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ARTICLE TITLE:	Localized EEG alpha feedback training: a possible technique for mapping subjective, conscious, and behavioral experiences.
ARTICLE AUTHOR:	Peper,
VOLUME:	11
ISSUE:	3
MONTH:	
YEAR:	1972
PAGES:	166-9
ISSN:	0023-5946
OCLC #:	GZN OCLC #: 1234048
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Kybernetik 11, 166—169 (1972)

Localized EEG Alpha Feedback Training: A Possible Technique for Mapping Subjective, Conscious, and Behavioral Experiences*

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Received: June 5, 1972

Abstract

Subjects who received EEG alpha feedback recorded from two homologous scalp areas (central-temporal) were trained to have ON-OFF control over the left and right sides. The partial success in demonstrating localized control suggests that subjects may be trained for very specific control. Localized training may be used to partition the subjective, conscious and behavioral experiences associated with selected EEG patterns and to develop an independent subjective physiological language. Applications to medicine and altered states of consciousness are discussed.

Introduction

While receiving feedback, subjects have learned to control their alpha, beta and theta electroencephalographic (EEG) patterns (Kamiya, 1968; Peper and Mulholland, 1970; Green *et al.*, 1970; Brown, 1971); in addition, some epileptic patients have learned to control (inhibit) their seizures by enhancing their sensory motor rhythm (Sterman, 1972). Eventhough subjects have learned to control their EEG, the mechanism, modes of control, and mapping of subjective conscious experience associated with certain EEG patterns are not understood. The EEG varies spontaneously in amplitude, frequency, and spatial location (the surface of the scalp) as the person is learning to control his EEG with feedback or shifts levels of alertness. In many cases, the subjective experience associated with EEG training (such as alpha) results from constraining the EEG within a narrow boundary and the subject's effort to stay awake and refraining from orienting commands while being in a sensory limited environment (Peper, 1971b).

The following experiment presents a methodology to explore the subjective experience and hopefully the mechanisms associated with localized EEG control. Instead of learning control over a certain EEG pattern, the subject controls one pattern at one scalp location and suppresses the pattern at another scalp location.

In human studies, the localized control of the EEG should tease out those subjective experiences associated with the varying and self-controlled EEG pattern. This paradigm may partially map the physiological language for internal states of consciousness that Kamiya (1968) has advocated. Moreover, if the strategies by which the subjects develop localized EEG control were known, they could be used to enhance the training of subjects with abnormal EEG's and the associated behavior aberrations – possibly offering treatment through self-control. In addition, if localized training is feasible, then the differential control would imply a greater learned specificity and not a general change in the level of arousal, alertness, or orienting. This localized control would be similar with human subjects to the results of DiCara and Miller (1968) who showed that curarized and artifically respirated rats could learn vasomotor dilation in one ear independent of the other ear. This demonstration of localized control self-control suggests applications for the understanding and treatment of psychosomatic illness.

A previous exploration (Peper, 1971a) indicated that localized EEG control may be feasible. In that initial experiment two out of six subjects were successfully trained to produce occipital asymmetry when given feedback. However, the feedback indicated only absolute asymmetry and the paradigm could not resolve subjective strategies or asymmetry because of an overall increase in percent time occipital alpha during the asymmetry trials.

When subjects were trained for absolute occipital alpha asymmetry, the extent of control was surprising: 31 sec out of 120 sec of alpha asymmetry for the asymmetry trial; contrasted with 3 sec out of 120 sec of alpha asymmetry for the symmetry trial; moreover, the seconds of asymmetry increased above the two baseline conditions.

* Presented in part at the Biofeedback Research Society Meeting, St. Louis, Mo. (1971).

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With a different experiment, Fehmi (1971) has reported that: after a 20-minute exposure to a feedback tone which signaled when the right and left occipital rhythms were within 15 degrees of being in phase, the subjects demonstrated an ability to increase and decrease phase synchrony with respect to the baseline values. He reported that these results are statistically significant; moreover, yoked controls who received non-contingent feedback, failed to demonstrate a difference. The verbal reports from these subjects and 87 others associated attentional focussing upon a relatively stable mental image with the occurrence of the feedback signal. When such a mental focus was disrupted, the phase synchrony of occipital waves was lost.

