BILATERAL EEG BIOFEEDBACK AND CREATIVITY

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

A cognitive dimension which might be called ideational fluency or creativity appears to have been isolated. It can be distinguished from general intelligence and tests of this variable are good predictors of non-academic achievement or originality of performance or products. The present study proposes to assess the extent that this dimension can be manipulated by electroencephalographic biofeedback procedures.

Fromme, Mercadal, and Mercadal (in press, 1976) demonstrated that the production of remote associations to stimulus words can be increased using an operant conditioning paradigm. They used two of Guilford's (1967) measures of ideational fluency, Plot Titles and Alternate Uses, to assess changes in this factor as a result of the training. A significant ($p < .05$) effect was found only for the originality measure of the Plot Titles Test. On this test the subject is required to write titles for short story plots. The Alternate Uses Test was administered but no significant effect was found.

Green, Green and Walters (1970 and personal communication with Alyce Green, October, 1975) demonstrated an indirect link between brain wave alpha and theta feedback and creativity. They have shown that hypnogogic imagery can be elicited by training an individual to produce slower alpha and theta frequencies. They also cite many reports of creative contributions of noted scientists and authors that were conceived in hypnogogic or dreamlike states of consciousness. They are currently involved in the analysis of the verbal reports elicited from subjects as they are aroused during different brain wave frequency categories. These reports are analyzed by "blind" examiners according to an image classification scheme adapted from Wallach and Kogan (1965).

Colin Martindale and his associates (1974, 1975) discovered some interesting differences in patterns of alpha brainwave output between high, medium, and low creatives as defined by a combined measure of the Remote Associates Test (RAT) (Mednick & Mednick, 1967) and the Alternate Uses Test. The right hemisphere was monitored during administration of the two creativity tasks and the Cattell Culture Fair Intelligence Test. The right hemisphere is believed by Robert Ornstein (1972), J. E. Bogen (1969), and others that they cite, to operate in a primary process manner while the left hemisphere operates in a secondary process manner. Martindale found that the low and medium creativity groups did not differ between groups or between tasks in their percentages of resting basal alpha. However, the high creativity group showed a higher level of percent of basal alpha than the other two groups on the RAT, and a still higher level on the more pure measure of creativity, the Alternate Uses Test. It appears that in the highly creative person his right hemisphere shows a level of arousal that moves closer to the resting baseline level as the task demands more and more divergent thinking. On the convergent thinking task of the intelligence test the high creatives are no different from the medium or low creatives in that they all show a level of arousal that is much higher than their resting baselines.

Martindale (1974) also considered the alpha output of both hemispheres during relaxation and during speech. The results are not clear cut. During relaxation the percentage of time in alpha was measured. With this measure the low creatives had the lowest alpha in both hemispheres but the medium creatives had the highest in the right hemisphere with the high creatives at a value in between. In the left hemisphere the medium and the high creative groups showed no difference. The percent of basal alpha in both hemispheres was monitored during speech. Using this measure it was found that in the right hemisphere the high creatives were highest, medium creatives were next, and the low creatives were lowest. However, in the left hemisphere, though the high creatives were still highest, the low creatives were next with the medium creatives showing the lowest percent of basal alpha. These findings are difficult to interpret. It may reflect more than one factor operating, e.g., creativity and intelligence. This is feasible since Martindale's criterion for creativity included the RAT which includes a significant intelligence component. The difference in ranks of high, medium, and low creatives in left and right hemisphere measures may result from certain interactions of these variables.

Murphy, Lakey, and Maurek (1976) used a differential EEG training technique to enable subjects to enhance alpha in one hemisphere while suppressing it in the other. Two treatment groups were trained to suppress alpha in one hemisphere while enhancing alpha in the other. Pre and post verbal and visual spatial tasks were administered. It was found that the verbal test scores were significantly more variable after the left hemisphere alpha enhancement and the visual spatial test scores were significantly more variable after the right hemisphere alpha enhancement. It should be noted that these changes in variability occurred without notable changes in the groups' mean scores. The findings can be considered to support a hypothesis that slower brain wave frequencies are correlated with more creative responses. In an alpha enhancement condition some subjects improved their scores and some got worse, but the greater variability suggests that these subjects were more open to alternative solutions. This may be the first process in generating a useful creative response.

Problem

Researchers have demonstrated a link between EEG patterns and creativity and it is now known that certain EEG patterns can be operantly conditioned (see Appendix A-II). However, it is not known if EEG conditioning results in changes to EEG correlates like creativity. The present study proposed to demonstrate that creativity as measured by the Ideational Fluency tests used by Wallach (Wallach & Wing, 1969; Wallach, 1970) and Mednicks' Remote Associates Test (1967) can be altered with certain kinds of EEG biofeedback training.

Barron and Welsh (1952) have shown that artists prefer more complex asymmetrical figures than non-artists. If one assumes that the artists are more artistically creative, then the previously mentioned correlates between EEG and creativity would also be true for EEG and artistic preference. The present study also assessed changes in esthetic preference using the Maitland Graves' Design Judgment Test (1948).

It is not known to what extent individuals of different creative abilities respond to EEG feedback training. Therefore, subjects in the present study were classified into groups of different creativity levels in order to assess the effect of this dimension on response to EEG feedback treatment.

In conclusion, various modes of EEG biofeedback were applied to subjects of different levels of creativity to assess changes in scores on test instruments that are related to creative performance.

CHAPTER II

METHOD

Subjects

The subjects were 45 freshman and sophomore women students from five sections of Introductory Psychology taught during the fall and spring semesters, 1975-76, at Oklahoma State University. They were given extra course credit for participation in the study. Only women were used because previous research suggests that the cerebral functions are more lateralized in women (Buffrey & Gray, 1972). A greater degree of lateralization was desired to maximize the differences on the differential biofeedback performance and on the responses to the Verbal vs. Visual Spatial Ideational Fluency tests.

Biofeedback Trainers

The trainers were 11 undergraduate and graduate psychology students who had been instructed in the design of the experiment and equipment, procedures for applying electrodes, conducting the training sessions, and instructions to the subject.

Trainers received practice on mock subjects until they could apply the six electrodes accurately, quickly, and smoothly. It was necessary to procure the subject's help each time the electrodes were applied. The subject held some electrodes in place while the trainer secured them with an elastic headband. Therefore, it was necessary that the trainers understood how to effectively enlist this help from the subject. Trainers then observed at least one complete training session by an experienced trainer. When it was judged that the novice trainer understood each aspect of the session he/she was allowed to conduct a session under observation of an experienced trainer. If the observing trainer judged the novice trainer competent in all phases of a session, then the novice was allowed to conduct a session without supervision. However, a novice trainer was never allowed to conduct his/her first solo session with a first session subject.

Apparatus

Brainwave biofeedback was given to the subjects via two Autogen 70 feedback units manufactured by Autogenic Systems, Inc. Feedback from the left hemisphere was delivered to the subject in the left side of a set of stereo headphones and right hemisphere feedback was delivered to the right side. In order to minimize confusion, the Autogens were set in such a way that the subject turned the feedback sound off whenever she was producing the appropriate brainwave. In the case of an increase frequency condition, the upper threshold was set at the subject's baseline and the lower threshold was set at 2 Hertz, the lowest frequency graduation on the Autogen 70. For a decrease frequency condition, the lower threshold was set at the baseline and the upper threshold was set at 20 Hertz, the highest frequency graduation on the Autogen 70. With the former setting the subject was required to increase brainwave frequency in order to move out of the band and turn the feedback sound off. With the latter setting the subject was reminded to lower her brainwave frequency in order to move out of the band and turn the sound off.

During the feedback sessions the Spectrum was set at 7, Integration at 6, Amplitude at 0, with the Scale at X1.

A signal integrator sampled the EEG output of the two hemispheres on a schedule outlined in Table 1. The integrator generated a signal corresponding to the area beneath the curve of the raw EEG signal. It therefore, served as a measure of the electrical power of the EEG which is inversely related to arousal in the waking subject.

Instructions for the Ideational Fluency tests and the Design Judgment Test were delivered by way of a cassette tape recording. Remote Associates Test instructions were given by the experimenter. Standard instructions were given for the Design Judgment Test and the Remote Associates Test. See Appendix C for Ideational Fluency instructions.

Procedure

The present study used the two measures of divergent thinking or creative ability that have been shown to have correlations with creative achievements. The two measures were Wallach's Ideational Fluency (IF) tests and Mednicks' Remote Associates Test (RAT). The IF was used as the criterion to distinguish between groups of High, Medium, and Low creativity because it is considered to be the more pure measure of the two tests. Ideational Fluency items were taken from the work of Wallach and Wing (1969). Those items which had the highest correlation with the overall score were the ones that were used (see Appendix B). The Verbal Items were ones calling for Alternate Uses of a common object (e.g., a brick) and ones calling for Similarities between two common things (e.g., a restaurant and a grocery store). The Visual Spatial Items were two sets of drawings (one was a geometric pattern, the other was a continuous line), for which the subject was asked to write all the things of which the design reminded her.

TABLE 1

TESTING ORDER AND HEMISPHERE INTEGRATION SCHEDULE

Test Administered	Hemisphere Integrated
Ideational Fluency	
Alternate Uses	Left
Pattern Meanings	Left
Similarities	Right
Line Meanings	Right
Design Judgment Test	
First half of items	Right
Second half of items	Left
Remote Associates Test	
Start to 10 minutes	Left
10 to 20 minutes	Right
20 to 30 minutes	Left
30 to 40 minutes	Right

Pilot work had been done to determine the distribution characteristics for a sample of female subjects in two sections (N = 80) of Introductory Psychology at Oklahoma State University that took the IF under time controlled conditions. The top, middle, and lower 16% of the distribution was marked off and the corresponding scores were determined. A total score of 23 or below on four IF items defined inclusion in the Low creative group, 31 to 35 were the Medium creatives, and 43 or above indicated the High creatives.

A third test, the Maitland Graves' Design Judgment Test (DJ) was included because it contained no verbal components except for the instructions. This nonverbal test was expected to detect differences in right hemisphere functioning. Barron and Welsh (1952) demonstrated that creative subjects (artists) preferred complex assymetrical figures over simple symmetrical ones. The Barron and Welsh test did not control for response sets of either "liking" most of the stimulus pictures or "disliking" most of them. The Graves' DJ test involved a forced choice between two alternatives so as to control for this type of response set. Also, the stimuli for the DJ are all abstractions. This was desirable in the present study to control for idiosyncratic preferences for certain real life objects. The Graves' DJ test was composed in such a way to determine agreement with artistic experts concerning rules of esthetic appeal.

There were four EEG biofeedback conditions: (1) left hemisphere to increase frequency while right hemisphere was to decrease frequency, (2) right hemisphere to increase frequency while left was to decrease frequency, (3) both hemispheres to increase in frequency, and (4) both hemispheres to decrease in frequency.

All subjects underwent a group administered test to screen out any subjects who were left handed or showed signs of ambidexterity. They also received a group administered set of IF items that served as a creativity screening test. Selection for inclusion in the main study was dependent on the subject's score falling within the High, Medium, or Low creative groups as defined above.

Subjects who passed both screening procedures were then contacted by phone and a time was scheduled to take the pre tests. The feedback training and post testing sessions were scheduled when the subject came in for her pre test.

During the pre test the RAT (form 1), the pre test IF, and the odd numbered items of the DJ were administered while the left and right hemisphere temporal-parietal EEG was being monitored. Three High, three Medium, and three Low creative subjects were assigned to each of the four biofeedback conditions and a control condition which consisted of pre and post testing sessions about two weeks apart without intervening biofeedback training. Then each biofeedback subject received ten 21-minute feedback sessions with appropriate instructions. Finally, the post measures of creativity and design preference were administered. These included a third set of IF items, form 2 of the RAT, and the even numbered DJ items. A correlation of .81 has been reported between the two alternate forms of the RAT (Mednick & Mednick, 1967), and the Graves' DJ Test has reported odd-even split half reliabilities of .81 to .93 (Graves, 1948).

For the pre and post test sessions, the subject was seated in a small sound attenuated room adjacent to the experimenter's room which contained the feedback and recording apparatus. The subject could be viewed via a one-way mirror. Six electrodes were attached to the subject at positions T3, T4, P3, and P4, with the two reference electrodes on the forehead at positions Fp1 and Fp2. The subject was informed as to the general nature of the study except she was not told of the differential feedback modes.

The instructions for the first two tests, the IF and DJ, were administered by a tape recording. The experimenter entered the room after the DJ and explained the instructions for the RAT. This was done so that the subject could freely respond to the example items on the RAT.

Before the first training session, the subject was familiarized with the feedback sound which was a type of white noise. She was also shown the sound that muscle artifact produced, a crackling sound, plus the noise produced by a misplaced electrode, a buzzing sound. She was instructed to keep the sound off as much as possible in both ears by any internal strategy that worked. If keeping both sides quiet was too difficult she was told to try to work on one side at a time until she got control of both. The subject was also told that if at any time during the session she was able to keep the sound off easily the experimenter would move the criterion threshold so as to make it more difficult. If this happened, the subject heard a burst of feedback sound following a quiet period and this meant that she was doing exceptionally well.

After these initial instructions and at the start of all subsequent training sessions the subject was asked to sit straight in the chair with feet on the floor, arms and legs uncrossed, and eyes closed while baseline readings were taken. Amplitude baselines were taken for each hemisphere by opening the lower and upper thresholds to 2 and 20 Hertz respectively, setting the time interval for the percent time time meter at 10 seconds, and slowly adjusting the amplitude threshold until the meter read between 40 and 60 percent. This value was recorded and the amplitude threshold control was returned to 0.

The upper frequency threshold was then lowered and adjusted until the percent time meter read between 40 and 60 percent. This value was recorded as the frequency baseline and it was used as the starting reference point for training in that session.

The percent time interval selector was then set at 100 seconds and the subject was instructed to begin trying to control the EEG feedback by making the sound stay off as much as possible. If at any time during the session the subject was able to keep the percent time meter below 10 percent for at least 30 seconds the reference was reset using the same procedure outlined above for setting the initial frequency baseline.

Throughout the testing and training sessions the subject was encouraged and supported in her efforts to control the EEG.

Design

Independent Measures

The two independent between subjects variables used in the study were Creativity Level and Treatment Condition. Creativity Level was determined from the total score on the four items on the screening IF test. Low creatives scored 23 or below, Medium creatives scored 31 to

35 inclusive, and High creatives scored 43 or above. Three subjects from each level were randomly assigned to each of 5 treatment conditions. There were 4 biofeedback modes; right hemisphere down, left hemisphere down (RDLD); right down, left up (RDLU); right up, left down (RULD); and right up, left up (RULU); plus one control condition (CONT).

Dependent Measures

Amplitude and frequency baseline measures for each hemisphere were taken before each testing and training session. Pre and post test baseline measures were obtained for all 5 treatment groups but because the CONT condition received no EEG feedback, training session baselines were available for only the 4 biofeedback groups. Therefore, 4 groups had 12 baseline measures.

Brainwave power measures were obtained only during the post test sessions due to equipment failure during the pre tests. During the post tests the signal integrator was switched back and forth between hemispheres according to the schedule outlined in Table 1. In this way right and left hemispheres, respectively, were integrated during half of the DJ and RAT, and during one Verbal and one Visual Spatial item each on the IF.

The pre and post test scores on the IF, DJ, and RAT constitute the third set of dependent measures. Each item on the IF was scored separately in order to detect different sensitivities of the items to the Level and Treatment manipulations. The separate IF items were Alternate Uses (AU), Similarities, (SIM), Pattern Meanings (PAT), and Line Meanings (LIN).

Analyses

A factorial analysis of Creativity Level by Treatment Condition was run on each measure to check for marked interactions. However, since this would involve only three subjects per cell, separate analyses for Level and Treatment were also performed.

For the frequency and amplitude baseline measures the data were analyzed across the four biofeedback treatment groups with 12 data points (two testing sessions and ten training sessions) and across all five groups with two data points (pre and post test baselines). The two hemispheres were a within subjects variable.

The power data were analyzed according to the test being taken and at what point or phase the power sample was taken.

Hence, for each test the data were analyzed by hemisphere and by phase. Due to lost data the DJ and RAT had only eight subjects per cell in the EEG power analysis and the IF had only seven subjects per cell.

The test score data was considered in two ways. It was analyzed using change (pre and post) as a variable with the actual test scores as the dependent measures. It was also analyzed using change scores as the dependent measure (post test scores minus pre test scores). With IF scores the four items constituted a within subjects variable. Table 2 outlines the different analyses.

Hypotheses

The following hypotheses were put forth. They are numbered sequencially and grouped according to phase of the experiment and analysis.

