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A Comparison of EEG Feedback Techniques in the Enhancement of Bilateral Theta: A Tri-Phasic Design

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A COMPARISON OF EEG FEEDBACK TECHNIQUES IN THE ENHANCEMENT OF BILATERAL THETA: A TRI-PHASIC DESIGN

by

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INTRODUCTION

Previous research in EEG biofeedback (Kamiya, 1958 and 1969) has shown that subjects provided with an auditory or visual feedback stimulus could learn to produce and discriminate between alpha and non-alpha states. Similar findings have also been reported with regard to the acquisition of theta (Green and Green, 1977). However, conflicting results among researchers appear to indicate that selective brain wave enhancement may be largely dependent upon the type of feedback provided during training. Hardt and Kamiya (1976) report that studies showing "weak" or "insignificant" alpha enhancement (Cleeland, Booker, and Hosokawa, 1971; Hord and Barber, 1971; Peper and Mulholland, 1971; Paskewitz and Orne, 1971, 1973; Honorton, Davidson, and Bindler, 1972; Mulholland, 1972; Walsh, 1972, 1974; and Podlesney and Raskin, 1973) have incorporated fixed threshold percent-time feedback signals and percent-time scoring techniques (binary, e.g. on/off). In contrast to these investigations, corroborating evidence demonstrating significant alpha enhancement (Brown, 1970; Engstrom, London, and Hardt, 1970; Kamiya, 1971; Gannon and Sternback, 1971; Travis, Kondo, and Knot, 1974a, 1974b; and Hardt, 1974) reflects the use of integrated amplitude designs (analogue or proportional) or more informative feedback models. These studies would also include the utilization of percent-time feedback procedures involving frequency feedback (Engstrom et al., 1970), threshold shaping procedures (Gannon and Sternback, 1971) and unique threshold settings for individual subjects (Travis et al., 1974a, 1974b) based on 50% of the peak alpha amplitude obtained during baseline.

Hardt (1975) has pointed out that differences in results among biofeedback researchers may be due to the following variables: length of time in training, threshold settings, type of feedback, method of data collection, and location of electrode placement. Hardt and Kamiya (1976) addressed these methodological considerations in an investigation comparing percent-time and integrated amplitude techniques. The results indicated that the integrated amplitude method was superior to a fixed percent-time model due to the range of information provided by the continuous proportional feedback signal.

Additional concerns have also been expressed with regard to both enhancement and suppression of selective brain wave patterns. A number of researchers (Brown, 1970; Hardt, 1974; and Travis, Kondo, and Knot, 1974a, 1974b) advocate that the acquisition of alpha can be demonstrated by method of reversal. On the other hand, there are those who indicate that acquisition occurs as a function of overcoming inhibition of alpha (Cleeland, Booker, and Hosokawa, 1971; Lynch, Paskewitz, and Orne, 1974; Walsh, 1974; and Plotkin and Cohen, 1976). Both Hardt (1975) and Hardt and Kamiya (1976) suggest that these conflicting viewpoints result from differing experimental methodologies rather than an inability to demonstrate learned control of the target response.

Experimental designs encompassing feedback techniques and scoring indices with respect to theta have not as yet evolved with the clarity of historical alpha findings. However, recent literature suggests that theta may not be amenable to "direct approach" training paradigms. Sittenfeld, Budzynski, and Stoyva (1976) report using a percent-time threshold shaping procedure in conjunction with a discrete two-phase training program (frontalis EMG + theta) which facilitated production of increased theta amplitudes significantly over subjects who were not provided with preliminary EMG training. A similar study by Birbaumer (1977) utilizing pre-training arousal reduction techniques (frontalis EMG + heart rate) produced results suggesting that substantial muscle relaxation must occur if the central nervous system is to respond in the direction of sleep-onset theta activity. From these findings it can be inferred that: (1) elevated somatic arousal may be contradictory to success in theta enhancement training, and (2) a substantial reduction in somatic arousal may need to be developed before awareness of more subtle cortical processes (brain activity) can take place.

Green and Green (1977) appear to support the notion of an "indirect approach" to theta by stating that, ". . . brain wave patterns have no sensory concomitants - that is, there are no sensory processes by means of which we can detect the presence of brain wave activity." These investigators report using a combination of autogenic training and alpha + theta feedback as a prelude to isolated theta training. This model would seem to be supported by previous lines of evidence suggesting that theta may gradually emerge by way of alpha. Kasamatsu and Hirai (1969, pp. 501-514) studied the brain wave activity of Japanese Zen monks and observed that, "(a) as the subject began to turn his attention inward, long trains of alpha rhythms appeared, (b) as time passed, the dominant frequency of the alpha pattern began to decrease toward the alpha - theta border region (8 Hz), and (c) some subjects (those considered most accomplished at reaching a state of deep meditation produced long trains of theta waves." Additionally, Banquet (1973), in studying meditators, found a two-stage brain wave process involved in meditation. Stage 1 consisted of "dramatic increases in alpha abundance" while Stage 2 revealed an "increase of trains of occipital theta with a consistent frequency that is different from the mixed frequencies found in drowsiness." These studies appear to suggest that access to theta may be achieved through a sequence of alpha training phases.

