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Alterations in EEG Amplitude, Personality Factors, and Brain Electrical Mapping after Alpha-Theta Brainwave Training: A Controlled Case Study of an Alcoholic in Recovery

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A controlled case study was conducted of effects of EEG alpha and theta brainwave training with a recovering alcoholic patient who experienced craving and fear of relapse after 18 months of abstinence. Training consisted of six sessions of thermal biofeedback to increase central nervous system (CNS) relaxation. Effects were documented with pretreatment and post-treatment personality testing, 20-channel digitized EEG evaluations both under relaxed conditions and under stress, minute-by-minute physiologic recordings of autonomic and EEG data during each training session, blood pressure, and heart rate indications taken both during relaxation and under stress, and by clinical observation.

Results replicated those of a previous controlled study with chronic alcoholic patients not abstinent prior to treatment. New findings include post-treatment indications of more relaxed CNS functioning under stress, and of reduced autonomic activation both during relaxation and under stress. Brain-mapping indications of anxiety associated with painful cold-pressor stimulation were seen only in the pretest readings; at post-test the brain map indicated pain-associated EEG activity in the contralateral somatosensory area, but no apparent anxiety-associated EEG activity.

At 4 months post-treatment the patient's wife and colleagues report the patient appears to function in a more relaxed way under the impact of stress, and he reports no longer experiencing craving for alcohol.

Overall, support is provided for the possibility that alpha and theta brainwave training may be a useful intervention for the abstinent alcoholic experiencing stress-related craving and fear of relapse.

Key Words: EEG, Biofeedback, Self-Regulation, Personality, Craving.

SOME INDIVIDUALS with a predisposition to developing alcoholism are characterized by deficient alpha activity as compared to controls,[1-4] and it has recently been hypothesized and reported that increases in alpha and theta EEG activity, typically associated with relaxed states,[5] have beneficial effects for some alcoholics. In a randomized controlled study, alcoholics given EEG brainwave alpha-theta training, a biofeedback technique used to learn control of particular brainwaves, showed increased percentages of alpha and theta in the EEG record, and increased alpha rhythm amplitudes post-training.[6] These changes were associated with reductions in depression, and anxiety and other personality changes.[7]

Digitized multichannel EEG may be used to examine characteristic patterns of brainwave activity with specific disorders and in relation to particular tasks.[8-10] Brain electrical activity mapping mathematically interpolates to estimate EEG activity occurring between electrodes of the montage.[11-12] Areas of given EEG amplitude may then be represented in topographic maps by specific colors, permitting visual evaluation of pretreatment/post-treatment EEG activity.[13]

The purpose of the present study was (1) to evaluate results of the previously reported protocol with a single individual from a different population, an abstinent alcoholic in recovery, and (2) to evaluate EEG activity under stress, pretreatment, and post-treatment.

METHODS

Subject

A 39-year-old alcoholic male executive was referred for EEG brainwave training (BWT) by his psychiatrist. By self-report and his therapist's evaluation, he had been abstinent for 18 months prior to treatment, but he continued to experience craving. During this period he had attended AA meetings regularly. He was not taking any psychotropic medication although he used 50 mg of Vasoretic daily to control essential hypertension. The patient signed an Institutional Review Board-approved statement of informed consent for the treatment and research procedures.

Personality Testing

Personality tests administered before and after BWT included the MMPI-2, Beck Depression Inventory, and the Personal Orientation Inventory (POI; Educational & Industrial Testing Service, San Diego, CA). The MMPI-2 was scored using The Minnesota Report Adult Clinical System Interpretive Report software on the Menninger mainframe computer. The Beck instruments were scored and reports were prepared by NCS Professional Assessment Services software, also on the Menninger mainframe computer.

Electroencephalogram Recording

A Neurosearch-24 (Lexicor Medical Technology, Inc., Boulder, CO) 24-channel digitizing EEG computer was used to register 60-min EEG recordings before and after BWT. The earlobes were cleaned with alcohol,

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rubbed with Omni Prep to reduce electrode resistance, and earclip electrodes were applied. Electrode impedance was tested and the electrodes reapplied as necessary if impedance exceeded 3000 Ohms. The main electrode array was then applied according to the standard 10–20 International System montage using an Electrocap and Electro Gel. Impedances were tested until satisfactory, with electrodes referred to linked ears.

