THE RELATIONSHIP OF INTELLIGENCE TO CORTICAL AROUSAL DURING VERBAL AND SPATIAL TASKS

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CHAPTER I

INTRODUCTION

Ever since Berger (1929) developed the electro-encephalographic technique, researchers have tried to tie cortical activity to intelligence. A number of scientists have reported a positive relationship between the amount of cortical arousal exhibited, measured by the lack of EEG alpha, and intelligence with both mental deficient (Kreezer, 1939; Kreezer, 1940; Lindsley, 1938) and normal subjects (Mundy-Castle, 1958; Mundy-Castle and Nelson, 1960).

The advances made in electronic and computer technology have enabled scientist to use evoked potentials as a measure of arousal in relation to intelligence. Ertle was among the first to take advantage of these technological advances. Ertle (1965) postulated that "a biologically efficient organism" should process information at a much faster rate than a inefficient organism. He felt that the amount of time between the onset of a stimulus and the evoked response by it was a reliable measure of neural processing efficiency. Using latency of the evoked potential after a visual or sensory stimulus as the dependent variable, researcher found a predictable relationship between the amount of time until processing of information and intelligence (Chalks and Ertle, 1965; Ertle and Schafer, 1969; Gucker, 1973; Plum, 1968; Shucard and Horn, 1972; Rhodes, Dustman, and Beck, 1969; Weinberg, 1969). There have been some conflicting reports, however, that did not find a significant relationship between evoked potential latency and intelligence (Shucard and Callawzy, 1973; Ertle, 1971; Rust, 1975).

In the late 1960s researchers began to look at cognitive functioning as varying according to the type of tasks in which the subject was engaged. Cerebral lateralization studies using brain damaged, commisurectomized, and normal subjects all found a significant difference between the two cerebral hemispheres functioning during specific tasks (Reitan and Tarshes, 1959; Kimura, 1964; Furst, 1976; Witelson, 1974; Berezkovskaya et al., 1980; Ehrlichman and Wiener, 1979).

Galin and Ornstein (1972) conducted a study using normal male and female subjects. The subjects were asked to complete two verbal and two spatial tasks while being monitored for the EEG alpha band. The results indicate that the left hemisphere was more aroused during the verbal tasks (reduced percent alpha) in relation to spatial tasks and the right hemisphere was more aroused during the spatial tasks in relation to the verbal tasks. A number of studies have confirmed these findings using both similar and different research techniques (Dumas and Morgan, 1975; McKee, 1973;

Doyle et al., 1974; Galin and Ellis, 1975; Ray et al., 1976; Amochaev and Salamy, 1979).

Recently, researchers have begun to look at the interaction between laterality and arousal in relation to intelligence. Zeaman and Burns (1980) used 20 male and female college students and 20 male and female retarded subjects in a study of this inter-relationship. Using the Berman's Index of Cerebral Dominance both male and female college students were shown to be more lateralized in the hand, foot, and eyes than the retarded subjects.

Walter (1953) reported that subjects who did well on intelligence tests seemed to be more flexible (arousal varied according to task) in terms of cortical arousal than were subjects who did poorly. It has been suggested that a number of learning disabled individuals show signs of cerebral dysfunction in relation to cortical arousal.

Murphy et al. (1977) compared learning disabled subjects who showed a discrepancy of at least 15 points between their Wechsler Performance IQ scores with learning disabled nondiscrepant subjects. The IQ discrepant subjects exhibited lower cortical arousal during the verbal and spatial tasks than the nondiscrepant subjects.

Cunningham and Murphy (1981) in a related research project, studied 24 learning disabled adolescent males with verbal intelligence deficiences. The subjects were assigned to one of two biofeedback training conditions or a control group according to convergent and divergent thought pretest measures. Training the right hemisphere to increase arousal and the left hemisphere to decrease arousal produced improvement in the subjects' ability to perform arithmetic problems.

Martindale and Greenough (1973) in a study concerned with EEG measured arousal during creative tasks used 80 male subjects divided into six groups. The researchers used three experimental conditions: Low Arousal (relaxed), Medium Arousal (stress), and High Arousal (white noise). Two groups were assigned to each experimental condition. One group was administered the WAIS Similarities subtest and the other was given the Remote Associates Test. Increments in arousal were observed to produce increments in performance on the Remote Associates Test and decrements in performance on the WAIS Similarities subtest.

In a related study, Martindale and Hines (1975) divided 32 male subjects into four groups according to their performance on the Remote Associates Test and the Alternative Uses Test. Three cognitive tasks were given to the subjects while they were being monitored by the EEG alpha band (Remote Associates Test, Alternative Uses Test, and the IPAT culture fair test). Subjects who scored high on the Alternative Uses Test operated at a high percent of basal alpha regardless of the test given. High scorers on the Remote Associates Test differed in respect to the amount of alpha shown in each test (more flexible). Remote

Associates high scorers exhibited the highest percent of basal alpha during the test of creativity and the lowest during the IPAT culture fair test. These findings suggest that High Remote Associates scorers may be more flexible in terms of cortical arousal.

Hypotheses

It was hypothesized that the subjects' electroencephalographic measures would change during task as a function of the task presented. During the verbal tasks, subjects were expected to show high levels of arousal in the left hemisphere compared to the right hemisphere. During spatial tasks, subjects were expected to show high levels of arousal in the right hemisphere compared to the left.

The second hypothesis is that the subjects in the WAIS-R groups will differ from one another in levels of cortical arousal as measured by average dominant frequency and peak-to peak amplitude. The high WAIS-R group was expected to show the most in-task asymmetry between the right and left hemisphere. The low WAIS-R group was expected to show the least in-task asymmetry between the right and left hemisphere. The medium WAIS-R group was expected to show a degree of in-task asymmetry between hemisphere but not to the extent of the high WAIS-R group.

The third hypothesis was that there would be a positive correlation between the WAIS-R pretest performance and the electroencephalographic measurment of task induced arousal changes from the resting baseline.

CHAPTER II

METHOD

Subjects

Subjects were 24 male and 24 female students chosen from undergraduate classes at a large southwestern university. Extra credit was given to the subjects for participation in the study by their class instructors. To help insure left hemisphere language dominance, only dextrals were selected as subjects. Research indicates that right handers show a greater prevalence of left hemisphere language dominance than left handers (Provins and Cunliffe, 1972; Zangwill, 1960; Levy, 1974). Hand preference was assessed by the modified Annett Handedness Questionnaire (Annett, 1970). A sample questionnaire is shown in Appendix B.

That half of the subjects should be male and the other half female was a decision made to allow for sex differences. A number or researchers have reported sex differences in task performance (Kimura, 1973; Levine, 1966), and in hemisphere lateralization during task (Ray et al, 1976).

Instruments

The Wechsler Revised Block Design (spatial) and Similarities (verbal) subtest (Wechsler, 1981) were given to each subject as a pretest measure of intelligence. On the completion of data collection, the subjects' intelligence pretest subscores were computed. The subjects were divided into three equal size groups on the basis of their combined WAIS-R subtest performance.

During EEG measurements, subjects completed 30 slide presented questions (15 verbal and 15 spatial). The verbal and spatial test stimuli were counterbalanced with respect to the order of presentation so as to control for fatigue.

Apparatus

EEG alpha band peak-to-peak amplitude and whole spectrum average dominant frequency were analyzed for all three WAIS-R intelligence groups via the Autogen 5100 and the Autogen 120 encephalographic analyzing units (Autogenic Systems, Inc.). The left and right cerebral hemispheres were monitored at homologous parietal and temporal sites. Reference electrodes were placed on the forehead. All EEG activity was fed into the Autogen 120. The 5100, a time period analyzer, was then used to average both the average dominant frequency and the peak-to-peak amplitude over a 30 second epoch. During each 30 second epoch a verbal or a spatial stimulus was presented to the subject by means of a

Model 8806 Caramate slide projector (Singer Education Systems, Inc.).

Procedure

Each subject was required to come into the electroencephalographic laboratory one time for testing. When the subject arrived at the laboratory, his or her name and course section number were recorded. The subject was then asked to fill out the modified Annett Handedness Questionnaire. When the questionnaire was completed the subject was then given the WAIS-R Block Design and Similarities subtests.

After administration of the WAIS-R subtests, the subject was asked to sit in an easy chair while the experimenter placed electrodes on the temporal and parietal lobes. Two reference electrodes were positioned on the subject's forehead. All electrodes were secured and held in place by an elastic band.

A five minute resting baseline was taken using EEG average dominant frequency and peak-to-peak amplitude measures. During the baseline readings subjects were asked to keep their eyes open, feet flat on the floor and arms resting on the chair with a clip board placed in their lap. The clip board was placed on the subjects' lap to ensure that baseline measure stimuli external to test stimuli were equivalent to those taken during cognitive tasks.

