The International Journal of Clinical and Experimental Hypnosis
1977, Vol. XXV, No. 4, 361–371

DEVELOPING A BIOFEEDBACK MODEL: ALPHA EEG FEEDBACK AS A MEANS FOR PAIN CONTROL[1]

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Abstract: 3 adept meditators voluntarily inserted steel needles into their bodies while physiological measures (EEG, EMG, GSR, EKG, and respiration) were recorded. Although each adept used a different passive attention technique, none reported pain. During the insertion, 2 of the 3 *S*s increased their alpha EEG activity. The role of alpha EEG and its relationship to pain control is discussed.

Biofeedback is a term that has come to be used for a technique in which physiological changes within the organism are amplified by electronic instruments and are selectively fed back (displayed) to the individual. Repeated feedback can help an individual identify the physiological and psychological cues associated with his internal changes. With repetition, one may learn not only to recognize these subtle internal changes but also to control them.

Human volunteers have been trained to control some autonomic functions such as heart rate and blood pressure, GSR, EMG, hand temperature, and EEG activity (Budzynski, Stoyva, & Adler, 1970; Kamiya, 1968; Peper & Mulholland, 1970; Sargent, Green, & Walters, 1973; Shapiro, Tursky, & Schwartz, 1970; Weiss & Engel, 1971). The ability to control these body functions may have many applications to clinical medicine, in addition to teaching self-awareness. The importance of voluntary control should not be underestimated since, with

Manuscript submitted June 8, 1972; final revision received December 13, 1976.

[1] Part of this paper was originally presented at the Biofeedback Research Society Meeting, St. Louis, October 1971.

[2] The authors would like to thank Jack Martz and Gay Luce for their assistance and J. Kamiya and B. Timmons for their critique of this research and article.

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feedback, an individual can learn how to sustain and stabilize a continuously varying physiological function. However, it is not always clear which physiological function one must control to obtain the desired effect.

There are at least three ways to identify the parameter one wishes to control.

1. Many *E*s have made serendipitous findings while pursuing other research paradigms. For example, *S* in a study on multiparameter feedback training for creativity observed that her migraine headache disappeared when she learned to increase her hand temperature. This led to a study to train migraine headache patients to increase hand temperature as a means to alleviate the disease (Sargent et al., 1973).

2. Clinical attempts to train patients to achieve self-control over a malfunctioning system have uncovered useful feedback parameters for training. For example, hypertensive patients have been trained to decrease their blood pressure (Shapiro et al., 1970), patients with PVC's have been trained to control their heart rate (Weiss & Engel, 1971), patients with tension headaches have been trained to reduce their frontalis muscle tension (Budzynski et al., 1970), and patients with Raynaud's disease have been trained to increase their hand temperature in order to enhance blood circulation (Surwit, 1973).

3. Occasionally, one can study unusually skilled individuals known for their "feats" of autonomic control and identify the physiological function (correlate) while *S*s achieve a special physiological and/or psychological state. The unique parameters may then become the basis for a biofeedback model in which normal *S*s are trained to attain similar physiological controls.

This paper will focus on the third method.

Previous studies have demonstrated that adept meditators have been able to achieve control over various autonomic, physiological functions (Akishige, 1973; Bagchi & Wenger, 1957; Kasamatsu & Hirai, 1966; Pelletier & Garfield, 1976; Pollini & Peper, 1976; Wallace, 1970). In the past 5 years, intensive laboratory studies have verified that research subjects can exercise marked control over EEG, heart rate, and blood flow (Hart, 1968; Kamiya, 1968; Miller, 1969; Pelletier, 1974).

The specific goal of the research described here was to discover whether there were unique psychophysiological parameters associated with the absence of pain and bleeding when the three adept meditators punctured themselves. The overall objective was to use the physiological findings to provide clues for the kinds of biofeedback training that might be helpful for other individuals to acquire similar control. Psychophysiological patterns were derived for such training, and methods were developed to test whether the training could effect pain control (Pelletier & Peper, 1977).