In view of the current research data available on EEG biofeedback, the present investigation was undertaken to determine: (1) the effects of three standard EEG feedback training procedures (integrated amplitude, percent-time, and percent-time shaping) on bilateral alpha and theta rhythms; (2) the effects of a tri-phasic (alpha, alpha + theta, theta) training paradigm aimed at increasing bilateral theta activity; (3) the use of feedback as a facilitator of alpha and/or theta suppression; and (4) the effects of training in developing and/or maintaining bilateral symmetry.

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 (Θ_1) 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 (O_1) and right occipital (O_2) 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 (O_1) 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 homogeniety. On the basis of this design, Ss were randomly assigned to one of the following three treatment groups: (1) Integrated Amplitude ($\int$), (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

	B_1 (α)	B_2 (α/Θ)	B_3 (Θ)	TOTAL
($\%_s$) A_1				
S_{003}	X_3	X_3	X_3	ΣX_{A_1}
S_{006}	X_6	X_6	X_6	•
S_{009}	X_9	X_9	X_9	•
S_{012}	X_{12}	X_{12}	X_{12}	•
	$\Sigma X_{B_1A_1}$	$\Sigma X_{B_2A_1}$	$\Sigma X_{B_3A_1}$	
($\%_t$) A_2				
S_{002}	X_2	X_2	X_2	ΣX_{A_2}
S_{005}	X_5	X_5	X_5	•
S_{008}	X_8	X_8	X_8	•
S_{011}	X_{11}	X_{11}	X_{11}	•
	$\Sigma X_{B_1A_2}$	$\Sigma X_{B_2A_2}$	$\Sigma X_{B_3A_2}$	
($\int$) A_3				
S_{001}	X_1	X_1	X_1	ΣX_{A_3}
S_{004}	X_4	X_4	X_4	•
S_{007}	X_7	X_7	X_7	•
S_{010}	X_{10}	X_{10}	X_{10}	•
	$\Sigma X_{B_1A_3}$	$\Sigma X_{B_2A_3}$	$\Sigma X_{B_3A_3}$	

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 ($\int$)

> Your brainwave activity will control a tone which will be fedback 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 ($\%_t$)

> Your brainwave activity will control a tone which will be fedback 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 ($\%_S$)

> Your brainwave activity will control a tone which will be fedback 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. 8) for each S. This procedure was carried out for both α and Θ brain wave rhythms recorded off occipital locations O_1 and O_2. 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 ($\bar{X}$) amplitude differences within individual groups and across sessions. Analysis by correlation was also performed on eyes closed "resting" α_1/α_2 and Θ_1/Θ_2 baselines obtained during the "orientation" session (first visit).

Statistical Analysis

Comparison of Pre- to Post-Baseline Differences

RMAOVs performed on pre- to post-sessions $\bar{X}$ amplitude differences did not yield significant findings on Θ_1, α_1, and α_2. However, an analysis of Θ_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 Θ_2 pairwise comparisons showed that the $\int$ group produced significant increases in right occipital Θ_2 when compared to the $\%_s$ and $\%_t$ groups in Phase III. These values are reflected in Table 2.

Bilateral changes in Θ activity within groups and across phases are depicted in Fig. 1. These data show sequential increases (by phase) in $\bar{X}$ pre- post- Θ differences for Ss receiving $\int$ 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 Θ across Phases I and II. Phase III effects for both of these groups generally reflected sharp decreases in bilateral Θ. Product-moment correlations performed on Θ_1/Θ_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 $\int$ group in the acquisition of Θ ($r = .76$, $p < .05$) across phases. Bilateral Θ correlated minimally for the $\%_s$ ($r = .14$) and the $\%_t$ ($r = .10$) groups.