Immediately after the baseline measurement, the experimenter described to the subject the type of response required by the visual stimulus and how to mark his or her response on the form provided. Subjects were requested not to respond on the form until the visual stimuls was no longer visible on the projector. The subjects were allowed 30 seconds to solve each of the 30 problems presented and five seconds to respond to the problem on the form provided. A pilot study was conducted to determine the interval required for solving each problem. It was observed that a 15 to 20 second trial was not sufficient to allow the subject to solve the problem where a 45 second interval seemed to cause boredom.

Before actual testing each subject was given two practice trials on each slide sequence (three verbal and one spatial). The researcher asked the subject before the practice trials were implemented if he or she understood the instructions and if there were any question.

Testing procedures consisted of monitoring the subject's EEG average dominant frequency and peak-to-peak amplitude scores in 30 second epochs that coincide with the presentation of the test stimulus. At the end of each 30 second epoch the experimenter recorded the EEG activity during the five second interval between stimulus presentations.

After the subject participated in all test trials, the experimenter removed the electrodes. The subject was then asked if he or she had any questions concerning the nature of the experiment. When all of the subject's questions had been answered satisfactorily, the subject was thanked for his or her help in the study.

Design

Independent Variables

Between subjects variables were intelligence group classification (high, medium, or low) and the subject's sex. The within subjects variables were the type of stimulus presented (task) and the hemisphere being measured (left or right).

Dependent Variables

Dependent variables in the study were: EEG resting baseline using average dominant frequency and peak-to-peak amplitude and EEG average dominant frequency during 30 second epochs of in-task presentation.

CHAPTER III

RESULTS

Introduction

Results will be presented in four separate sections. The first section will examine the intelligence test data used for the discrimination of groups in the study. The second section will analyze main effects and interactions for the baseline data. The third section will examine in-task arousal main effects and interactions. The fourth section will report task induced arousal changes from the baseline measures.

Intelligence Test Data

The analyses of variance reported below involve dividing subjects into three groups on the basis of WAIS-R total subscores (Block Design and Similarities subtests combined scores). To assess the homogeneity of the three groups in respect to sex, independent *t*-tests were performed. Table 1 presents the WAIS-R total mean scores for the three groups for males and females. No significant group sex differences were shown (see Appendix C).

Independent *t*-tests were performed on the three WAIS-R

TABLE I

MEAN WAIS-R SCALED SCORES BY INTELLIGENCE GROUP AND SEX

Group	Females	Males
High	26.13	28.75
Medium	22.25	23.63
Low	18.38	19.38

total groups to determine whether the range of scores would be sufficient to allow for three groups. As shown in Appendixes D and E, all three groups differed significantly from one another.

The WAIS-R total groups differed significantly on the Block Design subtest scores. The Similarities subtest, however, did not differ significantly for the three WAIS-R total groups. Table II shows the means, standard deviations, and ranges for the high, medium, and low intelligence groups by their WAIS-R total scores, Block Design subtest scores, and Similarities subtest scores. Appendix F presents the independent _t_-tests performed on the groups' subtest scores.

Correlational analysis for the WAIS-R subtest scores and percent correct on sentence completion, analogies, arithmetic, and Minnesota Paper Form Board tasks were examined to determine whether the in-task performance was positively related to the pretest WAIS-R scores. The total WAIS-R subtest measures did not correlate with any of the four in-task performance measures. The Block Design subtest scores were found to correlate negatively with the performance on the analogies tasks, $r=-0.30$, $p<0.04$. The Similarities subtest was observed to correlate positively with the sentence completion percent correct, $r=+0.54$, $p<0.0001$. All other correlations performed were not significant (see Appendix G). Table II presents the means,

TABLE II

WAIS-R TOTAL SUBTEST, SIMILARITIES SUBTEST, AND BLOCK DESIGN SUBTEST SCORES

	Total			Block Design			Similarities		
Group	X	SD	Range	X	SD	Range	X	SD	Range
High	27.44	2.94	9	14.56	1.93	6	12.88	1.96	7
Medium	23.19	2.01	5	11.69	1.74	5	10.69	3.14	6
Low	18.18	2.33	8	9.50	2.28	8	9.38	2.00	7

standard deviations, and ranges for the WAIS-R subtests. Table III presents the same descriptive statistics for the four in-task performance measures.

Baseline EEG

ANOVAS on intelligence group (3) X sex (2) X cerebral hemisphere (2) were performed for the dependent variables EEG baseline peak-to-peak amplitude and EEG baseline average dominant frequency to ensure that any obtained in-task differences are not a result of pre-existing baseline differences. No significant main effects were found for the baseline frequency measures. Baseline amplitude scores for Sex and Hemisphere showed no main effects. A significant main Group effect was observed on peak-to-peak amplitude measures, $\underline{F}(2,42)-4.51$, $p<0.02$. The analysis of variance for baseline peak-to-peak amplitude and baseline average dominant frequency are show in Appendix H.

Planned pairwise comparisons of the above main Group effect found that the low intelligence group is significantly less aroused (higher amplitude score) than the medium intelligence group, $\underline{t}(62)=2.64$, $p<0.05$, and the high intelligence group, $\underline{t}(62)=2.56$, $p<0.05$. The high intelligence group was not significantly different from the medium intelligence group, $\underline{t}(62)=-0.08$, $p>0.05$. Table IV presents the baseline means for the three intelligence groups.

TABLE III

VERBAL AND SPATIAL IN-TASK SCORES

Task	$\bar{X}$	SD	Range
Sentence Completion	0.61	0.14	1.00
Analogies	0.43	0.20	1.00
Arithmetic	0.63	0.15	0.60
Minnesota Paper Form Board	0.60	0.12	0.67

TABLE IV

MEAN EEG BASELINE FREQUENCY AND AMPLITUDE BY INTELLIGENCE GROUP

Group	Frequency	Amplitude
High	12.54	16.31
Medium	12.87	16.50
Low	12.71	22.69

In-Task EEG

To assess the differential effects of verbal and spatial convergent tasks for the three intelligence groups on cerebral hemisphere arousal during tasks, mixed model (two between subjects and two within subjects) ANOVA's were performed on the peak-to-peak amplitude and the average dominant frequency scores obtained during the administration of the verbal and spatial tasks described in the methods section. The two between subjects variables were sex (2) and intelligence group (3). The two within subjects variables were hemisphere (2) and task (4).

Analyses of the in-task data indicate significant main Sex effects for in-task frequency, $\underline{F}(1,42)=7.35$, $p<0.01$, and in-task amplitude data, $\underline{F}(1,42)=7.87$, $p<0.01$. The females in the study were shown to exhibit a higher level of cortical arousal than the males. Table V presents the EEG average dominant frequency and peak-to-peak amplitude means for the female and male subjects.

A significant main Hemisphere effect was also observed for the EEG amplitude data, $\underline{F}(1,126)=8.02$, $p<0.01$. A significant main Hemisphere effect was not found for the EEG frequency data, $\underline{F}(1,126)=1.45$, $p=0.24$. No other significant main effects were shown for either frequency or amplitude measures. Consideration of the main Hemisphere effect for EEG amplitude revealed that the right hemisphere ($\bar{X}=17.91$) was more aroused (lower amplitude score) than the left

TABLE V

MEAN IN-TASK FREQUENCY AND AMPLITUDE BY SEX

Sex	Frequency	Amplitude
Females	13.27	16.77
Males	12.13	23.94

hemisphere ($\bar{X}$=22.81) during convergent tasks.

The ANOVA's for EEG frequency measures found a significant interaction for Sex X Hemisphere X Task, $F(3,126)=2.78$, $p<0.04$. Figure 1 depicts the significant Sex X Hemisphere X Task interaction. Planned comparisons revealed that the frequency measures for the male subjects' left hemisphere during task differed significantly according to the specific task engaged in. The male subjects' right hemisphere during task did not differ significantly from one task to another. The females, however, showed no differences in left or right cerebral arousal according to the task being completed. Thus, sex differences indicate that the female subjects are not likely to exhibit a significant level of variation in arousal between the left and right cerebral hemispheres during task or between specific tasks by either the right or left hemisphere. Tables VI and VII show the frequency and amplitude means for the left and right hemispheres by the subjects' sex and task involved in at the time of measurement. Tables VIII and IX present the planned comparisons for males and females by hemisphere and task on EEG frequency measures.

