	12	11	11	16	11	10	12	14	12	12
Vocabulary	69	61	44	74	55	59	75	44	58	65
Digit Symbol	88	71	69	90	80	67	61	56	51	60
Picture Completion	18	17	11	14	15	10	15	9	18	19
Block Design	33	47	29	38	44	39	46	37	38	46
Picture Arrangement	22	24	17	29	31	26	29	24	26	33
Object Assembly	26	39	36	33	39	32	41	38	32	41
Verbal Score	83	74	56	87	75	79	82	53	72	82
Performance Score	59	64	47	72	68	54	64	51	54	70
Full Score	142	132	101	159	143	133	146	104	126	152
EEG Frequency	11.3	10	10.9	10.8	12	8.5	10.1	9.3	9	9.3
1st Measure Alpha Index	96.9	69	4.	94	98.8	97.9	48.5	92.2	93	55.5	70.8
2nd Measure Alpha Index	87.4	49	76.2	98.8	96.8	52	79.8	84.9	64	80.6