TABLE 2

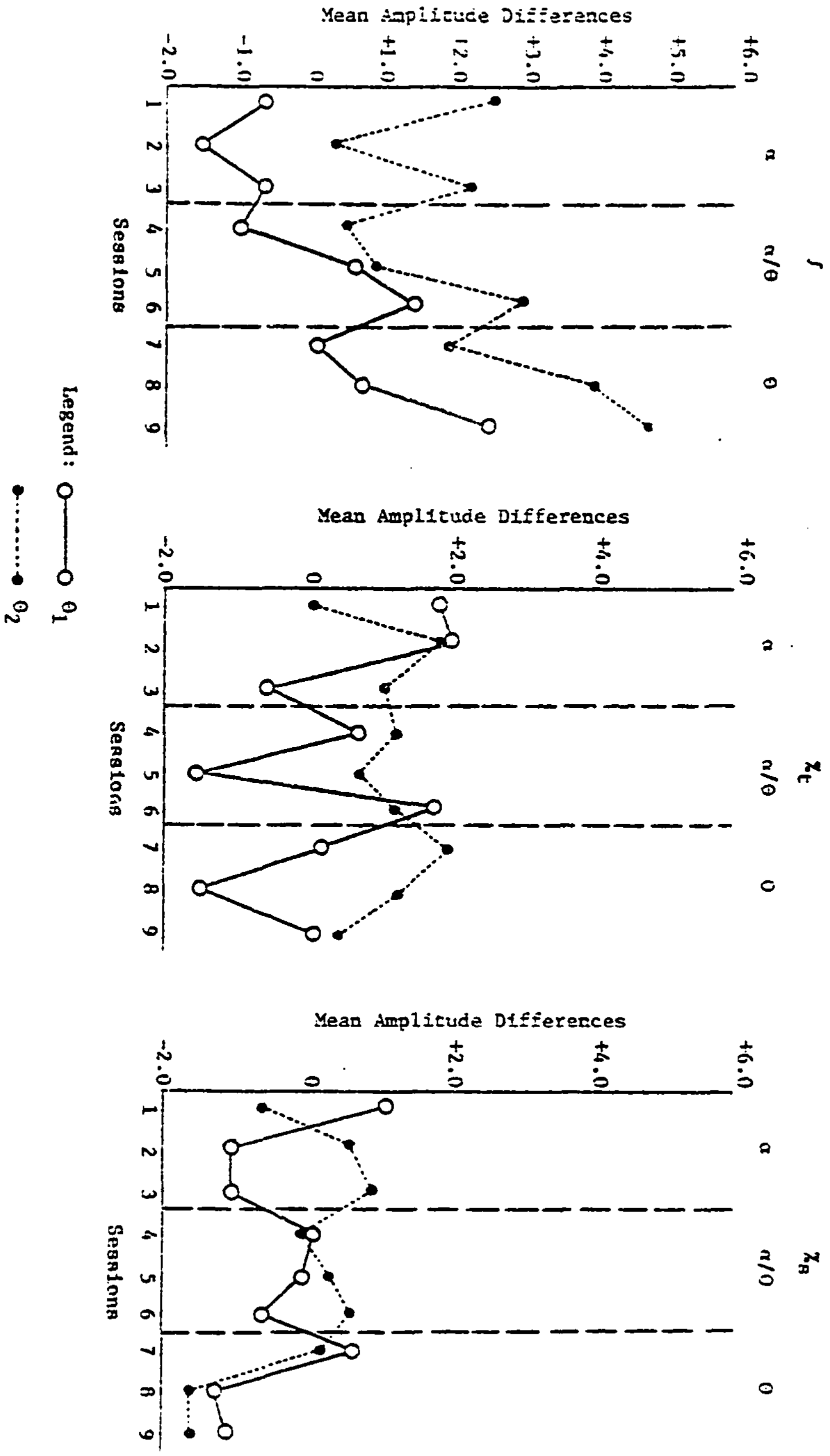
CRITICAL DIFFERENCES RATIOS (LSD) PERFORMED ON MAIN EFFECTS (FACTOR "A") FROM RMAOV ON Θ_2 (PRE- TO POST).

	POPULATION CONTRAST	SAMPLE CONTRAST	ABSOLUTE VALUE	t CRITICAL
PHASE I	$\%_s$ vs $\%_t$	-.725 - 1.050	1.775	1.212
	$\%_s$ vs $\int$	-.725 - 1.793	2.518	1.720
	$\%_t$ vs $\int$	1.050 - 1.793	.743	.507
PHASE II	$\%_s$ vs $\%_t$	-.333 - 1.173	1.506	1.029
	$\%_s$ vs $\int$	-.333 - 1.108	1.441	.984
	$\%_t$ vs $\int$	1.173 - 1.108	.065	.044
PHASE III	$\%_s$ vs $\%_t$	-1.142 - 1.290	2.432	1.66
	$\%_s$ vs $\int$	-1.142 - 3.140	4.282	2.92**
	$\%_t$ vs $\int$	1.290 - 3.140	1.850	1.85*

