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Alpha Enhancement, Autonomic Activation, and Extraversion[1]

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Autonomic activation as reflected by heart rate, skin conductance, muscle tension, and T-wave amplitude of the electrocardiogram were registered during biofeedback training of EEG alpha. The group of 25 subjects showed significant enhancement of alpha but no systematic change in autonomic activation. This result was interpreted as supporting Eysenck's theory of two feedback loops for mediating cortical arousal. According to this theory, autonomic changes would not be expected to accompany changes in cortical arousal during resting conditions lacking emotional content and, therefore, not involving the visceral brain. Although some of the subjects who succeeded in increasing alpha experienced it as positive and others as strenuous, alpha change did not correlate significantly either with the dimension of extraversion, or with those of locus of control and neuroticism.

Early reports of the experience accompanying increment of the alpha frequency during EEG biofeedback described it as relaxed, pleasant, and meditationlike (Kamiya, 1969; Brown, 1970, 1971, 1974). This type of subjective experience led to comparisons of alpha enhancement with relaxation techniques such as meditation and Autogenic Training (AT) where increases in alpha had also been found (Banquet, 1973; Elson, Hauri, & Cunis, 1977; Luthe, 1970). The decreases in sympathetic

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activation observed during meditation (Wallace & Benson, 1972; Bujatti & Riederer, 1976; Goleman & Schwartz, 1976) and AT (Luthe, 1970) led to speculation that similar benefits could be obtained from increases in alpha during biofeedback. If the pleasant mental state accompanying alpha during feedback were also accompanied by a similar decrease in sympathetic activation, alpha enhancement might be a fast and effective method for coping with and alleviating some of the tension caused by stress. But, despite widespread conjecture, very little research on the autonomic effects of alpha training has actually been conducted. One study by DeGood and Chrisholm (1977) reported that an increase in alpha was not accompanied by a decrease in muscle tension. Other studies measuring alpha but not registering enhancement have reported a lack of correlation between alpha and variables of sympathetic activation (Orne & Paskewitz, 1973; Lehrer, 1978; Frost, Burish, & Homes, 1978).

Recent research in the area of subjective experience and the alpha frequency has begun to cast doubts on the earlier generalizations about the "alpha experience" (Lynch & Paskewitz, 1971; Orne & Paskewitz, 1973; Plotkin, Mazer, & Loewy, 1976; Legewie, 1977; Tyson & Audette, 1979; Plotkin, 1979). It would seem that alpha is experienced in a variety of ways, not all of which are positive. Unfortunately, these studies did not measure autonomic activation and there is no way of knowing whether or not this variable was also affected.

If Eysenck (1967) is correct in his theories on cortical arousal, autonomic activation may not be affected by alpha feedback at all. He postulates that high EEG frequencies are related to introversion, lower frequencies to extraversion, and that the dimension of introversion-extraversion is dependent upon thresholds in the Ascending Reticular Activating System (ARAS). Neuroticism is dependent upon different thresholds in the visceral brain and is associated with autonomic activation. Functionally, these systems are separate but interrelated. Cortical arousal can exist with or without autonomic activation, as it arises through two different feedback loops: (1) that involving ascending afferent pathways, cortex and reticular formation, and (2) that involving the visceral brain in combination with the reticular formation. Loop 1 involves arousal without activation, Loop 2, autonomic activation accompanied by cortical arousal. If this theory is correct, a reduction of cortical arousal will not necessarily be associated with changes in autonomic activation. Such changes could only be anticipated when cortical arousal is contingent upon emotional factors (Loop 2). Alpha enhancement achieved under the usual conditions of quiet passivity would therefore not be expected to be correlated with changes in autonomic activation.

The following study was designed to examine possible connections between alpha enhancement and the dimensions of autonomic activation and extraversion. Each subject's scores for extraversion (and also for neuroticism) were assessed by the Eysenck Personality Inventory and he was then given alpha biofeedback training. Autonomic activation as reflected by heart rate (HR), skin conductance level (SCL), muscle tension (EMG), and the ratio of the QRS complex and T-waves of the electrocardiogram (EKG), were measured during each trial. The EKG analysis was included because of the positive relationship between T-wave amplitude and relaxation found by Polzien (1953) and Christie (1975). Individual scores for locus of control, which has been reported to influence successful EEG biofeedback learning (Goesling, May, Lavond, Barnes, & Carreira, 1974) were ascertained as a control variable to check for this influence and for possible correlation with extraversion and neuroticism.

METHOD

Subjects

The subjects were 25 students of psychology at the Univeristy of Stockholm, who participated to fulfill a course requirement for subject hours. Their ages ranged from 20 to 53, the median age being 34 years. All were non-smokers.

