

Behavioral Psychophysiological Intervention in a Mentally Retarded Epileptic Patient with Brain Lesion

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Behavioral psychophysiological treatment entailing Slow Cortical Potential (SCP) biofeedback training and behavioral self-control training was conducted with a 27-year-old male epileptic patient (seizures for 23 years) with Wechsler IQ 64 who underwent callosotomy. The patient had 12/week secondary generalized tonic-clonic seizures. The treatment, consisting of 43 SCP training sessions and 22 behavioral control sessions, yielded a highly significant reduction of seizure frequency to about 7.5/week; such a decrease had never been observed after administration of new anticonvulsant drugs, nor after the callosotomy. During SCP feedback training, the patient was able to produce highly-significant cortical differentiation of SCPs of about 4 μ V. In addition, he developed several new behaviors indicating growing ability of self-perception and self-regulation. These findings suggest that a combination of SCP biofeedback with behavioral treatment of epilepsy can be used even in mentally retarded patients with organic brain disorders.

KEY WORDS: behavioral therapy; biofeedback; epilepsy; mental retardation; self-regulation; slow cortical potentials (SCP).

INTRODUCTION

Research concerning behavioral therapy for seizure disorders was initiated by a single case study published by Efron (1956, 1957) documenting classical conditioning of aura disruption. An olfactory stimulus (having proved to arrest the aura in this patient) was paired with the sight of a bracelet. As a result, seizures were aborted when the patient looked at the bracelet. Even thinking about the bracelet proved sufficient to inhibit the seizure. Mostofsky and Balashak (1977) provided an analysis of different behavioral approaches to the treatment of seizure disorders, as well as psychological models underlying these approaches. Studies conducted during the last two decades have been reviewed in Goldstein (1990).

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Since the early 1970s, behavioral therapy for epileptic patients was enriched by biofeedback techniques (see Stermann 1982, 1996, for review). These techniques are based on the presentation of a physiological variable (e.g., the amplitude of the sensorimotor rhythm of the EEG) to the patient, whereby desired changes are rewarded. This allows the patient to reduce abnormal low frequencies or facilitate intermediate rhythmic frequencies. Stermann and Shouse (1980) and Lantz and Stermann (1988) suggested that the sensorimotor rhythm (SMR) recorded over the rolandic area raises seizure threshold. These authors reported seizure frequency reduction of 60% (on average) following SMR-biofeedback training. In individuals with abnormal sleep EEG patterns (more than 20% paroxysmal activity during stage 2 epochs), the abnormal sleep patterns dropped below baseline levels (Lubar 1984; Whitsett et al., 1982). However, patients with normal profiles did not show significant changes in seizures incidence following SMR-EEG training (Stermann, 1984).

Birbaumer et al. (1990; see also Rockstroh et al., 1989) put forward the hypothesis that negative shifts of slow cortical potentials (SCP) reflect increase of cortical excitability which may contribute to a spreading wave of dendritic depolarization and thereby elicit an epileptic attack in a seizure-prone subject. They further suggested that in normal subjects, thalamo-cortical feedbacks serve to compensate for this spreading excitation, but that these mechanisms are partially defective in epileptic patients (Elbert & Rockstroh, 1987; Elbert et al., 1990). It has been proved that healthy subjects can learn to manage their cortical excitability within 100–200 eight-second biofeedback trials (Birbaumer et al., 1981; Rockstroh et al., 1984), whereas epileptic patients need much longer training (Birbaumer et al., 1991; Elbert et al., 1990). Thus Birbaumer et al. (1991) suggested that by SCP biofeedback epileptic patients might acquire control of their cortical excitability, which is primarily related to the ability to suppress cortical negativity. Such a skill, employed in a critical situation and/or when the patient perceives cues of an imminent seizure, should yield suppression of the seizure and thus decrease seizure frequency.

Although several studies have already verified this assumption (e.g., Daum et al., 1993; Kotchoubey et al., 1996; Rockstroh et al., 1993), the question of underlying psychophysiological mechanisms remains open. Despite significant effects on the average, some of patients provided with appropriate feedback did not learn to control SCP or did not demonstrate clinical improvement after successful learning. The reason is uncertain, but it might be related to brain injury caused by severe epileptic seizure, or medication side effects, or surgical intervention. A primary goal of the present study was to determine whether such factors are insurmountable obstacles to the learning of SCP control or mere difficulties that could be overcome by using appropriate techniques.

The extant data about the possibilities of behavior therapy with brain-damaged patients are not convincing. Although Dahl et al. (1988) mentioned that one of their three epileptic children who significantly improved after a behavioral intervention was retarded, they did not report any data concerning the degree and quality of his retardation. In another study (Dahl et al., 1987) these authors reported that mentally retarded adults with epilepsy could profit from behavior therapy only if other persons observed beginning seizures and initiated activity directed to arrest the seizures; thus, no self-control was developed.

