A Triphasic Design for Comparison of Three Biofeedback Training Methods on Bilateral Theta EEG Wave Activity

Morris D. Edwards
Western Michigan University

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A TRIPHASIC DESIGN
FOR COMPARISON OF THREE BIOFEEDBACK
TRAINING METHODS ON BILATERAL
THETA EEG WAVE ACTIVITY

by
Morris D. Edwards

A Thesis
Submitted to the
Faculty of The Graduate College
in partial fulfillment
of the
Degree of Master of Arts

Western Michigan University
Kalamazoo, Michigan
December 1978
ACKNOWLEDGEMENTS

In writing this thesis, I must first acknowledge the close working relationship I have had with my partner, Gary Chavoya. His help and support enabled me to become involved with the biofeedback techniques and research needed to run a thesis of this magnitude. My deepest appreciation goes to Dr. Richard Williams for his patience, professional expertise, and design contributions. My most sincere gratitude goes to Dr. Chris Koronakos, my benefactor, whose ongoing help and close personal relationship greatly enhanced my educational experience at Western Michigan University. My thanks to Dr. Mai Robertson for serving on my committee and providing a clinical model. A most sincere thanks to Dr. Wayne Fuqua, my thesis advisor, for his keen insight, criticisms, friendship, and clinical tutelage at the Psychological Services Center. Thanks to all the Special People at Midwest Oncology Center for the use of their facilities and any inconvenience suffered while this project was being run. Most importantly, my indebtedness to my wife, Patricia Carlin, for her continual support, love, and belief in me. Finally, to the Graduate Administration, my appreciation for research money, but resentments for procedures that called for almost one hoop too many.

Morris David Edwards
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WESTERN MICHIGAN UNIVERSITY, M.A., 1978
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INTRODUCTION

Much of the research and popular interests in biofeedback procedures have arisen from Kamiya's work (1969), demonstrating that Ss could learn to discriminate between an alpha and a non-alpha state. Kamiya also showed that Ss could learn to enhance as well as suppress alpha activity when given a discrete auditory stimulus signaling increases in alpha wave activity.

After an initial period of extreme enthusiasm, discrepant findings led to a split between that faction whose studies indicated that EEG waves could be both enhanced and suppressed (Brown, 1970; Hardt, 1974; and Travis, Kondo, and Knott, 1974a, 1974b) and that faction whose studies seemed to indicate that EEG wave conditioning was not really conditioning at all, but rather explained by "the demand characteristics of the situation" and other factors such as overcoming inhibition of alpha (Cleeland, Booker, and Hosokawa, 1971; Lynch, Paskewitz, and Orne, 1974; and Walsh, 1972, 1974). Hardt (1975) and Hardt and Kamiya (1976a) point out that such discrepancies result from methodological problems rather than an inability to learn control of brain wave rhythms.

Hardt (1975) in a panel discussion of the Biofeedback Research Society pointed out the problem of evaluating biofeedback research. Hardt noted that all six of the studies presented used different procedures while giving biofeedback training. Among the variety of procedural differences addressed were: length of training, threshold settings, type of feedback, data collection, and electrode sites.
Hardt and Kamiya (1976a) attempted to help explain the discrepancies found in brain wave training by manipulating some of these crucial variables. Hardt and Kamiya related that most studies failing to find significant brain wave control used a strict percent time feedback signal (threshold is set and signal is activated only by surpassing that threshold; strictly an on-off signal) and data collection procedure (% of time in specific brain wave over total trial time). Those studies achieving successful training tended to use an analogue signaling procedure (in feedback signal is proportional to amount of EEG wave produced) and scoring index (increase or decrease in EEG wave amplitude). It is important to note that some percent time studies have shown positive results, but these used some additional training procedures as an adjunct to the strict percent time method. For example, Gannon and Sternbach (1972) used a shaping procedure as the $S$ gained proficiency. Travis, Kondo, and Knott (1974a) used unique threshold settings for each $S$ by taking 50% of the peak alpha amplitude produced by the $S$ during the baseline session.

Hardt and Kamiya (1976a) directly compared the percent time ($%_t$) and integrated amplitude ($I$) methods of biofeedback training. Sixteen college males were given 5.6 hours of alpha training from the midline occipital site ($O_2$) with both $%_t$ and $I$ scores collected. After a baseline session, training was given over seven consecutive days except Sunday. Sessions were broken down into five parts: 1st Baseline (8 min.), Alpha Enhancement training (32 min.), Break (10-15 min.), 2nd Baseline (8 min.), and Alpha Suppression training (16 min.). Results indicated that the $I$ procedure was different from and superior to the $%_t$. 

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The present study will attempt to systematically replicate and expand the Hardt and Kamiya study by comparing the effectiveness of different feedback methods at enhancing both alpha and theta amplitudes. In addition to the percent time and integrated amplitude methods, a changing criterion shaping procedure ($%\theta$) will be examined. All three methods will be studied for their ability to enhance alpha/theta production on both sides of the brain.