TABLE 2

ANALYSES WITH NUMBER OF LEVELS FOR EACH VARIABLE

A. Table of Variables

Dependent Variables	Between Subjects Variables	Within Subjects Variables
Baselines (Frequency and Amplitude		
	Creativity Levels (3)	Hemispheres (2)
	Treatment Groups (4 or 5)	Sessions (2 or 12)
Power (IF, DJ, and RAT)		
	Creativity Levels (3)	Hemispheres (2) Pre to Post Change (2)
	Treatment Groups (5)	Phase (3 or 6)
Test Scores (IF, DJ, and RAT)		
	Creativity Levels (3)	Change (2) Tasks (for IF: verbal-spatial (2)
	Treatment Groups (5)	Items (for IF) (2)
Change Scores (IF, DJ, and RAT)		
	Creativity Levels (3)	Items (for IF) (4)
	Treatment Groups (5)	

Table No. in Appendix D	B. Listing of Analyses of Variance with Number of Levels
	BASELINES (Frequency and Amplitude)
8 and 14	Creativity Levels (3) X Subjects (15) X Hemispheres (2) X Sessions (12)
9 and 15	Treatment Groups (4) X Subjects (9) X Hemispheres (2) X Sessions (12)
10 and 16	Creativity Levels (3) X Treatment Groups (4) X Subjects (3) X Hemispheres (2) X Sessions (12)
11 and 17	Creativity Levels (3) X Subjects (15) X Hemispheres (2) X Sessions (2)
12 and 18	Treatment Groups (5) X Subjects (9) X Hemispheres (2) X Sessions (2)

TABLE 2 (Continued)

Table No. in Appendix D	B. Listing of Analyses of Variance with Number of Levels
	BASELINES (Continued)
13 and 19	Creativity Levels (3) X Treatment Groups (5) X Subjects (3) X Hemispheres (2) X Sessions (2)
	POWER (IF, DJ, and RAT)
	IF:
20	Creativity Levels (3) X Subjects (12) X Hemispheres (2) X Verbal Spatial Task (2) X Phases (3)
21	Treatment Groups (5) X Subjects (7) X Hemispheres (2) X Verbal Spatial Task (2) X Phases (3)
	DJ:
22	Creativity Levels (3) X Subjects (12) X Hemispheres (2) X Phases (3)
23	Treatment Groups (5) X Subjects (8) X Hemispheres (2) X Phases (3)
	RAT:
24	Creativity Levels (3) X Subjects (12) X Hemispheres (2) X Phases (6)
25	Treatment Groups (5) X Subjects (8) X Hemispheres (2) X Phases (6)
	TEST SCORES (IF, DJ, and RAT)
	IF:
26	Creativity Levels (3) X Subjects (15) X Change (2) X Tasks (2) X Items (2)
27	Treatment Groups (5) X Subjects (9) X Change (2) X Tasks (2) X Items (2)
28	Creativity Levels (3) X Treatment Groups (5) X Subjects (3) X Change (2) X Tasks (2) X Items (2)

TABLE 2 (Continued)

Table No. in Appendix D	B. Listing of Analyses of Variance with Number of Levels
	TEST SCORES (Continued)
	DJ:
29	Creativity Levels (3) X Subjects (15) X Change (2)
30	Treatment Groups (5) X Subjects (9) X Change (2)
31	Creativity Levels (3) X Treatment Groups (5) X Subjects (3) X Change (2)
	RAT:
32	Creativity Levels (3) X Subjects (15) X Change (2)
33	Treatment Groups (5) X Subjects (9) X Change (2)
34	Creativity Levels (3) X Treatment Groups (5) X Subjects (3) X Change (2)
	CHANGE SCORES (IF, DJ, and RAT)
	IF:
35	Creativity Levels (3) X Subjects (15) X Items (4)
36	Treatment Groups (5) X Subjects (9) X Items (4)
37	Creativity Levels (3) X Treatment Groups (5) X Subjects (3) X Items (4)
	DJ:
38	Creativity Levels (3) X Subjects (15)
39	Treatment Groups (5) X Subjects (9)
40	Creativity Levels (3) X Treatment Groups (5) X Subjects (3)
	RAT:
41	Creativity Levels (3) X Subjects (15)
42	Treatment (5) X Subjects (9)

TABLE 2 (Continued)

Table No. in Appendix D	B. Listing of Analyses of Variance with Number of Levels
	CHANGE SCORES (Continued)
	RAT (Continued):
43	Creativity Levels (3) X Treatment Groups (5) X Subjects (3)

Training Phase

1. The four biofeedback groups were expected to differ across the training sessions in their respective right and left hemisphere baseline frequency and amplitude measures, such that down training in a specific hemisphere would result in a decreased frequency and an increased amplitude and up training would produce an increased frequency and a decreased amplitude.

2. The five groups (four biofeedback and one control) were predicted to differ from the pre to post test sessions in their respective right and left hemisphere frequency and amplitude according to direction trained. This would involve a Treatment Group by Hemisphere by Session (pre and post) interaction.

3. The three Creativity Levels were expected to differ in their respective hemispheres on the frequency and amplitude measures. No direction of difference was predicted as the previous research is not clear on this point.

Test Phase--Power Measure

4. The five treatment groups were expected to differ on the post test in their right and left hemisphere power measures according to direction of training, such that down training would result in increased power and up training would result in decreased power. It was assumed that during testing the subjects would be in EEG states of higher frequency than theta (four to seven Hertz associated with drowsiness and sleep). Therefore, level of arousal and EEG power could be considered to be related in a linear fashion.

5. The five treatment groups were also expected to differ on the post test in their right and left hemisphere power measures, such that the different Items on the IF would contribute to a power difference due to training. This would involve a Treatment Group by Hemisphere by IF Item interaction. It was hypothesized that the verbal creativity items (AU and SIM) would induce increased power in the left hemisphere while the visual spatial creativity items (PAT and LIN) would induce increased power in the right hemisphere.

6. Creativity Levels were expected to differ regardless of treatment in their respective hemispheres on the post test power measures.

Test Phase--Test Score Changes

7. No differences were expected among any of the five treatment groups on the pre test of any of the three test instruments. Planned comparisons were performed on the test score ANOVAs to assess this null hypothesis.

8. On all three test instruments the following pattern of

improvement was expected (in order of most improvement to least improvement from pre to post test): RDLD, RDLU, RULD, CONT, and RULU.

9. The three Creativity Levels were expected to differ in terms of improvement on all three test instruments.

Correlational Analyses of Test Scores

10. On the pre test the IF was expected to be highly correlated with the DJ. The RAT was also expected to be correlated to the other two test instruments on the pre test, however the size of the correlational coefficient was expected to be only minor to moderate because of the element of intelligence that accounts for some of the variance on the RAT but is not contained in the IF or DJ.

CHAPTER III

RESULTS

Training Phase

To investigate the differential effects of the Treatment Groups two analyses each were performed, using a mixed design (one between subjects variable: Groups; and two within subjects variables: Hemispheres and Sessions), for the two dependent variables of frequency and amplitude. One of the above ANOVAs used data from 12 sessions (pre, 10 training sessions, and post), and one used data from only two sessions (pre and post).

No significant differences were observed among the four biofeedback groups in terms of frequency or amplitude across the 12 sessions in which baselines were recorded. Therefore, hypothesis 1 was not supported. There was a significant main Hemisphere effect ($\underline{F}$ (1, 32) = 13.3409, $\underline{p} < .01$) in terms of frequency such that across all groups the right hemisphere was slower than the left. This is an outcome that has previously been reported in the literature.

There was also no significant interaction effect (Treatment Group by Session) on the pre and post session data on the dependent measures of frequency and amplitude. Therefore, hypothesis 2 was not supported. There was a significant main Session effect on frequency ($\underline{F}$ (1, 42) = 4.1345, $\underline{p} < .05$) and amplitude ($\underline{F}$ (1, 42) = 4.2297, $p < .05$). On the post test baseline, the subjects generally had higher frequencies and lower amplitudes reflecting a somewhat higher level of arousal. There was also a significant main Hemisphere effect (F (1, 42) = 6.4767, p < .025) on frequency such that the right hemisphere was lower in frequency than the left.

To investigate the differential effects of initial Creativity Level, two analyses each were performed, using a mixed design (one between subjects variable: Levels; and two within subjects variables: Hemispheres and Sessions). One of the above ANOVAs used data from 12 sessions (pre, 10 training sessions, and post), and one used data from only two sessions (pre and post).

There was a main Creativity Level effect on frequency (F (2, 42) = 3.4952, p < .05) and a marginal effect on amplitude (F (2, 42) = 2.7573, p < .10) on the analyses that were done on the pre and post test baselines, but on the analyses involving the 10 training sessions there was only a marginal effect on frequency (F (2, 33) = 2.6513, p < .10) and no significant effect on amplitude (F (2, 33) = .7988, n.s.). The mean square error terms for pre post ANOVAs were 3.309684 for frequency and 464.1270 for amplitude, while the mean square error terms for the 12 session ANOVAs were 11.72529 for frequency and 2977.424 for amplitude. This difference was due to the increased error that probably resulted because of the less controlled technique in obtaining training session baselines. These were done by several trainers of less experience and usually the subject was given less time to adjust to the experimental condition. On the pre and post test baselines the subject was given considerable time to relax and adapt to the experimental environment and all test session baselines were done by the same experimenter.

Planned comparisons were performed on the Creativity Level means and it was found that the Highs differed from the Mediums (t (40) = 2.3835) and the Lows (t (40) = 2.1828) at $p < .05$, but the Mediums were not significantly different from the Lows on the frequency measure (t (40) = .2007). On the amplitude measure although the pattern of the means was the same only the difference between Highs and Mediums reached statistical significance (t (40) = 2.347, $p < .05$). Hypothesis 3 was supported.

Test Phase--Power Measures

To assess the differential effects of the training groups an analysis was performed during the post test session using a mixed design (one between subjects variable: Group; and two within subjects variables: Hemisphere and Phase) on the EEG power data during each of the three test administrations (IF, DJ, and RAT).

As predicted in hypothesis 4 the Treatment Groups showed a differential effect on EEG power during post testing, however the ranks were not as expected. There was a significant main Treatment Group effect (IF: F (4, 30) = 2.5284, $p < .065$; DJ: F (4, 35) = 2.7820, $p < .05$; RAT: F (4, 35) = 3.3266, $p < .05$) during each of the tests but most of the effect was due to the extreme mean of the RULD group. Table 3 illustrates the pair wise comparisons of the Treatment Groups. It should be noted that in each case the RULD condition shows the most power but there is no consistent pattern among the remaining four groups and none of the pair wise differences among these four were significant.

TABLE 3

PAIR WISE COMPARISONS BETWEEN TREATMENT GROUPS
ON POWER MEASURE

IDEATIONAL FLUENCY--POWER--Significance Levels

RULD	↑ p < .01	↑ p < .05	↑ p < .05	↑ p < .06
RDLD	|	|	|	↓
RULU	|	|	↓	
RDLU	|	↓		
CONT	↓			

DESIGN JUDGMENT--POWER--Significance Levels

RULD	↑ p < .01	↑ p < .01	↑ p < .05	↑ p < .10
RDLD	|	|	|	↓
RULU	|	|	↓	
CONT	|	↓		
RDLU	↓			

REMOTE ASSOCIATES TEST--POWER--Significance Levels

RULD	↑ p < .01	↑ p < .02	↑ p < .05
RULU	|	|	|
RDLD	|	|	↓
CONT	|	↓	
RDLU	↓		

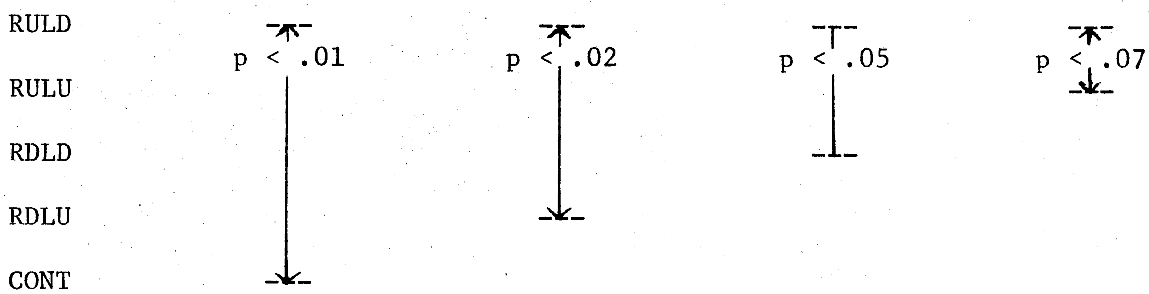
There was also a significant main Hemisphere effect on the DJ (F (1, 35) = 13.3044, $p < .01$) and the IF (F (1, 30) = 5.8561, $p < .05$) on the EEG power measure such that the right hemisphere exhibited more power during the tasks than the left. There were no significant Group by Hemisphere interactions so hypothesis 5 was not fully supported. However, there was a Treatment Group by Task (Verbal or Spatial) interaction on the IF power measure (F (4, 30) = 2.8516, $p < .05$). Table 4 shows the significant Verbal minus Spatial differences. The RULU group showed a significant difference ($p < .05$) with the Verbal tasks showing more power and the RDLU group showed a significant difference ($p < .055$) with the Spatial tasks showing greater power. When direction of training one hemisphere was analyzed through comparisons, it was found that the relevant dimension appears to be the direction that the right hemisphere is trained (see Table 4-D). The means of the two groups having the right hemisphere trained down in frequency (RDLD and RDLU) were found to have a significantly greater Spatial mean score ($p < .055$). On the other hand the means of the two groups having the right hemisphere trained up were found to have a significantly greater Verbal mean score ($p < .05$). Looking only at the direction of training of the left hemisphere revealed no significant effects on this variable. Hypothesis 5 was partially supported in that there was a Treatment Group by IF Task interaction in the expected direction for the right hemisphere training.

An unexpected significant effect was found on the DJ power measures in the Treatment Group by Time Phase interaction (F (8, 70) = 2.1034, $p < .05$). For each subject the left hemisphere was monitored first with three time samplings (beginning, middle, and end) during the first half of the DJ test and then the right hemisphere was monitored during the latter half of the test with three time samplings. However, since the left and right hemispheres were monitored successively the

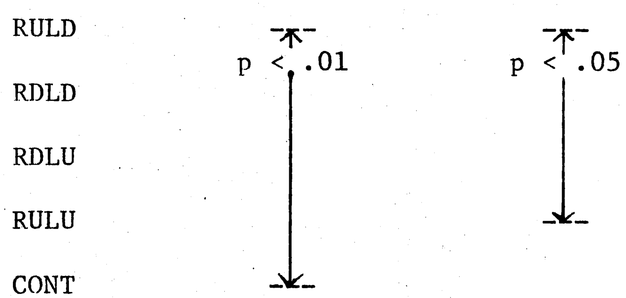
TABLE 4

SIGNIFICANT DIFFERENCES FROM THE TREATMENT GROUP BY IF TASK ON EEG POWER MEASURES

A. VERBAL TASK--Pair Wise Comparisons



B. SPATIAL TASK--Pair Wise Comparisons



C. VERBAL MINUS SPATIAL DIFFERENCE--For Individual Groups

Group	t-value	Significance Level
RULU	2.1728	$p < .05$
CONT	1.1753	n.s.
RULD	.9201	n.s.
RDLD	- .8505	n.s.
RDLU	-2.0297	$p < .055$

D. VERBAL MINUS SPATIAL DIFFERENCE--For Pairs of Groups

Groups	t-value	Significance Level
RDLD, RDLU — RD	-2.037	$p < .055$

TABLE 4 (Continued)

D. VERBAL MINUS SPATIAL DIFFERENCE--For Pairs of Groups (Continued)

Groups		t-value	Significance Level
RULD, RULU	RU	2.187	$p < .05$
RDLD, RULD	LD	.049	n.s.
RDLU, RULU	LU	.101	n.s.

time phases cannot be considered equivalent and meaningful interpretations cannot be made.

To assess the differential effects of the initial Creativity Levels an analysis was performed using a mixed design (one between subjects variable: Level; and two within subjects variables: Hemisphere and Phase) on the EEG power data of the post test session during each of the three test administrations (IF, DJ, and RAT).

There were no main or interaction effects due to Creativity Levels during any of the tests for the power measure. Therefore, hypothesis 6 was not supported.

Test Phase--Test Score Changes

To investigate the effects of the interaction of initial Creativity Level and Treatment Group on the test score changes nine analyses were performed using the test scores as the dependent variable. Three of these ANOVAs used two between subjects variables (Treatment Group and Creativity Level) to assess interaction effects. However, these analyses contained only three subjects in a cell, so separate ANOVAs were performed using only Treatment Group or Creativity Level as the single between subjects variable. Three ANOVAs were performed for Treatment Group and three were performed for Creativity Level. In each of the above cases the three analyses represent calculations on data from each of the three test instruments (IF, DJ, and RAT). On each of the above ANOVAs on the IF scores there were three within subjects variables: Task (Verbal (AU and SIM) and Spatial (PAT and LIN)), Item (nested in Task), and Time (pre or post test). On each of the DJ test score and RAT test score ANOVAs there was only one within subjects variable, Time (pre or post test).

To simplify interpretation of any interactions nine additional analyses were performed using change scores as the dependent variable (post test score minus pre test score). Again, three were performed using the two between subjects variables of Treatment Group and Creativity Level. Then because of small cell size (three per cell) separate ANOVAs were performed on the change scores for each of the between subjects variables of Treatment Group and Creativity Level. Three ANOVAs were performed with Treatment Group and three were performed with Creativity Level as the single between subjects variable on change scores. Each of the sets of three analyses on change scores represent an ANOVA on each of the three test instruments (IF, DJ, and RAT). On the IF change score analyses there was one within subjects variable, Item. Items were investigated separately because the two items on the Verbal Task could not be considered comparable to the two items on the Spatial Task. The influence of Verbal versus Spatial Task was assessed in the previously mentioned analysis using test scores. The change score analyses on the DJ and RAT scores used no within subjects variables.

No significant differences among Treatment Group means were found for the RAT (F (4, 40) = 2.180, n.s.) or for the IF (F (4, 40) = 0.14608, n.s.) on the pre test scores. Hypothesis 7 was supported for these tests. No comparison was performed on the pre test DJ scores because this test revealed no main or interaction effects for Treatment Group.