Apparatus

EEG was recorded from O_1-P_3, O_2-P_4, (Jasper, 1958) via 10 mm gold electrodes applied with collodium. Signals coming from both hemispheres were first amplified (Grass Model 7p511 pre-amplifier), then fed into two bandpass filters. The filters were set at 8 and 12 Hz and had an attenuation of 24 dB per octave. The signal then passed through a voltage comparator, was integrated electronically and converted to digital-integrated alpha scores, which were displayed on a digital time counter (Advance Instruments, TC17A). The feedback tone heard through earphones was a white noise modulated by the amplitude of the fullwave rectified alpha activity coming from both channels. It was designed to give the effect of ocean waves, so as to be soothing and not jar the subject into an alpha blocking response.

Skin conductance was measured by a constant voltage system which was free-floating in relation to the ground used for EEG, EKG and EMG measurements. Recordings were made on a flat bed recorder (Phillips PM 8010). Ag/AgCl disposable electrodes with a 100 mm^2 surface were applied to the 2nd and 4th proximal phalanxes of the left hand after cleaning the surface with 95% alcohol. Concentration of the external electrolyte medium was .58 g NaCl per 100 ml. Twenty of the 25 subjects were clearly right handed, as measured by the Edinburg Handedness Inventory.

Heart rate and ECG were measured peripherally using standard bipolar lead II (right wrist–left leg) and silver electrodes. Recording was done on a Grass Polygraph (Model 7P1 pre-amplifier). Analysis of the EKG was performed on line with the help of a Digital Linc-8 computer. Detection thresholds were set individually for each subject with the help of a potentiometer. The amplitude of the QRS complex and T-wave were measured separately and averaged every minute along with the T/R ratio. This allowed within but not between subject comparison of absolute amplitude.

Muscle tension was measured from the frontalis muscle using gold electrodes with an electrode impedance under 10 kΩ. The signal was amplified and integrated on a Grass Polygraph (Model 7P3 pre-amplifier-integrator).

Procedure

The subjects came to the laboratory on two separate occasions. During their first visit they filled in questionnaires for locus of control (Rotter, 1966; Berggren, 1977), extraversion-neuroticism (Eysenck & Eysenck, 1964), and circadian rhythm type (Horne & Ostberg, 1976). The time of day for the experiment was then booked on the basis of individual circadian rhythms. This was done in order to minimize the risk of subjects becoming drowsy, so that morning alert subjects were booked in the morning and evening alert subjects in the afternoon. Subjects who had no strong inclination towards either morning or evening type were permitted to choose the time of day they preferred.

During the second visit, the subject spent a total of three hours in the laboratory. Upon arrival the subjects were instructed as to the purpose of the experiment and the functions of the feedback tone. They were also informed that they wound be given additional verbal feedback at the end of each trial, i.e., that the experimenter would let them know the absolute amount of digital alpha for that particular trial. Electrodes were then applied and eyes closed base level measured.

The experiment was composed of a 10 min rest and base rate period plus eight 10 min trial periods. The morning subjects were booked so that the trial periods would fall between approximately 10:00 am and 11:30 am. The afternoon subjects were booked so that their experimental time would fall between approximately 2:00 pm and 3:30 pm. These times were chosen as the most optimal for minimizing within period variation in circadian rhythms. The trials were performed in an eyes closed, prone position using ambient lighting. During the inter-trial interval the subject was requested to open his eyes and stretch to prevent drowsiness. A "control" group was not included as previous research has shown that alpha is stable over time and does not increase significantly as a result of lying quiescently in a feedback situation (Knox, 1978, 1980).

To assist in interpreting the results, each subject was asked after the last trial to write an answer to two questions: (1) What did you experience during the time that the tone was on? (2) What technique did you use to try to influence the tone?

RESULTS

Alpha Enhancement

The mean values for integrated alpha per trial are shown in Figure 1. Three subjects were excluded from the analysis due to muscle artifacts in

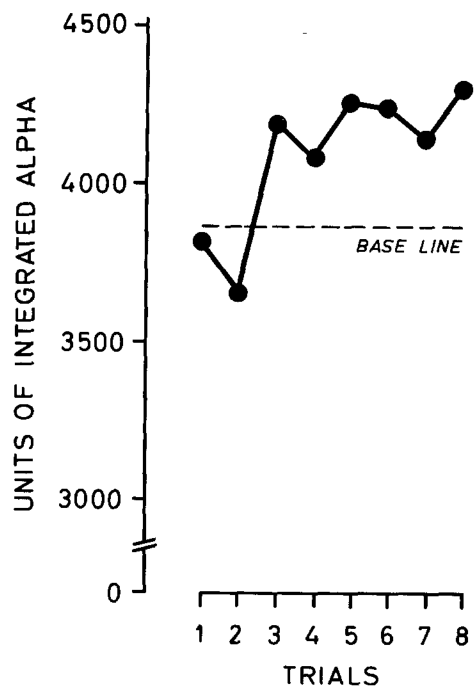

Fig. 1. Mean values of integrated alpha per trial.