Much of the debate over the enhancement of brain wave activity and training methods have centered around alpha. Until recently theta brain wave training has not been examined as thoroughly as alpha for a number of reasons. First, alpha has gotten more attention in the media with the coverage of all the mind expansion techniques such as transcendental meditation. A second and more important reason is the transitory nature of the theta phenomenon. Some have believed that theta was too transitory to condition. A third reason was a lack of awareness of what the subjective experiential correlates of theta were. Since theta was associated with extreme drowsiness, some researchers assumed that Ss would be unaware of what was happening while in a prolonged predominantly theta state. Recent studies (Green and Green, 1977, pp. 118-152; Sittenfeld, Budzynski, and Stoyva, 1976; Birbaumer, 1977; and Lutzenberger, Birbaumer, and Steinmetz, 1976) have encouraged studying theta for its enhancement and effects on consciousness.

A review of the literature indicates that attempts to begin directly training theta have not proven successful, but a "differential shaping" procedure has significantly enhanced theta amplitudes
(Sittenfeld, Budzynski, and Stoyva, 1976). Sittenfeld et al. used a two phase training procedure that entailed a lowering of somatic arousal (decreased frontalis tension training) before theta feedback training was initiated.

In that study, heart rate, theta EEG (θ), frontal EMG, and forearm EMG were measured while 20 subjects were given two types of θ enhancement training. The Ss were divided into high and low EMG groups. Four groups were then formed as follows: 5 low EMG Ss who received straight θ training, 5 high EMG Ss who received straight θ training, 5 low EMG Ss who received low EMG arousal training then θ training, and 5 high EMG Ss who received low EMG arousal training then θ training. One adaptation, three baseline, eight feedback, and two post-baseline sessions were attended by all Ss. Results indicated that baseline frontal EMG levels related to the effect of training methods. Ss with high EMG succeeded in increasing their θ production only when given the biphasic training procedure. Ss with low EMG levels performed better when given only θ feedback. Sittenfeld, et al. concluded that amounts of θ can reliably be increased, but that "training techniques should be adapted to the physiological characteristics of the individual — in this case, baseline levels of frontal EMG levels."

Birbaumer (1977) used a similar "differential shaping" procedure to enhance θ production. This study was designed to test the influence of pretraining frontalis reduction and simultaneous heart rate slowing on θ enhancement. Twenty normal Ss were given one baseline session then four half-hour pretraining sessions with simultaneous
heart rate and frontalis feedback. Ten Ss received contingent feedback (CF) on heart rate and frontalis tension, while the remaining ten received noncontingent feedback (NCF). Both groups attempted to reduce the two physiological measures. Only the CF group succeeded in lowering EMG during the first pretraining session and maintaining that level. Heart rate had a weak decrease over sessions because of a strong adaptation effect. After this pretraining, all Ss received eight sessions of θ feedback from the frontal area (Fz to mastoid) with four sessions of CF and four sessions of NCF in balanced order. Results showed a significant increase in theta activity for the CF group across sessions although pretraining had no influence on θ training. Birbaumer concludes that muscle relaxation must be very extensive before the central nervous system is affected in the direction of sleep onset theta rhythms.

Birbaumer's study also presented a brief review of θ literature and included a citation of Banquet's work with meditators (1973). Banquet's study revealed two stages of meditation that had specific characteristics. Stage 1 of meditation was found to consist of a "dramatic increase in alpha abundance." Stage 2 was characterized by an "increase of trains of occipital theta with a constant frequency that is different from the mixed frequencies found in drowsiness." Kasamatsu and Hirai (1969) found similar results studying Zen meditators. This indicates that θ enhancement may be possible by first taking a person through low arousal alpha training. It also points out that θ is associated with other thought processes besides drowsiness, perhaps information processing.
The present study attempted to utilize a "differential shaping" procedure with alpha enhancement as the first phase, alpha-theta as the middle phase, and finally a theta enhancement phase. Since alpha is a low-arousal state, the author believes that it may function in a similar manner to the EMG tension and heart rate lowering pretraining that appeared in previous studies. Aside from Green and Green (1977, pp. 118–152) who used two session alpha training as a lead into theta, no other attempt at θ enhancement through a triphasic training paradigm has been attempted.

A final word about the uniqueness of this present study. While much work has been done on hemispheric specialization and their activities during specific tasks (Galín, 1974; Ornstein, 1972; Bogen, 1969), little has been done in studying what goes on in both hemispheres during biofeedback training. Biofeedback given for hemispheric symmetry and asymmetry has been achieved (Schwartz, Davidson, and Pugash, 1976), but studying the electrical activity of the right hemisphere while doing training on the left has not been systematically observed. The present study attempts to look at alpha and theta activity in both hemispheres of the brain while biofeedback training is taking place.