Procedures

Case 1

In May 1971, Peper studied RCT, a 24-year-old Ecuadorian who previously had demonstrated control over pain by placing bicycle spokes through his body, being suspended from hooks inserted under his shoulder blades, and walking through fire – all without reported pain or observed damage to his skin. RCT appeared to have normal pain sensitivity, as ascertained by touching and pinching (Peper, 1976).

The physiological responses were recorded with a Beckman Dynograph. The electroencephalograph (EEG) was recorded with Grass electrodes from 02-P4, F4-Fp2, and the right mastoid as ground (International 10–20 system). The electromyogram (EMG) was recorded from the frontal placement with Beckman miniature electrodes, and the photoplethysmogram was recorded from the ring finger of the right hand. RCT sat in a chair or stood in the doorway of a soundproof chamber facing the polygraph equipment and *E*s. During the experiment, 35-mm photographs recorded the events.

After *E* attached the electrodes and recorded baseline conditions with RCT's eyes open and closed, RCT controlled the sequence of the experiment. First, he broke a 100-watt light bulb and chewed some of the glass carefully, swallowing it with a glass of red wine. After a short rest period, he pierced his body with three bicycle spokes: one through the left side of his abdomen (through the flesh only and not through the muscle tissue beneath it); one through a similar position on the right side of his abdomen; and one through his right cheek, running through the center of his mouth and out the left cheek, as shown in Figure 1. The spokes were later removed in the reverse order. Finally, baseline conditions of eyes open and closed were again recorded.

The recordings taken while RCT chewed the glass were obliterated by muscle artifacts, but no such artifacts occurred while he pierced his skin. The EEG showed prominent changes. The occipital alpha activity dominated the recording, and the amplitude increased to 26 uV as compared with the 15 uV maximum amplitude recorded during the eyes-closed baseline condition. Interestingly, the average peak-to-peak analysis indicated that the alpha amplitude was greater while RCT pierced his right side (25.7 uV) than while he pierced his

FIG. 1. RCT with bicycle spoke through his right cheek, running through the center of his mouth, and out his left cheek.

left side (20.0 uV). The frontal EMG activity indicated low muscle activity during the piercing of the right side. Once the bicycle spokes were in place, EEG consisted of low-amplitude alpha and beta activity.

Most likely, the increased alpha activity was not due to EMG artifacts, since during the first baseline recording EMG activity had been higher without concurrent alpha activity in the EEG record. The plethysmogram showed slightly less amplitude during the piercing than during the resting and baseline conditions. When RCT removed the bicycle spokes, no bleeding was apparent, and the puncture wounds healed rapidly without visible scarring.

RCT was able to repeat this procedure on demand and without preparation, as he later did for us on February 2, 1972.

Case 2

In July 1972, Peper, M. Toomim, and H. Toomim studied JSL, a 31-year-old Korean karate expert, who suspended a 25-pound bucket of water from a sharpened spoke placed through a fold of skin on his forearm. JSL showed alpha activity in his EEG during baseline recording. During the experiment, his occipital EEG consisted mainly of beta activity with some low-amplitude alpha; the frontal leads showed some slowing; and the electrocardiogram (EKG) increased from 81 to 100 beats per minute.

Case 3

Independently, Pelletier studied the neurophysiological alterations during pain control by JS, a 50-year-old Dutch meditator. JS previously had demonstrated pain and bleeding control in a study by Green, Green, and Walters (1972). Pelletier examined the psychophysiological parameters of sustained alpha and theta to determine whether either of those states might correlate with voluntary control of pain. His immediate objective was to establish clearly the neurophysiological parameters of sustained alpha and theta and to compare those parameters to the indices monitored during a subject's demonstration of voluntary control of pain and bleeding.