No main Treatment Group effects were found for DJ or IF on the change score analyses, therefore, hypothesis 8 was not supported for these tests. However, the hypothesis was supported for the RAT change scores (F (4, 40) = 2.5927, $p < .055$). The pattern of the effects was somewhat different than expected. The rank ordering of groups from highest improvement to lowest was: RDLD, RULU, CONT, RULD, and RDLU. Table 5 outlines the differences revealed by all of the more important comparisons that were significant at $p < .10$. Pairwise planned comparisons revealed that RDLD differed from both RDLU and RULD at $p < .05$. It was also found that RDLD differed from the mean of the other four groups at $p < .05$. RDLU also differed from the mean of the remaining four at $p < .055$. Perhaps a more meaningful comparison is the mean of the two groups whose hemispheres were trained in the same direction (RDLD and RULU) versus the mean of the remaining three. This difference was significant at $p < .05$. Likewise, the mean of the two groups whose hemispheres were trained in opposite directions (RDLU and RULD)

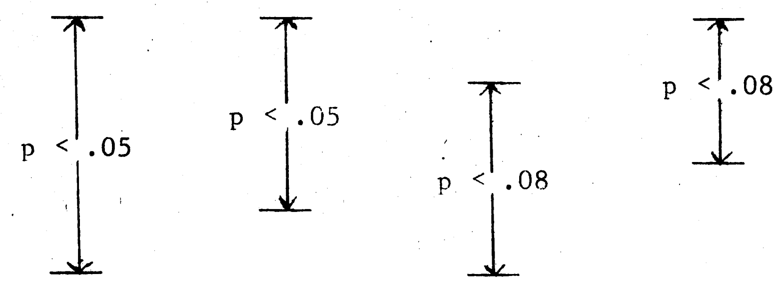
TABLE 5

SIGNIFICANT COMPARISONS BETWEEN TREATMENT GROUP MEANS ON RAT CHANGE SCORES

Group	Means	Significant Comparisons

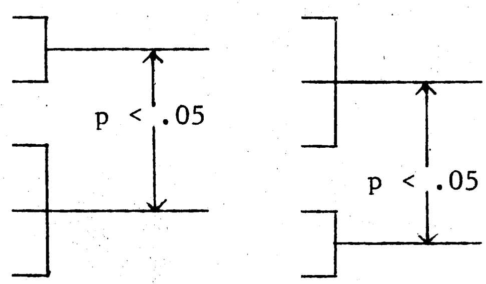
Pair Wise Comparisons

Group	Means
RDLD	3.22222
RULU	1.11111
CONT	-0.33333
RULD	-1.44444
RDLU	-2.44444



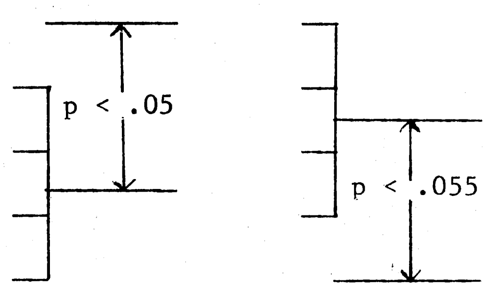
2 X 3 Comparisons

Group	Means
RDLD	3.22222
RULU	1.11111
CONT	-0.33333
RULD	-1.44444
RDLU	-2.44444



1 X 4 Comparisons

Group	Means
RDLD	3.22222
RULU	1.11111
CONT	-0.33333
RULD	-1.44444
RDLU	-2.44444



Note: A bracket represents the mean of the groups connected by the legs of the bracket.

differed significantly, $p < .05$, from the mean of the other three groups.

Although the IF change scores yielded no significant main effect on treatment groups there was a significant Treatment Group by Task Item interaction (F (12, 120) = 1.7505, $p < .07$). Also, the ANOVA showed a main significant effect among IF Items (F (3, 120) = 11.4731, $p < .01$). Post hoc Sheffe analyses of Treatment Groups at each Task Item (AU, SIN, PAT, and LIN) revealed no significant differences. However, pairwise post hoc Tukey analyses (see Table 6) between item means for each group did reveal some effects. RULD showed significant AU greater than SIM and AU greater than PAT differences at $p < .05$. RULU showed a significant AU greater than LIN difference at $p < .05$. There were no significant differences between IF Items for the RDLD and RDLU groups. These patterns of differences must be judged relative to the pattern of Item means for the CONT group which had a significant difference only for the AU and SIM comparison, AU being greater. The SIM, PAT, and LIN means were all close together for the CONT group and the AU mean was almost significantly greater than PAT and LIN. There is a possibility that the two RU conditions decrement one of the Spatial tasks relative to the Verbal Alternate Uses task.

Creativity levels were not significantly different on the change scores of the RAT and DJ, hence, hypothesis 9 was not supported for these two tests. However, the hypothesis was supported for IF, by a significant main Creativity Level effect (F (2, 42) = 3.2109, $p < .055$). The mean change scores for the three Levels in rank order are as follows: High creatives = 1.75, Low creatives = .8333, and Medium

TABLE 6

MEANS AND DIFFERENCES BETWEEN ITEM MEANS FOR THE GROUP BY ITEM INTERACTION FOR IF CHANGE SCORES

Group	Item AU	Item SIM	Item PAT	Item LIN
		A. Cell Means		
RDLD	2.77778	1.44444	0.00000	0.11111
RDLU	2.00000	0.88889	0.00000	1.22222
RULD	4.44444	0.55556	-0.77778	1.44444
RULU	1.77778	0.44444	1.66667	-1.77778
CONT	3.55556	-0.55556	0.44444	0.22222

Group	Item SIM	Item PAT	Item LIN
	B. Differences Among Item Means for RDLD Group		
AU	1.33334	2.77778	2.66667
SIM		1.44444	1.33333
PAT			0.11111
	C. Differences Among Item Means for RDLU Group		
AU	1.11111	2.00000	0.88888
SIM		0.88889	0.33333
PAT			1.22222
	D. Differences Among Item Means for RULD Group		
AU	3.88888*	5.22222*	3.00000
SIM		1.33334	0.88888
PAT			2.22222

TABLE 6 (Continued)

Group	SIM	PAT	LIN
	E. Differences Among Item Means for RULU Group		
AU	1.33334	0.11111	3.55556*
SIM		1.22223	2.22222
PAT			3.44445
	F. Differences Among Item Means for CONT Group		
AU	4.11112*	3.11112	3.33334
SIM		1.00000	0.77778
PAT			0.22222

*A difference of 3.50 or greater is needed to be statistically significant at $p < .05$.

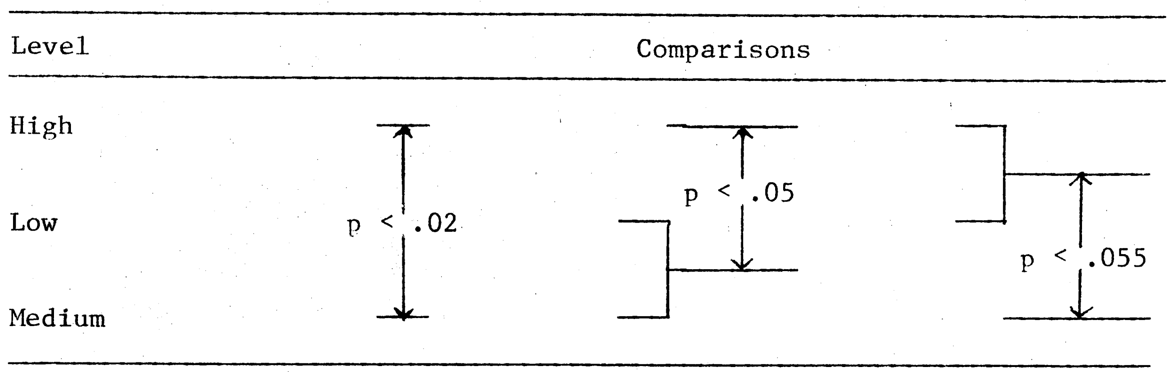
creatives = .35. Pairwise planned comparisons revealed that the Highs differed from the Mediums (t (42) = 2.5105, $p < .02$) but there were no significant pairwise differences between the Highs and the Lows (t = 1.5541, n.s.) or between the Mediums and the Lows (t = 0.9564, n.s.). Further comparisons show that the Highs differ from the mean of the Mediums and Lows at $p < .05$ (t = 2.3468) and that the Mediums differ from the mean of the Highs and Lows at $p < .055$ (t = 2.0016). Table 7 outlines these differences.

Correlational Analysis of Test Scores

The pre test IF and DJ correlation was .2909. This minor correlation accounts for only 8.46% of the variance and is much lower than expected. The pre test RAT had correlation coefficients of -.1354 with the pre test IF and 1.686 with the pre test DJ. These correlations are almost negligible.

TABLE 7

SIGNIFICANT DIFFERENCES ON CREATIVITY LEVELS
ON IF CHANGE SCORES



Note: A bracket represents the mean of the groups connected by the legs of the bracket.

One correlational finding did emerge that supports the previous finding of treatment effects on RAT performance. The pre test RAT (form 1) was found to be correlated with the post test RAT (form 2) with a coefficient of .5329. This is somewhat lower than the coefficient reported by Mednick and Mednick (1967) of .81 between the two alternate forms. It therefore supports the conclusion that the different Group Treatments were altering the subjects performance on the post test RAT and consequently reducing the comparability of performance on the alternate forms of the RAT.

CHAPTER IV

DISCUSSION

The two principal questions asked in this study were: "Did EEG biofeedback have an effect?" and "Did initial Creativity Level have an effect?". There are two areas that these independent variables can be shown to "have an effect." The first is the EEG data consisting of baseline frequency and amplitude, and power during the test administration. The second is the changes on the test scores from pre to post test.

Major Findings

The more important measure of the effects of Treatment or initial Creativity Level was the test scores: This is the measure that is actually linked to real life creative performance. Two of the tests, the Ideational Fluency and the Design Judgment, showed no significant main Treatment Group effects. The Remote Associates Test scores, however, were sensitive to Treatment modality. This is indicated by the significant difference between Groups on the RAT change scores and by the pre and post test RAT (forms 1 and 2, respectively) scores that had a lower correlation than that reported for reliability between the alternate forms for subjects with no experimental intervention (Mednick & Mednick, 1967). The relevant dimension in training was whether the two hemispheres were trained in the same or opposite directions.

It was hypothesized that down training would enhance test performance and this may have had some effect since the RDLD group showed the most improvement. However, the RULU group showed the second best RAT score improvement so the more important factor appears to be that the hemispheres were trained in the same direction.

There is the possibility that much material is stored in memory in both hemispheres of the brain. For instance, the written or spoken word "shoe" is perceived, processed, and stored in the left hemisphere. But at the same time, visual imagery associations of various kinds of shoes with which the perceiver is familiar may be laid down in the right hemisphere. Furthermore, there may be rhythmic or rhyming associations stored on the right side as a result of the right hemisphere's functional involvement with music (Bogen, 1973).

If dual storage of material is common and lower frequency training facilitates divergent remote associations it can be seen how the two contradirectional training groups, RULD and RDLU, could have been decremented in their preformance on a creativity task. As one hemisphere is trained down the remote associations in that hemisphere become available but the remote associations in the opposite hemisphere are unavailable because it is simultaneously being trained to increase in frequency. However, the incremented performance of the RULU group is not so readily understandable. With this group both hemispheres are trained up in frequency. Higher frequencies supposedly reduce the production of remote associations but the direction of training does not appear to be as crucial as the factor of training the hemispheres ipsidirectionally, at least according to the present data. Concentrated training in either direction may give the subject progressively more control in getting to EEG frequency states on a variety of levels. The process may be similar, or at least analogous, to the Jacobson (1938) method of progressive relation that first involves tensing the muscles to gain awareness and control. In the present study the RULU group as well as the RDLD group may have gotten the awareness and control that was necessary to move the EEG to a state that was conducive to good performance on the RAT.

A different theoretical explanation can be presented if one considers that the RAT is assumed to contain components of both divergent and convergent thinking or creativity and intelligence. If the right hemisphere is the divergent thinking processor and the left hemisphere is the convergent thinking processor then training the hemispheres in opposite directions may have dissociated the functions to the extent that RAT performance was decremented. If the divergent processor is being trained to be aroused while the convergent processor is being trained to be unaroused, then these processes are being trained out of synchrony. Conversely, training the hemispheres in the same direction may have had an effect of coordinating the functions which resulted in incremented RAT performance. A result that reduces the plausibility of this interpretation was the lack of correlation between the IF and RAT pre test scores. If the RAT does contain both divergent and convergent components then there should be some overlap with the IF which is assumed to be principally a divergent thinking task.

However, the IF test may not be as pure a measure of divergent thinking as Wallach (1970) has suggested. Many of Wallach and Wing's (1969) measures of non-academic achievement involved only participation in these types of activities; example: "Participated as an active member of one or more student organizations" and "Participated as a member of a science club or reading and discussion group." Also, Barlett and Davis (1974) administered the same four types of IF tests used in the present study to undergraduates who had contributed art work, writing, and innovative proposals that were evaluated for originality. The IF scores correlated .33 to .35 with the creativity ratings of the students. The correlations were significant although not very high. In comparison, Mednick and Halpern (1962) obtained a correlation of .70 between RAT scores and faculty ratings of the new designs and models of architecture students.

Wallach and Kogan (1965) demonstrated that high IF scorers exhibited a broader band width on the Pettigrew test, an assessment of the range of categorization breadth. Wallach and Kogan "suggested that the band-width index might be measuring a tolerance for deviant instances, hence accounting for its association with creativity." By creativity they mean, of course, indeationally fluent. However, this tolerance for deviancy may be a personality dimension that is independent from the ability to generate large numbers of ideas. The number of correct responses on the RAT is fixed at 30, but the number of appropriate responses on an IF test is open ended. Therefore, due to this personality dimension of tolerance for deviancy, there may be less overlap between the IF and RAT than what was originally thought and the IF may be the less sensitive measure of useful creative performance.

The question of EEG feedback treatment having an effect appears to have been answered affirmatively, but as is often the case in research, the explanations are not clear. Green, Green, and Walters (1970) have proposed that training to slower alpha and theta EEG states facilitates creativity but the more important dimension in training is training the hemispheres together in the same direction. The critical variable may be one of getting synchronous control of the hemispheres. If this is the relevant factor, a more effective EEG training program might include training the hemispheres to both increase and decrease in frequency upon cue.

Therefore, in summary, one major finding of this study has shown that ipsidirectional EEG biofeedback can effectively enhance creativity as measured by the Remote Associates Test. The second major finding of this study concerns the differential performance of the three Creativity Levels on the Ideational Fluency test and the differences between the Creativity Levels in terms of resting baselines.

Creativity Levels differed significantly in their magnitude of improvement on IF items. There was an interesting curvilinear relationship among the three Creativity Levels on IF change scores. The High creatives showed the most change and the Mediums showed the least with the Lows at a value in between. Phrasing the differences in a colloquial analogue, the rich get richer and the poor can move up to middle class but if one is already middle class he does not seem to be able to improve his lot much more.

This differential performance can be compared to the resting baselines among the Creativity Levels. The Highs showed the highest frequency and lowest amplitude while the Mediums showed the lowest frequency and highest amplitude. The Low creatives were at intermediate levels on both measures. It appears that the subjects with the most aroused resting baseline showed the greatest improvement on the IF test.

See Figure 1 for graphs of these curves and compare them with graphs of two other studies (Figure 2) that looked at differences between creativity levels. Martindale and Armstrong (1974) looked at amount of alpha in the right hemisphere during a resting condition between groups categorized into three creativity levels by a combined measure of the RAT, the Alternate Uses Test, and/or faculty ratings of creativity. They found that the High creative subjects showed significantly less alpha than the Lows while the Mediums showed insignificantly more than the Lows.

Wyspianski, Barry, and Dayhaw (1963) found similar results using a summed EEG amplitude measure from six recording sites in one hemisphere. They state that "the recording side (was) determined by the Subject's handedness," but do not state whether it was the side ipsilateral or contralateral to the dominant hand. They used five of Guilford's tests of divergent thinking to categorize creativity levels (Guilford & Merrifield, 1960). These were Word Fluency, Associational Fluency, Expressional Fluency, Alternate Uses, and Ideational Fluency. It should be noted that the last term carries a different meaning than in the present study. Wyspianski defines it as a test that "requires the Subject to list, as quickly as possible, ideas to meet meaningful requirements, such as the naming of fluids which will burn." In the present study Ideational Fluency is used in the generic sense to indicate the four tests of divergent thinking (AU, SIM, PAT, and LIN) that were used in the study.