Measures were then taken with eyes closed during several tasks including a self-relaxation baseline period (3.3 min), followed by cold press stressor (1.5 min), a second relaxation period (3.3 min), a serial sevens subtraction task stressor, and a final self-relaxation post-baseline period (3.3 min). The common laboratory stressors employed were selected for known ability to produce alpha and beta-adrenergic stress responses respectively. Blood pressure was taken and recorded automatically with a Vita-Stat 900-S and Model 2000 Vita-Stat Recorder during baseline, and again 30 sec after the hand was placed in icewater up to the wrist with the fingers spread apart. Pressure-taking concluded before the hand was removed, 90 sec after insertion.

Data collection continued with each task until preliminary observation suggested that at least 25 artifact-free epochs had been collected. Screening for movement artifacts was conducted on each epoch collected, and only artifact-free epochs were used in the analysis. Data was stored on tape for later analysis, including spectral analysis with Fast Fourier Transform of specific EEG segments, and evaluation of topographic brain-maps constructed from EEG activity occurring during specific tasks. With spectral analysis, brief segments of EEG data from a single lead are decomposed into specific frequencies, and EEG amplitude is plotted against EEG frequency for each time segment. The three-dimensional plot of amplitude, frequency and time form a "spectral array" as in Fig. 1. Alternatively, EEG amplitude data from multiple leads may be mapped to a representation of the head, with areas of given amplitude ranges represented by specific colors as in Fig. 2. This type of display permits ready comparison of pretreatment and post-treatment EEG amplitude.

Brainwave Training

The training protocol described by Peniston and Kulkosky[6] was followed in detail, beginning with six 30-min pretraining sessions of thermal biofeedback-assisted autogenic training[14] followed by one session for constructing images for visualization and 20 30-min brainwave training (BWT) sessions. During the pretraining session the experimenter collected an index of autonomic activity by attaching a temperature sensor to the tip of the finger of the subject's dominant hand and foot with micropore tape. Temperature data was collected with a T-68 Feedback Thermometer (J & J Enterprises, Poulsbo, WA). During both pretraining and training sessions, earlobes and the area around the inion were cleaned with alcohol prior to attaching the EEG electrodes. Hewlett-Packard Redux Paste was rubbed into the scalp at electrode sites to decrease skin resistance, and used as a conduction medium to fill the cups of the silver-silver chloride electrodes. An occipital electrode (01) was attached and held in place approximately 1 cm above and 1 cm left of the inion using a Velcro headband. Two earclip electrodes were attached, with the active electrode (01) referenced to the left earlobe (A1), and the ground electrode on the right earlobe (A2). A monopolar placement was used to prevent the differential amplifier from eliminating signals of interest that would be in common at two (bipolar) active sites, and to allow accurate, valid determination of waveform amplitude. Before recording commenced, electrode impedance was checked and electrodes were reapplied if necessary. EEG data was collected, stored, and analyzed on an IBM 386 computer using Clinical Group EEG Training System equipment and software (Discovery Engineering International, Topeka, Kansas). Hand temperature data were also collected during each BWT session.

The subject was instructed to sit in a comfortable reclining chair and to relax with eyes closed. The experimenter then introduced autogenic training exercises and rhythmic breathing techniques in order to induce relaxation of the body and to quiet the mind. Practice of temperature self-regulation was continued over six sessions until the subject could warm the hand to 95°F or above. Collection of EEG data during thermal training was added to the previous protocol in order to control for and to study possible EEG effects of thermal training.

After thermal training but prior to beginning BWT, one session was devoted to construction of images of turning away from alcohol intake in situations relevant to the patient's previous drinking behavior, and images of increasing brainwave amplitudes.[15] Images were constructed in the words of the patient for alcohol rejection, abstinence, and positive handling of personality and social issues in his life. BWT was then conducted as previously described by Peniston and Kulkosky.[6]

RESULTS

BWT Scores

Average hand temperatures during baseline for the six pretraining sessions were 82.9°F, short of our criterion of 88°F or greater for moderately relaxed autonomic levels. Average finishing hand temperatures for these sessions were 94.2°F. Finishing hand temperatures (°F) for the first six sessions were 94.7, 93.9, 92.3, 95.2, 94.1, and 95.1; the patient met our criterion of 95°F for deep autonomic relaxation in Sessions 4 and 6, and by Session 8 was able to maintain a hand temperature of 96°F or above for 21 min. For the 21 EEG training sessions, average baseline hand temperature was 83.8°F, while average finishing hand temperature was 96.2°F, exceeding our criterion for deep autonomic relaxation.