All testing was conducted during 1 week in Dr. Kamiya's laboratory at the Langley Porter Neuropsychiatric Institute. A shielded, soundproof room was used and a physician was in attendance. All EEG electrodes were placed according to the International 10–20 system with an ear reference. Indices monitored were: (*a*) left-central alpha and theta; (*b*) left-occipital alpha and theta; (*c*) EKG; (*d*) integrated and reset-integrated frontalis EMG; (*e*) transient and basal palmar electrodermal response (EDR); and (*f*) thoracic and abdominal respiration rates and patterns (RR). Clinical interviews were also conducted. Respiratory rates and patterns were monitored with two, mercury strain gauges containing a 26-centimeter column in capillary tubing placed across JS's chest and navel and stretched to 32 centimeters to allow for inspiration. All channels except the EDRs were recorded on a Beckman Type R Dynograph and on magnetic tape for computer analysis.

Audio feedback was given from the left-occipital electrode, either alpha or theta EEG. The data were stored online on a PDP-15 computer. Quantitative results were given to JS every 2 minutes in the form of a digital, integral score proportional to the energy of the rectified, integrated EEG, and corresponding to the area under the curve of the wave form.

Twelve alpha and 12 theta feedback sessions were conducted on 6 consecutive days, totalling 24 sessions. All indices were computer sampled at 1-second intervals throughout the experiment. There was no evidence of a gradually rising baseline due to JS's habituation to experimental conditions. Both alpha enhancement and suppression were demonstrated with eyes closed as an indication of bidirectional control. The *S* reacted to pain normally under nonmeditative conditions.

Alpha baselines were compared with recording from alpha feedback sessions by means of a multivariate analysis of variance (the Hotelling's T-squared), and results were evaluated as a unidirectional, one-tailed t test, since all hypotheses were expressed as directional changes. Baseline recordings differed from those from the feedback sessions as follows: (*a*) alpha production increased during feedback from an average of integral 34 to an average of integral 210 ($t = 2.15$, $85/d.f.$, $p < .025$); (*b*) heart rate decreased ($t = 1.96$, $85/d.f.$, $p < .05$) and remained regular; (*c*) respiration rate increased ($t = 8.63$, $85/d.f.$, $p < .001$); and (*d*) neither the EDR nor EMG indices recorded a significant difference.

Multiple correlation analysis of the alpha feedback sessions indicated that both EMG and EDR indices were negatively correlated with alpha ($r = -.23$, $p < .05$), and ($r = -.31$, $p < .01$) respectively. Further, no other variables were correlated with alpha increase during feedback sessions, and there were no correlations among any of the variables during baseline recordings. Alpha increase appeared to correspond with physiological relaxation, marked by distinct respiration patterns and accompanied by a sense of "heightened awareness," according to JS during the clinical interview. During the alpha feedback sessions, the following respiration characteristics were noted: (*a*) respiration was thoracic less than abdominal; (*b*) the length of inspiration was equal to that of expiration; and (*c*) there was no pause between inspiration and exhalation.

Theta baseline differed from the feedback sessions as follows: (*a*) theta production increased during feedback from an average of integral 28 to an average of integral 87 ($t = 4.43$, $98/d.f.$, $p < .001$); (*b*) both EMG indices decreased ($t = 2.42$, $98/d.f.$, $p < .01$); (*c*) respiration rate decreased ($t = 2.26$, $98/d.f.$, $p < .025$); and (*d*) neither EKG nor EDR recorded a significant difference. During the theta feedback sessions, (*a*) thoracic respiration was less than or equal to abdominal; (*b*) inspiration was of shorter duration than expiration; and (*c*) there was a long period of slow expiration before inspiration. This pattern was highly consistent. Multiple correlation analysis of the theta feedback sessions indicated that (*a*) EKG negatively correlated to theta ($r = -.55$, $p < .001$); (*b*) EMG negatively correlated to theta ($r = -.36$, $p < .001$); and (*c*) EDR negatively correlated ($r = -.23$, $p < .05$). Theta increase appeared to be a state of physiological relaxation, marked by a distinct respiration pattern, and was characterized by "vivid imagery and internal sensations" according to JS.