* $p < .20$

** $p < .05$

Fig. 1 θ Pre- Post-Baseline Session By Session Mean Amplitude Differences



Though main effects on α 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 α. 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 $\int$ and $\%_t$ groups did not demonstrate substantial α increases across phases. It was noted that both Θ and α 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 α_1/α_2 relationships indicated that the $\%_s$ group demonstrated a high degree of symmetry ($r = .94$, $p < .01$). The $\int$ group showed moderate correlations ($r = .49$) while the $\%_t$ group exhibited the lowest α 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 Θ_2 ($F = 5.869$, $p < .02$) and α_1 ($F = 4.318$, $p < .05$). LSD testing, by phase, on Θ_2 main effects showed that the $\int$ group significantly enhanced right occipital Θ when compared to the $\%_s$ group in all three phases and the $\%_t$ group in Phase I. Pairwise comparisons

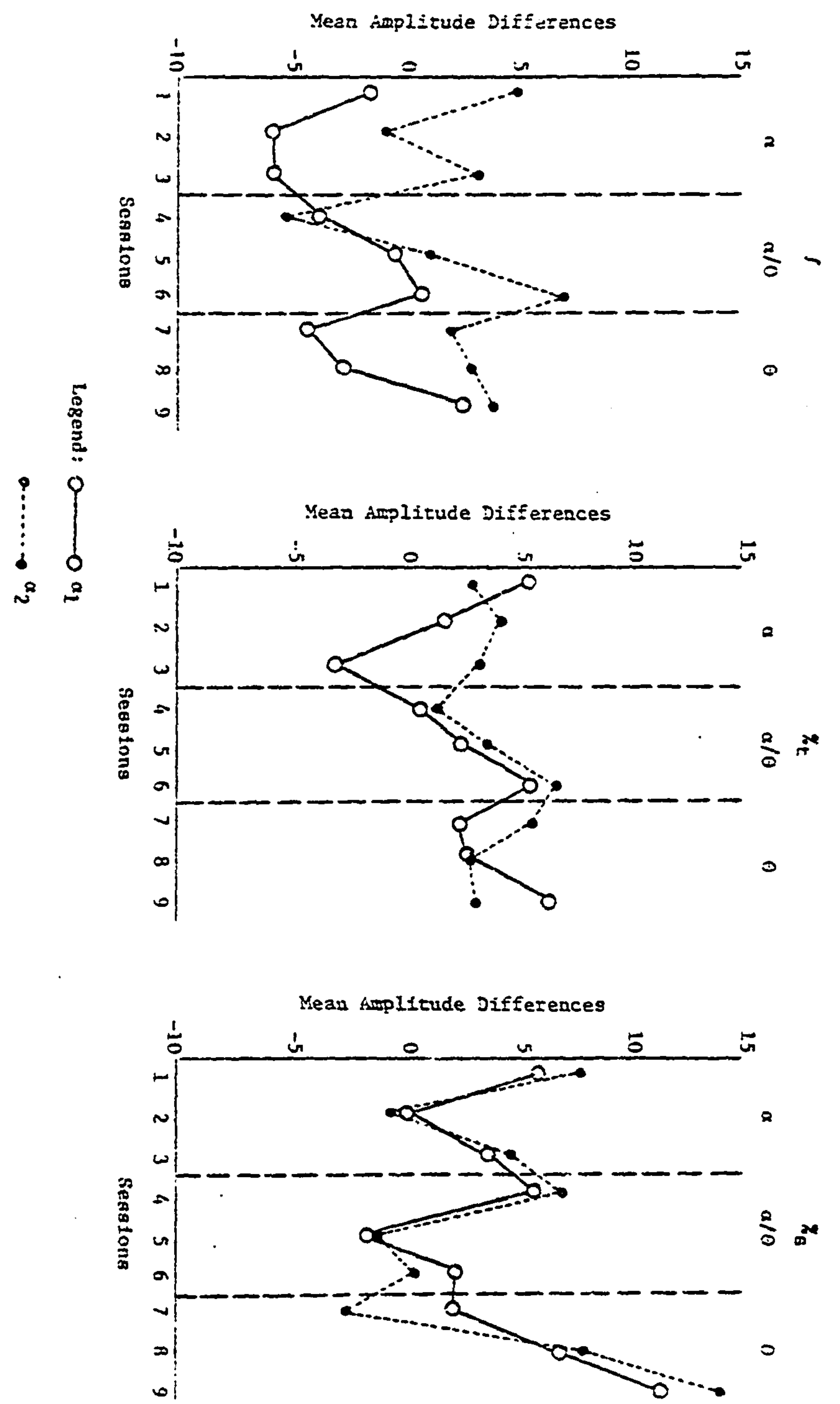


Fig. 2 α Pre- Post-Baseline Session Mean Amplitude Differences

between $\%_t$ and $\%_s$ groups revealed the superiority of the $\%_t$ group at enhancing Θ_2 in Phase II and Phase III. Values from group-wise comparisons are displayed in Table 3.