Spectral arrays of EEG activity occurring in the first and last training sessions are presented in Fig. 1. Compared with the first session, increased average EEG amplitudes may be observed in the alpha range centering on 10.5 Hz activity, together with increased amplitudes in theta frequencies (4–8 Hz).

Percent time scores were calculated for each minute of training in three EEG ranges, theta (4–8 Hz), alpha (8–13 Hz), and beta (13–20 Hz). While the spectral arrays were unaffected by threshold settings, the percentage of time scores was dependent on amplitude thresholds, with lower percentage of time in range seen with higher threshold settings. Since thresholds must be changed in the early sessions to facilitate self-regulation, percentage of time scores from early sessions are not comparable, but with this patient, thresholds were held constant for Sessions 13 through 27. Repeated measures analysis of variance (ANOVA) could not be conducted on average percentage of time data for theta, alpha, and beta frequencies due to possible autocorrelation of measures over time. Instead, this data was analyzed by using the split-middle technique[16] with binomial tests[17] on two blocks of training sessions (Block 1, Sessions 13–20; and Block 2, Sessions 21–27). Significant increases ($p < 0.01$) were observed in percentage of time above threshold for both alpha and beta EEG frequencies; theta percent time above threshold showed a nonsignificant trend toward increase across blocks which, on graphical inspection, was especially evident near the end of the second block of training sessions.