Wallach (1970) has reviewed the literature that has used Guilford's tests of divergent thinking and found that the only tests that had a high degree of correlation among themselves plus considerable

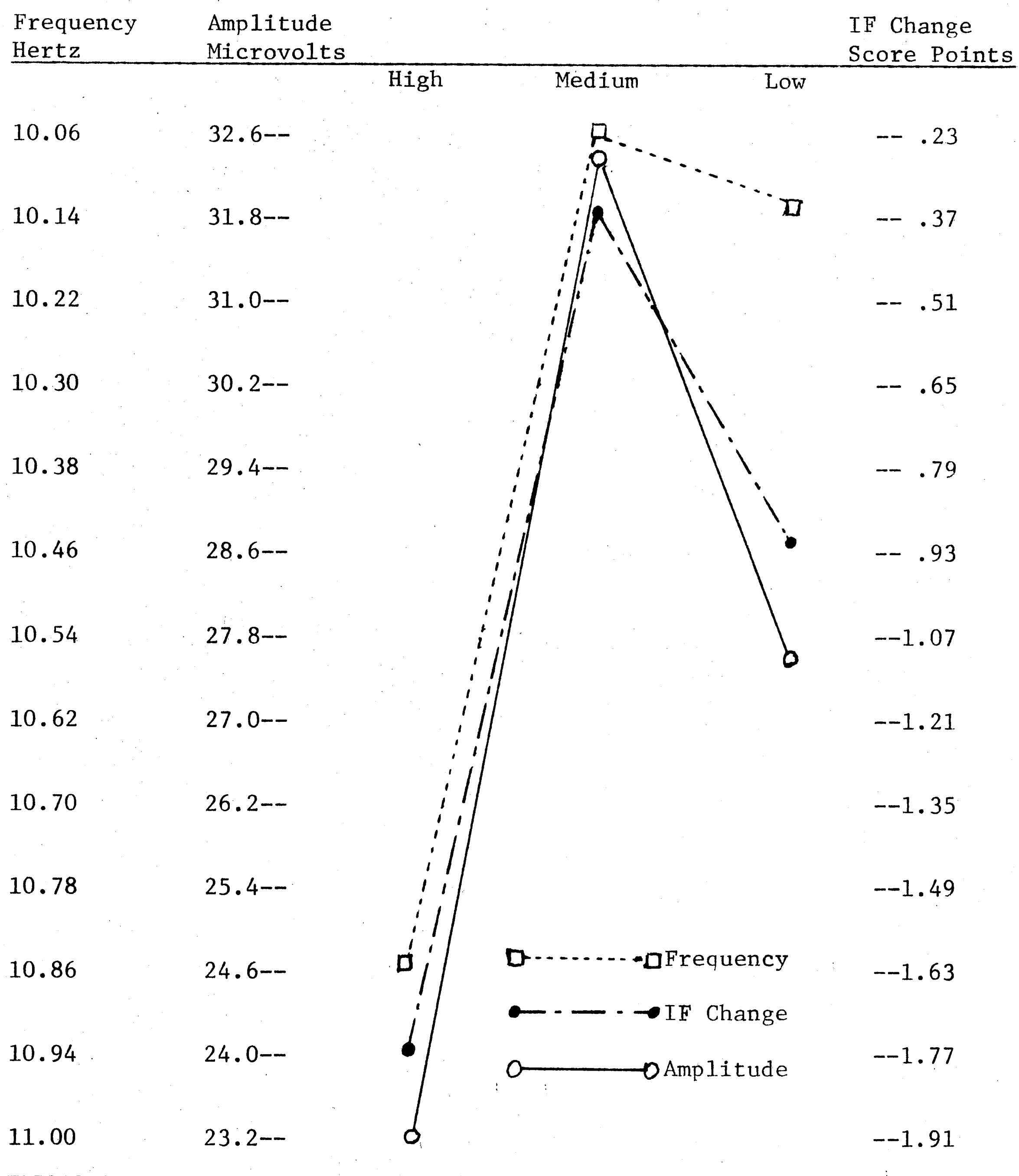


Figure 1. EEG Frequency, Amplitude and IF Change Scores in Three Levels of Creativity

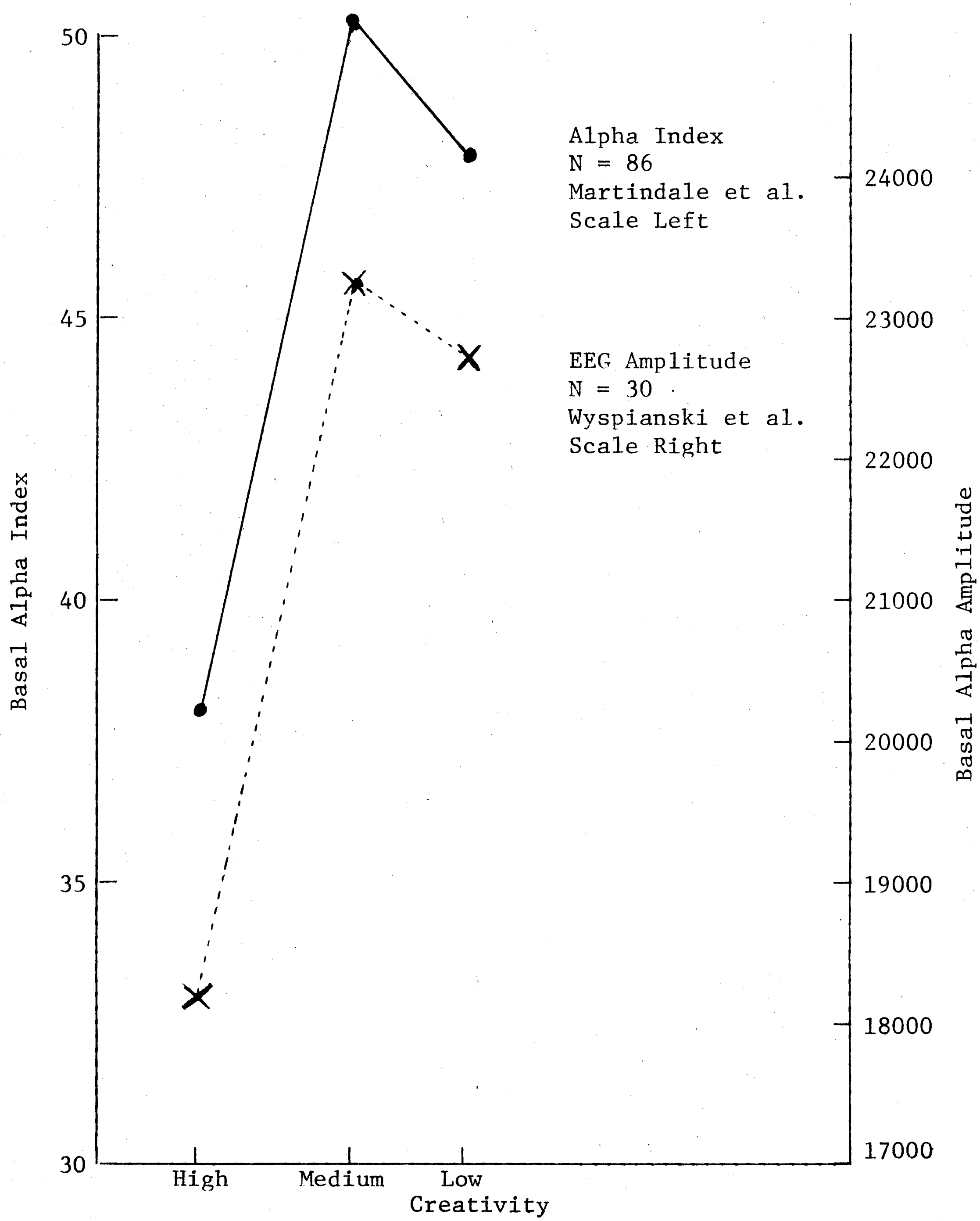


Figure 2. Alpha Index and EEG Amplitude During Resting State in Three Levels of Creativity

independence from convergent thinking tasks were the Ideational Fluency tests. One of the tests that is subsumed under Ideational Fluency is the Alternate Uses test. Figure 3 shows the results of these two tests in the Wyspianski study and Figure 4 shows the graphs of the other three tests used in the Wyspianski study. It can be seen that the Ideational Fluency and Alternate Uses tests (Figure 3) show the same pattern of EEG amplitude that was found in the present study while the other three tests (Figure 4) show a different pattern. This lends support to Wallach's contention that the Ideational Fluency and Alternate Uses tests are independent of the Word Fluency, Associational Fluency, and Expressional Fluency tests.

Wallach's (1970) hypothesis of attention deployment is useful in integrating some of the findings concerning the different levels of creativity. Medium creatives have low levels of resting baseline arousal. They may be able to do moderately well on an Ideational Fluency task because they can focus their attention to the task at hand effectively and produce responses that meet the criteria through a logical deductive line of reasoning that is more representative of a convergent mode of thinking. However, the efficiency of this method is very limited with this type of task. This inefficiency is evidenced by the minimal improvement of the Medium creatives on the IF tasks.

The High creatives are at the other extreme in terms of resting EEG baselines. They were highly aroused and it is assumed that they were receptive to a wide variety of stimuli from which to draw associations. Their Ideational Fluency scores started high and got progressively higher. Whatever they were doing was exactly what the task demanded.

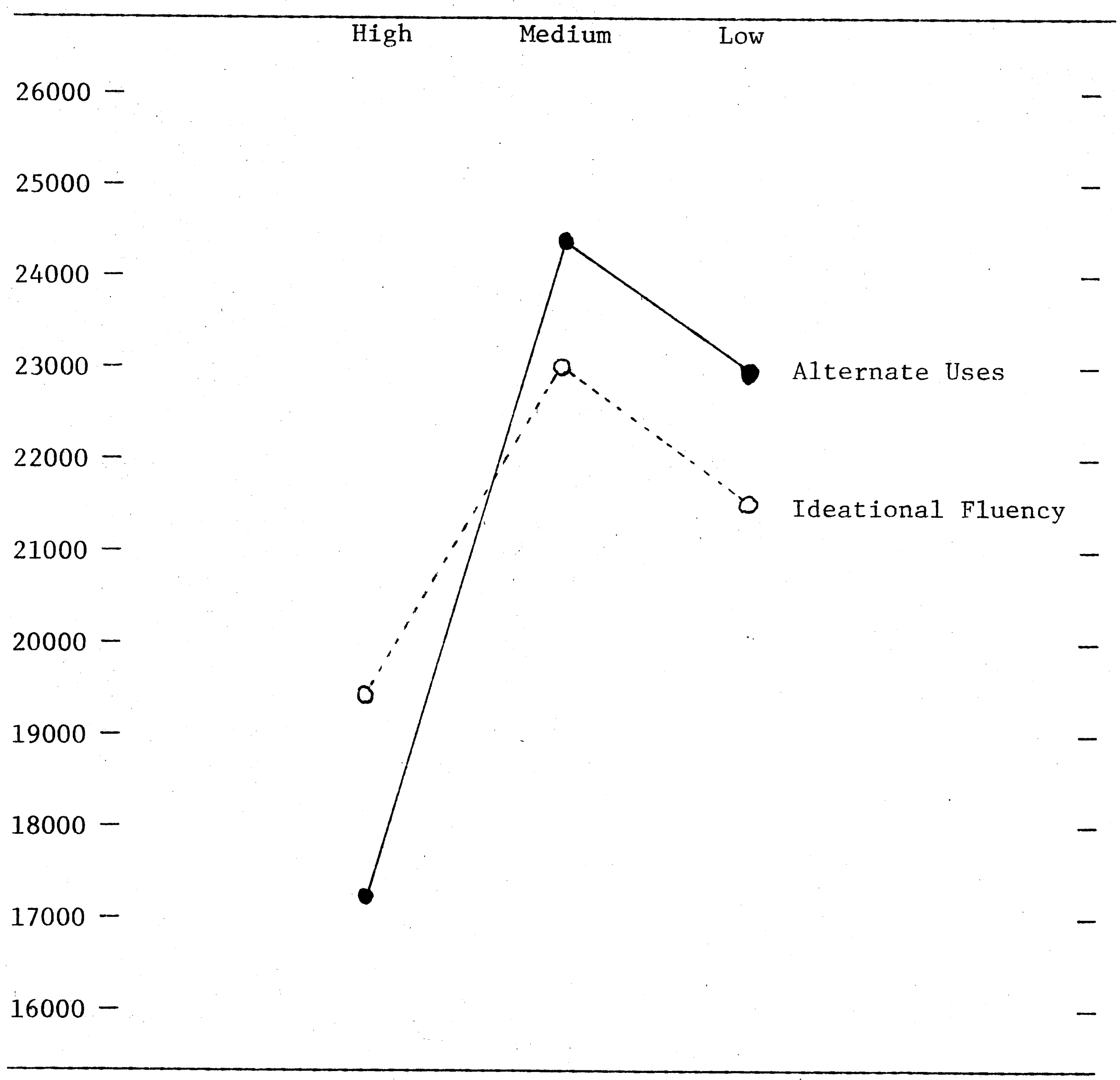


Figure 3. EEG Amplitude in Three Levels of Ideational Fluency and Alternate Uses--Wyspianski, Barry, and Dayhaw, 1963

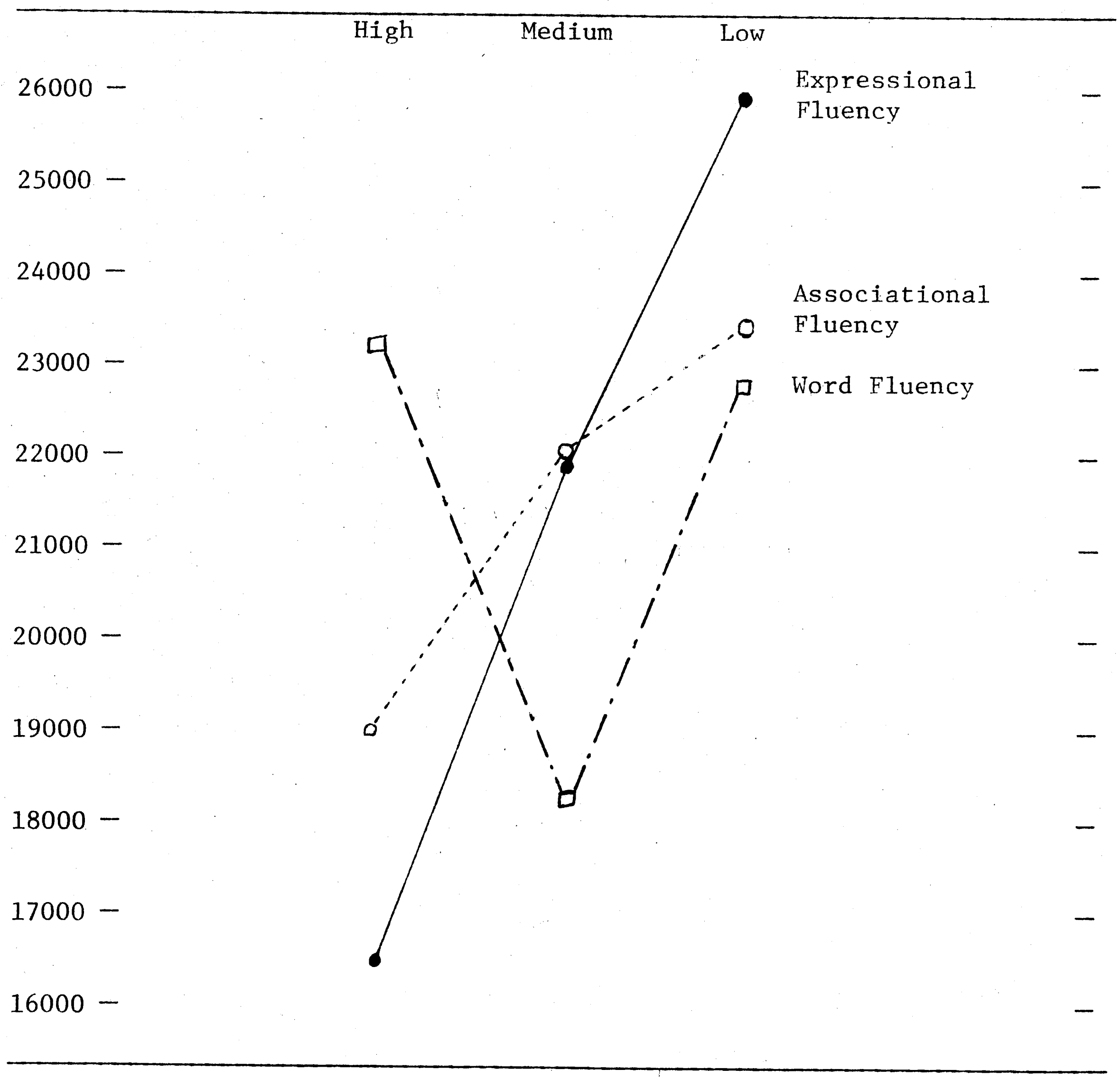


Figure 4. EEG Amplitude in Three Levels of Expressional Fluency, Associational Fluency, and Word Fluency--Wyspianski, Barry and Dayhaw, 1963

The group categorized as Low creatives complicate the picture somewhat. They show resting EEG baselines that are in between the other two groups in terms of arousal but they performed the poorest on their initial Ideational Fluency screening test which categorized them as Low creatives. However, they did rank a respectable second place in terms of improvement from pre to post test on the IF. An explanation that could account for this curvilinear effect is that the Low creatives were using the best method on the Ideational Fluency tests. They were open to divergent associations although they were not as adapt at it as were the High creatives. On the other hand, the Medium creatives were possibly using the wrong method. They were skilled with a focused attention approach but were unable to let go of this response set and become open to peripheral stimuli. Their approach gave them an advantage at first but soon proved to be a blind alley. There are many skills that necessitate disciplined practice of a correct technique to achieve excellence. For example, in learning to type a person who watches his hands and the keys may type somewhat faster and more accurately than the person who is trying to memorize the positions of the keys by touch. In the long run, though, the latter person will surpass the former in typing skill. This hypothesis would predict that with continued practice for both the Low and Medium creatives that the Lows would eventually surpass the Mediums.

For this theory to be tested it would be necessary to assess the initial Ideational Fluency creativity levels and the magnitude of improvement for individuals that were grouped according to their levels by EEG arousal. It appears from the present study that resting baseline EEG parameters are the most sensitive to this dimension but with better controlled assessment procedures arousal during several types of tasks might also show differences. Furthermore, there may be discrepancies depending on the measure of arousal. Three measures that are popularly used in the research literature are EEG frequency, amplitude, and percent of time in alpha. These measures are all correlated but not perfectly.

To conclude this section, it has been shown that resting baseline EEG parameters are intimately related to initial scores on Ideational Fluency tests as well as the ability to improve one's score on these tests. The greater the level of baseline arousal; the greater the improvement on these tests. However, although high levels of baseline arousal indicate a high initial performance on the Ideational Fluency tests, medium levels of arousal indicate a low initial performance and low levels of arousal indicate an intermediate initial performance.

Other Findings

The IF change scores showed no main Treatment Group effect but there was a Group by IF Item interaction. The mean change scores for the IF items were also significantly different which demonstrates the lack of comparability between Item scores. There were no significant differences between Groups on any Item but there were significant differences between some Items for the RULD, RULU, and CONT groups. The RDLD and RDLU groups showed no significant differences between Items. See Table 6 for differences between Items.