The marginally significant Sex X IQ X Hemisphere in-task EEG frequency interaction is shown in Table X. Planned comparisons, presented in Table XI, found the following results. The male subjects in the high intelligence group

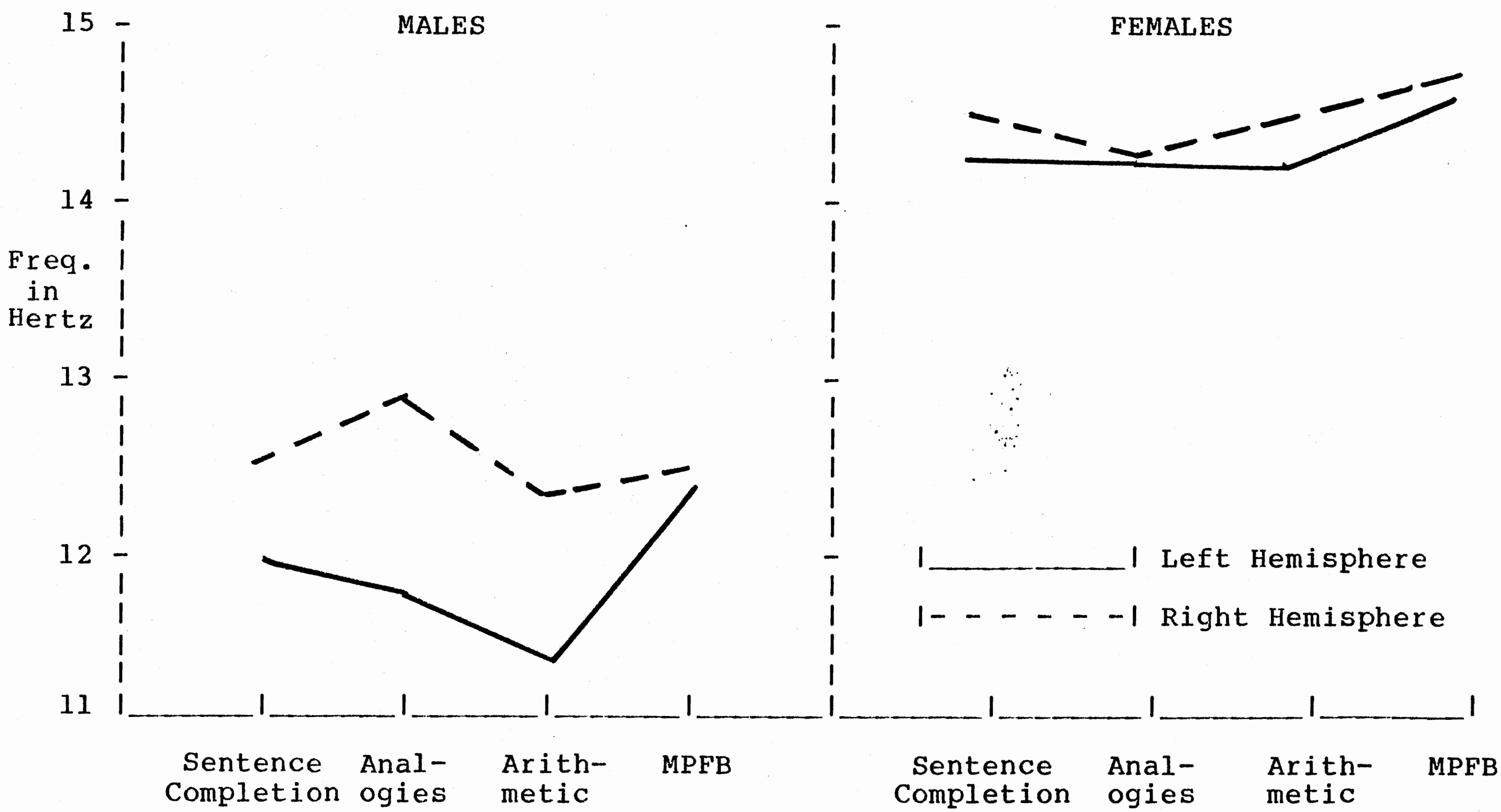

Figure 1. Sex X Hemisphere X Task Interaction

TABLE VI

MEAN IN-TASK FREQUENCY
BY SEX AND TASK

	Females		Males	
Tasks	Left	Right	Left	Right
Analogies	13.22	13.21	11.69	12.56
Arithmetic	13.17	13.30	11.29	12.33
Sentence Completion	13.28	13.43	11.98	12.45
Minnesota Paper Form Board	13.21	13.40	12.32	12.46

TABLE VII

MEAN IN-TASK AMPLITUDE BY
SEX AND TASK

	Females		Males	
Tasks	Left	Right	Left	Right
Analogies	19.39	12.78	27.05	22.50
Arithmetic	18.93	13.11	29.28	20.90
Sentence Completion	19.18	15.23	25.11	21.49
Minnesota Paper Form Board	20.49	15.07	23.01	22.19

TABLE VIII

PLANNED COMPARISON ON EEG MEASURES FOR THE RIGHT HEMISPHERE BY SEX AND TASK

Task	Males	Females
Sentence Completion vs. Analogies	1.43	0.31
Analogies vs. Arithmetic	2.09*	0.25
Arithmetic vs. MPFB	-5.25**	-0.20
Sentence Completion vs. Arithmetic	3.52**	0.56
Sentence Completion vs. MPFB	-1.73	0.35
Analogies vs. MPFB	-3.16**	0.05

* $p<0.05$
** $p<0.01$

TABLE IX

PLANNED COMPARISONS ON EEG MEASURES FOR THE LEFT HEMISPHERE BY SEX AND TASK

Task	Males	Females
Sentence Completion vs. Analogies	-0.56	1.07
Analogies vs. Arithmetic	1.17	-0.41
Arithmetic vs. MPFB	-0.66	-0.51
Sentence Completion vs. Arithmetic	0.61	0.66
Sentence Completion vs. MPFB	-0.05	0.15
Analogies vs. MPFB	0.51	-0.92

* $p<0.05$
** $p<0.01$

TABLE X

PLANNED COMPARISONS ON EEG FREQUENCY MEASURES
FOR SEX BY HEMISPHERE AND GROUP

Group	Males	Females
High	0.09	-0.77
Medium	-1.33	0.81
Low	1.65	-1.79*

All comparisons were made by subtracting the left hemisphere from the right hemisphere for the three intelligence groups for males and females.

* $p<0.05$

TABLE XI

MEAN IN-TASK FREQUENCY FOR GROUP
BY HEMISPHERE AND SEX

	Females		Males	
Group	Left	Right	Left	Right
High	13.20	13.78	12.77	12.69
Medium	12.71	13.71	11.18	11.79
Low	13.75	12.51	11.51	12.86

exhibited a nonsignificant difference between the left hemisphere ($\bar{X}$=12.77) and the right hemisphere ($\bar{X}$=12.69) in cortical arousal. The female subjects in the high intelligence group also, showed a nonsignificant difference between the left hemisphere ($\bar{X}$=13.20) and the right hemisphere ($\bar{X}$=13.78). The male subjects were observed to exhibit a nonsignificant higher aroused left hemisphere than the right. The females, on the other hand, showed a nonsignificant level of higher arousal in the right hemisphere compared to the left.

The males' left hemisphere ($\bar{X}$=11.51) was significantly different from their right hemisphere ($\bar{X}$=12.86) for the low intelligence group. The females in the low intelligence group also, showed a significant difference between the left hemisphere's arousal ($\bar{X}$=13.75) and the right hemisphere ($\bar{X}$=12.51). Thus, the low intelligence groups' dominant hemisphere arousal for both sexes was opposite that of the high intelligence group. Both male and female subjects in the low intelligence group showed a higher aroused left hemisphere compared to their right hemisphere. The high intelligence group did not differ significantly in hemisphere arousal but the female subjects appeared to be more aroused in the right hemisphere than the left. The male high intelligence group appeared to be more aroused in the left hemisphere than the right.

The medium intelligence groups' left hemisphere arousal

($\bar{X}$=12.71) was observed to be nonsignificantly different from the right hemisphere for the females. The males in the medium intelligence group also, did not differ significantly in left ($\bar{X}$=11.18) and right ($\bar{X}$=11.79) hemisphere arousal. Both males and females in the medium intelligence group appeared to show higher levels of in-task arousal in the right hemisphere than the left. These findings contrast with those observed for the high and low intelligence groups.

Task Induced Changes in Arousal
From Baseline

In order to examine the relationship between WAIS-R subtest scores and the subjects' in-task changes in arousal from the resting baseline one X sixteen correlation matrices were computed. EEG frequency baseline difference scores measured during the spatial stimuli were found to be positively related to the subjects' Block Design pretest score r=.29, p<.04. The Similarities subtest scores showed a negative relationship to EEG frequency difference scores obtained from the left hemisphere during the sentence completion task, r=.32, p<.03. A negative correlation was also, observed for the EEG amplitude difference scores obtained during the analogies tasks, r=.31, p<.03, and the arithmetic tasks, r=-.35, p<.02, and the Similarities pretest score. The WAIS-R combined subtest performance showed no significant relationship to the task induced EEG changes from the resting baseline. It appears that the subjects' intelligence pretest score on the Similarities subtest is inversely related to the subjects' left hemisphere EEG difference scores taken during the verbal tasks. The Block Design pretest score seems to be positively related to the subjects' left hemisphere EEG frequency difference scores obtained during the in-task presentation of the spatial stimuli. Tables XII and XIII present the means, standard deviations, and the ranges observed for the left and right hemispheres during the verbal and spatial tasks on the frequency and amplitude EEG baseline difference measure. Appendix I shows the correlation matrices described above.