At three instances chosen at random by *E*, JS pushed a 26-gauge steel needle through the medial aspect of his left upper arm approximately 9 centimeters up from the medial epicondyle of the elbow and completely through the biceps for 6 to 7 centimeters. All neurophysiological indices were monitored throughout the puncture demonstrations. Before the demonstrations, the physician performed an Ivy standard bleeding time test while JS was in a nonmeditative state. Average bleeding time was 3 minutes, and indices recorded a normal stress response of alpha blocking (a shift from alpha to beta activity). During the puncture demonstrations, JS received alpha feedback, since visual inspection of the EEG record indicated a predominance of alpha and a marked absence of theta activity. There was no evidence of alpha blocking and there was no spontaneous or subcutaneous bleeding at the puncture site.

Analysis of variance comparing alpha feedback sessions to the puncture sessions indices indicated that there was no significant difference among levels of integral alpha, respiration rate, or either EMG index. The EKG decreased ($t = 5.32$, $81/d.f.$, $p < .001$) and EDR increased ($t = 1.81$, $81/d.f.$, $p < .05$). Respiration patterns were of the alpha pattern noted earlier and multiple correlations were essentially identical between alpha feedback and the puncture indices. Both EMG and EDR indices were negatively correlated with alpha ($r = -.24$, $p < .05$) and ($r = -.35$, $p < .01$) and no other variables were correlated with alpha during the puncture demonstrations.

Discussion

The parameters of pain are numerous, and anxiety about pain appears to be a major component of the experience. A number of researchers, including Beecher (1959), have reported that reducing anxiety exerts an important effect on the pain experience, even if it does not significantly affect pain as a sensation. These observations are supported in this study. RCT, JSL, and JS each remarked that pain is principally fear of and attention to pain, and they maintained that anyone can learn to control pain through relaxation and passive attention.

Using a karate meditation technique, JSL reported that, instead of passively detaching his attention from his body, he focused totally on a small point of energy that he subjectively moved upward from the bottom of his abdomen to the point where he inserted the needle. He reported that:

> Once you concentrate on that square you can allow the energy to flow into any part of the body. The concentrated mind can be applied to anything it does, and when it is applied, it no longer feels; the concentrated mind is the activity itself; it does not exist in the world.

On the other hand, RCT had learned to control his fear by voluntarily dissociating himself from the stimulus sensation as he placed spokes through his skin. He explained that he diverted his awareness of the pain sensation by letting his consciousness drift away. In this state, "consciousness" is nonreacting and separated from the physical body, and *S* often is preoccupied by a distraction process. After sufficient practice of this state, *S* no longer needs the distraction technique and he can dissociate without relying on the procedure. RCT explained that in the beginning of the study, he was himself self-conscious about the laboratory setting and the slight pain he felt when he pierced his left side occurred because he had not yet dissociated.

JS used a slightly different unfocused meditation. Since childhood, he had learned to "ask his body for permission to allow the puncture and to heal himself." As he reports, he "did not stick a needle through my arm; I stuck a needle through *an* arm."

A significant observation of these studies was that JSL showed no alpha activity during piercing, whereas JS and RCT demonstrated increased alpha activity. A possible explanation may be that the karate expert practiced a very focused meditation, during which he mentally saw and felt the *ki* energy as a point, while RCT and JS employed passive attention and did not attend to the body stimuli. Thus, it is possible for physiological measurements to reflect strategies used in dissociation of pain perception, and that the quality of pain perception is altered if *S* is at either extreme of focused or unfocused conscious attention.

The change from EEG alpha-dominant activity to alpha-blocking activity could indicate that the adepts focused on and responded to internal stimuli. JSL's beta-dominant EEG, however, is more elusive, since it indicates no response to stimulation. Based on the EEG record and JSL's report, it may be possible that his focused attention to the "*ki* energy" did not allow his attention to drift from the immediate, intense experience to a normal awareness of pain. Such a phenomenon frequently is reported during combat, athletics, or sexual activity. Research of this strategy would require a more detailed analysis of subtle alterations in EEG beta activity.