In summary, the present study seeks to address the following experimental questions: 1) Can theta be enhanced by a "differential shaping" procedure? 2) Which of three training methods (integrated amplitude, percent time, and changing criterion shaping) is most effective at enhancing theta production? and 3) What effect does biofeedback training have on hemispheric symmetry or asymmetry?
METHOD

Subjects

Subjects (Ss) were 12 male college students ranging in age from 19 to 29 with a median age of 22 years. These Ss were selected from a field of right hand-dominant, male volunteers. This was done to ensure greater likelihood that hemispheric organization was consistent (Ornstein, 1972). Any medical disorders, history of drug abuse or previous exposure to formal training in relaxation techniques excluded a S from the study. The screening procedure also involved an assessment of each S with respect to the following personality variables: (1) Rotter Internal-External Controllers Scale, (2) Barron Ego-Strength Scale from the MMPI, and (3) State Trait Anxiety Scale. These measures have been significantly correlated with alpha enhancement through biofeedback training by other investigators (Hardt, 1975; Hardt and Kamiya, 1976a). S selection by personality factors was conducted by transforming each Ss test results to Z scores derived from the S sample. These scores were noted to range from +4.2 to -3.7 with an established cut-off of zero. All Ss falling above the zero cut-off level were accepted into the study and scored high on internal locus of control, high in "ego-strength", and maintained low anxiety profiles.

Pre-experimental data collected on alpha (θ1) were used to rank order and randomly assign Ss to one of three groups. Assignments were balanced for time of day and equal numbers of Ss in each group.
Setting and Apparatus

All experimental sessions took place in a local hospital setting where Ss were observed in a 10 x 12 ft. semi-soundproof, temperature and humidity controlled room. The experimental room was located in the Midwest Oncology Center of the Stryker Building, an affiliation of Borgess Hospital, Kalamazoo, Michigan. During the investigation, the room was equipped with an amply cushioned reclining chair, adjustable lighting, an intercom system, a digital (LED) display unit for visual feedback of alpha/theta amplitudes or percent times, and three pre-amplifiers accommodating power to the feedback console as well as electrode interfacing. The computer console itself was housed in an area adjacent to the experimental room.

In general, the purpose of the EEG feedback system was to: (1) detect and quantify the presence of bilateral alpha and theta amplitudes simultaneously; (2) present or remove auditory feedback (tone) according to the designated training paradigms; and (3) present an ongoing visual display (LED) of quantified alpha/theta amplitudes or percent time scores to the Ss.

A computerized modular feedback system, manufactured by Med. Associates, carried-out physiologic recording of the four channel EEG activity. The essential components involved were: (a) two alpha and two theta bandpass filters which selectively detected the presence of alpha and theta rhythms at a frequency of 8-13 Hz and 4-8 Hz, respectively, the bandpass filters maintained a roll-off of 30 dB/octave; (b) analog to digital converters were employed to process and relay EEG impulses to a DIG 800 computer system for
register counting and numerical digital displays; (c) EEG filters were interfaced with an integrating module where the output was then relayed to a threshold comparator. The comparator functioned as a binary control for establishing percent time thresholds and terminated audio feedback whenever EEG activity fell below pre-selected threshold levels; (d) an interface between the comparator and voltage controlled oscillator (VCO) produced a steady monotone for alpha/theta detected above threshold for Ss in the percent-time and changing-criterion (shaping) groups. Integrated amplitude Ss received a continuous analog signal above threshold in the absence of an auditory hold on the VCO. Alpha and theta amplitudes were recorded simultaneously from both the left occipital (O1) and right occipital (O2) lobes with reference to left and right ear lobes.

Alpha and theta were defined as: (1) the bandpass filter limits set to 8-13 Hz and 4-8 Hz traversing the dominant frequencies and (2) amplitude thresholds set at 50% of each Ss own eyes-closed "resting" alpha and theta levels (Travis et al., 1974a, 1974b).

Experimental Design

All Ss were given one preliminary recording session without feedback to familiarize them with the experimental setting, electrode attachment and recording procedures. During this session, pre-experimental data were obtained on eyes-closed "resting" alpha and theta levels (bilaterally) over a 40-minute baseline period. Scoring intervals were 100-seconds in duration. The highest alpha
amplitude score recorded off the left occipital (O1) site for each S was used as a blocking variable for classification in a randomized block design. It was determined that this design would accommodate amplitude variability among Ss and therefore maintain the assumption of homogeneity. On the basis of this design, Ss were randomly assigned to one of the following three treatment groups: (1) Integrated Amplitude (I), (2) Percent-time (%t), and (3) Percent-time shaping (%s). The experimental design can be seen in Table 1.

Feedback training was conducted over 9, 90-minute sessions. Ss were scheduled for training 3 days a week for a period of 3 weeks. With this arrangement, Ss were trained over the course of a three-phase feedback program including: (1) alpha - 3 sessions, (2) combined alpha and theta - 3 sessions, and (3) theta - 3 sessions. Following a five minute period of acclimation, individual sessions were divided into four recording conditions: (a) first baseline, 10 minutes no feedback; (b) EEG feedback with instructions to enhance either alpha, alpha and theta, or theta, 30 minutes; (c) second baseline, 10 minutes no feedback; (d) EEG feedback with instructions to suppress either alpha, alpha and theta, or theta activity, 10 minutes. Reversal of the auditory feedback tone was carried out on every third session. Recording conditions were separated by 100-second intervals. Pre-printed instructions were also prepared for introducing the Ss to a 5-minute breathing exercise. This was included as part of the biofeedback training and conducted just after the first baseline condition had been completed in each session (Green and Green, 1977). Each S received a total of
TABLE 1