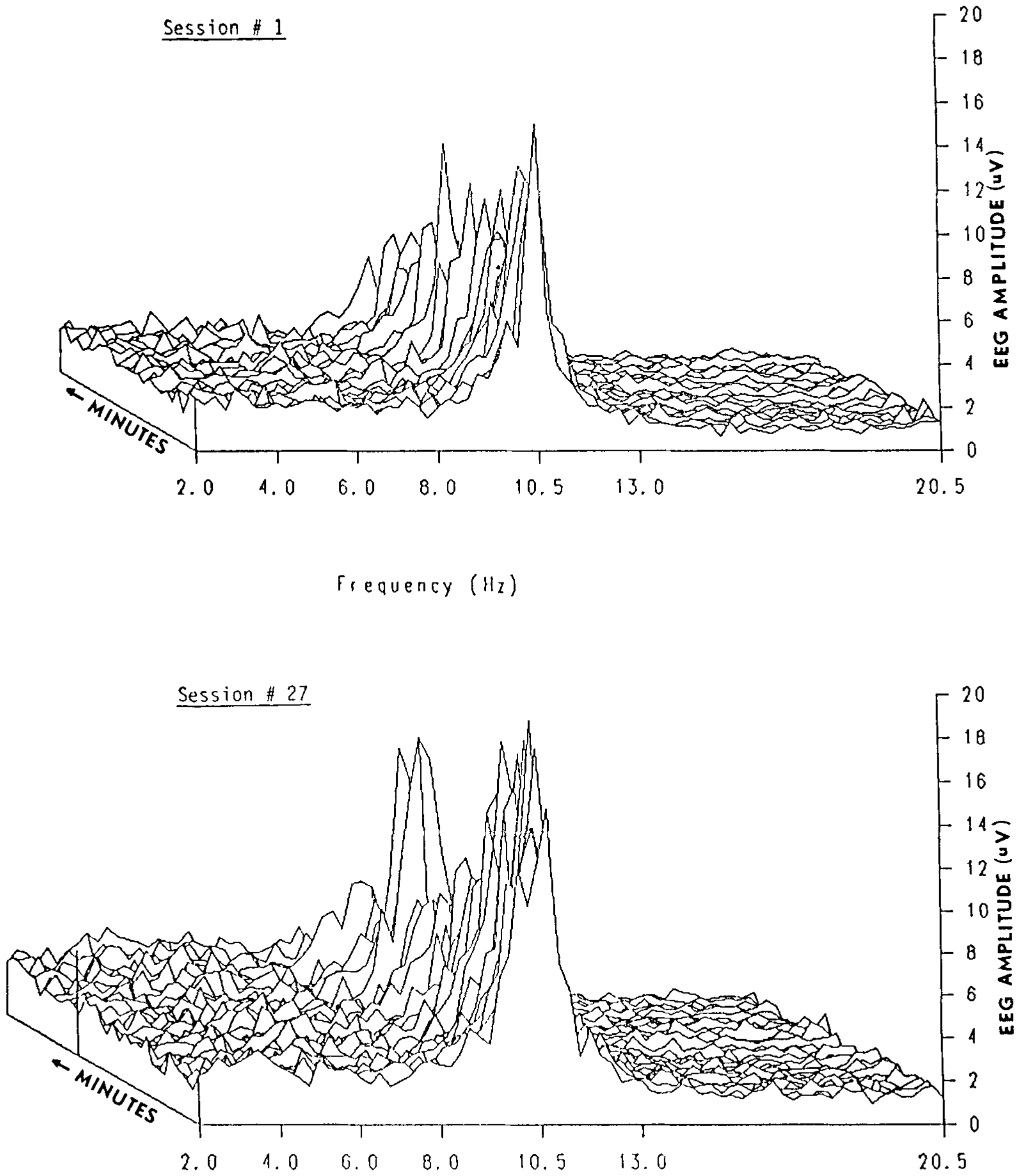

Fig. 1. Spectral arrays of EEG activity occurring during the first and last training sessions: EEG amplitude (μV) by EEG frequency across time (1-min epochs, beginning at the front and proceeding back to the end of the session).

Table 1. Pre/Post Treatment Change in Alpha EEG Amplitude (Binomial Test)

	Left occiput (01) means (μV)			Right occiput (02) means (μV)		
Task	Pre-	Post-	p	Pre-	Post-	p
Baseline	30.28	24.15	<0.01	32.47	29.15	<0.001
Cold Press	22.24	30.46	<0.001	26.91	32.58	<0.001
Relaxation	24.84	19.98	<0.001	30.76	20.52	<0.001
Serial 7s	13.78	29.52	<0.001	18.22	29.72	<0.01
Post-Baseline	19.99	28.73	<0.001	24.47	30.63	NS*

The sequence of tasks included (1) a baseline self-relaxation period (3.3 min), followed by (2) a cold pressor stressor (1.5 min), (3) a second self-relaxation period (3.3 min), (4) a serial sevens math stressor (3.3 min), and (5) a final post-baseline self-relaxation period (3.3 min).

* NS, not significant.

Electroencephalographic Scores

Repeated measures analysis of variance was not appropriate for this single case EEG data due to possible autocorrelation of measures over time. Analysis using the split-middle technique with binomial test was conducted on alpha activity (9–11 Hz band) in left (01) and right (02) occipital areas, pretreatment and post-treatment, during baseline, cold press, relaxation, serial seven subtraction and postbaseline relaxation tasks (Table 1). Highly significant reductions were seen in post-treatment alpha amplitudes during initial baseline and relaxation periods, while highly significant increases in post-treatment alpha amplitudes were seen during both cold-pressor and serial sevens stressors, and during the concluding post-baseline relaxation period.

Brain Electrical Mapping

At both pretreatment and post-treatment evaluation the patient rated cold-pressor pain at "5" on a 6-point scale, defined as "Severe pain, concentration poor, can perform only undemanding tasks." Indication of the pain is seen in the high frequency activation that occurs over the right somatosensory cortex when the left hand is in icewater (Fig. 2) both pretreatment and post-treatment. The left frontotemporal region, identified as the area expected to show high activation in the presence of anxiety, shows such activation only in the pre-treatment cold pressor brain maps. No pattern of activation in these two areas is seen during the serial sevens subtraction task at either testing.

Blood Pressure and Heart Rate

Average of two baseline (medicated) blood pressures pretreatment was 108/73, with mean blood pressure of 83 and average heart rate of 79.5. During cold press, blood pressure was measured at 123/93, with mean blood pressure of 103 and heart rate of 82. At post-treatment evaluation, average baseline blood pressures remained at 108/73, and mean blood pressure at 83, but heart rate decreased to 66. During cold press, blood pressure was measured at 123/88, with mean blood pressure of 103, and reduced heart rate of 70. The patient reported that he experienced generally being more relaxed in the face of stress. Subsequently, at 2 months post-treatment, he was able to discontinue all antihypertensive medication without returning to high blood pressure, and at the 4-month follow-up, he remained normotensive and medication-free.