their EEGs which could conceivably have increased their integrated scores. An analysis of variance for repeated measures showed a significant effect for trials ($F_{8/168} = 5.19$, $p < .001$). A one-tailed *t*-test for correlated observations calculated between base level and trial 8 was significant ($t_{21} = -2.35$, $p = .014$). Though the mean differences between trials are significant it should be pointed out that certain individuals demonstrated no learning at all, while others demonstrated very large increases. Only 10 of the 22 subjects showed an increase of 15% or more over base level.

Amount of Variance in Alpha Accounted for by Autonomic Activation

A multivariate regression analysis with alpha as the dependent variable and heart rate, skin conductance, and muscle tension (absolute T-wave amplitude was not excluded as it could not be compared between subjects) as the independent variables, was performed on the base rate measurements and each of the eight trials. Only 21 of the 22 individuals were included as one person lacked EMG data due to apparatus failure.

As can be seen in Table I, the highest multiple correlation was achieved during the base rate. But during this period only 13.1% of the variance in alpha could be accounted for by the linear dependence upon heart rate, skin conductance, and muscle tension. This does not differ significantly from zero ($F_{3/17} = .855$). Individual plots of each variable with alpha did not indicate any systematic linear or nonlinear relationships during the base rate or any of the trials.

Table I. Summary of Multiple Regression Analyses with Alpha as the Dependent Variable and Muscle Tension, Heart Rate, and Skin Conductance Level as the Independent Variables During Base Level and Trials 1–8

	Multiple R	R^2
Base level	.362	.131
Trial 1	.241	.058
Trial 2	.297	.088
Trial 3	.193	.037
Trial 4	.157	.025
Trial 5	.155	.024
Trial 6	.256	.065
Trial 7	.188	.014
Trial 8	.090	.008

Change in Alpha as a Function of Change in Autonomic Activation

In order to further investigate the relationship between alpha enhancement and activation, a multiple regression analysis was run on difference values. That trial in which the subject displayed the most integrated alpha was chosen and his base rate value subtracted. The resulting value was used as the dependent variable in the equation. Using the same trial, difference values were calculated for muscle tension, skin conductance, heart rate, and the T/QRS ratio of the EKG. These values were run as the independent variables in the multiple regression. The trial with the most alpha was often not the last trial. Several subjects complained of tiredness towards the end of the experiment and said that they had trouble concentrating. The number of subjects in this analysis was only 17, due to a weakness in the EKG program, which made data unavailable for six subjects besides the one who lacked EMG data. A summary of these results is listed in Table II.

A stepwise regression indicated that changes in the T/QRS ratio of the EKG account for the greatest proportion of the variance. The *F* value of this first step of the equation is also significant ($F_{1/15} = 8.52$, $p < .05$). Differences in heart rate, skin conductance, and muscle tension do not contribute significantly to the variance of the change in alpha.

Further correlation analyses indicated that it is changes in T-wave amplitude which account for changes in the T/QRS ratio ($r = -.44$, $p = .04$). However, when these variables are plotted against each other, it becomes evident that only two individuals are responsible for the significance of the equation, which is in the opposite direction from that expected. The significance should thus be interpreted with caution.

Levels of Autonomic Activation over Trials

One-way analyses of variance performed separately on skin conductance and muscle tension showed no significant effect of trials ($F_{8/168}$

Table II. Summary of Stepwise Regression Analysis with Alpha Change as the Dependent Variable and Change in T-wave/QRS Complex, Heart Rate, Skin Conductance Level, and Muscle Tension as the Independent Variables

Variable	Multiple R	R^2	r
T-wave/QRS Complex	.602	.362	–.602
Heart rate	.640	.410	–.043
Muscle tension	.644	.414	–.060
Skin conductance	.652	.425	.205

