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Reduction of Efferent Motor Commands during Alpha Feedback as a Facilitator of EEG Alpha and a Precondition for Changes in Consciousness* **

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Summary. Evidence is presented in support of the hypothesis that a basic component underlies the subjective experience of the EEG alpha state. Corrective commands to the oculomotor system, causing movement in extrinsic eye muscles and lens adjustment, suppress *occipital* alpha. Somatic commands to many muscle groups block or suppress *central* alpha, hence the absence of such commands may be the precondition for an altered state of consciousness that can be repeatedly demonstrated by alpha feedback.

Introduction

Because of the popular press, people have come to associate EEG alpha rhythm with a "turned on" state of consciousness. Alpha feedback has been described as a way to reach altered states of consciousness without drugs. How valid are these claims? Does alpha electroencephalogram (EEG) training enhance consciousness and, if so, what happens to the subject? Moreover, what has really been demonstrated—has alpha increased, has alpha blocked, and what are the physiological correlates of alpha?

What is alpha? Alpha is defined as synchronous activity recorded from electrodes on the outside of the scalp with a frequency of 8–13 Hz and an amplitude of about 30–80 μ V. This frequency can be recorded over the whole scalp; though it is predominantly recorded from the back of the head (occipital area) when the subject has his eyes closed and is relaxing. The pattern is markedly attenuated when the subject "pays visual attention".

The origin of alpha EEG has not been pinned down since the first of use electroencephalography; thus the neural or other possible origin of the alpha rhythm remains an enigma [1]. Among the theories attempting to explain the alpha rhythm an accepted hypothesis suggests that the thalamic regions are involved [2]. Moreover, there is a high inter- and intra-subject variability in the percent time of alpha occurrence. This EEG variability complicates the feedback paradigm, since electronic triggers are usually adjusted for a single frequency and amplitude range for the duration of an experiment. There has been no satisfactory solution to provide for the subject's shifts of EEG amplitude or frequency. In addition it is difficult to define an initial and final baseline because alpha may be enhanced independently of feedback training, as the subject relaxes and decreases his anxiety in the course of the experiment. Needless to say, this complicates measurement of feedback effectiveness [3]. Some of these problems may be bypassed if one sets the feedback contingency so that the EEG pattern is

blocked or enhanced by the stimulus in a one-to-one correlation. By such feedback methodology one can develop control over EEG events.

The author proposes that the underlying mechanism involved in alpha training experiments is the cessation of the functions that block alpha. Specifically, this alpha "blocking" at the alpha-beta transition is due to activity in those areas of the brain that are involved in generating efferent motor commands to muscles. In this case the alpha increase can indicate the absence of processes which produce alpha blocking. Note that this does not suggest what mechanism generates alpha. Moreover, the transition from alpha to a theta rhythm and on to sleep is assumed to use a different mechanism—one hypothetical mechanism could be the slowing down of the "alpha generator" as the system changes state.

There is considerable evidence of alpha control as reported by various experimenters [4]. In most of these cases the control appears to be produced through alpha blockage or inhibition [5], for blockage is a normal response to stimuli in the environment. Alpha enhancement, on the other hand, has been difficult to demonstrate because alpha increases without training over the course of the experiment. Certain subjects do appear to produce more alpha during training than during baseline; in addition, subjects can differentiate between alpha and non-alpha states: many of them positively enjoy the alpha state [6].

Some subjects have described the alpha state as follows: "letting go", "a relaxed passive awareness", "a lack of criticalness", "some desirable, undescrivable state with timeless dimensions". Moreover, EEG recordings from all over the scalp that are predominantly in the alpha range with an increase in alpha amplitude in the central areas [7] have been reported with practiced meditators and Yoga and Zen masters [8]. (Note: Zen masters also produce a high amount of theta.)

The high alpha levels in Yoga and Zen practitioners could concur with the reports that the greatest change in reported subjective states occurs when the subject produces a large increment (step increase) in his alpha activity during the experiment [9]. Hart has reported: "only subjects who achieved a doubling or tripling or greater increase of their alpha levels report much of a subjective change during the training sessions."