The RULD group revealed a significant Alternate Uses greater than Similarities difference and a significant Alternate Uses greater than Pattern Meanings difference. The CONT group also had a significant

Alternate Uses greater than Similarities difference. The RULD group may have had an effect of incrementing Alternate Uses performance relative to its decrement on the Pattern Meanings, but the CONT group came close to a significant Alternate Uses greater than Pattern Meanings difference also.

The RULU showed a significant Alternate Uses greater than Line Meanings difference so there may have been an effect of incrementing Alternate Uses performance relative to its decrement on Line Meanings. However, the CONT group also came close to a significant Alternate Uses greater than Line Meanings difference. Interpretations of this interaction should be made cautiously. If explanations are put forth on the basis of one group reaching statistical significance and another group just missing, then the two groups that received right hemisphere down training, RDLD and RDLU, could be considered to have decremented Alternate Uses performance relative to the increment on Similarities when these groups are compared with the CONT. With the present analysis, it is difficult to assess whether a difference between two IF Items for one Treatment Group is significantly greater than the difference between the same two Items for another Treatment Group.

The Ideational Fluency Items probably involve different degrees of divergent and convergent thinking as well as different degrees of Verbal and Spatial functioning used in each Task. For the Verbal Items the Similarities appears to involve more convergent thinking than the Alternate Uses. On the Similarities the subject not only has to generate associations to the stimulus words but must also converge on certain associations that are common for the two words.

Inspection of the two Spatial Items suggests differences here also. The responses to the Line Meanings stimuli usually involved closure of the stimulus line into a solid object. For example, seeing the Line Meanings screen test stimulus (Appendix B-IV) as the top of a bald man's head involves conceptualizing the rest of the head. On the other hand most of the associations to the Pattern Meanings stimuli did not necessitate adding more than what was actually bounded by the stimulus pattern. The process in Pattern Meanings seemed to be more like template matching.

It is likely that the treatment manipulations affected performance on the IF items differentially due to the subtle differences between the items. There may have been an effect such that training the right hemisphere up differentially decremented one of the Spatial IF Tasks. In order to test for such effects, a second derivative analysis would be necessary. However, these results are not sufficiently clear enough to make definitive statements possible.

The EEG baseline data revealed no Treatment Group effects either during the training sessions or the testing sessions. The lack of effect could have been because many of the baselines taken during the sessions early in training were before the subject had become adept at controlling the EEG in the desired direction. Another possibility might have been the crudeness of the measure. Frequencies were estimated to the nearest .5 Hertz and amplitudes were estimated to the nearest microvolt using the percent time meter to obtain the dominant parameters as outlined in Chapter II--Procedure. Another possible explanation for this lack of effect could be that EEG feedback training gives the subject the ability to get to certain brainwave states upon cue or "at will". The resting EEG may undergo no change at all with even extensive feedback training. Normal clinical EEG records, taken in a resting state, show a remarkable stability from early adulthood through middle age (see Appendix A-I).

Creativity Levels were significantly different on the testing session baselines. There was a curvilinear effect. In terms of arousal the High creative level was the most aroused (highest frequency and lowest amplitude) during the resting state in which the baselines were recorded; the Mediums were least aroused with the Lows at an intermediate level of arousal.

Unlike the baseline data the EEG power measures were obtained while the subject was actually working on the tests. Other differences between this measure and the baseline data are that the Treatment Groups showed a significant effect, but Creativity Levels did not on the power measure during the tasks.

It appears that EEG feedback training has little or no effect on resting state EEG parameters but the effect is evident on EEG parameters during task performance. DeGood (1976) reported a similar finding on heartrate biofeedback. He found that heartrate reductions in a biofeedback group were no different from a group in which subjects were induced to relax and reduce their heartrates by listening to music. However, the biofeedback group was significantly better in recovering from an electric shock stressor. As in the present study DeGood's biofeedback group was not different in terms of a resting baseline but were different in their reactions to a task: recovery from shock in DeGood's study and taking tests in the present study.

In contrast to the biofeedback Treatment Groups, the three

Creativity Levels were indistinguishable in terms of EEG power during the tasks but were significantly different on the resting state EEG parameters. Martindale (1974) also demonstrated differences in resting EEG parameters. His measure was percent time in alpha. Wallach (1970) has proposed an explanation that creative people differ in terms of attention deployment. That is, the more creative person has a less focused attention that is broad but narrow in depth. Supporting evidence for this theory comes from Mendelsohn and Griswold (1964, 1966) who demonstrated that high creatives as defined by RAT scores utilized more incidental cues than low creatives in solving anagram problems (scrambled letters to be rearranged into a word). Laughlin (1967) demonstrated that high RAT scores were strongly related to degree of incidental cue utilization and were also, although less strongly, related to degree of intentional cue utilization. This difference between Creativity Levels in openness to incidental environmental cues was shown in the present study by the different levels of arousal during the resting state in which the attention is supposedly not focused. The implication here is that the highly creative person is unable to screen out peripheral stimuli as effectively as the less creative individual. It should be emphasized that the term "peripheral stimuli" was used here instead of "irrelevant stimuli" because these borderline cues may provide better solutions to the problem at hand than cues in the focus of attention.

The two EEG measures, baseline and power data, are similar in that both revealed a significant hemisphere difference. The right hemisphere had more power and as in the resting baseline could be considered less aroused than the left hemisphere.

The pattern of Treatment Group effects on the power measure was quite different than expected and is difficult to explain. The RULD group showed the most power, while the other four groups showed no significant differences among them. Just the general statement that down training or up training increases power is not adequate because RULD, the extreme group, is a divergent training condition. Stating that training a given hemisphere in a given direction is likewise inadequate because there would be one other condition that would show the effect also. For example, if training the left hemisphere down were the relevant factor then RDLD should also show this significant increase in power. It appears that only the unique combination of training the right hemisphere up and the left hemisphere down in frequency gives the significant increase in EEG power while working on the tests.

One explanation arises when one considers the usual relationship between the hemispheres in terms of arousal, the right being less aroused. The RULD group is the only condition that necessarily trains the hemispheres "against the grain." In the RDLD and RULU groups the training could take place with the hemispheres remaining unchanged relative to each other. In the RDLU group training is merely in the further extreme of this normal relative direction. The RULD condition, however, trains the subject to distort the normal relative pattern in the opposite direction. If the goal of any manipulation of EEG parameters (experimental or otherwise) is to increase EEG power during tasks similar to those used in the present study then differentially training the right hemisphere to increase in frequency and the left to decrease in frequency clearly seems to be the treatment of choice. However, the RULD group did not do especially well in terms of change scores on the one test, the RAT, that responded to EEG feedback treatment. In fact, they showed negative change. Therefore, increasing overall EEG power during the task is not conducive to a more creative performance. However, the converse of this treatment, decreasing overall EEG power during the test, does not necessarily effect a more creative performance either. Of the four groups that clustered at the lower EEG power level, two showed significant positive change, RDLD and RULU, but one showed the greatest negative change, RDLU. In fact, RDLU showed a greater negative change than RULD.

As stated above there were no significant Creativity Level effects on EEG power during task performance. Martindale (1974) successfully demonstrated differences between creativity levels in terms of EEG parameters during tasks that involved various degrees of intelligence and creativity, or convergent and divergent thinking (Cattell's Culture Fair Intelligence Test, the RAT, and the Alternate Uses test). However, his measure was considerably different from the measures in the present study. He used percent of basal alpha as his dependent variable. It seems, therefore, that creativity levels do not differ on measures reflecting level of arousal during tasks but they do differ in terms of arousal during a task relative to their own resting baseline level of arousal. However, if the creativity levels start at different baselines and move to the same level of arousal during task this would show up a differences in percent of baseline level. It is not clear if Martindale's subjects actually show different levels of arousal during task.

There was also a significant Treatment Group by IF Task interaction on the power measure and further analysis revelaed that the relevant dimension was direction of training of the right hemisphere. If the right hemisphere was trained down then the whole brain showed more power on the Spatial IF Tasks, Pattern Meanings and Line Meanings. If the right hemisphere was trained up there was more power on the Verbal IF Tasks, Alternate Uses and Similarities. This finding supports the contention that the right hemisphere is more involved in divergent thinking tasks (Bogn, 1969; Ornstein, 1972). Direction of training of the left hemisphere had no statistically significant effect on Verbal vs. Spatial power on the Ideational Fluency Tasks but inspection of the Treatment Group means (see Table 4-C) suggests that training the left hemisphere up might have had an enhancing effect on the Verbal vs. Spatial IF power difference that resulted from a given direction of right hemisphere training. That is, left up training made the right hemisphere training effect more extreme.

For example, training the right hemisphere down resulted in greater EEG power while working on a Spatial Ideational Fluency Task than while working on a Verbal Ideational Fluency Task. But, training the left hemisphere up resulted in a still greater difference between Verbal IF power and Spatial IF power. Likewise, training the right hemisphere up resulted in greater EEG power while working on a Verbal Ideational Fluency Task than while working on a Spatial Ideational Fluency Task. Again, training the left hemisphere up resulted in a greater difference between Verbal IF power and Spatial IF power.

There was a significantly higher frequency and lower amplitude on the post test baseline compared to the pre test baseline. This indicates that the subjects generally showed a higher level of arousal while awaiting the post test. The reasons for the more aroused state are open to conjecture. The subject may have been excited about concluding a long involved study in which she felt challenged and stimulated. On the other hand, she may have been apprehensive about going through another long tiring ordeal of tests.

The two hemispheres showed differences such that the right hemisphere was slower in frequency and higher in amplitude than the left. This finding replicates Shagass' (1972) report that, in those individuals who show a difference in EEG parameters, the right hemisphere is slower in frequency and greater in amplitude. This finding lends validity to the present technique of basline measures mentioned above.

One aspect of this study that received little emphasis but should be again brought to the reader's attention was the fact that all subjects were women. Women were used because Buffery and Gray (1972) have suggested that the cerebral functions (spatial in the right hemisphere and verbal in the left hemisphere) are more lateralized in women. Hutt (1973) has discussed sex differences that have been shown with such factors as creative exploration, verbal fluency, and verbal vs. spatial reasoning ability that may be related to the kinds of tasks in the present study. Therefore, gender of the subjects should be kept in mind when comparing these results with the results of studies that used only males, e.g., Wyspianski et al. 1963.

Applications

The present study has revealed that individuals' scores on a predictor of creative performance, the RAT, can be improved with certain kinds of EEG feedback training. The next logical step would be to apply these techniques to groups working in a situation that demands original performance or the production of innovative designs for products. At this point, the question is whether or not the small but statistically significant increments in the RAT scores represent increments in performance that are significant in the practical sense.

The two most immediate areas of application would be education and industrial research. In education there has been a long time emphasis on the logical deductive, convergent thinking domain. These techniques could help round out the curriculum to include the other domain of divergent thinking. For individuals involved in research, the generation of fruitful alternatives is their _raison d'etre_. A method of enhancing this elusive quality of creativity would be welcomed with open arms.

CHAPTER V

SUMMARY

Previous research has indicated that creativity is associated with certain EEG states and that the two cerebral hemispheres are involved differentially in divergent thinking or creative thought. The present study used four bilateral EEG biofeedback modes to assess the effect on creativity as measured by three tests that are associated with creative performance. The four biofeedback treatments were: (1) training the right and left hemispheres to decrease in frequency, RDLD; (2) training the right to decrease and the left to increase in frequency, RDLU; (3) training the right to increase and the left to decrease in frequency, RULD; and (4) training both hemispheres to increase in frequency, RULU. There was also a control group, CONT, that received only pre and post testing without EEG biofeedback training.

The three tests used in this study were Ideational Fluency, IF, test items taken from the work of Wallach and Kogan (1965), the Maitland Graves' Design Judgment test, DJ, and Mednicks' Remote Associates Test, RAT.

Three creativity levels were used in the study. Subjects scoring in the high, middle, and lower 16% of the distribution of frequency scores on an IF screening test were designated as High, Medium, and Low creatives, respectively.

EEG feedback modalities effectively altered performance on only the

RAT test scores. The IF and DJ showed no main treatment group effects on change scores. The important factor for improvement on RAT test scores appears to be training the hemispheres in the same direction as in the RDLD or RULU groups. Training the hemispheres in opposite directions (RDLU or RULD) significantly decremented RAT performance.

One additional training group finding revealed that only if the two hemispheres are differentially trained in a direction opposite to the natural state of right hemisphere being less aroused does one get a significant increase in EEG power during divergent thinking tasks. However, this condition of right hemisphere up and left hemisphere down did not perform well on the RAT, which was shown to be sensitive to treatment modality. Also, the other four groups revealed no significant relationship with RAT test scores, therefore it appears that increases or decreases in EEG power are not related to increments or decrements in RAT scores.

Initial creativity levels produced different degrees of change on the IF test scores independent of treatment modality. The High creatives produced the most change and the Mediums produced the least with the Lows at a value in between. Creativity levels also produced different resting state baseline EEG parameters such that the Highs showed the greatest level of arousal and the Mediums had the least with the Lows again at a value in between. These curvilinear relationships between High, Medium, and Low creatives were compared with the results of other researchers who obtained similar results.

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APPENDIXES

APPENDIX A

LITERATURE REVIEW

I. Electroencephalography

The continuously oscillating electrical activity of the cerebral cortex was first observed in 1874 (reported in 1875) by Caton. He used rabbits and monkeys and was correctly convinced that this electrical activity was related to the functional activity of the brain. In 1924 Berger successfully recorded the electrical activity of the human brain through the scalp. He noted that changes in these cortical signals occurred with age, with sensory stimulation, and with seizure discharges. Berger distinguished two rhythms: (1) the alpha wave of approximately 10 Hertz that was dominant during a resting eyes closed condition. The alpha wave tended to drop out during attention and (2) the beta wave became dominant. These faster waves had frequencies of 14 to 60 Hz. Berger called the record of this brain wave activity the elektrenkephalogramm. The term has been translated to the present term electroencephalogram or EEG.

Electrical activities of the brain are of three types. There is a steady potential difference between the cortical surface and the white matter beneath it. This can only be recorded directly from the brain and the present discussion will not deal with this topic. The other two types are the spontaneously oscillating potential of the brain, the EEG; and the potential changes that result from sensory stimulation, or evoked potentials.

There are certain predictable nonpathological alterations in the EEG. The alpha wave is recorded mainly from parietal and occipital derivations and as Berger noticed, the alpha disappears with sufficient sensory stimulation and is replaced by the faster lower voltage beta wave.

The progression toward and through various sleep stages also produces identifiable changes. With initial levels of drowsiness the alpha decreases in amplitude and there is the appearance of some 4 to 5 Hz activity. Brain wave frequencies in the 4 to 7 Hz range are referred to as theta waves. With light sleep there are periods of 15 Hz activity alternating with 4 Hz activity, known as "K complexes." As sleep deepens there is the appearance of 1 to 3 Hz activity called delta waves.

After about 90 minutes into a normal sleep period there is a marked change in the EEG. It is composed of low voltage fast activity that resembles the waking state, even though the subject shows the behavioral components of sleep. It is this stage that has been shown to be correlated with rapid eye movements beneath the closed eyelids and dreaming.

There are certain normal changes of the EEG with age. In the infant the dominant frequency is at 5 Hz. This gradually increases through the developmental years to the usual 9 to 12 Hz activity of the normal adult and from early adulthood through middle age the EEG appears to be very stable. Then with advanced age (beyond 60 years) there is a slight slowing of dominant frequency with a higher incidence of abnormality in the EEG.

There are basically two types of abnormalities in the EEG record that are shown as departures from the two general characteristics of the nonpathological EEG. The normal EEG is (1) roughly symmetrical between hemispheres in terms of frequency and amplitude and (2) at a given age, the dominant activity falls within a specific frequency range and has a particular form, e.g., the alpha rhythm in the awake resting adult with eyes closed.

There have been numerous attempts to correlate the EEG with personality and cognitive measures. Saul, Davis, and Davis (1937) found a positive correlation between the amount of alpha activity and a passive, dependent, receptive attitude toward other persons. However, this relationship was true only in those individuals who freely accepted this attitude and were not thwarted or inhibited internally. This finding was confirmed by Saul, Davis, and Davis (1949) with a larger number of case studies.

Gottlober (1938) found a relation between an extroverted personality and predominance of alpha activity but none between introverted personalities and absence of alpha. Henry and Knott (1941), however, used Gottlober's rating scale with a larger group of subjects and found no significant relation between alpha index and extroversion-introversion.

Gallagher, Gibbs, and Gibbs (1942) found a higher incidence of abnormal EEGs in a group of adolescent boys whose school mates had categorized as having "bad" personalities, but the incidence of abnormal EEGs was almost as high in a group judged as having "excellent" personalities. The principal difference between the "bad" and "excellent" groups was that there was a greater incidence of slow waves in the "bad" group and a greater incidence of fast waves in the "excellent" group. The boys with normal personalities had the highest incidence of normal EEGs.

Many attempts have been made to relate the EEG to intelligence variables. The results are not conclusive as evidenced by the study of Knott, Friedman, and Bardsley (1942). They found that alpha frequency and intelligence level were significantly correlated ($r = .50$)

in the 8 year olds but not in the 12 year olds. More relevant to the present study was the research by Wyspianski, Barry, and Dayhaw (1963). They correlated EEG amplitude with a classification of creative thinking based on five tests derived from Guilford and Merrifield (1960): Word Fluency, Ideational Fluency, Associational Fluency, Expressional Fluency, and Alternate Uses. Wyspianski et al. (1963) found that amplitude was significantly lower in the group with the highest creativity scores than it was in the others during rest. However, the medium creatives actually had the higher alpha amplitudes than the low creatives.