Table III. Adjectives Used to Describe Subjective Experience

Passive	In between	Active
Relaxed, pleasant, alpha tone is ocean waves sloshing against the beach and I'm enjoying it	Nothing special–similar to when one can't sleep because of a strange environment, visions on the retina	It's been a long time since I've had such richness of ideas, speed and clearness of thought
	Thought about everyday things	Charging, pulsing warmth in my body like being in a tempestuous, glistening ocean, "mental orgasm," sensual pleasure
	Here and now	
	Concentration without mental activity–body somethimes disappeared but not the "point" I concentrated on–a sort of activity	Tense
		Strenuous (2)

Table IV. Technique for Controlling Feedback Tone

Passive	In between	Active
Relax, don't think about anything in particular, let thoughts flow as they will	Experience myself in the "here and now" and not in any fantasy, don't become tired, don't visualize	Was curious about how it changed, thoughts became very intensive
Turned my thoughts inward and told myself that I am good enough as I am, that I'm beautiful to myself, at the same time I relaxed more	Deep breathing with a certain degree of alertness (2)	Imagined a bookshelf with alpha waves on it, when they started to decrease, I tried to pull them up again
	Maintain a certain degree of concentration (not too much, not too little)	Most feedback and most mental pictures—I was thinking about other things (what I would do tomorrow), planning, but making logical mistakes of the kind one makes before falling asleep, wasn't interested in the tone
	Concentrate without thinking on a point between my eyes, stop thinking about irrelevant things	

$= 1.11, p > .05, F_{8/160} = 1.63, p > .05$). The ANOVA performed on heart rate showed a significant effect of trials ($F_{8/168} = 2.45, p = .02$), the lowest being 62, the highest 66. But a *t*-test for dependent measures showed that there were no significant differences between base rate and trial 8 (64.8 and 64.5, respectively, $t_{21} = .29, p = .36$). Product-moment correlations calculated separately on alpha amount and each of the autonomic variables during the base level period and trials 1–8 showed no correlation significant at the .05 level.

Psychological Variables

Correlations between extraversion, neuroticism, locus of control, and the same alpha difference value run in the previous analyses, showed no significant correlation between changes in alpha and any of these three dimensions. The correlation between extraversion and amount of integrated alpha in the resting base level was positive but also nonsignificant ($r = .15$, $p = .19$). There was however, a significant correlation between neuroticism and locus of control ($r = .50, p = .01$).

Subjective Experience

The answers to the questions concerning the subject's experience during feedback and his method for influencing the feedback tone were evaluated for the 10 subjects showing an increase of 15% or more over their base level. The purpose was to ascertain the experience and technique of those persons who could clearly be said to have shown control of the feedback tone.

Table III lists a summary of the type of comments used by subjects to describe their experiences. The author has divided them into three categories according to the dimension, active-passive. This division is subjective, but is an attempt to describe what are obviously different types of experience.

The techniques for controlling the tone followed a similar pattern (see Table IV).

DISCUSSION

The outcome of this study supports the hypothesis that alpha enhancement is not necessarily associated with any systematic change in autonomic activation. Only change in T-wave amplitude was significantly correlated with changes in alpha and this correlation was extremely ambiguous. These results are in line with Eysenck's theory that cortical arousal is mediated by two feedback loops, only one of which involves autonomic activation. According to this theory, changes in cortical arousal would not be expected to be associated with changes in autonomic arousal under conditions of quiet restfulness where emotional factors are not involved.

The subjective experience of the subjects who achieved 15% or more increase in alpha over baseline supports results of other recent studies concluding that the "alpha experience" is heterogeneous. Due to the range of "active" and "passive" states, it is tempting to speculate that enhancement of alpha follows an inverted U-shaped curve such that those with slower frequencies (extraverts) must increase, i.e., be active, and those with faster frequencies (introverts) must relax. However, the correlation between scores on extraversion and alpha change was not significant.

The fact that locus of control was not significantly correlated with alpha increment in this study (in contrast to that of Goesling et al., 1974) may be due to the fact that their study employed extreme groups of both internal and external control, while this study's subjects all scored on the internal half of the scale.

EEG alpha has often been defined as reflecting a state of relaxed wakefulness (Morgan, 1965; Brown, 1974) and pleasant mood states (Nowlis & Kamiya, 1970). Studies of various types of relaxation training have reported increases in EEG alpha that coincide with decreases in measures of autonomic activation. It therefore seemed meaningful to test whether or not alpha enhancement achieved through biofeedback would also be associated with decreases in activation. Eysenck's theory of cortical feedback loops led to the prediction that it would not. The data from this study show an augmentation of alpha which is not accompanied by any systematic change in autonomic activation or by a homogeneous subjective experience. These results indicate that alpha enhancement attained through biofeedback should not be confused with that occuring through the use of relaxation techniques such as Autogenic Training and Meditation, where alpha seems to play an integral but nondecisive role.

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