The change in subjective experience associated with alpha may be partly due to self-induced sensory limitation. The author suspects that the varieties of descriptions and interpretations of the alpha state, especially during sudden increases of alpha, is closely related to the subject's set and expectations and pro-

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poses that sensory limitation—high alpha state—is self-produced when the subject is not giving efferent motor commands, either in response to external or to internal stimuli. The sound attenuated, light-proof room in which most experiments are performed helps to optimize this condition.

In the next section, data is presented suggesting an underlying mechanism of alpha blocking and alpha recurrence,—the “alpha-attenuation” cycle. It is assumed that the same mechanism underlies the experiments in which subjects voluntarily control their own alpha rhythm, although they may be unaware of the nature of the mechanism.

Alpha blocking may be due to efferent motor processes occurring in the brain beneath the scalp recordings. Such processes usually occur in response to external stimulation, often as an orienting response. But subjects may be trained not to respond which may explain the data from Yogis who continue to produce alpha in spite of stimulation [10].

Some evidence suggesting that alpha blockage is due to efferent motor commands is as follows: Kreitman and Shaw [11] reported a small negative correlation between alpha and forearm EMG activity, while Crown (unpublished manuscript) [21] reported that integrated frontalis EMG levels were lowest when subjects were asked to keep occipital alpha on, during feedback training.

Jasper and Penfield [12] reported that desynchronization of the electrocorticogram at the precentral gyrus occurred with the initiation of voluntary movement. Similarly, Chatrian *et al.* [13] showed that the central alpha (Rolandic wicket rhythm) is blocked contralaterally when their arms were tensed as shown by the surface EMG. This is illustrated in Fig. 1.

In this case the blockage of the EEG preceded EMG activity. In a like manner, Klass and Bickford [14] reported that amputees blocked the contralateral central alpha when they were instructed to move their phantom hand. These cases point out that it is the efferent motor commands, not the incoming afferent somatosensory signals that block alpha activity. It should be pointed out that the usual mode of any subject, unless tired and exhausted, is to orient

and respond to stimuli which may be external or internal body changes (i.e., to respond with efferent motor commands). Therefore confusion can arise in studying alpha blocking, since stimuli which produce input also are followed by adjustment of effector organs.

A similar argument can be made to explain alpha and alpha blocking in the occipital-parietal region, the location most frequently used in EEG alpha training experiments. Mulholland [15] has shown that when subjects tracked both stationary and moving targets, alpha was most prevalent when the eyes were diverged and unaccommodated to the target, that is, not tracking the target. An example with a stationary target is shown in Fig. 2. As you can see in Fig. 2 when the eyes diverge alpha increases.

The following experiments explore and demonstrate this phenomena in more detail. Here various oculomotor functions were explored with subjects who could perform efferent oculomotor tasks involving minute changes in accommodation and divergence while tracking a small target, and at the same time produce alpha.

Methods

The experimental apparatus is shown in Fig. 3. The subjects, all unpaid volunteers, sat with their heads in a chin and head hold, 6 to 7 inches in front of a Techtronic Type 531 oscilloscope, with a P-15 tube, which, for all practical purposes, had zero persistence. The target made a 4.5 inch horizontal sweep. The visibility and movement of the target could be controlled by either the subject's EEG alpha or by the experimenter. An intercom linked the experimental chamber with the experimenter, and the subject had a hand key which was a marker on the EEG record. The subject's EEG was recorded from O_2-P_4 with the right mastoid as ground. The electro-oculograms (EOG) were recorded with slow or non-polarizing biopotential skin electrodes (Beckman) attached to the outer and inner canthi of each eye. The feedback circuit is shown in Fig. 4.