EXPERIMENTAL DESIGN. EACH SCORE REPRESENTS AMPLITUDE DIFFERENCES DERIVED FROM EACH OF THE FOUR WITHIN-SESSION RECORDING CONDITIONS

| (\%s) A₁ |  |  |  |  | Session 1 | 2 | 3 | Session 4 | 5 | 6 | Session 7 | 8 | 9 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S₀₀₃ | X₃ | X₃ | X₃ | | | | | | | | | | | | | ΣXₐ₁ |
| S₀₀₆ | X₆ | X₆ | X₆ | | | | | | | | | | | | |  |
| S₀₀₉ | X₉ | X₉ | X₉ | | | | | | | | | | | | |  |
| S₀₁₂ | X₁₂ | X₁₂ | X₁₂ | | | | | | | | | | | | |  |
| | ΣXₐ₁B₁ | ΣXₐ₁B₂ | ΣXₐ₁B₃ | ΣXₐ₁ |

| (\%t) A₂ |  |  |  |  |  | | | | | | | | | | | |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S₀₀₂ | X₂ | X₂ | X₂ | | | | | | | | | | | | | ΣXₐ₂ |
| S₀₀₅ | X₅ | X₅ | X₅ | | | | | | | | | | | | |  |
| S₀₀₈ | X₈ | X₈ | X₈ | | | | | | | | | | | | |  |
| S₀₁₁ | X₁₁ | X₁₁ | X₁₁ | | | | | | | | | | | | |  |
| | ΣXₐ₂B₁ | ΣXₐ₂B₂ | ΣXₐ₂B₃ | ΣXₐ₂ |

| (∥) A₃ |  |  |  |  |  | | | | | | | | | | | |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S₀₀₁ | X₁ | X₁ | X₁ | | | | | | | | | | | | | ΣXₐ₃ |
| S₀₀₄ | X₄ | X₄ | X₄ | | | | | | | | | | | | |  |
| S₀₀₇ | X₇ | X₇ | X₇ | | | | | | | | | | | | |  |
| S₀₁₀ | X₁₀ | X₁₀ | X₁₀ | | | | | | | | | | | | |  |
| | ΣXₐ₃B₁ | ΣXₐ₃B₂ | ΣXₐ₃B₃ | ΣXₐ₃ |

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120-minutes of training in each phase of the experiment or an overall total of 6.0 feedback hours. All scoring periods were 100-seconds long. At the close of each scoring period, during feedback training, the tone would terminate and the S would then see an illuminated 3-digit score for approximately 10-seconds.

Following electrode placement, Ss were seated in a well cushioned recliner maintained in a dimly lit room. The E then read a specific set of pre-printed instructions concerning training procedures associated with the ongoing training phase. The instructions were presented as follows:

**Integrated Amplitude (I)**

Your brainwave activity will control a tone which will be fed back to you through a set of earphones. The degree or amount of (alpha, alpha/theta, theta) you produce will determine the direction of the tone. As you increase ____________, the tone will also increase (rise). As ____________ decrease, the tone will decrease (fall). Finally, the tone will shut off entirely when _______ gets too low. The object then is to keep the tone on and as high in pitch as you can. One final source of feedback will be the digital display. Numbers will appear on the display to tell you how much ____________ you are producing. Use these numbers only as a reference point in determining your progress. At the end of each training trial I will ask you through the earphones to "assimilate". You will then open your eyes, look at the display, I will allow you 10-seconds then instruct you to begin the next training trial.

**Percent-Time (%)**

Your brainwave activity will control a tone which will be fed back to you through a set of earphones. The degree or amount of (alpha, alpha/theta, theta) you produce will determine whether or not a tone will be present. When you produce a sufficient amount of ____________ a tone will come on. However, if your _______ levels get too low, the tone will shut off. The object then is to keep the tone on as long as possible. One final source
of feedback will be the digital display. Numbers will appear on the display to tell you the percentage of time you are producing a sufficient amount of _________ above threshold. Use these numbers only as a reference point...

Percent-Time Shaping (%)

Your brainwave activity will control a tone which will be fed back to you through a set of earphones. The degree or amount of (alpha, alpha/theta, theta) you produce will determine whether or not a tone will be present. When you produce a sufficient amount of _________ a tone will come on. However, if your _________ levels get too low, the tone will shut off. The object then is to keep the tone on as long as possible. As you become more proficient at keeping the tone on for longer periods of time, the level or threshold at which you are able to turn the tone on will be raised. As threshold levels are changed upward, this will indicate that you are gradually increasing your _________ output. You will be informed each time one of these new thresholds is set for you. One final source of feedback will be the digital display. Numbers will appear on the display to tell you the percentage of time you are producing a sufficient amount of _________ above threshold. Use these numbers only as a reference point...