Another goal was related to the fact that both biofeedback learning and behavioral interventions (Dahl, 1992) are based on principles of operant conditioning and reinforcement. Despite this common theoretical basis, the two approaches have not been integrated

in a broader behavioral-therapeutic context. In the present study, we attempted to integrate various techniques based on operant learning principles (including SCP biofeedback).

METHOD

Subject

UB is a 27-year-old right-handed male, living together with his mother in a flat in a small town. His father died 10 years ago, and his younger brother died 2 years ago (both in traffic accidents). UB works under protected conditions in the office of a sheltered workshop. There he is occupied with dictating lists and bills to a colleague. Outside his office the patient has only few social contacts, except for his mother.

He was 3 years old when he had his first seizure. Presently he is suffering from complex partial seizures, some of them secondarily generalized (grand mal), some are Lennox-Gastaut seizures, with rare absences. Most seizures occur between 10 a.m. and 7 p.m. Mean seizure duration is about 30 s, sometimes followed by a sleeping period or a reorientation time up to 30 min.

In the 24-year seizure history, UB tested virtually all possible combinations of anti-epileptic substances. During the course of the present study, his drug regimen was kept constant and included carbamazepine (2400 mg/day) and primidone (1000 mg/day). Due to the lack of effect of drug therapy, he underwent surgical treatment in June 1995, whereby the anterior two-thirds of his corpus callosum were transected.

Apart from the epilepsy, his physical condition was good. Neurological examination revealed a moderate cerebellar ataxia, which was interpreted as drug-induced. Thinking and speech were slowed. No sign of disconnection syndrome was found.

Interictal EEG revealed a moderate to serious dysrhythmia and a heightened paroxysmal preparedness with diffuse integrated sharp wave elements (with left temporo-occipital prevalence), as well as fronto-temporal paroxysms consisting of sharp waves and slow waves. In a PET-examination 6 months before surgery, a diminished glucose metabolism in the left hemisphere, particularly in the prefrontal regions, was found, without indication of a single focus. A SPECT-examination (3 months before surgery) revealed pathological changes in the left temporal lobe, as well as in the dorsal part of the left parietal lobe. However, these lesions were not confirmed using NMR (1 month before surgery); instead, a cerebellar atrophy (obviously underlying the ataxia) was found.

These data confirm the diagnosis of multifocal epilepsy.

Neuropsychological Assessment

The patient's intelligence quotient, according to HAWIE-R (German version of WAIS-R; Tewes, 1994), was 64, including a verbal IQ and a performance IQ each of 70. A Cattell's "culture-free" measure of intelligence (CFT 20; Weiss, 1987) yielded IQ (general fluid ability, according to Cattell) of 71. In the Wechsler Memory Scale—subtest Visual Reproduction (Wechsler, 1987)—UB obtained percentile equivalents of 38 (immediate reproduction) and 37 (delayed reproduction after 1 hr).

UB was unable to perform the Wisconsin Card Sorting Test (Nelson, 1976), nor could he perform standard paper-and-pencil tests for sustained attention. No abnormality was found in BDI (Beck Depression Inventory; Beck, 1972), where the patient scored 7 points.

Treatment

The main aims of treatment were (1) to identify and prevent potential seizure triggers and reveal reinforcing contingencies, (2) to transfer the self-regulation skills acquired during psychophysiological training from the laboratory to everyday life conditions, (3) to establish the patient's self-management skills in order to make him less dependent on his mother's care.

The therapy consisted of two parts: Learning to produce positive or negative shifts of slow cortical potentials (SCP *self-regulation* using EEG-biofeedback) and learning to apply this and other methods for the reduction of seizure frequency (*behavioral self-control*). The whole therapy process was divided into two phases. During the first 3 weeks, UB received 24 sessions of biofeedback training and 13 sessions to establish behavioral self-control. Biofeedback sessions were conducted everyday except weekends, in the morning, and also three times a week in the afternoon. During the following 8-week break, the patient was instructed to practice at home daily by imagining the mental states that he had produced during biofeedback session on the preceding phase. In addition, he was told he should practice self-regulation skills acquired during behavior therapy. After this, another series of 19 biofeedback and 9 self-control sessions was administered for 3 weeks. Usually, self-control sessions followed biofeedback sessions.

SCP Self-Regulation

During biofeedback training sessions, the patient sat in a comfortable armchair in a separate room. He could communicate via loudspeaker with the therapist. A videocamera allowed the therapist to observe the patient. The EEG was recorded from Cz since SCPs at this site are usually well pronounced and represent the total activity of many cortical regions. Two mastoid electrodes linked through a 10 kOhm shunt served as reference. Ag/AgCl electrodes were affixed by means of Elefix (Nihon Kohden) electrode paste. EOG electrodes filled with TECA (Vickers) electrode jelly were placed 1 cm above and below one eye. Electrode resistance was kept below 5 kOhm. Data were amplified using a Neurofax (Nihon Kohden) amplifier with high-frequency cut-off filter set on 30 Hz and the time constant at 10 s and digitized with a sampling rate of 100 Hz.