TABLE XII

IN-TASK INDUCED AROUSAL CHANGES FROM EEG BASELINE FOR THE LEFT HEMISPHERE

	Frequency			Amplitude		
Tasl	X	SD	Range	X	SD	Range
Sentence Completion	.1660	1.86	8.04	3.125	11.15	59.80
Analogies	-.0123	2.30	11.47	4.200	14.63	73.80
Arithmetic	-.2332	2.18	9.39	4.136	13.19	65.90
Minnesota Paper Form	.0297	1.81	9.20	2.726	9.23	48.30

Induced arousal changes from the resting baseline were computed by subtracting the baseline measures from the in-task EEG measures.

TABLE XIII

IN-TASK INDUCED AROUSAL CHANGES FROM EEG BASELINE FOR THE RIGHT HEMISPHERE

	Frequency			Amplitude		
Task	X	SD	Range	X	SD	Range
Sentence Completion	-.0048	1.77	8.18	.3792	12.41	99.40
Analogies	-.0579	2.14	12.12	-.3375	15.36	135.40
Arithmetic	-.1306	2.36	13.29	-.9708	14.53	129.60
Minnesota Paper Form	-.0161	1.99	11.42	.6542	12.83	109.10

Induced arousal changes from the resting baseline were computed by subtracting the baseline measures from the in-task EEG measures.

CHAPTER IV

DISCUSSION

The general question addressed by the present study was whether or not intelligent subjects differ from less intelligent subjects on EEG arousal measures. The results indicate that subjects do differ in cortical arousal according to their intelligence. The resting baseline amplitude data showed a significant main Group effect for intelligence.

Analyses of the main Group effect revealed that the low intelligence group was significantly less aroused than the medium intelligence group or the high intelligence group. The medium intelligence group, however, did not differ significantly from the high intelligence group (see Table IV). These findings are in agreement with those of Mundy-Castle (1958) and Mundy-Castle and Nelson (1960). Mundy-Castle (1958) studied all normal college students and Mundy-Castle and Nelson (1960) studied normal subjects from a remote South African community. Both researchers reported a positive relationship between the subjects' Wechsler-Bellevue test score and cortical arousal measured by EEG alpha frequency and alpha index. A number of other researchers have reported similar findings using different types of mentally deficient subjects (Berger, 1933; Kreezer, 1939; Kreezer, 1940; Knott et al., 1942; Netchine, 1959; Bernhard and Skogland, 1939; Gunnarson, 1945).

In the present study, it was hypothesized that the three WAIS-R intelligence groups would also, differ from one another according to in-task EEG measures. The results support a marginally significant Sex X Intelligence Group X Hemisphere interaction for the EEG frequency measures. It was proposed that the high WAIS-R group would show more in-task asymmetry than the medium or low WAIS-R groups. The low WAIS-R group was expected to produce the least amount of in-task asymmetry. The medium WAIS-R group was expected to exhibit less asymmetry than the high WAIS-R group but more than the low WAIS-R group. The results did not support the hypotheses.

Examination of the findings showed that the high intelligence group exhibited less hemisphere asymmetry than the medium or low intelligence groups. The low intelligence group produced the most in-task asymmetry. The medium intelligence group showed less variation in hemisphere arousal than the low intelligence group and more than the high intelligence group. Martindale (1977) in a research project dealing with creativity and cortical arousal reported conflicting results with those of the present study. Dividing the subjects into three groups on the basis of pretest creativity scores, the subjects' percent of basal alpha was measured during vocalized speech. High creative subjects showed a moderate nonsignificant degree of arousal differences in the left and right hemispheres. The largest amount of hemisphere variation was shown between the medium creative subjects. The low creative subjects exhibited the least asymmetry in cortical arousal. The differences observed in the present study and the one cited above could be explained by convergent and divergent task requiring different levels of variation in cortical arousal. Bowers and Kieling (1971) reported a positive correlation of 0.49 between creativity scores and heart rate variability in normal subjects obtained during perceptual tasks. Martindale and Hines (1975) observed subjects' alternating 100-second suppression and enhancement of EEG alpha waves on five test trials. When the subjects were broken down into three groups on the basis the Alternative Uses Test or the Remote Associates Test, the highly creative subjects performed better at suppression and enhancement on the first few trials but did not maintain their level of performance. The low creative subjects maintained increases in suppression and enhancement performances across all five trials where the high creative subjects fluctuated in suppression and enhancement performance from one trial to the next. Schwartz (1973) reported in a study using teachers of transcendental meditation, who should have been excellent at control over their physiological processes, performed worse or no better on tests of creativity than the control group. Johnson (1973) found that transcendental meditators show low levels of galvonic skin response while Martindale and Hine (1975) observed that creative subjects exhibited high levels of galvonic skin response. Collier (1973) compared college students' cumulative grade point average before and three semesters after transcendental meditation training with a control group. The transcendental meditators achieved a higher cumulative grade point average at the end of three semesters than the control group. Transcendental meditators have also, been reported as being superior to controls on perceptual motor tasks (Blasdell, 1971) and improved reaction time (Knobb, 1973; Kanellahas and Lukas, 1974). There are no direct findings that transcendental meditators are more intelligent than nonmeditators. Blanquet (1972) reported, however, that meditators showed what he called a "hypersynchronization" of the right and left cerebral hemispheres. Later Blanquet (1973) and Glueck (1975) as cited earlier, reported that superior verbal and spatial task performance was found in subjects with synchronized hemispheres. In a related study, Whisenant and Murphy (1977) using biofeedback techniques to train subjects' right and left hemispheres to increase or decrease in arousal observed that when both hemispheres were trained in the same direction, the subjects' Remote Associates test scores improved. If the subjects' hemispheres were trained in opposite directions, the subjects' Remote Associates test scores showed a decrement in performance. The findings mentioned above suggest that a creative subject processes information differently than a intelligent subject. Further, high intelligent subjects would be expected to perform tasks with less hemisphere variation in cortical arousal than the medium or low intelligent subjects.

Further analyses of the results revealed differences in hemisphere dominance according to the subjects' sex and intelligence group. the females in the high intelligence group exhibited a dominant (more aroused) right hemisphere compared to the left. Hemisphere differences in the male subjects for the high intelligence group demonstrated a dominant left hemisphere compared to the right hemisphere. The medium intelligence group showed higher cortical activation in the left hemisphere than in the right hemisphere for both males and females. The low intelligence group, however, produced higher levels of cortical arousal in the left hemisphere compared to the right hemisphere for the female subjects and higher right hemisphere arousal compared to the left hemisphere for the male subjects (see Table X and XI). Martindale (1977) in the study cited earlier on creativity using all male subjects found that the high creative group had a dominant left hemisphere and the most aroused right hemisphere of the three groups tested (high, medium, and low). The medium creative group showed a dominant right hemisphere with the lowest left hemisphere activation. The low creative group exhibited a slight left hemisphere dominance with a moderately aroused right hemisphere. Thus, the high creative subjects showed a high degree of arousal in both hemispheres while the medium creative subjects showed moderate levels of arousal in the left hemisphere but the least in the right hemisphere and the low creative group showed very little left hemisphere arousal in the left hemisphere. It would appear from these findings that a creative individual has an activated right hemisphere. Bogen (1973) and Ornstein (1972) have suggested that the right hemisphere functions in a primary process manner where the left hemisphere functions in a secondary process manner. A number of researchers have found a indirect relationship between creativity and the right hemisphere of the brain. Harnard (1972) reported a low positive relationship between spontaneous leftward eye movements and creativity. Martindale and Hine (1975) observed that when the left eye movements were induced a weak improvement in performance on creativity measures was shown. The studies cited above, however, did not control for sex differences. The findings presented by Martindale (1977) on creativity are opposite those found for the male subjects in the present study. It seems that the high intelligence male used a highly activated left hemisphere as does the creative subject but the creative subject also enlist the right hemisphere in activation where the high intelligence subject does not. The females in the high intelligence group exhibited a dominant right hemisphere unlike the males in the creativity study (Martindale, 1977) or the present study on intelligence but were found to produce the most cortical activation in the right hemisphere compared to the medium and low intelligence groups and similar to the high creative males. The medium and low intelligence groups showed the opposite hemisphere activation trends than the medium and low creative subjects in the study referred to above (Martindale, 1977) for both the males and the females. In summary, it would appear that the high, medium, and low intelligence groups process verbal and spatial problems differently. The subjects' sex also, seems to be a factor in how intelligence tasks are cortically processed. It can further be concluded that normal subjects process creative problems in a different manner than intelligence problems. Whether these differences in cognitive processing activities coincide with sociocultural experiences of the subject or physical brain structure variability or a combination of the two factors cannot be determined by the present study.