Bilateral changes in Θ activity derived from pre-baseline to training within groups are shown in Fig. 3. These data indicate that both $\int$ and $\%_t$ groups demonstrated general trends toward increasing Θ_2 during Phases I and II. The $\%_s$ group showed no significant change across phases. All three treatment groups exhibited sharp decreases in Θ_2 during Phase III. It was also observed that $\bar{X}$ amplitude differences for the $\int$ and $\%_t$ groups by phase were substantially higher during pre-baseline to training than pre- to post. Correlations performed on Θ_1/Θ_2 relationships within groups did not render any significant findings.

LSDs were also performed on α_1 main effects by phase. Results revealed that the $\%_s$ group significantly enhanced left occipital α when compared to the $\int$ 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 $\int$ 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 $\int$ group was the least effective at increasing left occipital α when compared to either of the binary groups. Results from the LSDs are shown in Table 4.

Bilateral changes in α activity occurring from pre-baseline to training conditions within groups are presented in Fig. 4. Correlations conducted on the α_1/α_2 data generated from pre-baseline to

TABLE 3

CRITICAL DIFFERENCES RATIOS (LSD) PERFORMED ON MAIN EFFECTS (FACTOR "A") FROM RMAOV ON α_1 (PRE-BASELINE TO TRAINING)

	POPULATION CONTRAST	SAMPLE CONTRAST	ABSOLUTE VALUE	t CRITICAL
PHASE I	$\%_s$ vs $\%_t$	4.632 - 3.200	1.432	.974
	$\%_s$ vs $\int$	4.632 - .225	4.407	2.998**
	$\%_t$ vs $\int$	3.200 - .225	2.975	2.023*
PHASE II	$\%_s$ vs $\%_t$	5.325 - 6.700	1.375	.930
	$\%_s$ vs $\int$	5.325 - 2.025	3.300	2.24*
	$\%_t$ vs $\int$	6.700 - 2.025	4.675	3.18**
PHASE III	$\%_s$ vs $\%_t$	6.825 - 1.125	5.700	3.877***
	$\%_s$ vs $\int$	6.825 - .367	1.468	4.393***
	$\%_t$ vs $\int$	1.125 - .367	.758	.515