Instructions for appropriate conditions were always presented to each S prior to the initiation of a session. The S was then prepared for two-way communication (intercom) through the use of earphones and a clip-on microphone. The E then left the room and closed the door. The intercom system permitted continuous monitoring of the S. Physiologic recording was initiated and appropriate feedback (alpha, alpha/theta, theta) was provided only during the training and suppression conditions. Ss were instructed to avoid movements and to keep their eyes closed at all times with the exception of brief periods when the illuminated 3-digit scores were displayed (feedback conditions only).
RESULTS

Data Analysis Methods

Data breakdown for analysis for EEG training effects was accomplished by obtaining differences in mean amplitudes from each of the four within-session recording conditions (see pg. 10) for each S. This procedure was carried out for both α and θ brain wave rhythms recorded off occipital locations O1 and O2. The critical analysis in the present investigation focused on amplitude differences derived from pre- to post-session baselines. It was determined that these scores would most accurately reflect acquisition of the target response (θ) as a function of the training variables across phases.

The following analyses were performed to reveal the effects of treatments and treatments by phase on bilateral EEG activity: (1) Repeated Measures Analysis of Variance (RMAOV) with one repeated factor ("B") where all Treatments were aligned on factor "A" and Phases on factor "B"; and (2) Correlation coefficients and scatter plots generated from bilateral θ and α for each group across phases. Correlations analyses were based on mean (X̄) amplitude differences within individual groups and across sessions. Analysis by correlation was also performed on eyes closed "resting" α1/α2 and θ1/θ2 baselines obtained during the "orientation" session (first visit).
Statistical Analysis

Comparison of Pre- to Post-Baseline Differences

RMANOVs performed on pre- to post-sessions $\bar{X}$ amplitude differences did not yield significant findings on $\theta_1$, $\alpha_1$, and $\alpha_2$. However, an analysis of $\theta_2$ activity revealed significant main effects on factor "A" ($F= 4.286, p< .05$). A test of Critical Differences Ratios (LSD) by phase on all $\theta_2$ pairwise comparisons showed that the $f$ group produced significant increases in right occipital $\theta_2$ when compared to the $z_s$ and $z_t$ groups in Phase III. These values are reflected in Table 2.

Bilateral changes in $\theta$ activity within groups and across phases are depicted in Fig. 1. These data show sequential increases (by phase) in $\bar{X}$ pre- post- $\theta$ differences for $S$s receiving $f$ feedback training. Bilateral increases of approximately 50% were observed from Phase I to Phase III and Phase II to Phase III. The binary feedback groups did not produce significant changes in $\theta$ across Phases I and II. Phase III effects for both of these groups generally reflected sharp decreases in bilateral $\theta$. Product-moment correlations performed on $\theta_1/\theta_2$ relationships were then conducted to determine degree of symmetry on the learning tasks. Data analysis revealed that bilateral hemispheric changes correlated highly for the $f$ group in the acquisition of $\theta$ ($r = .76, p < .05$) across phases. Bilateral $\theta$ correlated minimally for the $z_s$ ($r = .14$) and the $z_t$ ($r = .10$) groups.
<table>
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<td>1.050 - 1.793</td>
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<td>.507</td>
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<tr>
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<td>1.029</td>
</tr>
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<td>-.333 - 1.108</td>
<td>1.441</td>
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<td>.044</td>
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<tr>
<td>( %_S ) vs ( f )</td>
<td>-1.142 - 3.140</td>
<td>4.282</td>
<td>2.92**</td>
</tr>
<tr>
<td>( %_T ) vs ( f )</td>
<td>1.290 - 3.140</td>
<td>1.850</td>
<td>1.85*</td>
</tr>
</tbody>
</table>

* \( p < .20 \)

** \( p < .05 \)
Fig. 1: Pre-Post-Baseline Session By Session Mean Amplitude Differences
Though main effects on $\alpha$ in the pre- to post- analysis did not emerge at the .05 level, a treatment effect was found at the .10 level of significance. Graphic configurations on this finding are displayed in Fig. 2 as changes in bilateral $\alpha$. Visual inspection of the graph shows that the $%s$ group demonstrated bilateral increases of approximately 25% from Phase I to Phase III and approximately 80% from Phase II to Phase III. Both $f$ and $%t$ groups did not demonstrate substantial $\alpha$ increases across phases. It was noted that both $\theta$ and $\alpha$ generally decreased during sessions four and five (Phase II) in all treatment groups while increases began to develop during session six (Phase III). Correlations performed on the $\alpha_1/\alpha_2$ relationships indicated that the $%s$ group demonstrated a high degree of symmetry ($r = .94, p < .01$). The $f$ group showed moderate correlations ($r = .49$) while the $%t$ group exhibited the lowest $\alpha$ correlations ($r = .31$).

Comparison of Pre- Baseline to Training Differences

Pre- to post-session baseline results were corroborated by findings revealed in multiple RMAOVs performed on $\bar{X}$ amplitude differences from pre-session baseline to training conditions. These analyses were conducted to determine variability to amplitude change as a function of the feedback techniques used during the training "proper". Significant main effects were found on factors "A" for both $\theta_2$ ($F = 5.869, p < .02$) and $\alpha_1$ ($F = 4.318, p < .05$). LSD testing, by phase, on $\theta_2$ main effects showed that the $f$ group significantly enhanced right occipital $\theta$ when compared to the $%s$ group in all three phases and the $%t$ group in Phase I. Pairwise comparisons
between \( \%t \) and \( \%s \) groups revealed the superiority of the \( \%t \) group at enhancing \( \theta_2 \) in Phase II and Phase III. Values from group-wise comparisons are displayed in Table 3.