The subjects' WAIS-R pretest performance was expected to be related to the electroencephalographic measures of task induced arousal changes from the resting baseline. A significant negative correlation was observed between the Similarities subtest and the left amplitude measure during the sentence completion tasks, *r*=-.32, $p<.03$, the analogies tasks, *r*= -.31, $p<.03$, and the arithmetic tasks, *r*= -.35, $p<.02$. A significant relationship was not found for the right hemisphere on either frequency or amplitude measures or the left hemisphere on frequency measures and Similarities subtest performance. A significant relationship would be expected by chance in sixteen correlations. Thus, we can conclude that the Similarities pretest performance does correlate with electroencephalographic measures of task induced arousal changes.

It was proposed that during the verbal tasks subjects would show higher levels of arousal in the left hemisphere compared to the right hemisphere. During the spatial tasks subjects were expected to exhibit higher levels of arousal in the right hemisphere compared to the left hemisphere. The hypothesess were not supported by the data. All subjects regardless of the task engaged in showed a higher degree of arousal in the right hemisphere than the left hemisphere. These findings are not in agreement with previous research results on in-task asymmetry (Ehrlichman and Wiener, 1979; Galin and Ornstein, 1972; Doyle et al., 1974). A possible explanation for the extreme arousal of the right hemisphere over the left could be a difference in cognitive strategies. The subjects could have used a divergent (creative) strategy or a combination of divergent and convergent strategies to solve the problems. A number of researcher have reported that the conscious intentions and strategies used in cognitive processing influence the way we process information (Posner and Snyder, 1975; Anerson and Farkas, 1973). In that case one would expect the right hemisphere to be highly engaged in cognitive processing. In order to fully understand the trend observed it would be necessary to know the type of strategy used to complete each task.

The WAIS-R Block Design subtest was found to correlate positively with the left hemisphere frequency measures of task induced arousal changes from the resting baseline, $\underline{r}=.29$, $p<.04$. However, one significant relationship would be expected to occur by chance alone out of sixteen correlations performed. The WAIS-R combined score did not correlate with any of the in-task changes in arousal measured by the electroencephalogram. In summary, we may conclude that the Similarities subtest does relate to the subjects' changes in arousal from the baseline measures for the EEG peak-to-peak amplitude scores. The Block Design and the combined WAIS-R scores do not correlate with any of the EEG task induced arousal changes from the resting baseline. Related literature reported similar correlations EEG resting baseline scores and intelligence test scores (Mundy-Castle, 1958; Mundy-Castle and Nelson, 1960). A number of studies have cited an inverse relationship between in-task average evoked potential and intelligence scores (Plum, 1968; Everhart et al., 1974; Gucker, 1973; Weinberg, 1969; Rhodes et al., 1969; Shucard and Horn, 1972). In agreement with the present study we find that a great deal of research has shown electroencephalographic measures to be related to test intelligence using different experimental techniques (see Appendix A).

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APPENDIXES

APPENDIX A

LITERATURE REVIEW

Intelligence and the Electroencephalogram

The concept of intelligence has been reported to go back as far as the fifteenth century (Spearman, 1927). Spencer (1895), a scientist interested in the evolutionary and biological aspects of intelligence, has been credited with the introduction of the construct of intelligence into use in the field of Psychology (Guilford, 1967).

Around the same period of time electrical potentials in the brain were being discovered. Caton in 1875, observed that electrical currents are present in the brain of laboratory animals. Berger (1929) was the first to develop a means of studying brain waves in a quantitative manner, the electroencephalogram. The main thrust of his research was aimed towards linking brain waves to intelligence. Berger (1933) observed three "moderately" retarded and four "severely" retarded subjects. Both groups exhibited lower "voltage" and "longer" alpha waves than was shown in normal subjects.

Kreezer (1936, 1937, 1938, 1939, 1940) in a number of publications examined the empirical relationship between electroencephalographic properties and variation in intelligence. Kreezer (1939) studied fifty subjects that were classified as having the mongolian type of mental deficiency. He used all mongolian deficient individuals in order to allow for a homogenous population with varying levels of intelligence. The subjects ranged in chronological age from 16 to 56 years. The Stanford-Binet 1916 Form supplemented by the Kuhlman-Binet Scale (for test levels under three years of age) was used to determine the subjects' level of intelligence. Subjects were placed in a darkened room in a reclining position. Electrodes were placed over the occiput, the motor area, and the anterior frontal area. Alpha wave frequency, alpha wave amplitude, and alpha index were correlated to the subjects' mental age tested. Alpha wave frequency and mental age was significant with a correlation coefficient of -.291. Alpha index and mental age was significant with a correlation coefficient of -.316. Alpha amplitude and mental age was not significant with a correlation coefficient of +.114.

Kreezer (1940) conducted a similar project using nondifferentiated type of mental deficient subjects. Correlation coefficients for this particular population were +.32 for mental age and alpha frequency and +.16 for mental age and alpha index. Mental age and alpha frequency were found to be significant. Similar findings were reported by Knott et al. (1942) using eight and twelve-year-old children. The eight-year-old subjects sampled from three different populations: University of Iowa Elementary school, Iowa Soldiers' Orphans' Home, and the Hospital for

Epileptics and School for Feeble-Minded. The mean IQ for the three groups were respectively 127, 87, and 51. The twelve-year-old subjects were also, sampled from three different populations: Iowa Soldiers' Orphans' Home, University of Iowa Junior High School, and Iowa City Elementary and Junior High School. The mean IQ for the three groups respectively were 87.9, 122,6, and 125. The Stanford-Binet test of intelligence supplemented by the Kuhlman-Binet was used in scoring mental ages for the three groups of children. Alpha frequency and alpha index were measured with electrode placement on the occipital area and the motor area. The eight-year-old children showed a significant correlation between intelligence level and alpha frequency (+.50) and a nonsignificant correlation between intelligence level and alpha index (+.23). The twelve-year-old children showed no significant correlation between intelligence level and alpha frequency or alpha index. The difference in groups has been suggested to be due to the developmental stage of the twelve-year-olds or the narrow range of IQs exhibited by the twelve-year-olds. Kreezer and Smith (1950) found a significant relationship between alpha frequency and mental age in famial defectives (r=.323). A number of Europeans have confirmed a correlation between intelligence and alpha frequency in the mental deficient (Netchine, 1959; Bernhard and Skogland, 1939; Gunnarson, 1945; Novikova, 1965).

However, there have been conflicting reports in this area of research. Lindsley (1938) reported no significant difference between normals and mentally deficients in their occipital alpha frequency or index. Literature overviews on the subject have voiced the opinion that there is no relationship to be found for EEG measurements and intelligence (Lindsley, 1944; Ostow, 1950; Ellingson, 1956). Ellingson (1965) argues that the majority of relationships proven to exist between the two variables in question are in abnormal subjects or children.

In 1958, Mundy-Castle reported a positive correlation using all normal adults in his research. The mean age of his subjects was 24 years. Thirty-four subjects (25 women and 9 men) were administered the Wechsler-Bellevue test of intelligence and an electroencephalographic examination. The researcher placed the EEG electrodes on the occipital area to observe the mean alpha frequency and the alpha index for the subjects while their eyes remained closed in a passive position. A significant correlation was found for alpha frequency and the Vocabulary, Verbal IQ, Practical IQ, and General IQ. Mundy-Castle and Nelson (1960) using a remote South African community found equivalent results. It has been postulated that the wide discrepancy in findings is largely due to the use of different intelligence test (Mundy-Castle, 1958; Vogel and Broverman, 1964).

The recent introduction of advanced electronics and computers have enabled researchers to study the actual "nonrandom changes of electrical activity in response to sensory stimulations Jacobs, 1968, p. 14)." These non-random electrical changes have been labeled evoked potentials (Jacobs, 1968). This research technique opened new doors in the empirical study of intelligence and cortical activation.

Ertle was among the first to take advantage of these advances in technology to study intelligence. Ertle (1965) postulated that a "biologically efficient organism" should process information at a much faster rate than an inefficient organism. He felt that the amount of time between a stimulus and an evoked response was a reliable measure of processing efficiency. Using latency of the evoked potential as the dependent variable Chalks and Ertle (1965), observed 48 subjects ranging from 17 to 41 years of age. Thirty-three subjects were postgraduate students with superior IQs, 11 subjects were Army Cadets with average IQs, and four subjects were mentally retarded. A bright light was used as the experimental stimulus (Grass P5 Photostimulator). The stimulus was presented at brief, random intervals. The electrodes were placed over the left motor area of each subject. Zero-crossing analysis was used to study the evoked potentials. Statistical analysis by the Mann-Whitney U test showed significance between all three groups for mean latency scores for each component of the evoked potential.

sample of 573 randomly selected primary school children found significance for test intelligence (WISC, Otis Quick, and Primary Mental Abilities) and evoked potential latency using Pearson's r. High IQ subjects were shown to have shorter evoked potential latency and a more complex wave form.