* $p < .10$

** $p < .05$

*** $p < .01$

Fig. 3 θ Pre-Baseline To Training Session By Session Mean Amplitude Differences

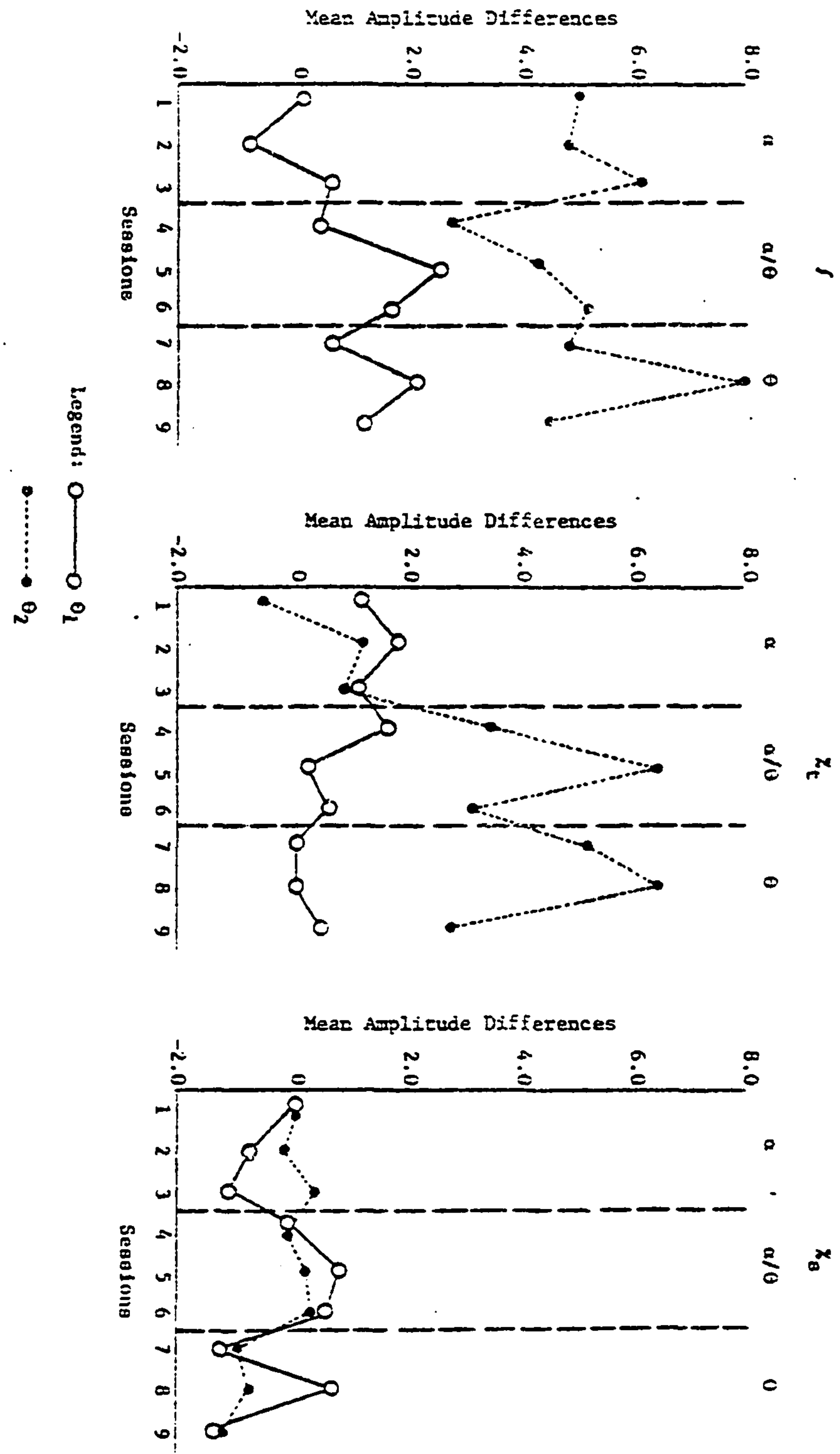


TABLE 4

CRITICAL DIFFERENCES RATIOS (LSD) PERFORMED ON MAIN EFFECTS (FACTOR "A") FROM RMAOV ON Θ_2 (PRE-BASELINE TO TRAINING)

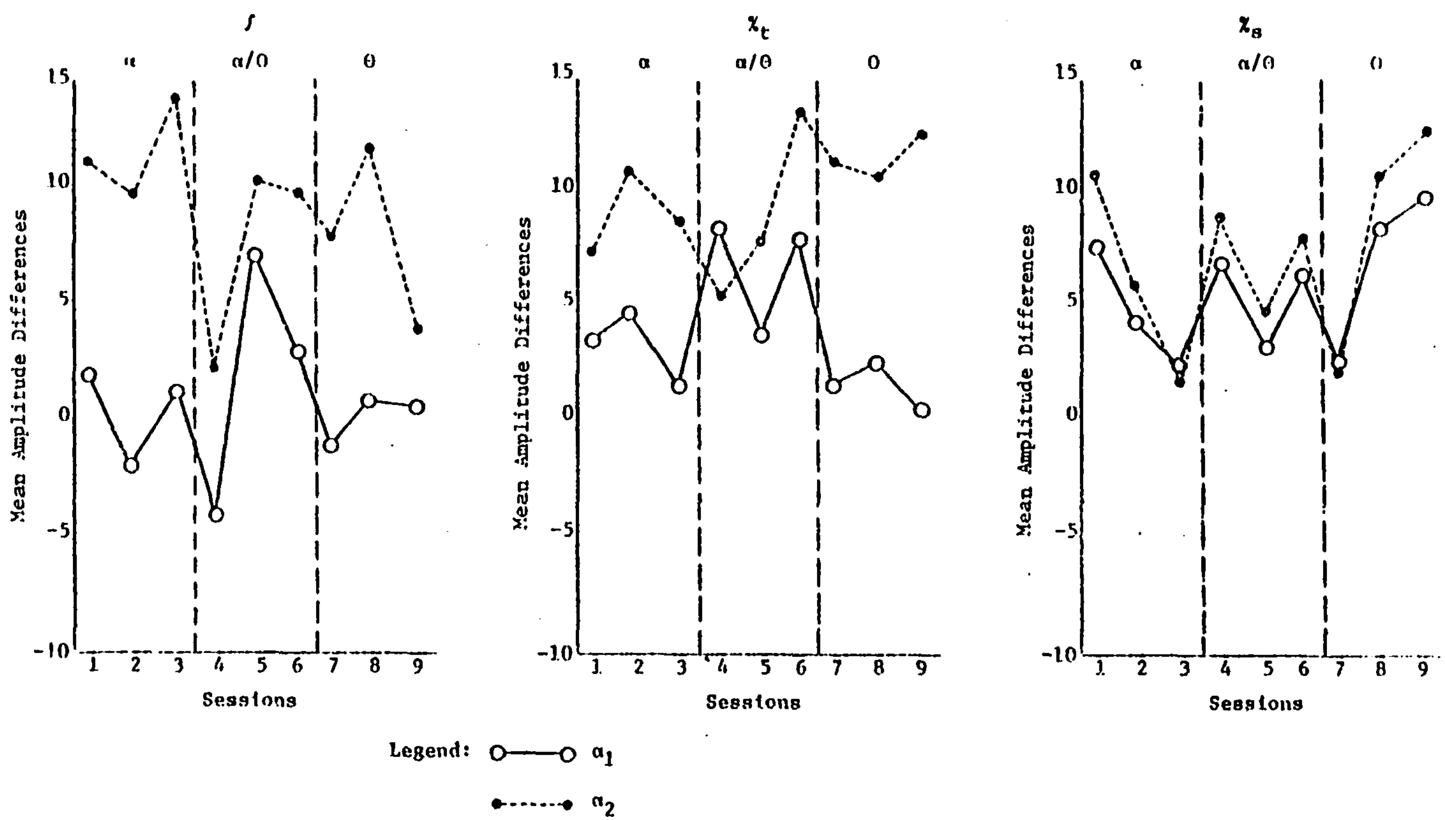
	POPULATION CONTRAST	SAMPLE CONTRAST	ABSOLUTE VALUE	t CRITICAL
PHASE I	$\%_s$ vs $\%_t$	-.175 - 3.250	3.425	1.999*
	$\%_s$ vs $\int$	-.175 - -6.882	7.057	4.120***
	$\%_t$ vs $\int$	3.250 - -6.882	3.632	2.120*
PHASE II	$\%_s$ vs $\%_t$	.067 - 4.358	4.291	2.505**
	$\%_s$ vs $\int$	.067 - 4.033	3.966	2.315**
	$\%_t$ vs $\int$	4.358 - 4.033	.328	.192
PHASE III	$\%_s$ vs $\%_t$	.383 - 4.790	4.407	2.573**
	$\%_s$ vs $\int$	.383 - 5.710	5.327	3.110**
	$\%_t$ vs $\int$	4.790 - 5.710	.920	.538