In addition, psychological and behavioral correlates have been associated with localized brain disorders and epileptic foci. The localization of cerebral function has been repeatedly demonstrated in the brain injured and split brain studies (Sperry, 1964; Gazzaniga, 1970). This data indicates that the left hemisphere is dominant in processing language functions, mathematical and analytic tasks; while the right hemisphere is dominant in processing spatial relations and gestalt tasks. Although the data comes from split brain and brain-damaged subjects; data from normal subjects also suggests that the two sides of the brain act differently.

Recently in an ingenious study, Galin and Ornstein (1972) looked at the power of the EEG spectrum in normal subjects when those subjects where presented with predominantly right (spatial) or left (verbal) hemisphere tasks. EEG recording were made from the left and right temporal-parietal areas and the rations of average power (1-35 Hz) in homologous T4/T3 and P4/P3 were computed. This ratio, average power of the homologous areas (right over left), was greater in the verbal tasks than in the spatial tasks. Using this measure from scalp recordings, they have been able to distinguish between these two cognitive modes as they occur in normal subjects. Generally, verbal behavior is mediated in the left hemisphere; a finding that may explain why a large number of subjects show alpha rhythms of higher mean voltage and of somewhat wider distribution over the right hemisphere (non-dominant) than the left hemisphere (Kiloh and Osselton, 1966). Subjects when tested are somewhat nervous, anxious and continuously analyzing the situation; that behavior would decrease the alpha amplitude on the left side since that side is giving more efferent commands.

One hypothesis suggests that alpha EEG activity may attenuate when efferent commands are given. Specifically, occipital alpha will attenuate when the person is no longer "passively observing" but giving visual motor commands – accommodation and convergence – while looking and orienting (Mulholland and Peper, 1971; Peper, 1971b).

Procedure for Localized Central-Temporal Alpha EEG Training

The EEG was recorded on a Grass model 5 and the two feedback paths were identical. The feedback system for each channel has been described previously (Peper, 1971a); Except that the electrodes were placed at the mid-points between P4–T4 and F4–T4 on the right side of the scalp and P3–T3 and F3–T3 on the left side of the scalp; the right mastoid was ground. The bandpass filter for each channel was set ± 1 Hz for each individual's resting alpha frequency. The criterion to define alpha was set and measured by an optical meter relay at the output of the bandpass filters. The relay was set to close when the alpha amplitude reached 30% of the resting amplitude and this system has been described in detail (Boudrot, 1972). The relays operated a timer and closed the circuits to present the feedback tones. A high tone was presented when ever alpha was defined in one of the channels and a low tone was present when alpha was defined in the other channel. The sound was 50 Db and presented by a speaker behind the subject.

Eight unpaid volunteers were trained for 2 sessions, four of the subjects received the high feedback tone when alpha occurred in the right hemisphere while the other 4 subjects received the high feedback tone when alpha appeared in the left hemisphere. The low tone was present when alpha occurred in the other hemisphere. The subject sat in a comfortable reclining chair in a sound attenuated light-proof room. An intercom linked the experimental chamber with the experimenter.

For each session, the subjects were instructed that after the two baseline conditions (eyes open and closed) with no feedback, two tones would sporadically go on. These tones were produced by their own brain waves and that during the session they would attempt to gain voluntary control over these tones (their EEG). The subjects were then given a 10 min practice session with feedback which was followed by four or six 180 sec training trials in which the subjects would attempt in the first trial to keep the high tone on and suppress the low tone; in the second trial, the directions were reversed, the subject would attempt to keep the low tone on and suppress the high tone. This pattern was repeated for the following trials. After the feedback trials, 2 trials were given without feedback to check whether the subject had any method of control. Final baselines were recorded and the subjects were interviewed. Since this study was an exploratory approach, in some cases the subjects were asked to keep their eyes open while in other cases the light was on in the experimental room.