Personality Scores

Pretreatment/post-treatment MMPI scores are indicated in Fig. 3. These profiles were obtained approximately 1 month apart. Both testings produced valid profiles within normal limits. There were indications from the post-treatment profile, compared with the first, of increased frankness and openness, even to the point of self-criticalness. While the first profile was indicated to be "relatively stable over time," and as "not likely to change significantly if retested at a later date," it is apparent that a trend toward increased normalization of response together with greater openness occurred at post-treatment.

There were no indications of depression on the Beck Depression Inventory scale at either testing. Thus, neither the MMPI nor the Beck scale indicated the presence of significant depression at pretest, nor a change in level of depression at post-test.

POI profiles from before and after treatment were both within normal limits. Trends observed included increased capacity toward intimate contact, sensitivity to own needs and feelings, spontaneity, and inner-directedness.

Clinical Observations

Following training the patient's wife was interviewed concerning her observations of the patient's behavior. She reported subtle changes had begun to occur in the patient between the third and seventh BWT sessions. She had noticed that he became calmer and worried less about things, while before he had constantly worried about things. She noted that his calmness was particularly noticeable in tense, stressful situations; now he showed restraint and understanding. She described him as less frustrated, more comfortable about handling things, and as more confident, thoughtful, and reflective. In the past he could reportedly be cranky and critical; now he was pleasant and fun to be around. He was seen as more accepting of things that were inevitable, and his sleep was improved.

At 4 months after completing training, the patient reports he is no longer experiencing craving for alcohol.

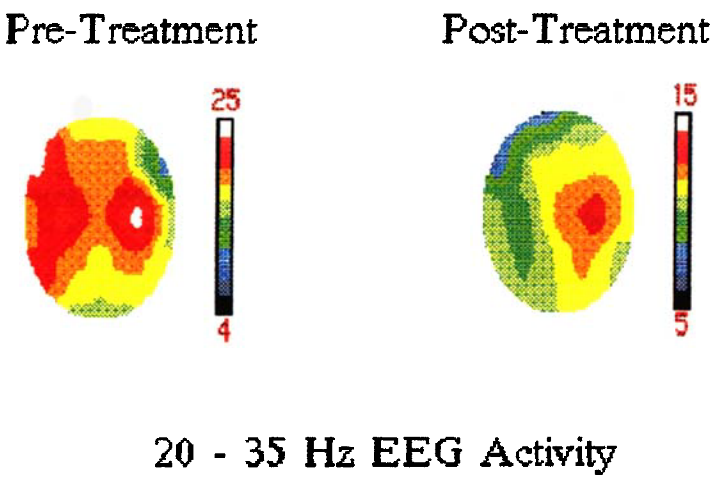

Fig. 2. High frequency beta EEG activation patterns during cold pressor pretreatment and post-treatment. At both testings activation is seen over sensory-motor cortex contralateral to the hand in ice water. Activation is seen in frontal-temporal cortex (previously observed to be associated with anxiety) only during pretreatment testing.

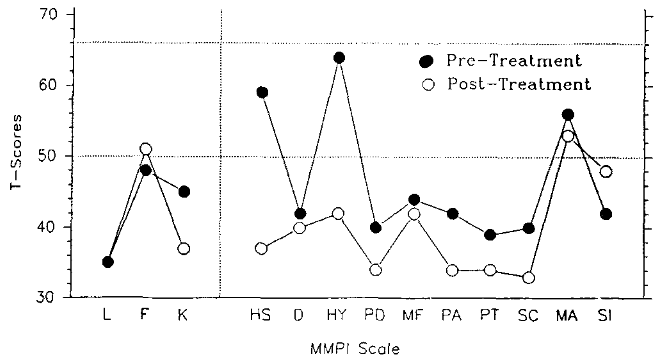

Fig. 3. MMPI scores before and after treatment.

Both his psychiatrist and business associates have noted that he is more calm in stressful situations than prior to training.

