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EEG CORRELATES OF ATTENTION IN HUMANS*

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Abstract—An attempt is made in this report to extend the Bremner attention model to human EEG data. Data are present which show changes predicted by the expectancy subset originally defined by animal EEG data. An additional subset, internal focus, is proposed and partially supported by changes in human EEG. It is suggested that this subset is unique to humans.

AN ATTENTION model has been presented by Bremner and his co-workers which makes uses of EEG changes as a dependent variable [1, 2, 3, 4]. This model considers that there are different classes or subsets of attention but that while these subsets are orthogonal they are not arranged in a hierarchy. The subsets already defined are: expectancy, counter-expectancy, orientation, arousal, and non-focus [4].

The utility of the above model will increase as its generality increases. The present study attempts to extend the generality of the model from the animal data used for its original conception to data concerning human attentional states. The present study concentrated on two aspects of generalizing the model. One of these aspects was to see if human EEG was sensitive to changes relative to any of the previously proposed subsets. The other aspect was to determine if there was any unique attentional subset present in humans but either not present in animals or not testable in animals.

Because much of the experimentation used to test the model has been directed toward the expectancy subset this was the subset chosen to test human attention. The reader is reminded that expectancy is used here to mean that the *S*s have learned a relationship that stimulus B follows stimulus A.

Since the details of the procedure will be elaborated in the method section suffice it to say that this will be done by means of a classical conditioning paradigm. This paradigm followed as closely as possible that used to gather the animal data. The animal data however capitalized on the ready availability of theta rhythm. Human EEG data on the other hand are characterized by high probability of alpha rhythm. Therefore alpha rhythm was used as data for the dependent variable. The second aspect of this study may well be the more interesting. Psychologists have often debated the existence of a human inner consciousness. The present model addresses itself to this question by making internal focus a subset of attention. The internal focus subset is characterized by the absence of exteroceptive S and by being testable only in the human. It is proposed that this subset can be measured by EEG changes that occur following *S*s responses during meditational and deep relaxation states.

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METHOD

Subjects

The *S*s were 20 volunteer male college students from an introductory psychology class, ranging in age from 18 to 25. The *S*s were told that the experiment was about self-control of brain waves, and were assigned irregularly to two groups of 10 *S*s each.

Apparatus

A Beckman Type T electroencephalograph was used. Electrodes were stainless steel, attached subcutaneously over the vertex and occipital area. EEG data were visually monitored as well as tape recorded. Through an auditory biogenic feedback system, the brain waves in the alpha range (8–13 Hz.) could be filtered from the occipital EEG and presented to the *S* through earphones as an analog of the alpha frequency. A Digital Equipment Corporation logic programmer was arranged to indicate a binary number, turn on a half-second CS, and 10 sec later turn on a 10 sec UCS. The CS was a click delivered to the earphones worn by *S*, and consisted of the opening and closing of a relay connected to a 6V battery. The UCS was a Grass PS 2 Photostimulator strobe light set at the *S*'s eyes-closed alpha frequency. All data were recorded on an 8-track Ampex Sp300 Analog tape deck, and the completed analog tape was digitized by an A–D converter connected to an IBM 360/44 computer before analysis.

Procedure

This experiment was reviewed and approved by a University Committee for Humane Treatment or Humans as Experimental Subjects. Each *S* was asked to fill out a protocol sheet asking for such information as last use of alcohol or drugs, history of epileptic seizure, and previous experience with hypnosis, Yoga, of Alpha conditioning. In addition, the first time a *S* was brought into the lab., he was asked to sign a statement consenting to participate in the experiment and asserting that the nature and purpose of the procedure had been explained to him.

A baseline EEG was run on each *S*, with no feedback provided. The *S* was given a "close eyes" instruction as a stimulus. The graph was marked with a binary number, and separate recording channels were used for the unfiltered and filtered brain waves. This procedure was then repeated with an "open eyes" instruction. The *S*'s face was monitored with a closed-circuit television, and the total time in the chamber for the baseline data was approximately 30 min for each *S*. If the baseline reading was inadequate, the baseline procedure was repeated until artifact free data were obtained.

Following the baseline procedure, *S*s were divided into two groups of 10 *S*s each. One group (Silva) was given a 14 hr weekend session of the Jose Silva† Mind Control training course [5]. While the Silva "mind control technique" is unique unto itself it capitalizes on both deep relaxation and group hypnosis like procedures. Some time is also spent in what best can be described as ESP exercises. At the beginning of the following week, the *S*s were brought into the lab., and an EEG was taken for 20 min. Recordings were made both with eyes-closed and eyes-open, while the *S*s were practicing their "mind control" technique. On another occasion, and EEG was taken on the same *S*s, with auditory biogenic feedback under similar instructions.