Results

Even though localized control of the EEG is extremely difficult at least one subject showed control, see figure 1. Although the subject did not have control over the per cent alpha in the left central-temporal areas – it stayed relatively constant; the subject demonstrated independent control over her right

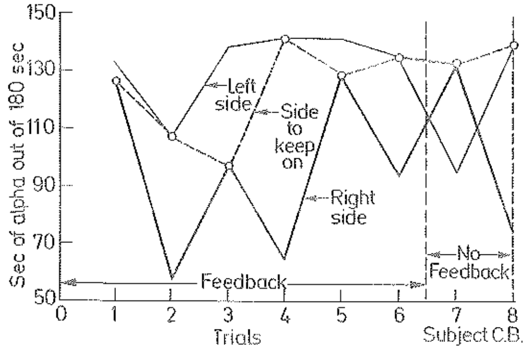

Fig. 1. Seconds of EEG alpha recorded from the homologous areas of the scalp (central-temporal) are shown, while the subject alternately enhances alpha on the left or right side by maintaining a feedback tone on one side (designated by small circles) and suppressing the tone on the other side. The subject demonstrates right hemisphere control when feedback tone is given (trials 1–6) and demonstrates both right and left hemisphere control when no feedback is given (trials 7 and 8)

central-temporal alpha EEG. Ironically, once the feedback was removed the subject had some control over the alpha EEG on the left side. This subject (C. B.) reported that to keep the low tone on (left central-temporal alpha), she quietly sang to herself, felt the rhythm of dancing and noticed (felt) how relaxed she was; to keep the high tone on (right central-temporal alpha) she spelled things named the states of the U. S. and multiplied high figures.

Only one other subject (T. M.) reported that the tones made sense to him although he could not control them. To keep the high tone on (right central-temporal alpha) he talked and issued verbal commands; to keep the low tone on (left central-temporal alpha) he relaxed his tongue and felt like a zombie. He reported that his main difficulty was that he could not stop self-observing and analyzing his own behavior. The low tone kept going off as he inadvertently observed, gave strong verbal commands and fixated visually.

Discussion

Localized EEG alpha control appears feasible and was demonstrated by C. B. It seems likely that many more training sessions are necessary (two sessions are not enough) for subjects to learn extremely fine control of their EEG patterns at selected locations, especially if shaping procedures are used. In order to "learn" control, subjects have to "learn to forget about trying" and just "let it occur".

The limited subjective reports corroborated Galin and Ornstein's (1972) results, who found that alpha amplitude is less in the hemisphere which is performing a cognitive task. For example, subject, C. B., kept the left central-temporal alpha on by singing and feeling the rhythm of dancing which would activate the EEG and therefore suppress alpha on the right side (non analytic – spatial analyses). She kept alpha on on the right side by spelling things, naming the states and multiplying high figures which would activate the left side, allowing relatived more alpha on the right side.

Perhaps her inability to change the percent alpha on the left side during feedback conditions meant that she continued to subverbalize at a certain level, analytically observed herself while attempting to keep the tones on and off. Only after she no longer "heard" the tones did she relax and modulate the alpha on the left side. The other subject's (T. M.) subjective reports fit a similar hypothesis. His constant level of self-awareness or mentation prevented any control which supports the localization of function.

Though this is an exploratory study, learned localized EEG control may have applications to the study of altered states and medicine. Localized training may help partition the unique altered states and subjective experiences associated with a particular EEG pattern. It might be used to enhance differential experience by training relative suppression or enhancement of left hemisphere orienting (analytic functions) and right hemisphere responses (spatial and global tasks). Furthermore, this technique, used in longitudinal study of children may help to explore how language functions consolidate in the left hemisphere.

In the clinical context this method of partitioning the EEG may be used to train people to recognize and abort epileptic discharges and other localized EEG disturbances. Finally, it may be used to develop diagnostic tests which would identify the conditions under which EEG asymmetry is pathological.

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