Everhart et al. (1974) performed a replication of Ertle's work using his technique and the WAIS. The subjects were 20 females between the ages of 21 and 26. A correlation analysis revealed a significant inverse relationship for the EEG measures and the WAIS Verbal, Performance, and each subscale score and full-scale score.

Gucker (1973) conducted a similar research project. He found a significant correlation between the subjects' evoked potentials and their intelligence scores. Seventeen subjects participated in the experiment. Their ages ranged from 30 to 99. All subjects were tested with the Wechsler Intelligence Scale for children or the Peabody Picture Vocabulary Test, Form A. During the experiment subjects were placed in a darkened room and asked to sit upright with their eyes shut. A 24 inch strobe lamp was placed in front of the subject's face. The strobe lamp was used as the stimulus to evoke the cortical response measured. A Rho of -.75 was obtained reaching a level of significance of .01 using the zero-crossing stimulus method.

Many more experimental reports have shown evoked potentials to be correlated with intelligence (Plum, 1968;

Weinberg, 1969; Rhodes et al., 1969; Shucard and Horn, 1972). As was the case with the earlier EEG and intelligence studies, there are some conflicting reports. Shucard and Callaway (1973) found no relationship between intelligence and evoked potentials. In this particular project, the researchers observed 107 subjects. The subjects were 16 to 68 years old at the time of testing. Sixty of the subjects were males and 47 were females. An attempt was made to allow for variability in occupation, age, sex, and socio-economic class in order to insure a broad spectrum of evoked responses and intelligence levels. The visual stimulus was a brief light. Electrodes were placed on the right and left parietal and frontal areas. Ertle (1971) using the same electrode placement also, found no significance between variables.

Rust (1975) measured the average evoked potential in 296 male subjects given the Mill-Hill Vocabulary Scale and the Ravens Progressive Matrices. Electrodes were placed at Cz and T3 scalp positions. In the first study, a 95 db tone was used with 84 of the male subjects. In the second study, a 75 db and a 55 db tone was used with 212 of the male subjects. Rust found that the latency of the evoked potential differed depending upon the loudness of the tone. Only one latency measure came close to significance for intelligence, however. Hendrickson (1973) using the same electrode placement sites and experimental method as Rust

(1975) found a significant relationship using different intelligence subtests.

Mundy-Castle (1958) found a significant correlation between general arousal level of subjects and test performance. The study examined the alpha frequency displayed in subjects after they were labeled as either having a primary functioning personality type or a secondary personality type. A primary functioning personality was described as "quick, impulsive, variable, stimulable." A secondary functioning personality was described as "slow, steady, hyporeactive," A correlation coefficient of +.464 was found between alpha frequency and personality type. Alpha frequency and previously administered WAIS subtest scores for Vocabulary, Verbal IQ, Practical IQ, and General IQ were positively correlated with alpha frequency. Mundy-Castle (1955) reported a positive correlation with speed of perception and the Wechsler Adult Intelligence Scale.

Similar observation have been reported using different methods of measuring or creating arousal than the EEG. Spielberger and Katzenmeyer (1958, 1959) performed a study in which 1142 college students enrolled in introductory psychology were tested with the Taylor Manifest Anxiety Scale. The Taylor Manifest Anxiety Scale was positively correlated with previous ACE Psychological Examination for College Freshmen. The correlations for all males and all females did not differ significantly from zero, though, a negative correlation for a subsample of low ACE scoring negative correlation for a subsample of low ACE scoring subjects was found to be significant. It is interesting to note that "where there were few subjects with low ACE scores, the correlation approached zero" (Spielberger and Katzenmeyer, 1959, p. 278).

Spielberger (1962) further studied anxiety and academic performance. The MMPI was used to rate the anxiety level of each subject. Grade point averages on a four point scale were used to determine academic achievement. ACE scores were used to access ability. Spielberger found that anxious students in the middle range of ability had a higher probability of academic failure than non-anxious students. Students judged as having a high level of ability by the ACE scores were found to do better if they were an anxious person. Low ACE students tended to earn poorer grades regardless of the level of anxiety displayed.

Shucard and Horn (1972) studied the same phenomenon using three induced levels of arousal on subjects tested by the Form Board Abilities Test. In the High Arousal induction group subjects were required to push a button in response to a light stimulus. In the Medium Arousal induction group subjects were required to count the number of light flashes observed. The Low Arousal induction group was required to lie quietly and attend to the visual stimulus. EEG measures of average evoked potential amplitude and average evoked potential latency were used as quantitative measures of arousal. Low arousal subjects were found to exhibit high average evoked potential amplitude scores and high average evoked potential latency scores. High alert or arousal subjects were found to exhibit low average evoked potential amplitude and low average evoked potential latency scores. Average evoked potential latency was found to correlate inversely with test intelligence. Average evoked potential amplitude and average evoked potential latency were also found to be positively correlated.

In a related study Klinger et al. (1973) used 21 female undergraduate students. They measured EEG alpha in two separate groups under three different conditions as follows: 1. subjects "imagining a liked person, suppressing thought of the person, searching one's mind for alternative solutions, 2. arithmetic involving little concentration, problem solving involving high concentration, and choosing a preferred activity (p. 473)." Imagining, suppression, and searching (divergent thought activities) show a significantly larger amount of alpha waves than low concentration, high concentration and choice (convergent thought activities). These results correspond with findings from other investigators that EEG activity measured while the subject is in a relaxed state without any visual stimulation or problem solving, is usually quite high (Brown, 1970; Glass, 1966).

Cerebral Lateralization

The human brain consists of two separate cerebral hemispheres joined by a bundle of nerves called the corpus callosum. Though the cerebral hemisphere gives the appearance of being anatomically symmetric, they function asymmetrically. Clinical and laboratory research findings indicate that the cerebral hemispheres of the brain are programmed to perform predominantly different cognitive functions. The left hemisphere was associated with the function of language by Broca in 1861. Werniche in 1874, confirmed and expanded on Broca's findings. He observed that different types of aphasia could be linked with different lesion sites (Dimond and Beumont, 1974).

For many years researchers believed the left hemisphere to be dominant with little if any ability credited to the right hemisphere. In 1959, Reitan and Tarshes noticed that subjects with left hemisphere lesions when given part B of the Trailmaking Test did poorly but when given part A of the test no deficit was observed in their performance. On part B subjects were asked to follow points marked by alternating letters and numbers (1,a,2,b,3,c, etc.). On part A subjects were only required to follow sequential numbers (1,2,3,4, etc.).

Kimura (1964) using dichotically presented melodies to normal and right temporal lobectomized subjects. A significant larger number of correct melody identifications were made for the left ear (right hemisphere) than the right ear (left hemisphere). Lobectomized subjects exhibited a significant deficit in performance compared to the normals.

The use of subjects that had undergone commissurotomy for the treatment of epilepsy helped to confirm the processes involved in the right hemisphere. Levy-Agresti and Sperry (1968) designed a visio-spatial test that called for cognitive transformations in split-brain (comissurectomized) subjects. The test consisted of a modified Space Relations Test of Differential Aptitude Test Battery (Bennett et al., 1947). The task called for the subject to match a three-dimensional wooden block with its two dimensional representation that was unfolded. Thirteen such sets of wooden blocks were constructed with three blocks to each set. Within a set all three blocks differed in some small degree according to shape or texture of the block's surface. One block at a time was given to the subjects to feel using either the left or right hand. Neither the wooden block or the subject's hand could be viewed by the subject. The subject after feeling of the wooden block was asked to point to the visual representation which matched the block. Out of the six patients tested, three subjects who had right hemisphere damage were totally unable to perform the task. Two of the other three subjects were found to perform the task above the chance level with their left hand (right hemisphere) but not with their right hand. The other subject was above the level of chance when using either the left or right hand. It was observed, however, that the left hand made more correct responses than the right hand. It was concluded that the right hemisphere was superior to the left hemisphere in performing the task and that the left and right hemispheres use different methods of processing materials.

While this and other research using split-brain or brain damaged subjects is informative it must be viewed with caution, especially when generalizing the findings to "normal" individuals. Of principle interest to this study are the experimental paradigms implementing EEG recording techniques with normal subjects to demonstrate functional cerebral lateralization. A number of reliable studies have concerned themselves with whether there are electro-physiological differences in the cerebral hemisphere during verbal and spatial tasks.

Galin and Ornstein (1972) used five normal male and five female subjects in a study conducted on EEG asymmetry. The subjects were asked to perform a series of four cognitive tasks both with and without motor responses. Two of the tasks were verbal in nature (writing a letter and mentally composing a letter with the subjects' eyes open and fixated on a central spot) and two of the tasks were spatial in nature (Modified Kohs and Minnesota Paper Form Board Test). The EEG results were quantified in terms of power by integrating the 1-35 hz. raw signal and computing the ratios in homologous leads from the parietal and temporal lobes. As hypothesized, the ratio (right over left) was greater during the verbal tasks than the spatial tasks regardless of whether motor output was involved. Both parietal and temporal leads produced significant results ($p<.023$ and $p<.05$ respectively). These results indicate that the left hemisphere was more aroused during the verbal tasks in relation to the spatial tasks and the right hemisphere was more aroused during the spatial tasks in relation to the verbal tasks.