This finding closely mirrors the results of a study by Martindale et al. (Martindale, 1974). They measured the right hemisphere basal alpha of groups that they had classified as high, medium, or low creatives on the basis of the Remote Associates Test, the Alternate Uses Test, and/or faculty ratings of creativity. They found that high creatives showed less alpha than low creatives while medium creatives showed insignificantly more than low creatives during rest. Martindale superimposed the graphs of his studies with those of Wyspianski et al. (1963) to demonstrate that the curves are almost identical.

With the technique of evoked cortical responses the usual procedure involves repeated presentation of a stimulus and the successive EEG responses are then averaged. The stimulus which is time locked into a given point will show up as a bump on the EEG record against a rather smooth background that results when the random noise fluctuations cancel each other out.

Evoked responses follow a developmental pattern similar to the dominant frequency. They are generally large during infancy and childhood and reach their lowest amplitude between 20 and 40 years, after which amplitude once again increases.

There are some studies that suggest a correlation between latency of the evoked responses and psychological I.Q., but the results are equivocal (Shagass, 1972).

Shagass and Schwartz (1965a, 1965b) found a relationship between amplitude of evoked responses and the extraversion measure (E) of the Maudsley Personality Inventory. However, the relationship was age dependent, so that the direction of differences was of opposite sign in a teen-aged group and in a group that was over 40 years old. For the teenagers high amplitude was associated with high E, whereas in the over 40 group high amplitude was associated with low E.

Shagass and Canter (1966) also found a significant relationship with the Witkin Rod-and-Frame test within a psychiatric patient population. Individuals with high field dependence scores had larger evoked potential amplitudes than subjects with lower scores.

In summary, the electroencephalogram, though still in its early stages of research, has been shown to be related to various personality styles and cognitive abilities even though the relationships are not sufficiently understood at this time to provide much predictive power.

II. Biofeedback

Learning theory texts as recent as 1967 have supported Skinner's (1938) early theoretical formulations on the difference between classical and instrumental conditioning. Deese and Hulse (1967, p. 21) stated:

> In short, when it is possible to make some kind of comparison, the two training procedures appear to produce conditioned responses that are not at all the same. Skinner's approach

> is also strongly supported by the fact that there is apparently no instance of successful instrumental conditioning of a respondent, such as the human heartbeat, which is clearly under autonomic, 'involuntary' control.

However, subsequent research has demonstrated that even the example of Deese and Hulse (heartbeat) could be instrumentally conditioned in both animals (Miller & DiCara, 1971) and humans (Hnatiow & Lang, 1974). Kamiya laid the groundwork for the present research by demonstrating that the EEG alpha rhythm could be discriminated by the subject and operantly controlled (Kamiya, 1969).

Biofeedback training has been shown to be much more than an interesting laboratory exercise. It has caught the imaginations of both the layman and the scientist. Many exaggerated and unsubstantiated claims have been made. For example, in a catalogue publication from Biofeedback Recordings, Inc. (1976), there is an educational tape recording for sale listed under the title "Let Your Cancer Disappear with Image Rehearsal and Biofeedback." This title clearly implicates biofeedback with the treatment of cancer, but to date there is no solid evidence that this type of treatment for cancer is efficacious.

However, certain practical therapeutic effects have been demonstrated for some biofeedback procedures. Frontalis EMG feedback was shown to be effective in treating tension headache (Budzynski, Stoyva, Adler, & Mullaney, 1973). Heartrate feedback has been used to treat premature ventricular contractions (Weiss & Engel, 1971) and blood pressure feedback has been used to control essential hypertension (Elder, Ruiz, & Deabler, 1973). Feedback of skin temperature of the body extremities has been shown to be a useful adjunct in treating migraine headache (Adler & Adler, 1976). A combination of frontalis

EMG and EEG theta feedback have been used to treat sleep onset insomnia (Budzynski, 1973). Recently feedback of the EEG sensorimotor rhythm has been used to control epileptic seizures with promising results (Sterman, 1974; Finley, 1973).

Some non-clinical applications of biofeedback have been explored also. Budzynski (1972) has proposed a procedure for producing hyper-suggestible states of consciousness with EEG theta feedback. Hardyk and Petrinovich (1969) have used feedback of speech muscle activity during silent reading to control subvocalization.

The present study is a potential example of a non-clinical application. The implications of a procedure to enhance creativity are far reaching. The most immediate applications might be in artistic pursuits, education, and industrial research. It may soon be discovered that creative genius is no longer a fixed commodity but a product that can be cultivated and expanded.

III. Creativity

In recent years an attempt has been made to isolate a cognitive ability that is distinguishable from the general intelligence functions as measured by the popular standardized tests (e.g., the Wechsler scales and Stanford-Binet) or other indices that are closely correlated with the intelligence tests (e.g., tests of academic ability or achievement). J. P. Guilford and his associates (1967, 1971a, 1971b) have accumulated much data through factor analytic studies that delineate various processes of cognitive functioning. The core of Guilford's analysis of the processes by which thinking is carried out consists of his distinguishing between convergent and divergent cognitive operations:

> In view of the active nature of creative performance, the production aspects or steps are most conspicious and probably most crucial. Among the productive-thinking abilities another logical distinction appears. With some productive-thinking factors and the tests that measure them, thinking must at some time converge toward one right answer; the significant type of thinking involved has been called 'convergent thinking.' With other productive-thinking factors and their tests, thinking need not come out with a unique answer; in fact, going off in different directions contributes to a better score in such tests. This type of thinking and these factors come under the heading of 'divergent' thinking. It is in divergent thinking that we find the most obvious indications of creativity (Guilford, 1957, pp. 111-112).

It is this divergent thinking type of creativity with which the present study proposes to deal.

Under divergent thinking Guilford lists the factors of word fluency, associational fluency, ideational fluency, expressional fluency, spontaneous flexibility, adaptive flexibility, redefinition, and originality. Four of these divergent thinking factors concern some form of fluency, three concern some sort of flexibility, and one involves novelty or uniqueness.

Convergent thinking refers to tests that prove such abilities as verbal comprehension, verbal reasoning, the size of a person's vocabulary, and the ability to solve mathematical problems.

Michael Wallach in an excellent review article (1970) criticizes Guilford's factor analytic techniques as being too liberal in assigning abilities the status of unique cognitive dimensions.

Wallach and Kogan (1965) propose a different approach to the dimensionality issue.

> They argue that the warrant for claiming an empirically separable divergent-thinking domain depends--once the matter of face validity is taken care of--upon showing that the divergent-thinking tasks share a substantial amount of

> variance in common, that they share substantially less variance with convergent-thinking tasks than they share with one another, and that the measures of convergent thinking share a substantial amount of variance in common as well (Wallach, 1970).

Wallach goes on to illustrate that of Guilford's divergent thinking factors the only one that shows considerable independence from the convergent thinking domain, plus a strong coherence within itself is ideational fluency.

Ideational fluency refers to the ability to generate, within a limited time, ideas that will fulfill particular requirements, such as naming uses for bricks, naming problems that are suggested by certain situations, writing titles for a story plot, or naming the consequences that might be entailed by certain changes (Wallach, 1970).

Wallach and Wing (1969) attempted to validate this concept of creativity by showing it to be predictive of non-academic achievement and only minimally or not at all related to general intelligence. They took a sample of 503 students who had been accepted for admission (incoming freshmen) at Duke University. They mailed to these people materials containing a self administered time unlimited battery of tests of the kind described above as assessing ideational fluency. There were three items of Alternate Uses for common objects, three for pattern meanings, three for similarities (e.g., all the ways a restaurant and a grocery store are alike), and three for line meanings. The pattern and line meanings involve listing all the things that a particular geometric pattern or continuous line reminds the subject.

Also included were questions pertaining to the student's involvement and success in various non-academic pursuits. These were leadership, art, social service, literature, dramatic arts, music, and science.

With each of the creativity measures a score was obtained on total responses or productivity and one on statistical uniqueness. A unique response was defined as having been given by no one else in the sample.

Wallach found repeatedly that the creativity measures were predictive of the various items in four of his measures of non-academic achievement. These were leadership, arts, writing, and scientific achievements. He also demonstrated that general intelligence as assessed by their Scholastic Aptitude Test scores did not predict these variables. The social service, music, and dramatic arts accomplishments were not correlated with either intelligence or creativity. Wallach discussed this finding in terms of what is involved in these activities. Most of his questions pertaining to music and drama had to do with activities involving reproducing the work of others instead of making an original contribution (e.g., composing music or writing a play) and in social activities the necessary prerequisite appears to be a strong concern for ethical or humanitarian values.

Guilford (1971b) criticizes Wallach's lack of control on the time consumed by the subject in completing the creativity tests. Guilford argues that if one gives the subject "liberal time . . . he may invent strategies that may unduly facilitate performance. These special advantages may change the character of the test and the variable that it measures." Also, there may have been large differences in the length of time people spent at the task depending on personality variables related to compulsivity. However, as long as time is held constant for everyone, the lengthening or shortening of the duration of the task seems to make little difference. Pilot work done by the present author using Wallach's items involves that as time progresses the respondents' rank scores do not change appreciably. Also, Mednick (1967) reports that given additional on his Remote Associates Test (RAT), another widely used measure of creativity, the subjects also do not appreciably change in their rank scores.

The RAT has been demonstrated to predict creativity as assessed by supervisors' ratings and ratings of the products or performances of the examinees. The RAT is somewhat correlated with intelligence and appears to be an intermediate assessment between the more pure creativity measures (like the Ideational Fluency tests) and the intelligence tests.

APPENDIX B

STIMULUS ITEMS

VERBAL IDEATIONAL FLUENCY STIMULUS ITEMS

I. Alternate Uses

Screening Test--SHOE

Pre Test---------CORK

Post Test-------CHAIR

II. Similarities

Screening Test--CURTAIN AND RUG

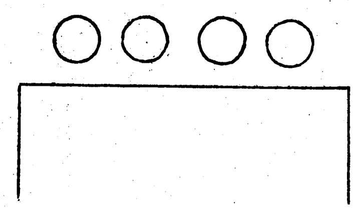
Pre Test---------WATCH AND TYPEWRITER

Post Test-------MILK AND MEAT

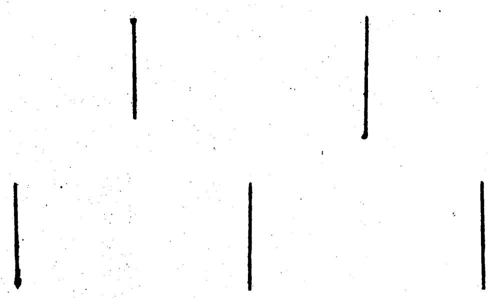
SPATIAL IDEATIONAL FLUENCY STIMULUS ITEMS

III. Pattern Meanings

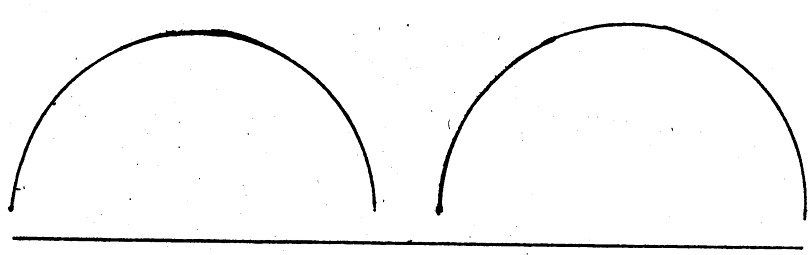
Screening Test



Pre Test

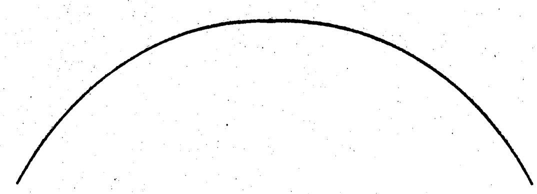


Post Test

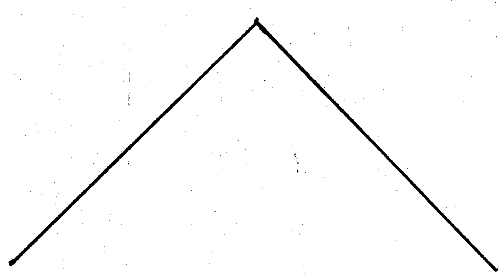


IV. Line Meanings

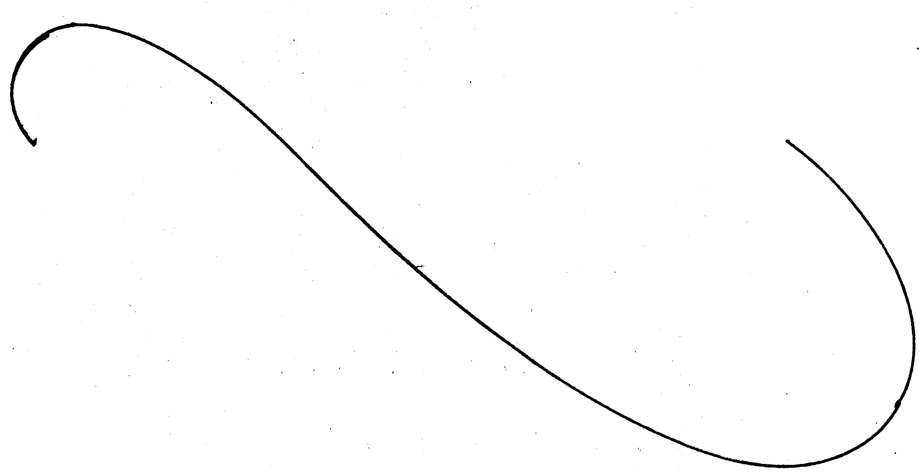
Screening Test



Pre Test



Post Test



APPENDIX C

INSTRUCTIONS FOR IDEATIONAL FLUENCY TESTS

Pre Test

The first test is a creativity test just like one you have taken before.

Post Test

The first test is a creativity test just like two others that you have taken before.

Would you please put your name on the top of the first sheet of this test.

Immediately below the place for your name you will see the word (<u>SHOE, CORK, CHAIR</u>). You are instructed to list as many uses as you can for a (__________________). These can be unusual uses or common uses but list as many uses as you can. Please number the uses that you write down. Ready, begin.

(Subject is then allowed three minutes to work on the item.)

Stop. Finish up an item if you are still working on one right now, and when you have finished turn over to the next page.

On the next page at the top you will see a pattern and for this part of the test you are to list all the things that the pattern reminds you of; list all the things that pattern could be, all the things that it looks like. Again, please number your responses. Ready, begin.

(Subject is given three minutes to work on the item.)

Stop. Finish up an item if you are still working on one right now, and when you have finished turn over to the next page. At the top of the next page you will see the words (CURTAIN AND RUG, WATCH AND TYPE-WRITER, MILK AND MEAT). Your instructions for this part are to list all the ways in which (____________________________) are alike. List all the ways that you can think of in which (____________________________) are similar. Please number your responses. Ready, begin.

(Subject is given three minutes to work on the item.)

Stop. If you are still working on an item finish it up, and when you are finished turn over to the next page of this test. On this page up at the top you will see a line. The instructions for this part are to list all the things which this line reminds you of. List all the things that it could be; all the things that it looks like. Please number your responses. Ready, begin.

(Subject is given three minutes to work on the item.)

Stop. Finish up an item if you are still working on one. Then when you have finished, put this test aside.

APPENDIX D

ANOVA SUMMARY TABLES

Frequency

TABLE 8

CREATIVITY LEVELS (L) X SUBJECTS (S) X HEMISPHERES (B) X SESSIONS (X)

Source	F	Sum of Squares	df	Mean Square	P
L	2.6513	62.17358	2	31.08679	n.s.
B	13.7976	11.22946	1	11.22946	< .01
X	0.7218	7.375861	11	.6705328	n.s.
S(L)		386.9346	33	11.72529	
LB	2.2924	3.731390	2	1.865695	n.s.
LX	1.2252	25.04152	22	1.138250	n.s.
BX	0.9030	3.593444	11	.3266767	n.s.
SN(L)		26.85771	33	.8138700	
SX(L)		337.2388	363	.9290324	
LBX	1.2875	10.24730	22	.4657863	n.s.
SBX(L)		131.3286	363	.3617868	

TABLE 9

TREATMENT GROUPS (G) X SUBJECTS (S) X HEMISPHERES (B) X SESSIONS (X)

Source	F	Sum of Squares	df	Mean Square	P
G	1.9508	69.43605	3	23.14534	n.s.
B	13.3409	11.22946	1	11.22946	< .01
X	0.6868	7.375861	11	.6705328	n.s.
S(G)		379.6721	32	11.86475	
GB	1.4469	3.653646	3	1.217882	n.s.
GX	0.5778	18.61581	33	.5641155	n.s.
BX	0.8619	3.593444	11	.3266767	n.s.
SB(G)		26.93546	32	.8417330	
SX(G)		343.6660	352	.9763239	
GBX	0.6537	8.175660	33	.2477472	n.s.
SBX(G)		133.74098	352	.3790050	

TABLE 10

CREATIVITY LEVELS (L) X TREATMENT GROUPS (G) X SUBJECTS (S) X HEMISPHERES (B) X SESSIONS (X)

Source	F	Sum of Squares	df	Mean Square	P
L	2.5294	62.17358	2	31.08679	n.s.
G	1.8832	69.43605	3	23.14534	n.s.
B	15.3070	11.22946	1	11.22946	< .01
X	0.7041	7.375861	11	.6705328	n.s.
LG	0.3055	22.52979	6	3.754964	n.s.
LB	2.5432	3.732390	2	1.865695	< .10
GB	1.6601	3.653646	3	1.217882	n.s.
LX	1.1952	25.04152	22	1.138250	n.s.
GX	0.5923	18.61581	33	.5641155	n.s.
BX	0.8799	3.593444	11	.3266767	n.s.
S(LG)		294.9685	24	12.29035	
LGB	1.2716	5.597095	6	.9328492	n.s.
LGX	1.0691	67.19701	66	1.018136	n.s.
LBX	1.2546	10.24730	22	.4657863	n.s.
GBX	0.6673	8.175660	33	.2477472	n.s.
SB(LG)		17.60675	24	.7336146	
SX(LG)		251.4258	264	.9523704	
LGBX	1.0259	25.13913	66	.3808959	n.s.
SBX(LG)		98.01369	264	.3712639	

TABLE 11

CREATIVITY LEVELS (L) X SUBJECTS (S) X HEMISPHERES (B) X SESSIONS (T)

Source	F	Sum of Squares	df	Mean Square	p
L	3.4952	23.13609	2	11.56805	< .05
B	6.4767	5.338888	1	5.338888	< .01
T	4.1345	3.472221	1	3.472221	< .05
S(L)		139.0067	42	3.309684	
LB	0.0219	.3608131E-01	2	.1804066E-01	n.s.
LT	0.8947	1.502739	2	.7513695	n.s.
BT	0.1935	.8889008E-01	1	.8889008E-01	n.s.
SB(L)		34.62160	42	.8243237	
ST(L)		35.27258	42	.8398234	
LBT	0.4021	.3694534	2	.1847267	n.s.
SBT(L)		19.29433	42	.4593887	

Comparisons of Creativity Levels on Pre Post Session Baseline Frequency Levels Means

High Creatives	Medium Creatives	Low Creatives
10.85000	10.05833	10.12500

t-test Values for Pair Wise Comparisons

High vs. Medium	2.3835	p < .05	42 df
High vs. Low	2.1828	p < .05	42 df
Medium vs. Low	.2007	n.s.	42 df

t-test Values for 1 X 2 Comparisons

High vs. Mean of other 2 Levels	2.6363	p < .05
Medium vs. Mean of other 2 Levels	1.4920	n.s.
Low vs. Mean of other 2 Levels	1.1443	n.s.