Bilateral changes in \( \theta \) activity derived from pre-baseline to training within groups are shown in Fig. 3. These data indicate that both \( f \) and \( \%t \) groups demonstrated general trends toward increasing \( \theta_2 \) during Phases I and II. The \( \%s \) group showed no significant change across phases. All three treatment groups exhibited sharp decreases in \( \theta_2 \) during Phase III. It was also observed that \( \bar{x} \) amplitude differences for the \( f \) and \( \%t \) groups by phase were substantially higher during pre-baseline to training than pre- to post. Correlations performed on \( \theta_1/\theta_2 \) relationships within groups did not render any significant findings.

LSDs were also performed on \( \alpha_1 \) main effects by phase. Results revealed that the \( \%s \) group significantly enhanced left occipital \( \alpha \) when compared to the \( f \) group in Phases I and III. In contrast to the \( \%t \) group, the \( \%s \) group was found to be superior only in Phase III. A significant finding for the \( \%t \) group did emerge in comparison to the \( f \) group during Phase II. In this analysis, these data appear to indicate that overall, the \( \%t \) group was never superior to the \( \%s \) group. Additionally, the \( f \) group was the least effective at increasing left occipital \( \alpha \) when compared to either of the binary groups. Results from the LSDs are shown in Table 4.

Bilateral changes in \( \alpha \) activity occurring from pre-baseline to training conditions within groups are presented in Fig. 4. Correlations conducted on the \( \alpha_1/\alpha_2 \) data generated from pre-baseline to
### TABLE 3

**CRITICAL DIFFERENCES RATIOS (LSD) PERFORMED ON MAIN EFFECTS**  
(Factor "A") from RMAOV on α₁ (Pre-Baseline to Training)

<table>
<thead>
<tr>
<th>Population Contrast</th>
<th>Sample Contrast</th>
<th>Absolute Value</th>
<th>t Critical</th>
</tr>
</thead>
<tbody>
<tr>
<td>%s vs %t</td>
<td>4.632 - 3.200</td>
<td>1.432</td>
<td>.974</td>
</tr>
<tr>
<td>%s vs f</td>
<td>4.632 - .225</td>
<td>4.407</td>
<td>2.998**</td>
</tr>
<tr>
<td>%t vs f</td>
<td>3.200 - .225</td>
<td>2.975</td>
<td>2.023*</td>
</tr>
<tr>
<td>%s vs %t</td>
<td>5.325 - 6.700</td>
<td>1.375</td>
<td>.930</td>
</tr>
<tr>
<td>%s vs f</td>
<td>5.325 - 2.025</td>
<td>3.300</td>
<td>2.24*</td>
</tr>
<tr>
<td>%t vs f</td>
<td>6.700 - 2.025</td>
<td>4.675</td>
<td>3.18**</td>
</tr>
<tr>
<td>%s vs %t</td>
<td>6.825 - 1.125</td>
<td>5.700</td>
<td>3.877***</td>
</tr>
<tr>
<td>%s vs f</td>
<td>6.825 - .367</td>
<td>1.468</td>
<td>4.393***</td>
</tr>
<tr>
<td>%t vs f</td>
<td>1.125 - .367</td>
<td>.758</td>
<td>.515</td>
</tr>
</tbody>
</table>

* P < .10  
** P < .05  
*** P < .01  

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TABLE 4
CRITICAL DIFFERENCES RATIOS (LSD) PERFORMED ON MAIN EFFECTS
(FACTOR "A") FROM RMAOV ON $\theta_2$ (PRE-BASELINE TO TRAINING)

<table>
<thead>
<tr>
<th>POPULATION CONTRAST</th>
<th>SAMPLE CONTRAST</th>
<th>ABSOLUTE VALUE</th>
<th>t CRITICAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHASE I</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>%s vs %t</td>
<td>-.175 - 3.250</td>
<td>3.425</td>
<td>1.999*</td>
</tr>
<tr>
<td>%s vs f</td>
<td>-.175 - -6.882</td>
<td>7.057</td>
<td>4.120***</td>
</tr>
<tr>
<td>%t vs f</td>
<td>3.250 - -6.882</td>
<td>3.632</td>
<td>2.120*</td>
</tr>
<tr>
<td>PHASE II</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>%s vs %t</td>
<td>.067 - 4.358</td>
<td>4.291</td>
<td>2.505**</td>
</tr>
<tr>
<td>%s vs f</td>
<td>.067 - 4.033</td>
<td>3.966</td>
<td>2.315**</td>
</tr>
<tr>
<td>%t vs f</td>
<td>4.358 - 4.033</td>
<td>.328</td>
<td>.192</td>
</tr>
<tr>
<td>PHASE III</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>%s vs %t</td>
<td>.383 - 4.790</td>
<td>4.407</td>
<td>2.573**</td>
</tr>
<tr>
<td>%s vs f</td>
<td>.383 - 5.710</td>
<td>5.327</td>
<td>3.110**</td>
</tr>
<tr>
<td>%t vs f</td>
<td>4.790 - 5.710</td>
<td>.920</td>
<td>.538</td>
</tr>
</tbody>
</table>

* p < .10
** p < .05
*** p < .01

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Fig. 4 Pre-Baseline - Training Session By Session Mean Amplitude Differences

Legend: 
- - - - - $a_2$
- - - - - $a_1$
training indicated that bilateral hemispheric changes correlated highly for the % group in the acquisition of \( \alpha \) (\( r = 0.82 \), \( p < 0.01 \)) across phases. Non-significant correlations were found for % (\( r = 0.07 \)) and \( \beta \) (\( r = 0.39 \)) groups.