Doyle et al. (1974) in a follow-up study used a frequency analysis of hemispheric EEG asymmetries as the dependent variable. The same tasks were used as above with the addition of serial arithmetic (visual, motor), verbal listening (auditory, verbal, nonmotor), Seashore Tonal Memory Test (auditory, nonverbal, nonmotor), and Magic Etch-a-Sketch (visual, motor). Power ratios from homologous leads for both parietal and temporal lobes were computed for alpha, theta, and delta frequency bands. As in the previous study, the ratio right over left was significantly higher for the verbal tasks than the spatial tasks. The alpha band was shown to manifest the most significance for comparisons. The delta band exhibited no test effects while beta and theta band exhibited only slight consistency among tasks. When the alpha band alone was used in analysis, a task-dependence was found two to five times greater than that reported in the previous report.

McKee (1973) in a similar study observed alpha activity over the temporal and parietal sites while subjects performed one of four tasks. Three of the tasks were verbal in nature, varying in degree of difficulty. Subjects were asked to listen to an banal reading from the Congressional Records. Linguistic I task required the subject to report each time the speaker used the term "NAACP". Linguistic II task required the subject to report all instances of the words "liberal" or "conservative". Linguistic III task required the subject to report all instances of the usage of the verb "to be". The fourth task was musical in nature. Each subject was requested to listen to a Bach concerto and count the number of occurrences of a particular two measure theme. Left over right alpha ratios were computed for all four tasks using only four subjects (2 males and 2 females). Alpha ratios were highest for the musical task, indicating that the right hemisphere was aroused. During the linguistic tasks, the alpha ratio tended to decrease with the level of difficulty of the task.

In 1975, Dumas and Morgan tested nine male artists and eight male engineers for asymmetry using occipital alpha activity as a function of occupation, task, and subjective task difficulty ratings. Two integrated voltage scores (one for the right hemisphere and one for the left hemisphere) were used as the raw data from which laterality scores for each experimental condition were derived by using a per cent difference calculation. Using an analysis of variance with scores entered for each subject by right or left hemisphere, two occupational groups and two levels of difficulty. The results were significant at a 0.005 level for task. As predicted, the liguistic and mathematical tasks were shown to lower the alpha activity in the left hemisphere in relation to the baseline measure. Spatial tasks were shown to lower the alpha activity in the right hemisphere in relation to the baseline measure.

A number of other researchers have confirmed the findings cited above using different and similar techniques (Furst, 1976; Witelson, 1974; Galin and Ellis, 1975; Ray et al., 1976; Amochaev and Salamy, 1979; Mcleod and Peacock, 1977; Berezhkovskaya et al., 1980; Ehrlichman and Wiener, 1980). In all of the studies cited the cerebral hemispheres were shown to exhibit different forms of EEG activity dependent on the tasks the subject was engaged in. Verbal tasks were found to produce higher levels of arousal in the left hemisphere while spatial tasks were found to produce higher levels of arousal in the right hemisphere.

Recently researchers have begun to look at the question of laterality in relationship to creativity and intelligence. Kaltsounis (1980) divided 125 subjects into two groups according to their grade point average in college. The subjects were then required to complete four sets of questionnaires with open-ended and forced choice questions. The questionnaires evaluated whether the subject was left or right hemispherically oriented in processing cognitive material. It was found that subjects who showed a right hemisphere specialization on three out of four criterion were found to have above average grade point averages.

Zeaman and Burns (1980) conducted a research project to access the relationship between laterality and intelligence. The Berman's Index of Cerebral Dominance was administered to 20 male and female college students and 20 male and female retarded subjects (IQs 32-75). The college students were shown to be more lateralized in the hand, foot, ear, and eye. It was foot lateralization that distinquished the two groups significantly. A significant positive correlation was found between laterality scores and intelligence.

Doktor and Bloom (1977) reported a frequency analysis of hemispheric EEG asymmetries using 14 right-handed subjects performing two cognitive tasks (verbal-analytic problems and spatial-intuitive problems). Eight of the subjects were Presidents or Chief Operating Officers and six were Operations Researchers. EEG alpha recordings were made from homologous temporal sites. Operation Researchers exhibited a consistent shift in arousal specific to task. A consistent shift in arousal was not exhibited by the Presidents or Chief Operating Officers. A statistically significant difference was found between the two groups using a Mann-Whitney U test. No relationship was found to exist between performance and EEG recordings. The Operations Researchers, however, generally did better than the Executives on the tasks.

Walter (1953) reported that "less" intelligent subjects showed a lack of versatility in EEG frequency. The "very" intelligent subject was one whose EEG frequency output changes from one short ten second epoch to another (Ellingson, 1957).

Martindale and Greenough (1973) hypothesized that a decrease in arousal would facilitate creative abilities in their subjects while an increase in arousal would improve their intellectual abilities due to the effect arousal has on cue utilization. Eight male subjects were divided into six groups. The researchers used three experimental conditions: Low Arousal (relaxed), Medium Arousal (stress), and High Arousal (white noise). Each condition contained two groups, one which was administered the Remote Associates Test, the other the WAIS Similarities. Increments in arousal were shown to produce increments in performance on the Similarities Test and decrements in performance on the Remote Associates Test. The trends found were significant at the 0.05 level using Jonchjeere's (1954) S statistic. Low and medium arousal groups administered the Remote Associates Test were not significantly different, but the High Arousal group was significantly different from the Low and Medium Arousal group. For the WAIS Similarities Test, the medium and high arousal groups were not significantly different, but the difference between both the high and medium arousal group versus the low arousal group approached significance.

In a related study, Martindale and Hine (1975) divided 32 male subjects into four groups according to their performance on the Remote Associates Test and the Alternative Uses Test (High and Low groups on each designated by the group mean). Three cognitive tasks were then used in testing while monitoring the EEG alpha band (Alternatives Uses Tests, Remote Associates Test, and the IPAT Culture Fair Test). The alpha index for each phase of the experiment was found by dividing the time in alpha by the total time and multiplying by 100. Percent of basal scores were computed by dividing the alpha index by the basal alpha index. Subjects who were rated high on the Alternative Uses Test operated at a high percent of basal alpha index regardless of test. High scores on the remote Associates Test differed in respect to the amount of alpha shown across tests. Remote Associate high scores exhibited the highest percent of basal alpha during test of creativity and the lowest per cent during the IPAT. These findings suggest that high Remote Associates scorers may be more flexible in respect to cerebral arousal.

APPENDIX B

MODIFIED ANNETTE HANDEDNESS
QUESTIONNAIRE

NAME:

ADDRESS:

TELEPHONE NUMBER:

WITH WHICH HAND DO YOU NORMALLY PERFORM EACH OF THE FOLLOWING ACTIVITIES? PLACE AN X IN THE APPROPRIATE SQUARE TO INDICATE YOUR ANSWER.

	EITHER LEFT OR RIGHT	LEFT		RIGHT	
		ALWAYS	USUALLY	USUALLY	ALWAYS
Write with Penci or Pen					
Draw with Pencil, Crayon or Charcoal					
Dial a Telephone					
Hold a Match While Striking It					
Use a Toothbrush					
Use a Hammer					
Hold a Knife While Cutting Food					
Hold Scissors While Cutting Fabric					
Use a Ping-Pong Paddle					
Serve the Ball With a Tennis Racket					
Throw a Baseball					
Pull Back a Bow-String					
Roll a Bowling Ball					
Which Hand Plays the Most Active Role While Clapping					
Upon Which Knee Do You Genuflect & Touch the Floor					
Clasp the Fingers & Thumbs of Both Hands Together, Naturally & Comfortably. Which Thumb is Uppermost?					
Conflict Drawing Test #1.					
#2.					
#3.					

APPENDIX C

T-TEST ON WAIS-R TOTAL MEANS FOR INTELLIGENCE GROUPS BY SEX

TABLE XIV

T-TEST ON WAIS-R TOTAL MEANS FOR
INTELLIGENCE GROUPS BY SEX

Group	*t* value	p value
High Females vs. High Males	-.743	N.S.
Medium Females vs. Medium Males	+.090	N.S.
Low Females vs. Low Males	+.050	N.S.