* $p < .10$

** $p < .05$

*** $p < .01$

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



training indicated that bilateral hemispheric changes correlated highly for the $\%_s$ group in the acquisition of α ($r = .82$, $p < .01$) across phases. Non-significant correlations were found for % ($r = .07$) and $\int$ ($r = .39$) 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 α_1/α_2 and Θ_1/Θ_2 baselines obtained during the "orientation" session. Multiple correlations were run on bilateral α_1/α_2 and Θ_1/Θ_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 5

CORRELATION COEFFICIENTS GENERATED FROM "RESTING" BASELINES OBTAINED DURING THE ORIENTATION SESSION

	SUBJECTS	CORRELATION COEFFICIENTS	
		Θ_1 vs Θ_2	α_1 vs α_2
$\%_s$	S_{003}	.325	-.431
	S_{006}	.994	.996
	S_{009}	.990	.871
	S_{012}	.982	.991
$\%_t$	S_{002}	-.046	-.384
	S_{005}	.798	.845
	S_{008}	.985	.991
	S_{011}	.865	.629
$\int$	S_{001}	.986	.957
	S_{004}	.965	.995
	S_{007}	.732	-.568
	S_{010}	.864	.691

DISCUSSION

Research findings from the present investigation are considered preliminary in view of the small sample sizes. However, the data rather clearly show enhancement of bilateral theta associated with the integrated amplitude procedure. This finding was of interest in several respects. First, it was observed that while right occipital theta progressively increased, left occipital theta assumed an inferior following pattern (see Fig. 2). These bilateral relationships were found to occur within each of the training groups. While it might be expected that the greatest degree of change should result from the feedback site (O_1), this was not the case. This common finding within groups is suspect to the manner in which information may be hemispherically processed. "Does this have impiications for a left - right theory of consciousness in which left hemisphere 'thinks' and right hemisphere 'knows' (Green and Green, 1977, p. 123)." This question would seem to imply that the right hemisphere directly benefits from the analytical operations performed by the left. Similarly, Givens et al., (1978), suggest that certain types of cortical theta activity may be associated with the transmission of information from one region of the cortex to another. This process of intra-communication would also require a higher expenditure of energy originating from the hemisphere involved in encoding, decoding, and transmitting the information (Richard R. Williams, personal communication). Viewed in this context, inhibition of left occipital theta could then be expected.