The bandpass filter was set at ± 0.5 Hz of the subject's resting alpha frequency. The state relay turned ON when alpha lasted longer than 0.3 sec with an amplitude greater than 25% of the maximum amplitude recorded when the eyes were closed. The relay was OFF when alpha amplitude fell below 20% of the maximum resting amplitude. Between 20–25% of the resting amplitude, it was unpredictably ON. The input attenuators were adjusted for each subject so that

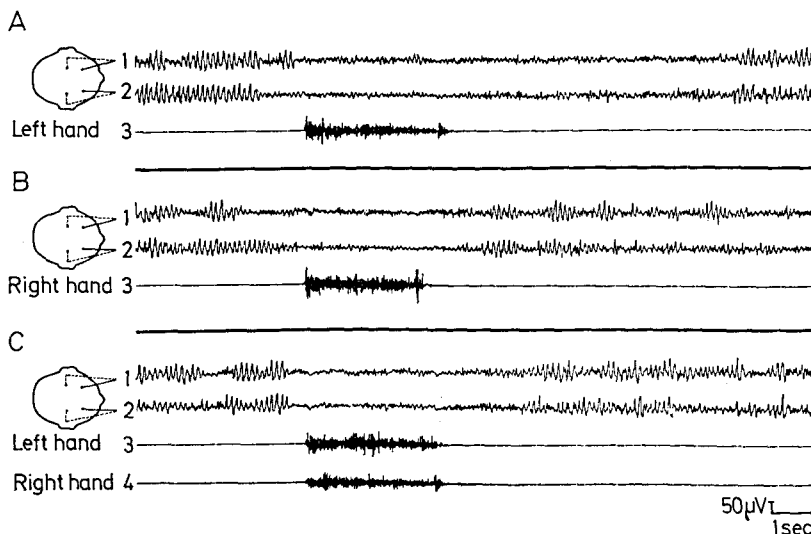


Fig. 1A-C. From Chatrian, G. E., *et al.*, in: *Electroenceph. clin. Neurophysiol.* 11, 497–510 (1959) Fig. 6. Motor responses are associated with disappearance of synchronous activity (central μ). Note that blocking occurs at the same time on each side when both hands are involved. The blocking reaction on the contralateral side clearly occurs *before* the hand response is given

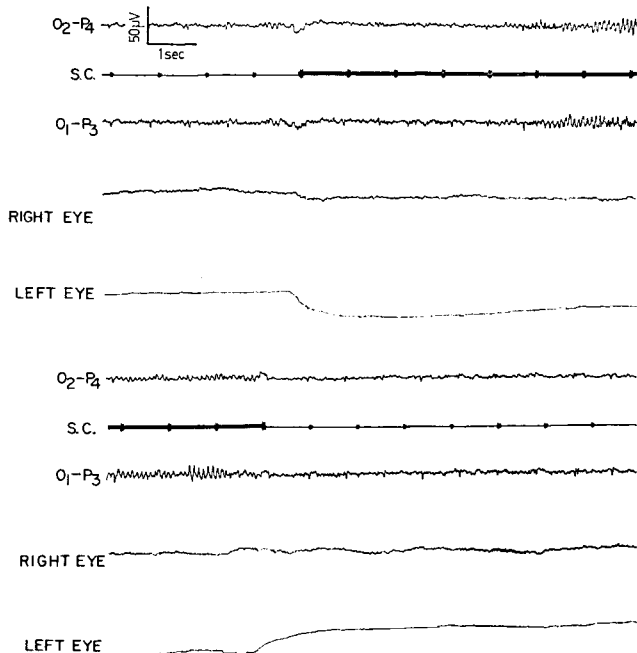


Fig. 2. *Top half.* Alpha occurs with a delay, after a shift from convergence and a report of a clearly focussed target to divergence and a report of a blurred target. *Bottom half.* Alpha is blocked just prior to a shift from divergence and report of blurred target to convergence and report of a focussed target. Tracings are RP-O EEG; subjective clarity of the target superimposed on a 1 sec time mark; LP-O EEG; right EOG, Left EOG. [From: Mulholland, T., Peper, E., in: *Psychophysiology* (in press, 1971)]



Fig. 3. Experimental set-up used in tracking studies

maximum alpha with eyes closed was approximately 1 cm peak to peak.

Various target speeds were used, and the target visibility was sometimes contingent and sometimes not contingent upon the subject's alpha EEG, by means of the feedback circuit. Both monocular and binocular conditions were used.

