Alpha control: Effectiveness of two kinds of feedback*

DAVID HORD and JOSEPH BARBER

Navy Medical Neuropsychiatric Research Unit, San Diego, Calif. 92152

Eleven volunteer Ss participated on 2 separate days in an alpha control study. On Day 1, an auditory feedback tone was on during the presence of alpha and S was instructed to turn alpha on or off during alternating 8-min feedback sessions. Preceding each feedback session, S was instructed to turn alpha on or off for 8 min without the feedback tone. On Day 2, the same procedure was followed, except that tone-on meant a low level of alpha and tone-off meant a high level of alpha. Alpha control, defined as the percent alpha during the alpha-on session minus the percent alpha during the alpha-off session, was significant on both days and was positively correlated with baseline percent alpha. Feedback sessions showed significant appropriate changes compared to no-feedback sessions only during the first sessions of Day 1. Heart rate was not significantly related to percent alpha.

In everyday experience, people are not aware of the "state" of their EEG, alpha, or of any brain wave. Through alpha feedback training, the individual is made aware of the presence of alpha by hearing or seeing a contingent signal. Individuals presumably learn to alter their subjective "state" in order to generate alpha for greater and more frequent lengths of time. The individual becomes aware of a difference in his subjective feeling when the feedback indicates that his alpha is present, and eventually he can "turn on alpha" without the aid of the feedback.

Experiments involving alpha feedback have been accumulating since Adrian & Mathews's (1934) report of a correlation between a subjective impression of looking or not looking and the absence or presence of the alpha rhythm in the EEG. More recently, Kreitman & Shaw (1965) found evidence for alpha enhancement in seven Ss doing mental tasks—tasks traditionally considered "alpha blockers." The operant technique, using a feedback paradigm in which a visual or auditory signal serves as a positive reinforcer, does not require a particular way to enhance alpha and has been shown to be effective in alpha control (e.g., Nowlis & Kamiya, 1970; Brown, 1970). Subjective reports obtained in these studies indicate that a wide range of methods are effective for increasing or decreasing alpha. Voluntarily

enhanced alpha has also been attributed to "reduced inhibition" as opposed to operant conditioning (Lynch, Orne, Paskewitz, & Costello, 1969) and to classical conditioning (Cleeland, Booker, & Hosokawa, 1970).

The purpose of the present experiment was to (1) replicate those studies reporting rapid alpha control with a contingent auditory feedback signal, (2) test whether or not alpha control will continue without the feedback, (3) test whether or not feedback where tone-on accompanies high alpha is any better than feedback where tone-off accompanies high alpha, and (4) study the relation of heart rate (HR) to alpha. Four hypotheses have been formulated and tested:

Hypothesis 1

Volunteer Ss will show enhanced alpha when instructed to keep alpha on, using a contingent feedback tone as a guide, and will show diminished alpha when instructed to keep alpha off, using the feedback tone as a guide.

Hypothesis 2

Following the first alpha on session with feedback, alpha control, defined as the difference between alpha levels during the alpha on and alpha off sessions, will be no greater under the feedback condition than under the no-feedback condition.

Hypothesis 3

Alpha control, as defined above, will be the same when tone-on accompanies alpha as it is when tone-off accompanies alpha.

Hypothesis 4

Mean HR levels will be positively correlated with percent-alpha, as suggested by Lacey (1967).

SUBJECTS

Sixteen volunteer male and female Ss from local colleges (age range: 19-35) agreed to come to the

laboratory on at least two separate occasions to take part in an "alpha feedback experiment." The records of 11 Ss were retained on the basis of completeness and freedom from extensive artifact.

APPARATUS

EEG (O_2-A_2), filtered EEG (through a Krohn-Hite Model 330 bandpass filter, set at 10 Hz), a relay state indicator to show when the feedback circuit was enabled, EOG, finger pulse, skin potential from the palmar surface of the left hand, HR (through a Beckman 9857 cardi tachometer), and respiration were recorded on a Beckman Type R dynograph. The filtered EEG was amplified by a Tektronix 2A61 differential amplifier and rectified. The output of the rectifier entered a Schmitt trigger, and, subsequently, a BRS relay and audio generator provided the feedback tone. A Hewlett-Packard Model 5321B electronic counter, activated by the same relay closure that enabled the feedback circuit, counted the time the relay was closed to the nearest 10th of a second.