RMAOVs were also run on training to post-baseline and post-baseline to suppression conditions. These analyses did not reveal any significant main effects on interactions.

One final analysis was performed on \( \alpha_{1}/\alpha_{2} \) and \( \theta_{1}/\theta_{2} \) baselines obtained during the "orientation" session. Multiple correlations were run on bilateral \( \alpha_{1}/\alpha_{2} \) and \( \theta_{1}/\theta_{2} \) within each individual S. It was determined that these findings would reveal naturally occurring hemispheric relationships. Individual correlations by S within groups are displayed in Table 5.
<table>
<thead>
<tr>
<th>SUBJECTS</th>
<th>CORRELATION COEFFICIENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( \theta_1 ) vs ( \theta_2 )</td>
</tr>
<tr>
<td>( S_{003} )</td>
<td>.325</td>
</tr>
<tr>
<td>( S_{006} )</td>
<td>.994</td>
</tr>
<tr>
<td>( S_{009} )</td>
<td>.990</td>
</tr>
<tr>
<td>( S_{012} )</td>
<td>.982</td>
</tr>
<tr>
<td>( S_{002} )</td>
<td>-.046</td>
</tr>
<tr>
<td>( S_{005} )</td>
<td>.798</td>
</tr>
<tr>
<td>( S_{008} )</td>
<td>.985</td>
</tr>
<tr>
<td>( S_{011} )</td>
<td>.865</td>
</tr>
<tr>
<td>( S_{001} )</td>
<td>.986</td>
</tr>
<tr>
<td>( S_{004} )</td>
<td>.965</td>
</tr>
<tr>
<td>( S_{007} )</td>
<td>.732</td>
</tr>
<tr>
<td>( S_{010} )</td>
<td>.864</td>
</tr>
</tbody>
</table>
DISCUSSION

The most important finding of this study is a definite enhancement of right occipital theta. While this finding was unexpected, it may fit in with more recently altered views of what increased theta densities signify as well as new implications for hemispheric symmetry and information processing. Recent research (Gevins, Zeitlin, Doyle, Yingling, Yeager, and Callaway; 1978) suggests that increases in theta activity may indicate a state of low arousal, but more active processing of information rather than mere drowsiness as was first suspected.

The data indicate that the / group not only enhanced $\Theta_{02}$ amplitude, but may also have retained the necessary conditions for a greater degree of bilateral symmetry of these phenomena. This is evidenced by the high correlation. The pattern exhibited in Fig. 1 indicates that there is a shared learning pattern (the hemispheres showed similar patterns of acquisition of amplitude differences) of $\Theta$ amplitude differences in the / group. It might be expected that the hemisphere where feedback is derived should show greater amplitude increase. This need not be so, as the training hemisphere may be expending more energy acquiring the response. Theta$_{01}$ amplitude difference levels may be the result of greater involvement by that analytical hemisphere and therefore slightly lower amplitude changes. Gevins et al. also intimate that some type of cortical theta activity may be associated with transmission of information from one region of the cortex to another. This may be what is operating here.
The left hemisphere may be doing the initial processing, but that is also shared with the right hemisphere. This interpretation may be viewed as speculative until further research analyzing bilateral changes during EEG training takes place.

The symmetrical line-up of the two hemispheres is unmistakable. While further correlative study of trial by trial feedback effects is necessary, the present study's findings indicate that feedback does not disturb naturally occurring correlations (See Fig. 3 and Table 5). The high correlation exhibited by the / group may indeed shed some light on the physiology of the complex learning task. Schwartz (1977) states "The activation of both hemispheres may typically involve the generation of complementary behavior and cognition." This implies that a complex learning task that is composed of two or more specialized facets may align both hemispheres. Biofeedback is just such a task. The fact that the / group showed a significant difference may show that it is more successful at retaining symmetry due to the nature of the feedback tone and the more abundant amount of information. The percent time groups may hinder or disrupt this symmetry because less information is received and the two hemispheres are trying to analyze what is happening.

Another aspect of the high symmetry may be the accompaniment of a greater relaxation response. Patel (1977) indicates that EEG desynchronization is linked with stressful situations. While symmetry (amplitude measures) and synchronization (frequency measures) are not equal measures, the author believes the present
results point toward lessened arousal with increases in theta and greater hemispheric symmetry. Greater relaxation may be a product of the type of feedback presented. The $\downarrow$ group retained symmetry while the $\%$ time groups disturbed symmetry. Receiving more information may enable a person to be less anxious in a learning situation and it seems that $\downarrow$ group feedback offers more information. The percent time type feedback may run counter productive to learning the target response, $\Theta$, as it appears from the present study. Not only does $\Theta$ production drop sharply, but there are all kinds of asymmetry created between the hemispheres. This may be caused by greater arousal by the person due to less information received. More time is spent trying to figure out what the feedback means. Additionally, percent time feedback procedures may present the $S$ with the task of actively asserting oneself in a situation that requires a highly passive approach (Williams, 1976). Further research into the relationship of amplitude and frequency changes during feedback training is necessary to establish high symmetry as an indicator of low arousal.