Results and Discussion

In all cases, the alpha burst in the occipital-parietal area could be associated with loss of tracking

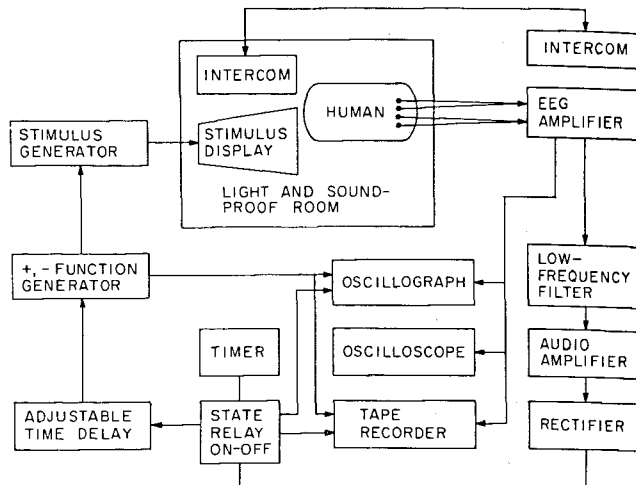


Fig. 4. Flow diagram of the alpha feedback system

performance by the subject, which upheld the possibility that oculomotor functions, probably accommodation and convergence of tracking cause alpha suppression. Some of the results are shown as follows: First, is an example of smooth pursuit tracking by the subject, shown in Fig. 5. When the subject deteriorates in his tracking performance, alpha reappears in the record as is shown in Fig. 6. As you can see in this figure, when the eyes diverged the recorded tracings converged. During alpha the eyes diverged. Similarly Fig. 7 demonstrates that loss of tracking amplitude coincides with alpha. In this case the subject was highly trained and could track the target while seeing it blurred and doubled. Moreover, the subject reported that he tracked while the target was not on his fovea. If the target is on the fovea, usually there occurs an initiation of corrective, accommodative, and convergent commands (reflexes) which are almost impossible to control. For example, in a separate experiment the subjects saw the Heider brush which is due to differential sensitivity of the fovea to rotating blue polarized light which causes a blurred rotating image like a propeller on the fovea; and here it appears impossible for the subject to resist giving corrective, accommodative and convergent commands (reflexes). Inevitably, alpha was always absent.

In all these cases, occipital-parietal alpha blocked when the subject initiated pursuit tracking, which again involves accommodation and convergence. A feedback system in this tracking task clearly displayed [16] the relationships between alpha EEG, pursuit tracking, and accommodation and convergence. In these experiments, the target visibility was contingent upon the subject's production of alpha. In all cases, every time the subject initiated tracking, alpha blocked, as is shown in Figs. 8 and 9.

In Fig. 8, because there was a small delay before the no-alpha condition opened the relay, the target stayed visible into the no-alpha period. Consequently the subject continued to track for a short period until the target disappeared.

Alpha blockage is not necessarily due to the onset of the light, but rather to the oculomotor changes, since alpha is not blocked when the subject does not initiate tracking, as shown in Fig. 10. This subject

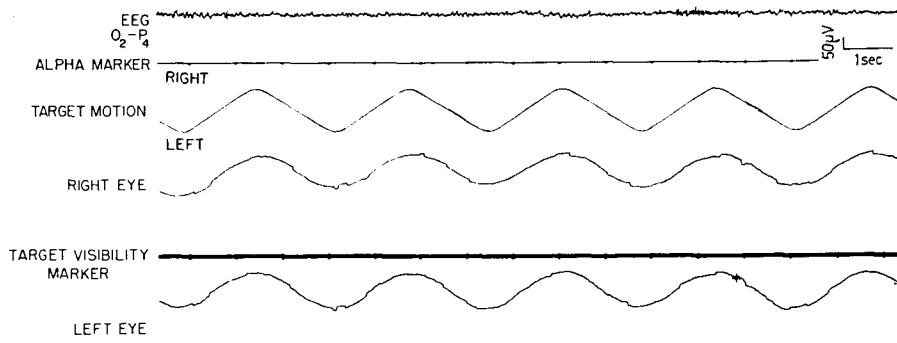


Fig. 5. Example of smooth tracking by subject. Note there is no alpha activity in the EEG recording