PROCEDURE

Each experimental day included (1) attachment of electrodes and transducers, (2) brief discussion of the general purpose and nature of the experiment (S was encouraged to move as little as possible and to keep his eyes open at all times during the experiment), (3) brief period of familiarization with the feedback signal (S closed his eyes temporarily while the pitch and loudness of the tone were modified as necessary to provide a feedback signal that was not aversive but clearly discernible), and (4) instruction of S to open his eyes and a trial-and-error adjustment of the amplifier in the feedback so that the relay would be enabled approximately 20% of the time, when S was resting. (Our intention was to equalize, across Ss, the baseline "alpha level," independent of each S's absolute abundance of alpha.)

Each 8-min session was initiated by a brief explanation and appropriate set of instructions from the E: (1) *Baseline (BL)*. S is instructed to sit quietly for 8 min. (2) *Alpha on, no feedback (ON,NFB)*. S is instructed to try to produce alpha activity on the basis of whatever understanding he might have about alpha. (3) *Alpha on, with feedback (ON,FB)*. S is instructed to keep alpha on as much as possible, using the contingent feedback tone as a guide. (4) *Alpha off, no feedback (OFF,NFB)*. S is instructed to keep alpha off, on the basis of whatever understanding he might now have about alpha. (5) *Alpha off, with feedback (OFF,FB)*. S is instructed to

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Table 1
Percent Alpha for the Baseline-Recovery Sessions, On vs Off Instructions, and the Feedback vs No-Feedback Conditions on Day 1 and Day 2

Session	Baseline-Recovery (1 and 8)	Turn Alpha Off		Turn Alpha On	
		NFB (4)	FB (5)	NFB (6)	FB (3 and 7)
Day 1					
VAC	42.0	50	25	76	65.5
GB	13.5	9	2	18	11.0
EM	20.5	21	4	9	40.0
IA	14.5	9	5	8	23.5
GW	20.5	19	19	42	24.0
MH	34.0	9	9	39	36.5
TD	27.5	8	4	40	29.5
KJ	5.5	5	2	17	36.0
MA	20.5	8	10	60	41.0
LM*	—	18	16	15	12.5
VA	27.0	7	1	28	32.0
Mean	22.55	14.82	8.82	32.00	31.95
SD	10.56	12.87	7.96	21.83	15.06
Day 2					
VAC†	—	—	—	—	—
GB	7.0	7	1	29	28.0
EM	15.5	2	1	15	18.0
IA	25.0	31	9	54	42.5
GW	6.0	11	15	31	22.5
MH	6.5	20	21	13	31.0
TD	22.5	10	9	35	22.5
KJ	32.5	15	18	14	69.5
MA	14.0	19	12	27	30.5
LM	17.5	24	16	21	22.0
VA	41.0	49	62	74	73.5
Mean	18.75	18.80	16.40	31.30	36.00
SD	11.66	13.60	17.35	19.38	19.93

*S LM misunderstood baseline instructions; data is not included in baseline comparisons.

†S VAC data available for Day 1 only; not included in Day 1 vs Day 2 comparisons.

keep alpha off, using the tone as a guide. (6) *Alpha on, no feedback (ON,NFB)*. Same as Session 2. (7) *Alpha on, with feedback (ON,FB)*. Same as Session 3. (8) *Recovery (R)*. Same as Session 1.

The procedure described above was followed on Day 1. On Day 2, the same procedure was followed, except that the tone was off when alpha appeared. The S was told to control alpha and to use the tone as a guide, but that now *tone off* meant *alpha present*, and conversely.

QUANTIFICATION OF DATA

Cumulative alpha time was read to the nearest second from the Hewlett-Packard counter at 30-sec intervals for each 8-min session. After each session, the counter was reset to zero and a cumulative record for the next 8-min session was started. HR was read for the first five beats at the end of each 30-sec epoch. The average HR for a given 8-min session is the mean of 16 sample means, each sample mean being associated with a corresponding measure of cumulative alpha time.