While these conclusions are not definitive, they offer some interesting implications for practical life situations such as education or other learning situations. It may mean that continuous feedback may produce less anxiety while acquiring the target responses. The availability of more information will necessitate the expenditure of less energy (lower arousal) (R.R. Williams, Informal communication, 1978). It may be that discrete feedback
after a task is more anxiety producing and hinders acquisition during learning.

Results surrounding $\alpha_1$ enhancement may at first seem inconsistent, but need not necessarily be so. Although pre- to post-baseline scores did not reach the author's critical cut-off level, the trend of a slight superiority of the percent time groups may be seen (This is also true of the pre-baseline to training segment). This may indicate that the % groups performed adequately though erratically during the first two phases of training, but they did not allow the $S_s$ to make the critical transition to $\theta$. The $f$ group may have been able to adapt more easily since they received more information on their performance. It is also important to note that the present study was designed with $\theta$ as the target response and not $\alpha$. Due to the greater $\theta$ enhancement and symmetry, the author encourages the use of the integrated amplitude procedure.

One last result deserves passing mention. The author's analysis revealed no significant differences in post-suppression scores. It may be that the author did not allow sufficient time for training of that behavior. Hardt and Kamiya (1976a) may have been successful in training suppression due to the extended training time. The author agrees with Brown (1974, p. 335) that enhancement and suppression of EEG brain wave activity are two different learning tasks that may be governed by different mechanisms.

There are several improvements that could be applied to the present experimental design that would produce a tighter study and
yield more conclusive results. First, there should be a greater flexibility in phasic division. The author's arbitrary establishment of three sessions per phase should be forsaken for a more individually based model. Learning criteria should be established so that sufficient acquisition of the phasic target response is achieved before entering the next phase. In this respect our findings support Hardt and Kamiya (1976a) that length of training time is important in learning control of brain wave patterns. Secondly, better provisions can be made so that Ss receive more specific information during the α/θ phase. In the present study, the nature of the feedback signal was such that Ss did not know what proportion of θ was responsible for producing the tone. The feedback machine could be programmed differently so that more theta would be produced to set off the tone. Another addition to the current experimental design would include increased data collection on EMG levels, EEG frequency, heart rate, and skin response. These additional measures would corroborate that brain wave measures (higher θ) would appear as less arousal (anxiety) is experienced. A more complete psychophysiological profile could then be established and connections between central and peripheral neural linkages and their relationship to human behavior arrived at (Schwartz, 1977). A final design change might come in S selection. A greater reliance on physiological profiling rather than personality variable might be more practical in regard to the measures that are target responses.
Several facets of the present study have not been thoroughly explored. The findings of this research may prompt greater exploration in several areas. First, more multiple site EEG recording studies might be done to assess simultaneous effects of feedback training on numerous areas of the brain. More study needs to be done on right hemisphere training to see if similar symmetry occurs. Study should be undertaken to determine the effects of a triphasic training paradigm. Research comparing monophasic, diphasic, and triphasic approaches could be done to evaluate the necessity of a triphasic approach. And perhaps most importantly, advanced research comparing hemispheric effects during resting, relaxed, and learning situations under different feedback conditions would establish arousal levels of the different methods. The present study may have raised more questions than it answered, but it seems to have opened doors to some extremely interesting places.


Beatty, J.  *Similar effects of feedback signals and instructional information on EEG activity.*  *Physiology and Behavior,* 1972, 9, 151-154.


Cleeland, C.S., Booker, H.E., & Hosokawa, K.  *Alpha enhancement: Due to feedback or the nature of the task?*  *Psychophysiology,* 1971, 8, 262-263.

Galin, D.  *Implications for psychiatry of left and right cerebral specialization.*  *Archives of General Psychiatry,* 1974, 31, 572-583.


Hardt, J.V. Alpha EEG responses of low and high anxiety males to respiration and relaxation training and to auditory feedback of occipital alpha. Dissertation Abstracts International, 1974, 35(4), Catalog No. 74-19309.


Hardt, J.V., & Kamiya, J. Conflicting results in EEG alpha feedback studies: Why amplitude integration should replace percent time. Biofeedback and Self-Regulation, 1976, 1, 63-76. (a)


Lutzenberger, W., Birbaumer, N., & Steinmetz, P. Simultaneous biofeedback of heart rate and frontal EMG as a pretraining for the control of EEG theta activity. Biofeedback and Self-Regulation, 1976, 1, 4, 395-410.


Travis, T.A., Kondo, C.Y., & Knott, J.R. Alpha conditioning: A controlled study. The Journal of Nervous and Mental Disease, 1974, 158, 163-173. (a)


Williams, R.R. Personal communication, October, 1978.