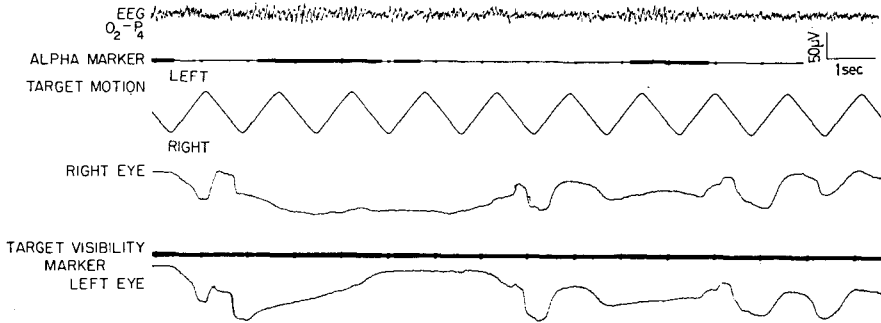


Fig. 6. Example of tracking record. Note loss of tracking is associated with the occurrence of alpha in the EEG. This concurs with the divergence of the eyes as indicated by the convergence on the EOG record

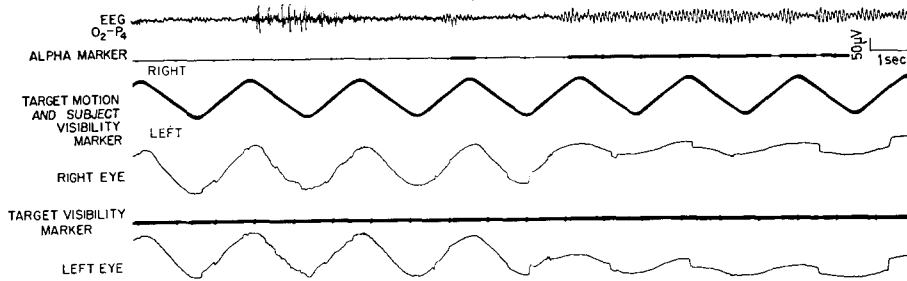


Fig. 7. Example of tracking. Note that subject can still track although the target is not on the fovea and eyes are diverged

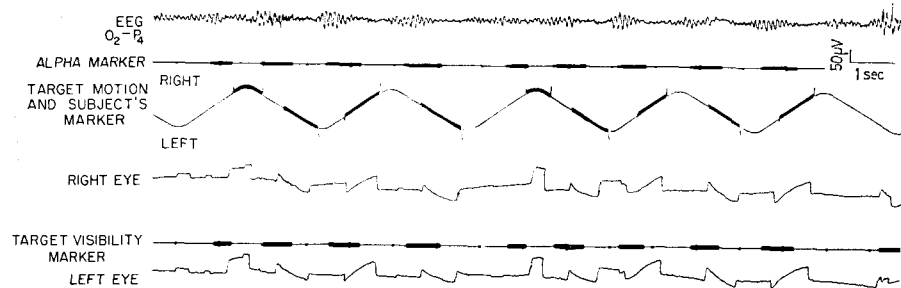


Fig. 8. Example of feedback tracking in which target visibility is contingent upon subject's alpha production. Note that alpha is always blocked when subject initiates tracking