The critical question – whether there is a specific neurophysiological state as indexed by an increase in alpha, theta, or some other specific brain wave activity which is concomitant with or causally related to the adept's skill in rising above the pain experience – has not been answered. These three adept meditators showed two distinct EEG patterns. We suspect that a process of training *S*s to enhance alpha without alpha blocking to stimuli could be a way by which *S*s could learn some form of pain control. Some of this evidence is derived from the experiments by Mulholland and Peper (1971) who investigated the relationship of oculomotor functions and the occipital alpha EEG and showed that occipital alpha always disappears when *S* accommodates and converges. If *S* does not give these oculomotor commands, even though he can recognize the stimuli, the occipital alpha EEG persists (Peper, 1971). Similarly, Anand, Chhina, and Singh (1961), found that two yogis showed persistent alpha activity both before and during the periods in which their hands were immersed in cold water. During the meditative *samādhi* experience, alpha activity could not be blocked by various sensory stimuli. On the other hand, the yogis did show alpha EEG blocking during stimulation in the nonmeditative state. In most normal cases, alpha EEG is blocked during stimulation; for example, Ádám (1967) showed that painless stretching of the duodenal wall usually causes alpha blocking.

Studies of the adept meditators suggest avenues to explore and indicate that most individuals who possess average patience and fortitude can have some control over their own reactions to pain and stress. We hypothesize that, for nonadepts, alpha EEG training without alpha blocking to stimuli could become a distraction technique whereby *S* again could learn self-control and competence as he becomes more successful in controlling his EEG.

The question as to whether alpha EEG states decrease pain sensation or whether learning to increase alpha EEG activity can block pain perception is not answered. Derived from the study of these adepts are suggestions for future research which need to be explored.

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Die Bildung eines Biofeedback-Modells: Alpha-EEG als ein Mittel für Schmerzkontrolle

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Abstrakt: 3 Personen, die Erfahrung mit Meditation hatten, stachen sich freiwillig Stahlnadeln in ihren Körper, während physiologische Masze (EEG, EMG (Eletromyogramm), GSR (galvanische Hautreaktion), EKG und Atmung registriert wurden. Obgleich jede der erfahrenen Personen eine unterschiedliche, passive Konzentrationstechnik gebrauchte, berichtete doch keine von Schmerzen. 2 der 3 *Vpn.* zeigten einen Anstieg in der Alpha-EEG-Aktivität. Die Rolle des Alpha-EEG und sein Verhältnis in der Schmerzkontrolle werden hier erörtert.

La conception d'un modèle de rétroaction biologique: le rythme alpha de l'EEG en tant que moyen de contrôler de la douleur

Kenneth R. Pelletier et Erik Peper

Résumé: Trois adeptes de la méditation ont volontairement inséré des aiguilles de fer dans leur corps, pendant que des mesures physiologiques (EEG, EMG, RPG, ECG et respiration) étaient enregistrées. Bien que chaque adepte ait utilisé une technique d'attention passive différente, aucun n'a rapporté de la douleur. Pendant l'insertion, 2 des 3 sujets ont augmenté leur activité alpha à l'EEG. Suit une discussion du rôle de l'activité alpha dans l'EEG et de ses rapports avec le contrôle de la douleur.

Desarrollo de un modelo de biorretroacción: el ritmo alfa como medio de control del dolor

Kenneth R. Pelletier y Erik Peper

Resumen: 3 expertos en meditación se implantaron voluntariamente agujas de acero mientras se tomaban ciertas medidas fisiológicas (EEG, EMG, GSR, EKG, y respiración). Aunque cada experto utilizó una técnica diferente de atención pasiva, ninguno dijo haber experimentado dolor. Durante la implantación, 2 de los sujetos acusaron un aumento de actividad alfa. Se discute el papel del ritmo alfa y su relación con el control del dolor.