TABLE 12

TREATMENT GROUPS (G) X SUBJECTS (S) X HEMISPHERES (B) X SESSIONS (T)

Source	F	Sum of Squares	df	Mean Square	p
G	0.7144	10.81111	4	2.702777	n.s.
B	6.6970	5.338888	1	5.338888	< .01
T	3.8403	3.472221	1	3.472221	< .06
S(G)		151.3317	40	3.783293	
GB	0.8693	2.773282	4	.6930456	n.s.
GT	0.1690	.6111050	4	.1527762	n.s.
BT	0.1877	.8889008E-01	1	.8889008E-01	n.s.
SB(G)		31.88831	40	.7972076	
ST(G)		36.16629	40	.9041572	
GBT	0.3784	.7166996	4	.1791749	n.s.
SBT(G)		18.94270	40	.4735675	

TABLE 13

CREATIVITY LEVELS (L) X TREATMENT GROUPS (G) X SUBJECTS (S)
X HEMISPHERES (B) X SESSIONS (T)

Source	F	Sum of Squares	df	Mean Square	p
L	3.2159	23.13609	2	11.56805	< .06
G	0.7514	10.81111	4	2.702777	n.s.
B	7.2539	5.338888	1	5.338888	< .01
T	3.5017	3.472221	1	e.472221	< .08
LG	0.7047	20.28046	8	2.535057	n.s.
LB	0.0245	.3608131E-01	2	.1804066E-01	n.s.
GB	0.9416	2.772182	4	.6930456	n.s.
LT	0.7577	1.502739	2	.7313695	n.s.
GT	0.1541	.6111050	4	.1527762	n.s.
BT	0.1916	.8889008E-01	1	.8889008E-01	n.s.
S(LG)		107.9152	30	3.597172	
LGB	1.6592	9.769464	8	1.221183	n.s.
LGT	0.6195	4.913927	8	.6142409	n.s.
LBT	0.3981	.3694534	2	.1847267	n.s.
GBT	0.3862	.7166996	4	.1791749	n.s.
SB(LG)		22.07994	30	.7359980	
ST(LG)		29.74753	30	.9915842	
LGBT	1.2549	4.658083	8	.5822604	n.s.
SBT(LG)		13.91954	30	.4639846	

Amplitude

TABLE 14

CREATIVITY LEVELS (L) X SUBJECTS (S) X HEMISPHERES (B) X SESSIONS (X)

Source	F	Sum of Squares	df	Mean Square	p
L	0.7988	4756.816	2	2378.408	n.s.
B	1.6120	224.9741	1	224.0741	n.s.
X	1.1737	1138.299	11	103.4817	< .10
S(L)		98255.00	33	2977.424	
LB	0.8184	227.5197	2	113.7598	n.s.
LX	1.4675	2846.623	22	129.3920	n.s.
BX	0.9896	492.0090	11	44.72809	n.s.
SB(L)		4587.105	33	139.0032	
SX(L)		32005.69	363	88.16994	
LBX	1.3476	1339.989	22	60.90857	n.s.
SBX(L)		16406.43	363	45.19678	

TABLE 15

TREATMENT GROUPS (G) X SUBJECTS (S) X HEMISPHERES (B) X SESSIONS (X)

Source	F	Sum of Squares	df	Mean Square	p
G	2.0499	16605.11	3	5535.035	n.s.
B	1.6113	224.0741	1	224.0741	n.s.
X	1.1398	1138.299	11	103.4817	n.s.
S(G)		86406.75	32	2700.211	
GB	0.8741	364.6836	3	121.5612	n.s.
GX	0.9665	2895.639	33	87.74663	n.s.
BX	0.9903	492.0090	11	44.72809	n.s.
SB(G)		4450.129	32	139.0665	
SX(G)		31958.42	352	90.79097	
GBX	1.2402	1848.418	33	56.01268	n.s.
SBX(G)		15897.88	352	45.16443	

TABLE 16

CREATIVITY LEVELS (L) X TREATMENT GROUPS (G) X SUBJECTS (S) X HEMISPHERES (B) X SESSIONS (X)

Source	F	Sum of Squares	df	Mean Square	p
L	0.7485	4756.816	2	2378.408	n.s.
G	1.7419	16605.11	3	5535.035	n.s.
B	1.9956	224.0741	1	224.0741	n.s.
X	1.1955	1138.299	11	103.4817	n.s.
LG	0.2826	5388.309	6	898.0513	n.s.
LB	1.0131	227.5197	2	113.7598	n.s.
GB	1.0826	364.6836	3	121.5612	n.s.
LX	1.4948	2846.623	22	129.5920	< .10
GX	1.0137	2895.639	33	87.74663	n.s.
BX	1.0063	492.0090	11	44.72809	n.s.
S(LG)		76261.56	24	3177.565	
LGB	2.2673	1527.519	6	254.5865	< .10
LGX	1.0953	6257.793	66	94.81503	n.s.
LBX	1.3703	1339.989	22	60.90857	n.s.
GBX	1.2602	1848.418	33	56.01268	n.s.
SB(LG)		2694.856	24	112.2856	
SX(LG)		22852.21	264	86.56139	
LGBX	0.9624	2823.414	66	42.77899	n.s.
SBX(LG)		11734.54	264	44.44902	

TABLE 17

CREATIVITY LEVELS (L) X SUBJECTS (S) X HEMISPHERES (B) X SESSIONS (T)

Source	F	Sum of Squares	df	Mean Square	p
L	2.7573	2559.509	2	1270.755	< .10
B	0.0079	.6722222	1	.6722222	n.s.
T	4.2297	396.0498	1	396.0498	< .05
S(L)		19493.33	42	464.1270	
LB	0.8856	149.9100	2	74.95502	n.s.
LT	0.4194	78.53247	2	39.26624	n.s.
BT	0.0978	6.805420	1	6.805420	n.s.
SB(L)		3554.660	42	84.63477	
ST(L)		3932.698	42	93.63567	
LBT	1.6307	226.9800	2	113.4900	n.s.
SBT(L)		3922.967	42	69.59444	

Comparisons of Creativity Levels on Pre Post Session Baseline Amplitude Levels Means

High Creatives	Medium Creatives	Low Creatives
23.21666	32.45000	27.61665

t-test Values for Pair Wise Comparisons

High vs. Medium	2.3470	$p < .05$	42 df
High vs. Low	1.1186	n.s.	42 df
Medium vs. Low	1.2288	n.s.	42 df

t-test Values for 1 X 2 Comparisons

High vs. Mean of other 2 Levels	1.733	$p < .10$
Medium vs. Mean of other 2 Levels	1.788	$p < .10$
Low vs. Mean of other 2 Levels	.055	n.s.

TABLE 18

TREATMENT GROUPS (G) X SUBJECTS (S) X HEMISPHERES (B) X SESSIONS (T)

Source	F	Sum of Squares	df	Mean Square	p
G	1.6877	3184.363	4	796.0906	n.s.
B	0.0081	.6722222	1	.6722222	n.s.
T	4.6295	396.0498	1	396.0498	< .05
S(G)		18868.39	40	471.7095	
GB	1.0965	366.0803	4	91.52008	n.s.
GT	1.7223	589.3608	4	147.3402	n.s.
BT	0.0934	6.805420	1	6.805420	n.s.
SB(G)		3338.599	40	83.46498	
ST(G)		3421.979	40	85.54947	
GBT	0.8109	236.2778	4	59.06946	n.s.
SBT(G)		2913.661	40	72.84152	

TABLE 19

CREATIVITY LEVELS (L) X TREATMENT GROUPS (G) X SUBJECTS (S) X HEMISPHERES (B) X SESSIONS (T)

Source	F	Sum of Squares	df	Mean Square	p
L	2.5863	2559.509	2	1279.755	< .10
G	1.6089	3184.363	4	796.0906	n.s.
B	0.0090	.6722222	1	.6722222	n.s.
T	4.8784	396.0498	1	396.0498	< .05
LG	0.3700	1464.586	8	183.0733	n.s.
LB	1.0045	149.9100	2	74.95502	n.s.
GB	1.2265	366.0803	4	91.52008	n.s.
LT	0.4837	78.63247	2	39.26624	n.s.
GT	1.8149	589.3608	4	147.3402	n.s.
BT	0.0876	6.805420	1	6.805420	n.s.
S(LG)		14844.38	30	494.8125	
LGB	1.5916	950.0950	8	118.7619	n.s.
LGT	1.3978	907.8147	8	113.4768	n.s.
LBT	1.4602	226.9800	2	113.4900	n.s.
GBT	0.7600	236.2778	4	59.06946	n.s.
SB(LG)		2238.483	30	74.61610	
ST(LG)		2435.517	30	81.18390	
LGBT	0.5709	354.9827	8	44.37283	n.s.
SBT(LG)		2331.699	30	77.72330	

Power

Ideational Fluency

TABLE 20

CREATIVITY LEVELS (L) X SUBJECTS (S) X HEMISPHERES (B) X VERBAL SPATIAL TASK (T) X PHASES (P)

Source	F	Sum of Squares	df	Mean Square	p
L	1.6071	1087.954	2	543.9768	n.s.
B	8.3849	240.1492	1	240.1492	< .01
T	0.5735	5.814331	1	5.814331	n.s.
P	0.8796	10.67718	2	5.288589	n.s.
S(L)		11169.67	33	338.4749	
LB	1.0978	62.88380	2	31.44189	n.s.
LT	0.0134	.2725830	2	.1362915	n.s.
BT	0.7741	5.676010	1	5.676010	n.s.
LP	1.7227	41.43257	4	10.35814	n.s.
BP	0.6681	7.117904	2	3.558951	n.s.
TP	0.5393	7.857833	2	3.928916	n.s.
SB(L)		945.1472	33	28.64082	
ST(L)		334.5398	33	10.13757	
SP(L)		396.8330	66	6.012621	
LBT	0.7989	11.71584	2	5.857918	n.s.
LBP	0.1698	3.617448	4	.9043620	n.s.
LTP	0.9463	27.57820	4	6.894550	n.s.
BTP	0.5743	9.088334	2	4.544167	n.s.
SBT(L)		241.9753	33	7.332585	
SBP(L)		351.5925	66	5.327159	
STP(L)		480.8411	66	7.285470	
LBTP	1.8336	58.p3688	4	14.50922	n.s.
SBTP(L)		522.2532	66	7.912927	

TABLE 21

TREATMENT GROUPS (G) X SUBJECTS (S) X HEMISPHERES (B) X VERBAL SPATIAL TASK (T) X PHASES (P)

Source	F	Sum of Squares	df	Mean Square	p
G	2.5284	1327.431	4	331.8577	< .065
B	5.8561	197.8878	1	197.8878	< .05
T	0.3858	3.072449	1	3.072449	n.s.
P	1.0976	14.44986	2	7.224929	n.s.
S(G)		3937.636	30	131.2545	
GB	0.6355	85.89273	4	21.47318	n.s.
GT	2.8615	90.84943	4	22.71236	< .05
BT	1.3095	9.306458	1	9.306458	n.s.
GP	0.5788	30.48032	8	3.810040	n.s.
BP	1.1453	11.00231	2	5.501152	n.s.
TP	0.5127	8.371156	2	4.185577	n.s.
SB(G)		1013.757	30	33.79189	
ST(G)		238.9406	30	7.964686	
SP(G)		394.9385	60	6.582308	
GBT	0.8414	23.91693	4	5.979233	n.s.
GBP	1.3026	50.05359	8	6.256699	n.s.
GTP	0.6983	45.60442	8	5.700552	n.s.
BTP	0.4428	7.996902	2	3.998450	n.s.

Comparisons of Treatment Groups on EEG Power During IF Administration Group Means

RDLD	RDLU	RULD	RULU	CONT
25.02846	24.60110	28.54039	24.64037	23.21420

t-test Values for Pair Wise Comparisons

	RDLU	RULD	RULU	CONT
RDLD	.2418	1.9866*	.2195	1.0263
RDLU		2.2284**	.0222	.7845
RULD			2.2060**	3.0129***
RULU				.8067

Critical t values (30 df): For p < .01*** = 2.750
For p < .05** = 2.042
For p < .06* = 1.973

TABLE 21 (Continued)

Comparisons of Treatment Groups X IF Task on EEG Power

Verbal Task Comparisons, t-Values

	RDLU	RULD	RULU	CONT
RDLD	.4342	2.2283**	0.2982	.6539
RDLU		2.6626***	0.7324	.2197
RULD			1.9302*	2.8823
RULU				.9521****

Critical t values (30 df): For $p < .01$**** = 2.750
For $p < .02$*** = 2.457
For $p < .05$** = 2.042
For $p < .07$* = 1.904

Spatial Task Comparisons, t-Values

	RDLU	RULD	RULU	CONT
RDLD	.0535	1.6295	.7245	1.3391
RDLU		1.6648	.6891	1.3038
RULD			2.3540*	2.9686**
RULU				.6146

Critical t values (30 df): For $p < .01$** = 2.750
For $p < .05$* = 2.042

Verbal Minus Spatial EEG Power, t-Values

RDLD	-0.8505	n.s.		
RDLU	-2.0297	$p < .055$		
RULD	0.9201	n.s.		
RULU	2.1728	$p < .05$		
CONT	1.1753	n.s.		
Mean of RDLD and RDLU			-2.0366	$p < .05$
Mean of RULD and RULU			2.1870	$p < .05$
Mean of RDLD and RULD			.0492	n.s.
Mean of RDLU and RULU			.1012	n.s.