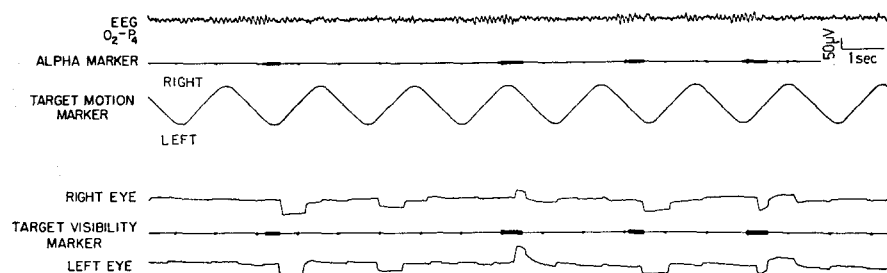


Fig. 9. Same as above

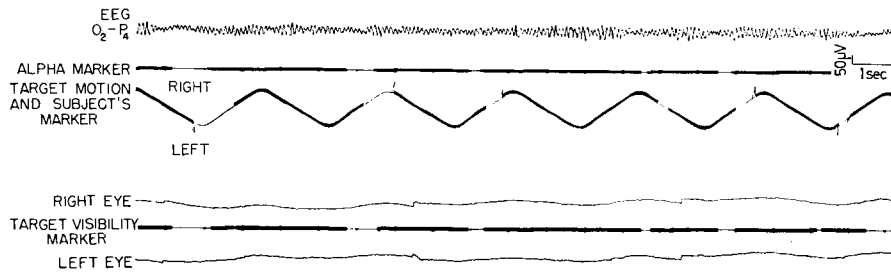


Fig. 10. Example of tracking in which the onset of a moving target does not necessarily block the subject's alpha rhythm as long as he does initiate tracking. Nevertheless, the subject is paying "attention" to the onset of the stimulus as is indicated by the key press. [From: Mulholland, T., Peper, E., in: *Psychophysiology* (in press, 1971)]

reported that he could perceive changes in the environment without having to respond with his eyes, but this takes some training and naive subjects in this experiment could not do this. Note in this case that the subject did respond to the visibility of the target with his hand key, yet the onset of the target did not block his alpha. Orienting to a visual cue is the usual response for most people because the afferent somatosensory input and efferent motor output are closely related.

Occipital-parietal alpha may be blocked by changes in accommodation and vergence, and by tracking processes. Central alpha is blocked by movement responses; and frontal alpha possibly by oculomotor activity, since the frontal eye fields are located there. In this way, the alpha blockage may reflect in a gross way the functional changes in the brain involved in efferent motor commands. This appears to fit the suggestion of David Galin and Robert Ornstein [17] that the hemisphere which is performing a localized functional task, should show less alpha activity than the other hemisphere. Further possible evidence for this hypothesis comes from an asymmetry training experiment in process [18] in which subjects are asked to control two alpha feedback tones triggered from different locations on the scalp. When the feedback was taken from the right and left temporal-central areas, the subject reported, "Verbal passivity with the absence of verbal criticism: thinking and imagined speech caused the low tone to stay on." the low tone was triggered by alpha from the left side. In other subjects, learning was demonstrated in changes of percent time alpha in right hemisphere while keeping percent time alpha in the left hemisphere constant. These experiments suggest that alpha can be sustained during external and internal stimulation—that it is not sensory stimulation, per se, that blocks alpha, but rather the response, i.e. efferent commands. For example, when a subject contracts a muscle, he stimulates both efferent and afferent systems. Orienting usually blocks alpha, but lack of orienting to afferent input, may allow EEG alpha to continue. Therefore, the author would like to suggest that the subjective changes of consciousness reported during the high alpha states, are due to the absence of efferent motor commands. Thus, the subject who attains a high alpha state all over the scalp, may induce sensory limitation by not sending corrective efferent motor commands from the brain to his oculomotor system, arms, legs and body. In turn, this would create a lack of change in the subject's peripheral regions, and massive

decrease in his somatosensory input. If he can sustain this state long enough the subject may become unaware of his body bounds by absence of internal changes. This may be similar to our usual unawareness that we are wearing clothing, a watch, glasses or dentures. These commonplace examples could be analogous to the extreme states experienced by some subjects, although most subjects merely report passivity during the alpha state.

Conclusion

It is my hypothesis that some subjects experience altered states of consciousness during high alpha states. This is due to the absence of efferent motor commands, such as the oculomotor components in occipital alpha attenuation, which may be tantamount to a state of self-induced sensory limitation as well as a limitation of cerebral processing. The use of the sound-attenuated, light-proof room, aids the naive subject to such a state, but evidence from skilled meditators or yogis suggests that such self limitation can be accomplished anywhere. The importance of set, expectation, and verbal mediation in interpreting this state cannot be overlooked. Two subjects, may give vastly different subjective descriptions, yet the polygraph data suggest that the same mechanism and state obtain in both.

This relation between somatic response and "conscious processes" may remind some readers of the pioneering therapeutic work of Jacobson [19] and of the autogenic training methods of Luthe [20] although they did not make correlation with EEG recordings.

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