RESULTS

The results of the experiment on which tests of the first three hypotheses are based are given in Table 1. BL (Session 1) and R (Session 8) were combined. The

percent alpha (that is, the percent of time the relay was closed, indicating the presence of alpha) for the two ON sessions (3 and 7) were also combined. The test of Hypothesis 4 consisted of obtaining a correlation between percent alpha and HR for each S and then determining if this distribution had a mean different from zero. These distributions are given in Table 2.

Hypothesis 1

Average percent alpha for the ON sessions (3 and 7) is significantly greater than the average percent alpha during BL and R sessions (1 and 8) on Day 1 ($t = 3.37$, $p < .01$) and Day 2 ($t = 4.42$, $p < .01$).¹ Percent alpha during the OFF,FB session (5) was significantly less than the average percent alpha during BL and R sessions (1 and 8) on Day 1 ($t = 5.27$, $p < .01$); there was no significant difference on Day 2 ($t > 1.0$).

Hypothesis 2

Our measure of alpha control without feedback is the percent alpha during the ON,NFB session (6), minus the percent alpha during the OFF,NFB session (4). Our corresponding measure of alpha control with feedback is the percent alpha during the ON,FB sessions (7 and 3), minus the percent alpha during the OFF,FB session (5). These two measures did not differ significantly for either day

($t = 1.00$ on Day 1 and 1.30 on Day 2). Alpha control was as good without the feedback as it was with the feedback.

Hypothesis 3

Can Ss control alpha levels independently of whether tone-on or tone-off is used as feedback? The same measure of alpha control was used as in Hypothesis 2 (Sessions 7 and 3), minus Session 5 for the feedback condition). The mean alpha control was 23.1 on Day 1 (tone-on accompanies alpha) and 19.6 on Day 2 (tone-off accompanies alpha). A t test indicated no difference between the 2 days. Tone-on as feedback for alpha enhancement is as effective as tone-off.

Hypothesis 4

On each day, for each S, HR and percent alpha were obtained for each session, eight sessions in all. The product-moment correlation between HR and percent alpha was calculated for each S. These correlations, listed in Table 2, tend to be similar within a S (suggesting some relation between the variables), but the average does not differ significantly from zero (indicating that the relationship is not the same across Ss, if there is any relationship at all).

There was a significant positive correlation of about .60 between alpha control (ON minus OFF) and the BL alpha level. A rather wide distribution of percent alpha levels for the BL session occurred despite attempts to adjust each person's threshold such that he would receive 20% feedback. The distribution ranged from 7% to over 50%. The regression of the alpha control measure on BL percent alpha is shown for Days 1 and 2 in Fig. 1.

DISCUSSION

The results of the experiment are generally consistent with those reported by Nowlis & Kamiya (1970); both alpha enhancement and suppression are possible in volunteer Ss. In the present experiment, control was better for the ON condition than

Table 2
Linear Correlation of Heart-Rate Level and Percent Alpha for Each S on Day 1 and Day 2

S	r	
	Day 1	Day 2
GB	.11	.30
EM	.47	.12
IA	-.84	-.06
GW	-.84	-.47
MH	-.39	-.13
TD	.51	.02
KJ	.52	.74
MA	.55	-.20
LM	.34	.00
VA	-.01	-.14

for the OFF condition. There was no significant alpha suppression during the OFF condition on Day 2. Part of the inability to suppress alpha on Day 2 may be due to the procedure used for determining the threshold of the feedback device (rather than to limitations of alpha control). In the present experiment, the intensity of EEG alpha which triggered the relay was set so that the relay was closed approximately 20% of the time during BL. The five Ss who were below 20% during BL found it very difficult to reduce their alpha further. The optimal level of feedback for alpha control in humans has not been determined, but it appears to be an important variable.

It seems clear that the degree to which an individual can demonstrate control of his alpha is closely dependent on the threshold level initially set for him. If an individual begins the BL session with the relay closing 20% of the time, then he has a rather wide range of improvement possible to him in subsequent feedback sessions. If he begins the BL session with the relay closing 50% of the time, his range for subsequent improvement is comparatively limited. This reasoning follows from the premise that little or no learning will result when the tone is on (or off) 100% of the time.