Source	F	Sum of Squares	df	Mean Square	p
SBT(G)		213.2010	30	7.106701	
SBP(G)		288.1890	60	4.803149	
STP(G)		489.7925	60	8.163208	
GBTP	0.5833	42.13991	8	5.267488	n.s.
SBTP(G)		541.7856	60	9.019760	

Design Judgment

TABLE 22

CREATIVITY LEVELS (L) X SUBJECTS (S) X HEMISPHERES (B) X PHASES (P)

Source	F	Sum of Squares	df	Mean Square	p
L	1.4146	224.8701	2	112.4351	n.s.
B	12.8616	253.7159	1	253.7159	.01
P	0.7369	8.523458	2	4.261728	n.s.
S(L)		2622.980	33	79.48424	
LB	0.6946	27.40549	2	13.70274	n.s.
LP	0.3816	8.828105	4	2.207026	n.s.
BP	1.1301	1.362987	2	.6814933	n.s.
SB(L)		650.9775	33	19.72658	
SP(L)		381.7200	66	5.783635	
LBP	0.1815	3.802286	4	.9505717	n.s.
SBP(L)		345.6448	66	5.237041	

TABLE 23

TREATMENT GROUPS (G) X SUBJECTS (S) X HEMISPHERES (B) X PHASES (P)

Source	F	Sum of Squares	df	Mean Square	p
G	2.7820	859.5837	4	214.8959	< .05
B	13.3044	285.3618	1	285.3618	< .01
P	0.9924	10.86153	2	5.430764	n.s.
S(G)		2703.551	35	77.24431	
GB	0.4910	42.12256	4	10.53064	n.s.
GP	2.1034	92.08157	8	11.51020	< .05
BP	0.0802	.8599062	2	.4299531	n.s.
SB(G)		750.7051	35	21.44872	
SP(G)		383.0527	70	5.472181	
GPB	0.6645	28.50435	8	3.563044	n.s.
SBP(G)		375.3333	70	5.361903	

Comparisons of Treatment Groups on EEG Power During DJ Administration--Group Means

RDLD	RDLU	RULD	RULU	CONT
25.45824	23.71239	28.88535	25.02908	23.73326

t-test Values for Pair Wise Comparisons

	RDLU	RULD	RULU	CONT
RDLD	.9732	1.9104*	.2392	.9615
RDLU		2.8836***	.7339	.0116
RULD			2.1495**	2.8718***
RULU				.7223

Critical t values (35 df): For $p < .01$*** = 2.727
For $p < .05$** = 2.032
For $p < .10$* = 1.691

Remote Associates Test

TABLE 24

CREATIVITY LEVELS (L) X SUBJECTS (S) X HEMISPHERES (B) X PHASES (P)

Source	F	Sum of Squares	df	Mean Square	p
L	0.3613	100.4667	2	502.3332	n.s.
B	4.9244	223.0036	1	223.0036	< .05
P	0.8437	20.16345	5	4.032690	n.s.
S(L)		4588.539	33	139.0466	
LB	0.8688	78.79125	2	39.34563	n.s.
LP	1.6055	76.74391	10	7.674391	n.s.
BP	1.8903	50.92770	5	10.18554	< .10
SB(L)		1494.410	33	45.28516	
SP(L)		788.7012	165	4.78006	
LBP	1.6089	86.69450	10	8.669450	n.s.
SBP(L)		889.0886	165	5.388415	

TABLE 25

TREATMENT GROUPS (G) X SUBJECTS (S) X HEMISPHERES (B) X PHASES (P)

Source	F	Sum of Squares	df	Mean Square	p
G	3.3266	1359.721	4	339.9302	< .05
B	5.5911	252.3058	1	252.3058	< .05
P	0.5115	13.46726	5	2.693451	n.s.
S(G)		3576.439	35	102.1840	
GB	0.6325	114.1689	4	28.54221	n.s.
GP	0.7528	79.29128	20	3.964563	n.s.
BP	1.6314	46.77287	5	9.354574	n.s.
SB(G)		1579.423	35	45.12636	
SP(G)		921.5933	175	5.266247	
GBP	0.8262	94.75211	20	4.737605	n.s.
SBP(G)		1003.465	175	5.734086	

Comparisons of Treatment Groups on EEG Power During RAT Administration--Group Means

RDLD	RDLU	RULD	RULU	CONT
25.12282	23.03116	28.09781	25.71864	24.30408

t-test Values for Pair Wise Comparisons

	RDLU	RULD	RULU	CONT
RDLD	1.4336	2.0397*	.4081	.5611
RDLU		3.4733***	1.8421	.8735
RULD			1.8316	2.6000**
RULU				.9695

Critical t values (35 df): For $p < .01$*** = 2.727
For $p < .02$** = 2.440
For $p < .05$* = 2.032

Test Scores

Ideational Fluency

TABLE 26

CREATIVITY LEVELS (L) X SUBJECTS (S) X CHANGE (C) X TASKS (T) X ITEMS (I)

Source	F	Sum of Squares	df	Mean Square	p
L	49.2503	4466.754	2	2233.377	< .01
C	19.0853	89.00278	1	89.00278	< .01
T	13.0391	135.6694	1	135.6694	< .01
I	1.3097	3.802777	1	3.802777	n.s.
S(L)		1904.594	42	45.34746	
LC	3.2112	29.95035	2	14.97517	< .06
LT	1.0646	22.15479	2	11.07739	n.s.
CT	15.5125	49.13589	1	49.13589	< .01
LI	5.5250	32.08394	2	16.04196	< .01
CI	9.7022	31.80276	1	31.80276	< .005
TI	59.1992	241.7360	1	241.7360	< .001
SC(L)		195.8631	42	4.663407	
ST(L)		437.0039	42	10.40485	
SI(L)		121.9490	42	2.903547	
LCT	0.4866	3.082855	2	1.541428	n.s.
LCI	0.5830	3.822235	2	1.911118	n.s.
LTI	2.3368	19.08403	2	9.542015	n.s.
CTI	8.0358	30.62456	1	30.62456	< .01
SCT(L)		133.0348	42	3.167496	
SCI(L)		137.6714	42	3.277889	
STI(L)		171.5041	42	4.083429	
LCTI	2.4759	18.87099	2	9.435493	< .10
SCTI(L)		160.0625	42	3.811010	

TABLE 27

TREATMENT GROUPS (G) X SUBJECTS (S) X CHANGE (C) X TASKS (T) X ITEMS (I)

Source	F	Sum of Squares	df	Mean Square	p
G	0.0845	53.39998	4	13.34999	n.s.
C	16.3005	89.00278	1	89.00278	< .01
T	12.3969	135.6694	1	135.6694	< .01
I	1.9798	3.802777	1	3.802777	n.s.
S(G)		6317.949	40	157.9487	
GC	0.3388	7.399750	4	1.849937	n.s.
GT	0.4889	21.39977	4	5.349941	n.s.
CT	15.1526	49.13589	1	49.13589	< .01
GI	0.9339	13.15552	4	3.288879	n.s.
CI	10.4563	31.80276	1	31.80276	< .01
TI	52.7358	241.7360	1	241.7360	< .01
SC(G)		218.4049	40	5.460123	
ST(G)		437.7524	40	10.94381	
SI(G)		140.8679	40	3.521697	
GCT	0.4916	6.376999	4	1.594250	n.s.
GCI	1.6293	19.82239	4	4.955597	n.s.
GTI	0.3938	7.220261	4	1.805065	n.s.
CTI	8.9410	30.62456	1	30.62456	< .01
SCT(G)		129.7094	40	3.242735	
SCI(G)		121.6596	40	3.041489	
STI(G)		183.3562	40	4.583904	
GCTI	3.0572	41.88651	4	10.47163	< .05
SCTI(G)		137.0078	40	3.425195	

Comparison of Treatment Group Means on IF Pre Test Scores--
Group Means on Pre Test

RDLD	RDLU	RULD	RULU	CONT
9.97222	9.63889	8.91667	9.55556	9.30556

Source	F	Sum of Squares	df	Mean Squre	p
G at C 1	0.14608	47.740205	4	11.935051	n.s.
Pooled error term					
S(G)		6317.949	40	81.70442	
SC(G)		218.4049	40		

TABLE 28

CREATIVITY LEVELS (L) X TREATMENT GROUPS (G) X SUBJECTS (S) X CHANGE (C) X TASKS (T) X ITEMS (I)

Source	F	Sum of Squares	df	Mean Square	p
L	53.0114	4466.754	2	2233.377	< .01
G	0.3169	53.39998	4	13.34999	n.s.
C	16.3289	89.00278	1	89.00278	< .01
T	12.3199	135.6694	1	135.6694	< .01
I	1.3906	3.802777	1	3.802777	n.s.
LG	1.7425	584.2913	8	73.41141	n.s.
LC	2.7474	29.95035	2	14.97517	n.s.
GC	0.3394	7.399750	4	1.849937	n.s.
LT	1.0059	22.15470	2	11.07739	n.s.
GT	0.4858	21.39977	4	5.349941	n.s.
CT	14.2220	49.13589	1	49.13589	< .01
LI	5.8662	32.08394	2	16.04196	< .01
GI	1.2027	13.15552	4	3.288879	n.s.
CI	9.7997	31.80276	1	31.80276	< .01
TI	61.6934	241.7360	1	241.7360	< .01
S(LG)		1263.902	30	42.13007	
LGC	0.5720	24.94385	8	3.117981	n.s.
LGT	0.9675	85.23695	8	10.65462	n.s.
LCT	0.4462	3.082855	2	1.541428	n.s.
GCT	0.4614	6.376999	4	1.594250	n.s.
LGI	1.2229	26.75443	8	3.344303	n.s.
LCI	0.5889	3.822235	2	1.911118	n.s.
GCI	1.5270	19.82239	4	4.955597	n.s.
LTI	2.4352	19.08403	2	9.542015	n.s.
GTI	0.4607	7.220261	4	1.805065	n.s.
CTI	8.5901	30.62456	1	30.62456	< .01
SC(LG)		163.5193	30	5.450643	
ST(LG)		330.3669	30	11.01223	
SI(LG)		82.03903	30	2.734634	
LGCT	0.8325	23.00972	8	2.876215	n.s.
LGCI	0.7892	20.49011	8	2.561264	n.s.
LGTI	1.4908	46.73294	8	5.841618	n.s.
LCTI	2.6466	18.87099	2	9.435493	< .10
GCTI	2.9373	41.88651	4	10.47163	< .05
SCT(LG)		103.6480	30	3.454933	
SCI(LG)		97.35880	30	3.245293	
STI(LG)		117.5503	30	3.918343	
LGCTI	0.3935	11.22237	8	1.402796	n.s.
SCTI(LG)		106.9533	30	3.565108	

Design Judgment

TABLE 29

CREATIVITY LEVELS (L) X SUBJECTS (S) X CHANGE (C)

Source	F	Sum of Squares	df	Mean Square	p
L	1.2879	375.0886	2	187.5543	n.s.
C	9.1786	120.1778	1	120.1778	< .01
S(L)		6116.078	42	145.6209	
LC	0.1841	4.821991	2	2.410995	n.s.
SC(L)		549.9163	42	13.09324	

TABLE 30

TREATMENT GROUPS (G) X SUBJECTS (S) X CHANGE (C)

Source	F	Sum of Squares	df	Mean Square	p
G	0.2763	174.5555	4	43.63889	n.s.
C	8.8675	120.1778	1	120.1778	< .01
S(G)		6316.598	40	157.9149	
GC	0.2324	12.59995	4	3.149986	n.s.
SC(G)		542.1030	40	13.55258	

TABLE 31

CREATIVITY LEVELS (L) X TREATMENT GROUPS (G) X SUBJECTS (S) X CHANGE (C)

Source	F	Sum of Squares	df	Mean Square	p
L	1.2833	375.0886	2	187.5443	n.s.
G	0.2986	174.5555	4	43.63889	n.s.
C	9.5822	120.1778	1	120.1778	< .01
LG	1.3320	1557.242	8	194.6552	n.s.
LC	0.1922	4.821991	2	2.410995	n.s.
GC	9.2512	12.59995	4	3.149986	n.s.
S(LG)		4384.277	30	146.1426	
LGC	1.6053	161.0610	8	20.13261	n.s.
SC(LG)		376.2515	30	12.54171	

Remote Associates Test

TABLE 32

CREATIVITY LEVELS (L) X SUBJECTS (S) X CHANGE (C)

Source	F	Sum of Squares	df	Mean Square	p
L	0.0577	3.888887	2	1.944444	n.s.
C	0.0011	.1111111E-01	1	.1111111E-01	n.s.
S(L)		1414.595	42	33.168082	
LC	0.0076	.1555549	2	.7777745E-01	n.s.
SC(L)		432.3164	42	10.29325	

TABLE 33

TREATMENT GROUPS (G) X SUBJECTS (S) X CHANGE (C)

Source	F	Sum of Squares	df	Mean Square	p
G	1.7349	209.7111	4	52.42776	n.s.
C	0.0013	.1111111E-01	1	.1111111E-01	n.s.
S(G)		1208.773	40	30.21931	
GC	2.5938	89.04417	4	22.26103	<.055
SC(G)		343.4304	40	8.585760	

Comparison of Treatment Group Means on RAT Pre Test Score--
Group Means on Pre Test

RDLD	RDLU	RULD	RULU	CONT
9.11111	14.33333	9.11111	10.66667	11.66667

Source	F	Sum of Squares	df	Mean Square	p
G at C 1	2.1801254	169.1999	4	42.299975	n.s.
Pooled error term					
S(G)		1208.773	40	19.402542	
SC(G)		343.4304	40		

TABLE 34

CREATIVITY LEVELS (L) X TREATMENT GROUPS (G)
X SUBJECTS (S) X CHANGE (C)

Source	F	Sum of Squares	df	Mean Square	p
L	0.0602	3.888887	2	1.944444	n.s.
G	1.6226	209.71111	4	52.42776	n.s.
C	0.0011	.1111111E-01	1	.1111111E-01	n.s.
LG	0.9113	235.5553	8	29.44441	n.s.
LC	0.0080	.1555549	2	.7777745E-01	n.s.
GC	2.2924	89.04417	4	22.26103	< .10
S(LG)		969.3281	30	32.31093	
LGC	0.6688	51.95444	8	6.494305	n.s.
SC(LG)		291.3176	30	9.710588	

Change Scores

Ideational Fluency

TABLE 35

CREATIVITY LEVELS (L) X SUBJECTS (S) X ITEMS (I)

Source	F	Sum of Squares	df	Mean Square	p
L	3.2109	59.91109	2	29.95554	< .055
I	10.8649	223.1278	3	74.37592	< .01
S(L)		391.8303	42	9.329305	
LI	1.2552	51.55484	6	8.592473	n.s.
SI(L)		862.5342	126	6.845509	

Comparisons of Creativity Levels on IF Change Scores--
Level Means

High Creatives	Medium Creatives	Low Creatives
1.75000	0.35000	0.88333

t-test Values for Pair Wise Comparisons

High vs. Medium	2.5105	p < .02	42 df
High vs. Low	1.5541	p < .13	42 df
Medium vs. Low	.9564	n.s.	42 df

t-test Values for 1 X 2 Comparisons

High vs. Mean of other 2 Levels	2.3468	p < .05
Medium vs. Mean of other 2 Levels	2.0016	p < .055
Low vs. Mean of other 2 Levels	.3451	n.s.

TABLE 36

TREATMENT GROUPS (G) X SUBJECTS (S) X ITEMS (I)

Source	F	Sum of Squares	df	Mean Square	p
G	0.3387	14.79999	4	3.699998	n.s.
I	11.4731	223.1278	3	74.37592	< .01
S(G)		436.9421	40	10.92355	
GI	1.7505	136.1772	12	11.34810	< .07
SI(G)		777.9131	120	6.482609	

TABLE 37

CREATIVITY LEVELS (L) X TREATMENT GROUPS (G) X SUBJECTS (S) X ITEMS (I)

Source	F	Sum of Squares	df	Mean Square	p
L	2.7468	59.91109	2	29.95554	< .10
G	0.3393	14.79999	4	3.699998	n.s.
I	10.8525	223.1278	3	74.37592	< .01
LG	0.5716	49.86652	8	6.233315	n.s.
LI	1.2538	51.55484	6	8.592473	n.s.
GI	1.6558	136.1772	12	11.34810	< .10
S(LG)		327.1641	30	10.90547	
LGI	0.6661	109.5544	24	4.564766	n.s.
SI(LG)		616.8025	90	6.853360	

Design Judgment

TABLE 38

CREATIVITY LEVELS (L) X SUBJECTS (S)

Source	F	Sum of Squares	df	Mean Square	p
L	0.1841	9.644444	2	4.822222	n.s.
S(L)		1099.995	42	26.19035	

TABLE 39

TREATMENT GROUPS (G) X SUBJECTS (S)

Source	F	Sum of Squares	df	Mean Square	p
S	0.2324	25.19998	4	6.299995	n.s.
S(G)		1084.439	40	27.11096	

TABLE 40

CREATIVITY LEVELS (L) X TREATMENT GROUPS (G) X SUBJECTS (S)

Source	F	Sum of Squares	df	Mean Square	p
L	0.1922	9.644444	2	4.822222	n.s.
G	0.2511	25.19998	4	6.299995	n.s.
LG	1.6050	322.1323	8	40.26654	n.s.
S(LG)		752.6584	30	25.08861	

Remote Associates Test

TABLE 41

CREATIVITY LEVELS (L) X SUBJECTS (S)

Source	F	Sum of Squares	df	Mean Square	p
L	0.0076	.3111108	2	.1555554	n.s.
S(L)		864.6619	42	20.58717	

TABLE 42

TREATMENT GROUPS (G) X SUBJECTS (S)

Source	F	Sum of Squares	df	Mean Square	p
G	2.5927	178.0887	4	44.52219	< .055
S(G)		686.8850	40	17.17212	

Comparisons of Treatment Groups for RAT Change Scores--
Group Means

RDLD	RDLU	RULD	RULU	CONT
3.22222	-2.44444	-1.44444	1.11111	-0.33333

t-test Values for Pair Wise Comparisons

	RDLU	RULD	RULU	CONT
RDLD	2.901**	2.389**	1.081	1.820*
RDLU		.512	1.820*	1.081
RULD			1.308	.569
RULU				.739

Critical t values (40 df): For p < .05 = 2.021**
For p < .08 = 1.819*

TABLE 42 (Continued)

t-test Values for 1 X 4 Comparisons

RDLD vs. Mean of other 4 Groups = 2.590	p < .05
RDLU vs. Mean of other 4 Groups = 1.977	p < .055
RULD vs. Mean of other 4 Groups = 1.943	p < .065
RULU vs. Mean of other 4 Groups = 1.267	n.s.
CONT vs. Mean of other 4 Groups = .288	n.s.

t-test Values for 2 X 3 Comparisons

RDLD & RDLU vs. other 3 Groups = .485	n.s.
RDLD & RULD vs. other 3 Groups = 1.146	n.s.
RDLD & RULU vs. other 3 Groups = 2.834	p < .05
RDLD & CONT vs. other 3 Groups = 1.880	p < .075
RDLU & RULD vs. other 3 Groups = 2.599	p < .05
RDLU & RULU vs. other 3 Groups = .911	n.s.
RDLU & CONT vs. other 3 Groups = 1.865	p < .075
RULD & RULU vs. other 3 Groups = .250	n.s.
RULD & CONT vs. other 3 Groups = 1.204	n.s.
RULU & CONT vs. other 3 Groups = .485	n.s.

TABLE 43

CREATIVITY LEVELS (L) X TREATMENT GROUPS (G) X SUBJECTS (S)

Source	F	Sum of Squares	df	Mean Square	p
L	0.0080	.3111108	2	.1555554	n.s.
G	2.2924	178.0887	4	44.52219	< .10
LG	0.6688	103.9103	8	12.98878	n.s.
S(LG)		582.6584	30	19.42194	

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