DISCUSSION

The observed results substantially confirm the reports by Peniston and Kulkosky[6,7] of increased amplitude in alpha and theta EEG activity following BWT, particularly during stress, and during the concluding period of the test. Although increased percentage of time in alpha and theta were observed here, as seen by the previous authors, only the increase in alpha was significant in the present case. This difference in results may have occurred due to reduced statistical power with a single subject design, or because this patient, unlike those of Peniston and Kulkosky,[7] had been in recovery for a number of months at treatment onset and already had well-formed alpha activity. The observed change in CNS physiology was also associated with change in physiologic indices of autonomic quieting including increased hand temperature and lowered heart rate both at rest and under stress. Medication is no longer required to maintain blood pressure in a normotensive range.

It is of interest that post-treatment alpha amplitude increased under stress and during the final relaxation period as previously reported, but that alpha amplitude showed highly significant decreases in the early relaxation periods. This individual, post-treatment, seems to have responded to the tasks in a more differentiated way than previously. It is not unusual for abstinent alcoholic individuals to experience significant dysfunction under stress. However, these data suggest that BWT may promote greater relaxation under stress, providing a useful intervention for the abstinent alcoholic experiencing stress-related craving and fear of relapse.

While, in the absence of a control group, it cannot be proven that the post-treatment results reported here, in comparison to pretreatment observations, were not simply the product of passage of time, placebo, or Hawthorne or other nonspecific effects of repeated testing, several factors mitigate against such a conclusion. As noted above, in the automated interpretation the initial MMPI profile was categorized as unlikely to change, but clinically significant post-testing change was subsequently observed. Studies repeatedly examining EEG variables in various populations have reported that no significant changes in alpha and theta occurred over periods of up to 3 years.[18,19] Although increased EEG alpha production in accord with instructions has been reported, the level of non-specific changes in alpha has been quite small[20,21] in contrast to those observed here. We have also observed that the stressors used, cold pressor and serial sevens tasks, in almost daily use in our laboratory, show high test/retest reliability without significant adaptation effects in untrained individuals retested after 2 or 3 months.

In summary, while nonspecific effects cannot be ruled out as contributing factors in these results, it is unlikely that the changes observed are merely the result of such factors. The strength of the present study in comparison to previous literature is that this patient had been in remission for 18 months prior to treatment, obviating attribution of the observed changes to simple withdrawal from addictive substances.

Using positron emission tomographic (PET) measures of regional brain blood flow, Talbot et al.[22] have recently indicated unexpectedly specific representation of pain in forebrain areas thought to regulate emotions. Other recent neuroanatomic studies using PET measures of brain blood flow have implicated bilateral regions of the temporal poles in normal and pathologic forms of human anxiety.[23] Previous research has suggested that these areas could be involved in evaluating environmental situations characterized by uncertainty, helplessness, or danger.[24,25] Stimulation of temporopolar cortex in nonhuman primates produces a syndrome comprised of behavioral inhibition, hypervigilance, and altered facial expressions characteristic of arousal, attention, or anxiety.[26] Bilateral lesions of temporopolar cortex in nonhuman primates attenuate fear responses to normally threatening situations.

As might be expected from these blood flow studies, an EEG pattern of left hemispheric frontal activation has been noted to be associated with anxiety, although similar activity in the right frontal area is observed to be more closely related to depression.[27,28] The left frontal area is typically active during executive functions such as planning and sequencing of behavior, while right frontal cortex is expected to be active during executive functions such as pattern recognition and comparison. The continuous nature of activation of these areas during anxiety and depression suggests the occurrence of a process of fixed limbic driving of frontal cortex by internal emotional states as opposed to the normal variability in frontal and limbic activity seen in response to external events. Such states do, in fact, interfere with normal perceptual responsiveness and with learning, processes that require flexibility in cognitive and autonomic functioning.

The indication of high frequency EEG activity seen in the left frontotemporal region during cold press would be expected in an individual experiencing anxiety associated with severe pain, together with activation over the somatosensory area contralateral to the hand in ice-water. Nevertheless, to our knowledge this phenomenon has not previously been reported. What is especially of interest is the post-treatment change in this pattern: while an activation pattern still is seen over the contralateral somatosensory area with the hand in ice water, no indication appears of high frequency EEG activity in the left frontotemporal region. This result points to reduced anxiety in the face of stress.

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