The issue of the appropriate threshold level is largely settled by the purpose of the training. If the object of the training is to turn alpha off (and presence of the tone means presence of alpha), then the higher the threshold level, the more learning is possible. (Eighty percent during BL would then be a good level for turning alpha off.) If the same training were to use the presence of the feedback tone to mean absence of alpha, the same procedure would of course be employed. The data of Fig. 1 make it clear that those Ss who did receive the higher BL levels (due to our inability to adjust the level precisely to 20%), tended also to show the greatest degree of control, as it was defined here.

If alpha training is to include both turning alpha on and off (using the same design as in the present study), then probably a 50% level is best. However, it would seem that optimal control would result from a different design, one that would allow for changing the threshold level between the two conditions (say, 20% for alpha on and 80% for alpha off).

Alpha control during feedback sessions was not significantly greater than alpha control during no-feedback sessions. This conclusion is based on our measure of alpha control (which is the difference between percent alpha

Fig. 1. Linear regression of alpha control on threshold level during baseline. (S LM misunderstood instructions for baseline and is not included here.)

during ON and OFF sessions). Other comparisons of feedback vs no-feedback can be made within the ON and OFF sessions, and they generally indicate that feedback is better than no feedback. [Compare Sessions 4 and 5 for the OFF condition and Sessions 6 and (3 and 7) for the ON condition shown in Table 1.] But only one of these comparisons is significant: Sessions 4 and 5 on Day 1, which includes the first exposure to the feedback signal. Apparently this initial 16-min period, which includes both feedback and no-feedback conditions, is sufficient to increase the effectiveness of the no-feedback situation. Brown (1970) has also concluded that rapid alpha control can occur within the first practice session.

The test of Hypothesis 3 showed that the measure of alpha control was no better for the *tone-on alpha present* feedback than for the *tone-off alpha present* feedback (Day 1 vs Day 2). Possibly *tone-off alpha present* feedback will be useful for long-term high-alpha training, since presence of a constant tone over long periods of time could lead to auditory fatigue or habituation. A disadvantage of this type of feedback is indicated in S's reports that, after a prolonged absence

of the tone (presence of alpha), they could easily forget the nature of the task, the importance of keeping their eyes open, etc. With the *tone-on alpha present* feedback, Ss were constantly "reminded" of the nature of the task, etc.

It is possible that the lack of support for a hypothesized relationship between alpha level and HR level is due to inappropriate sampling techniques. Analysis of data in subsequent studies continues to indicate a correlation between these two variables during certain, as yet unspecified, periods.

The important question of what is occurring at the level of neural activity in the brain during alpha regulation can be discussed only within the limits set by our knowledge of the intrinsic rhythms involved. One point of view, which is based on extensive experimental work with animals, has recently been summarized by Andersen & Andersson (1968). Their theory of a *facultative* pacemaker at the level of specific and association nuclei in the thalamus views these structures as the primary synchronizing mechanism of alpha waves. Intrathalamic intrinsic rhythms, which are postulated to be a function of the inhibitory properties of the thalamic cells involved, modulate thalamocortical projection system neurons at a rate that corresponds to the alpha range of frequencies. Synchronization, which, in the present context, corresponds to sustained alpha activity, is thus a thalamic rather than a cortical phenomenon and, as such, occurs when peripheral sensory inputs are minimal. This interpretation is generally consistent with the subjective state that is usually associated with high alpha activity: passive, attending to internal as opposed to external stimuli, etc.

CONCLUSIONS

(1) Voluntary increases or decreases in alpha are possible in Ss with eyes open. In this study, where the threshold was adjusted to enable the relay about 20% of the time during the baseline, the Ss could enhance alpha more easily than they could suppress it.

(2) Alpha control, defined as the difference in alpha level during alpha ON and alpha OFF sessions, is possible without the feedback signal (following initial alpha feedback training).

(3) *Tone-on alpha present* and *tone-off alpha present* are equally effective kinds of feedback.

(4) There is no significant correlation between HR and percent alpha during alpha training.

(5) Alpha control is positively correlated with the amount of feedback provided, which is

determined by the threshold of the feedback circuit.

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- NOTE
1. Data for SLM, Day 1, was not included because he closed his eyes during BL, giving inordinately high alpha levels.

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