The second group (CC) of 10 *S*s was run through a classical conditioning paradigm of 50 trials per session. Each trial consisted of a CS of a half-second click, followed by a 10 sec interstimulus interval (ISI), followed by a UCS consisting of a 10 sec duration of a strobe light set at the *S*'s eyes closed alpha frequency. The intertrial interval (ITI) was irregular, with *E* starting the trial when *S* appeared relaxed. No feedback was provided for this set of trials. A 50 trial session lasted 20–30 min, and the sessions were repeated until *S* was conditioned to produce alpha, or until *E* was convinced *S* could not produce alpha sufficiently. The final 50 trial session was conducted for the CC group, with biogenic feedback provided. All classical conditioning data reported were taken under eyes-open conditions.

Treatment of results

For purposes of analysis, the EEG data were sampled in terms of epochs, one epoch being 10 consecutive seconds of data. For the baseline data, one epoch was taken for each *S* under eyes-closed and one epoch under eyes-open conditions. For the Silva *S*s, after the 14 hr training session, one epoch was taken for eyes-closed, and one epoch for eyes-open conditions, without feedback. Eyes-closed and eyes-open epochs were also taken on the Silva group when feedback was provided. For the CC group, an early trial (trial 3 if it was artifact-free) was taken, and the epoch was the 10 sec ISI. A similar epoch was taken from the last trial before the biogenic feedback, and a final epoch was taken after the feedback was started.

Each epoch was A–D converted and spectrally analyzed, yielding the power at various EEG frequencies [6]. Only the eyes open data will be reported in this paper.

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RESULTS

Figures 1 and 2 summarize the results of the CC group and Silva group respectively. The effect of biogenic feedback can also be seen in each figure. The three aspects of the experiment were projected on a common axis, thus, a comparison between baseline readings, improvement in alpha frequency production through either experimental procedure, and the influence of biogenic feedback can be observed on the figure for each group.

Turning first to the CC group (Fig. 1) a definite increase in alpha production due to the CC procedure is indicated by a peak in the middle line at frequencies 8–9 Hz. The baseline data did not appear to indicate a dominant alpha rhythm output as seen by the broad and rather flat spectra. The increase in mean percent power is distributed among a fewer number of frequencies. An additional change in the alpha band is observed when biogenic feedback is introduced, and this is accompanied by a further narrowing of the spectra. That is, the introduction of biogenic feedback yielded yet another frequency shift.

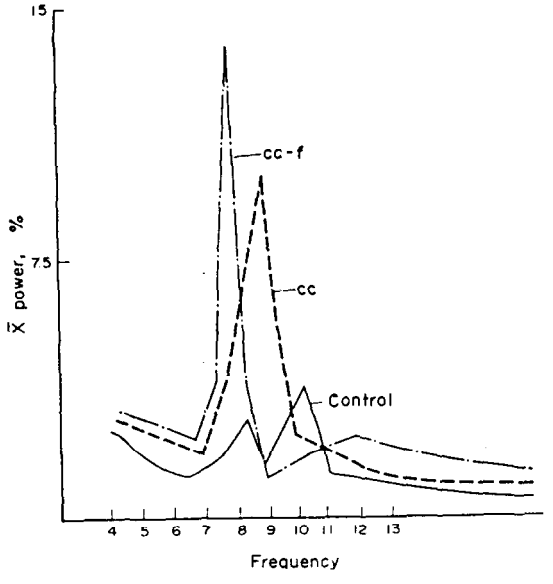

FIG. 1. Power spectra for the classical conditioning group, showing baseline (control), conditioning (CC), and biogenic feedback (CC-f) data.

Similar observations can be made of the Silva group data (Fig. 2) but caution must be exercised in comparing the figures between groups. Observation of the figure, however, indicates that the Silva *S*s were quite capable of producing the alpha rhythm following treatment, although not in the quantity demonstrated by the CC *S*s. Again a downward frequency shift occurred and it appears to be greater here than in the CC group. This conclusion may not be entirely correct because the Silva group baseline readings included elevated production of higher frequencies, such as in the 10–12 Hz range, while baseline readings in the CC group did not. It is difficult, therefore, to make a judgement on the degree of relative shift between groups. It is worth noting, however, that the frequency shift occurred in the same direction in each group and that the biogenic feedback had the same effect in each case.

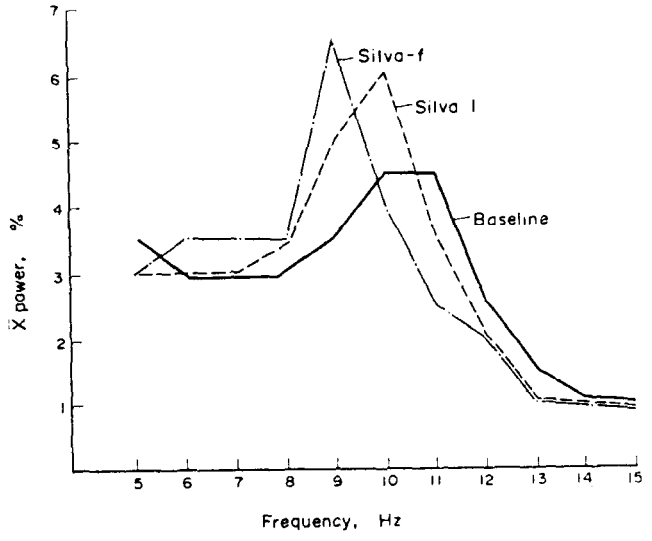

FIG. 2. Power spectra for Silva-trained group, showing baseline data, training data (Silva 1), and biogenic feedback data (Silva-f).