APPENDIX D

T-TEST ON WAIS-R TOTAL MEANS FOR INTELLIGENCE GROUPS

TABLE XV

T-TEST ON WAIS-R TOTAL MEANS FOR INTELLIGENCE GROUPS

Group	*t* value	p value
High vs. Low	16.92	$p<.001$
High vs. Medium	14.21	$p<.001$
Medium vs. Low	10.76	$p<.001$

APPENDIX E

T-TEST ON WAIS-R SUBTESTS FOR INTELLIGENCE GROUPS

TABLE XVI

T-TEST ON WAIS-R BLOCK DESIGN SUBTESTS
MEANS FOR INTELLIGENCE GROUPS

Group	*t* value	p value
High vs. Low	18.46	$p<.001$
High vs. Medium	9.91	$p<.001$
Medium vs. Low	8.99	$p<.001$

TABLE XVII

T-TEST ON WAIS-R SIMILARITIES SUBTEST
MEANS FOR INTELLIGENCE GROUPS

Group	*t* value	p value
High vs. Low	3.45	p<.ol
High vs. Medium	3.02	p<.01
Medium vs. Low	.11	N.S.

APPENDIX F

CORRELATION MATRIX FOR WAIS-R SCORES AND IN-TASK PERFORMANCE MEASURES

TABLE XVIII

CORRELATION MATRIX FOR WAIS-R SCORES AND PER CENT CORRECT PERFORMANCE ON TASKS

	Similarities	Block Design	Total Subtest	Sentence Completion	Arithmetic	Analogies	MPFB
Similarities	1.00000 0.0000	0.11160 0.4501	0.93095 0.0001	-0.09800 0.5076	0.13036 0.3772	-0.29605 0.0410	0.13364 0.3652
Block Design	0.11160 0.4501	1.00000 0.0000	0.46677 0.0008	0.53608 0.0001	0.17714 0.2284	0.25218 0.0838	-0.07642 0.6057
Total Subtest	0.93095 0.0001	0.46677 0.0008	1.00000 0.0000	0.10977 0.4577	0.18111 0.2180	-0.17080 0.2458	0.09085 0.5391
Sentence Completion	-0.09800 0.5076	0.53608 0.0001	0.10977 0.4577	1.00000 0.0000	-0.01562 0.9161	0.13798 0.3497	0.01538 0.9174
Arithmetic	0.13036 0.3772	0.17714 0.2284	0.18111 0.2180	-0.01562 0.9161	1.00000 0.0000	-0.30484 0.0351	0.16952 0.2494
Analogies	-0.29605 0.041	0.25218 0.0838	-0.17080 0.2458	0.13798 0.3497	-0.30484 0.0351	1.00000 0.0000	0.07674 0.6042
MPFB	0.13364 0.3652	-0.07642 0.6057	0.09085 0.5391	0.01538 0.9174	0.16952 0.2494	0.07674 0.6042	1.00000 0.0000

APPENDIX G

ANALYSIS OF VARIANCE SUMMARY TABLES FOR EEG BASELINE FREQUENCY AND AMPLITUDE

TABLE XIX

ANALYSIS OF VARIANCE SUMMARY TABLE
FOR EEG BASELINE FREQUENCY

Source	df	SS	F	Pr F
Sex	1	19.5933	3.00	.0904
IQ	2	1.7640	0.14	.8739
IQ X Sex	2	23.0868	1.77	.1829
Error	42	273.9954		
Hemisphere	1	5.4674	1.87	.1790
Sex X Hemisphere	1	3.1792	1.09	.3033
IQ X Hemisphere	2	9.4167	1.61	.2123
IQ X Sex X Hemisphere	2	13.1639	2.25	.1181
Error	42	122.9532		

TABLE XX

ANALYSIS OF VARIANCE SUMMARY TABLE
FOR EEG BASELINE AMPLITUDE

Source	df	SS	F	Pr F
Sex	1	00.6667	0.01	.9331
IQ	2	842.2500	4.51	.0169
IQ X Sex	2	102.0833	0.55	.5832
Error	42	3925.0000		
Hemisphere	1	26.0416	0.26	.6156
Sex X Hemisphere	1	15.0416	0.15	.7026
IQ X Hemisphere	2	142.3333	0.70	.5027
IQ X Sex X Hemisphere	2	17.5833	0.09	.9174
Error	42	4275.0000		

APPENDIX H

MIXED ANALYSIS OF VARIANCE SUMMARY TABLES FOR EEG IN-TASK FREQUENCY AND AMPLITUDE

TABLE XXI

MIXED ANALYSIS OF VARIANCE SUMMARY TABLE
FOR IN-TASK FREQUENCY

Source	df	SS	F	Pr F
Sex	1	125.2645	7.35	.0097
IQ	2	37.5046	1.10	.3423
Sex X IQ	2	16.6297	0.49	.6175
Error	42	716.0385		
Hemisphere	1	13.1836	1.45	.2352
Sex X Hemisphere	1	6.2927	0.69	.4101
IQ X Hemisphere	2	9.5505	0.53	.5952
Sex X IQ X Hemisphere	2	51.8189	2.85	.0690
Error	42	381.7435		
Task	3	5.8147	1.62	.1836
Sex X Task	3	3.1559	0.88	.3397
IQ X Task	6	3.6367	0.51	.4736
Sex X IQ X Task	6	9.2833	1.29	.2125
Error	126	151.0968		
Hemisphere X Task	3	2.2628	1.63	.1834
Sex X Hemisphere X Task	3	3.8490	2.78	.0433
IQ X Hemisphere X Task	6	4.02700	0.82	.4323
Sex X IQ X Hemisphere X Task	6	4.02900	1.45	.1536
Error	126	58.19091		

TABLE XXII

MIXED ANALYSIS OF VARIANCE SUMMARY TABLE
FOR IN-TASK AMPLITUDE

Source	df	SS	F	Pr F
Sex	1	4930.1889	7.87	.0076
IQ	2	1203.8781	0.96	.3909
Sex X IQ	2	1115.8823	0.89	.4181
Error	42	26316.8198		
Hemisphere	1	2299.4100	8.02	.0071
Sex X Hemisphere	1	29.6667	0.10	.7493
IQ X Hemisphere	2	702.8951	1.23	.3037
Sex X IQ X Hemisphere	2	144.8545	0.25	.7779
Error	42	12039.2998		
Task	3	8.0656	0.50	.8238
Sex X Task	3	301.5181	1.80	.1586
IQ X Task	6	140.7414	0.42	.8776
Sex X IQ X Task	6	181.5372	0.54	.8193
Error	126	7022.2360		
Hemisphere X Task	3	233.0559	1.58	.1957
Sex X Hemisphere X Task	3	162.9914	1.11	.3498
IQ X Hemisphere X Task	6	333.7661	1.13	.3475
Sex X IQ X Hemisphere X Task	6	331.0989	1.12	.3481
Error	126	6190.7194		

APPENDIX I

CORRELATION MATRICES FOR WAIS-R SUBTEST SCORES AND EEG BASELINE DIFFERENCE SCORES

TABLE XXIII

CORRELATION MATRICES FOR WAIS-R SUBTESTS SCORES AND EEG BASELINE DIFFERENCE SCORES FOR THE LEFT HEMISPHERE

	Sentence Completion Frequency	Arith- metic Freq.	Analo- gies Freq.	MPFB Freq.	Sentence Completion Amplitude	Arith- metic Ampl.	Analo- gies Ampl.	MPFB Ampl.
Block Design	0.24980 0.0868	0.20964 0.1527	0.23834 0.1028	0.29374 0.0427	0.01630 0.9124	-0.01483 0.9203	0.02414 0.8706	0.22462 0.1248
Simil- arities	-0.02686 0.8562	-0.03969 0.7888	-0.08052 0.5864	0.03999 0.7873	-0.31645 0.0284	-0.34639 0.0159	-0.31382 0.0298	-0.13584 0.3572
Total WAIS-R	0.21244 0.1472	0.17198 0.2425	0.18252 0.2144	0.17198 0.0575	-0.10177 0.4913	-0.14048 0.3409	-0.09384 0.5258	0.14999 0.3089

TABLE XXIV

CORRELATION MATRICES FOR WAIS-R SUBTESTS SCORES AND EEG BASELINE DIFFERENCE SCORES FOR THE RIGHT HEMISPHERE

	Sentence Completion Frequency	Arith- metic Freq.	Analo- gies Freq.	MPFB Freq.	Sentence Completion Amplitude	Arith- metic Ampl.	Analo- gies Ampl.	MPFB Ampl.
Block	0.20903	0.12445	0.17390	0.21930	0.15816	0.01057	0.00574	0.07595
Design	0.1539	0.3993	0.2372	0.1342	0.2830	0.9431	0.9691	0.6019
Simil-	-0.18303	-0.19047	-0.18205	0.02841	0.04317	0.17678	0.16838	0.18755
arities	0.2131	0.1947	0.2156	0.8480	0.7708	0.2294	0.2526	0.2018
Total	0.11877	0.04077	0.08787	0.20561	0.15661	0.07437	0.06698	0.13651
WAIS-R	0.4214	0.7832	0.5526	0.1609	0.2878	0.6154	0.6510	0.3549

VITA [2]

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