Second, changes in theta activity were highly correlated between hemispheres for Ss receiving integrated amplitude training. In order to interpret the significance of this finding, individual correlations, by S, were performed on bilateral EEG activity recorded during a "resting" baseline condition. Table 5 reflects these values and indicates that 10 out of 12 Ss showed highly significant bilateral theta correlations and 9 out of 12 significant alpha correlations. These naturally occurring events appeared to be undisturbed by the integrated amplitude feedback intervention. From these data the author determined that a continuous feedback model allowed the theta learning task to take place with continued bilateral symmetry. Conversely, the percent-time groups exhibited considerably lower bilateral theta correlations across phases. This form of asymmetrical patterning appears to represent a state of conflict resulting from a more limited information model (binary, e.g. on/off). Additionally, binary feedback systems may also present the S with the task of actively asserting oneself in a situation that requires a highly passive approach (Williams, 1976). In other words, the less information received in the process of attempting to succeed on a given task, the greater the degree of arousal (e.g. anxiety or frustration) associated with one's performance.

Third, notably higher increments in theta were observed in pre-baseline to training conditions (see Fig. 3) than in the pre- to post-session baseline evaluation for both integrated amplitude and percent-time (non-shaping) groups. This finding would appear to substantiate the effectiveness of the feedback training variable on influencing baseline theta levels. However, absence of a significant theta result for the percent-time group would suggest that this binary feedback method did not provide the Ss with a sufficient amount of information for transfer of learning to occur in a no-feedback condition. Hence, fine discrimination between theta and non-theta states was not acquired with either of the binary techniques. The present author concurs with Hardt and Kamiya (1976) in support of integrated amplitude training as the preferred method of selective brain wave discrimination and enhancement.

The alpha enhancement effects noted for the percent-time groups were not determined to be reliable but indicate that these Ss may have acquired some ability to increase alpha and discriminate between alpha and non-alpha states. The high bilateral alpha correlations were interpreted to indicate that the percent-time shaping model provided sufficient information to cue in on only half of the learning task. It is quite evident that Ss in both percent-time groups were unable to make the critical transition to theta despite following through the tri-phasic design.

Results on the suppression tests indicated that none of the Ss were able to effectively decrease or inhibit alpha or theta activity with the assistance of feedback. Also, reversing the feedback tone or conditions under which feedback would be presented did not generate decreases in brain wave activity. While it seems likely that insufficient time in training suppression (Hardt and Kamiya, 1976) could account for this finding, the author concurs with Brown

(1974) that the ability to enhance or suppress specific types of EEG activity may consist of two distinct learning tasks.

The intent of the present investigation was to serve as a pilot study for determining more effective and reliable methods of examining and developing self-regulatory behavior involved in selective brain wave patterning. It was determined from this study that (1) the analogue feedback approach was superior to binary feedback models in achieving higher theta amplitudes; (2) continuous feedback systems facilitate hemispheric symmetry in the acquisition of the target response (Θ) while on/off learning models (non-proportional feedback) appear to disturb hemispheric alignment and create conflict; (3) the tri-phasic training paradigm appeared effective in allowing a gradual transition to theta with the integrated amplitude approach. However, until this design is tested against other training combinations, conclusive evidence is not at hand; and (4) though alpha or theta suppression was not evident, definite enhancement effects were observed indicating that perhaps acquisition of suppression skills is a different task.

From this study it was determined that several improvements in design might yield more conclusive results in future experiments. First, increasing the number of training sessions within phases might allow sufficient time for sequential information processing to occur. The present study allowed a total of 120 minutes of training time within each phase. When compared to the 5.6 hours of alpha training per S in the Hardt and Kamiya (1976) investigation, less than 2 hours of feedback training may be inappropriate, particularly with the binary feedback models. Additionally, steps should probably be taken to insure that training sessions take place on consecutive days in view of the complexity of the learning task. Second, the single tone representing a combination of alpha + theta activity did not accommodate the Ss in making accurate discriminations between the two states. Green and Green (1977) suggest using two individual tones fedback through stereo earphones to the S. Third, in view of the literature (Sittenfeld, Budzynski, and Stoyva, 1976; Birbaumer, 1977) implicating elevated somatic arousal with low theta density, it would appear advantageous to collect baseline data on EMG levels, heart rate, and skin conductance levels as well as bilateral EEG activity. From these data, future experiments could be designed to determine somatic response patterns associated with changes in EEG activity. Finally, the use of frequency feedback in place of amplitude feedback may be more effective in the tri-phasic design. This may hold particularly true for the percent-time feedback models. Frequency feedback would also supply the experimentor with sufficient information to determine the effect of the training variables and conditions underlying EEG syncronization.

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