DISCUSSION

The data reported above would apparently support the Bremner attention model, particularly the expectancy and internal focus subsets. It is rather interesting to compare the human data recorded in this study with animal data originally used to define the expectancy subset (see Fig. 3).

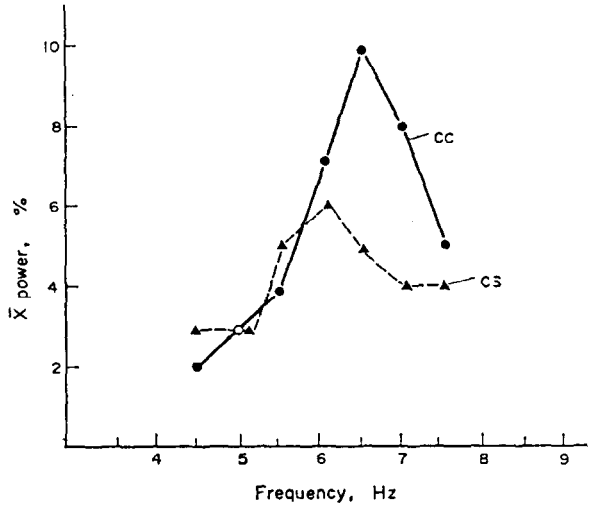

FIG. 3. Power spectra for hippocampal data of rats during classical conditioning (CC) and habituation of a light (CS).

If one compares Figs. 1 and 3, a certain similarity becomes apparent. The baseline and CS alone curves are broad and flat while the conditioning curves are peaked. Also, both graphs show a frequency shift. The authors realize that the frequency shift is in the opposite direction. This is attributed to the fact that the animal data is from hippocampal cities while the human data is most closely associated with occipital cortex. It seems, therefore, that expectancy as conceived by the model is correlated with the shape of the spectra and a frequency shift. Other authors have reported frequency shifts in human alpha rhythm that would support an expectancy subset [7, 8] or at least a correlation of alpha with attention [9].

It is the contention of the authors that the subset internal focus is demonstrated by Fig. 2. These *S*s trained by the Silva Mind Control System used no external stimuli to generate their data but rather what can best be described as mental imagery. One of the values of the Bremner model in this regard is that by defining the subset internal focus it is not necessary to use terms like consciousness or mental imagery. Internal focus depends on antecedent conditions such as instructions to the *S*s and on the EEG changes observed. It is, of course, realized that additional controls will be needed in order to test the reliability and validity of the internal focus subset. This is particularly true in the light of HART's [10] criticism that *S*s left to themselves in a dimly lit, quiet room for several minutes will increase their alpha production. The present study [11] may not be as vulnerable to this criticism since it makes use of frequency shifts and shape of spectrum as opposed to those studies which rely on quantity or amplitude of alpha [12]. Nevertheless, it is interesting to speculate about the additional frequency shift following introduction of the biogenic feedback. In the case of the CC group it might have served to make the UCR and CR more overt, thus changing the classical conditioning paradigm into an instrumental conditioning situation with a CR of high incentive value. For the Silva trained group, on the other hand, the feedback might make explicit to the *S*s a correlate of internal focus that is not subjective.

KARL PRIBRAM has suggested [13] that the subsets listed in the introduction as well as the subset internal focus could be pooled along three dimensions (i.e. expectancy–counter–expectancy, internal–external focus, orienting–arousal). Because of its parsimony this scheme has a great deal of appeal. However, it does not provide for the subset non-focus. It is the feeling of the present authors that non-focus is a subset of the same set as expectancy or internal focus, etc. Moreover, it would seem that in the logic of the general rubic of the PRIBRAM system [14, 15] non-focus is nested within the selection process. The present authors make on value judgment on either of these schemes but only point out that the logic of each scheme while generally similar differ at least with regard to the subset non-focus.

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Résumé—On a tenté dans ce travail d'étendre le modèle d'attention de Bremner aux données EEG humaines. On présente des données montrant les modifications prédites par le sous-ensemble d'expectation originellement défini par les données EEG animales. Un sous-ensemble additionnel (foyer interne) est proposé et les modifications de l'EEG humain sont partiellement en sa faveur. On suggère que ce sous-ensemble est spécifique des humains.

Zusammenfassung—In diesem Bericht wurde der Versuch gemacht, Bremners Aufmerksamkeits-Modell auf EEG-Befunde beim Menschen auszuweiten. Es liegen Ergebnisse vor, die Veränderungen durch Erwartungsmomente zeigen, wie es vorausgesagt wurde. Diese wurden/ ursprunglich durch Tier-EEG-Daten genau bestimmt. Es wird eine zusätzliche Untereinheit —innerer Fokus—vorgeschlagen und teilweise durch Veränderungen im menschlichen EEG unterstützt. Es wird vermutet, daß diese Untereinheit nur beim Menschen vorkommt.