The training paradigm is described in detail elsewhere (Birbaumer et al., 1981; Elbert et al., 1980; Rockstroh et al., 1984, 1993). In each training session, the subject received continuous visual feedback of SCPs during feedback trials lasting 8 s each. The SCP amplitude averaged over 500-ms intervals (sliding with a step of 100 ms) was fed back as a movement of a rocket ship on the computer screen, placed 140 cm in front of the patient. Discriminative stimuli (letters A and B appearing on the screen simultaneously with the rocket) indicated whether the patient had to produce an SCP shift in the negative (A) or positive (B) direction.

In addition to feedback trials, the patient received transfer trials during which the discriminative stimulus (A or B) appeared on the screen without the rocket. The patient's

task was to generate the required SCP shift without feedback. These trials were included to assess learning and generalization. Feedback trials and transfer trials were presented in blocks of 20–40 trials, with the number of transfer trials increased as the patient's performance progressed. Trials with required negativity versus required positivity were randomly distributed within each block. During sessions, pauses could be set whenever the patient wanted or the therapists decided to be useful.

On-line control procedures (described in detail in Kotchoubey et al., 1996) prevented artifactual movements of the feedback signal caused by eye movements or muscular artifacts. Slow vertical eye movements were corrected by subtraction of 10% of their amplitude from the simultaneous EEG amplitude. The subtraction procedure was conducted only if the polarity of the EOG signal movements corresponded to the required polarity. Thus eye movement artifacts could interfere with the patient's performance, but they could not help. Trials containing blinks, body movements, or amplitudes larger than 200 μ V were aborted.

After SCP training in the laboratory, the patient was instructed to practice his strategies for achieving SCP control on positivity and negativity trials five times per day at home without a computer device.

Behavioral Self-Control

The seizures occurred only during the day time, with high risk times being from 2 to 3 p.m. and 6 to 7 p.m., and high risk situations being those in which UB was allowed to relax: coming home from work and sitting down, going home from therapy, riding in a car next to his mother who drove. Another typical high risk situation was shopping and making decisions about what to buy. Therefore the intervention methods concerning the *antecedents* (i.e., events which occur immediately prior to a seizure) were concentrated on time and specific activities.

Apart from identifying the critical situations, we tried to establish a conditioning process between an antecedent (as a CS) and a seizure for application of self-regulation skills acquired during biofeedback training. Due to the lack of patient's ability to report (or lack of sensitivity to) his own bodily sensations and emotional states, we had to develop his self-perception skills during the therapy itself. The main negative *consequences* of seizure behavior were impairment of learning and memory, poor education, lifelong dependency on others, injuries, few social contacts, impossibility of practicing sports. UB did not appreciate the deleterious nature of these restrictions. Having to wear a helmet and being overly protected by his mother were the matters that troubled him most. She however, explained her overprotective behavior in regard to the negative consequences mentioned above. She tried to alleviate these consequences, e.g., by allowing UB not to wear the helmet whenever she was nearby.

As we did not know from the behavioral assessment which value the consequences of seizures had, we started with a goal discussion. UB had to find out whether he really wanted to reduce seizures, whether he wanted to become more independent from his mother's care, and whether he would like to establish and pursue goals for his future (Table I). With the help of imagination techniques, a kind of cost-benefit analysis was made.

Having set the goals, we could determine the target behaviors. They were classified as seizure related and independence-related behaviors. As preventing seizures needs self-control capacities, we had to train independence first. By the help of a token plan several

Table I. Goals of the Therapy as Seen by the Patient and Their Importance (+ important, ++ very important)

Goal	Importance
"To move into my brother's flat"	+
"To go out with others, e.g. playing Billiard"	++
"Not to wear the helmet anymore"	++ (He realized sometimes this goal as unrealistic, since wearing the helmet is necessary to reach the other goals.)
"Less worries for my mother"	+
"To go alone to the Body-building"	+

behaviors could be established. The token-plan was implemented after the first training period. UB could receive up to 30 tokens (coloured paper clips) per week if he had demonstrated the desired behaviors (e.g., wearing the helmet, exercising self regulation etc), otherwise he had to pay tokens back. Thirty tokens could be exchanged for little presents UB liked to receive (e.g., a poster of his favorite athlete, Michael Schuhmacher).

In order to develop self-perception skills, progressive relaxation training (Jacobson, 1938) and techniques of self-observation (e.g., body-image by Pearson) were applied. Techniques to build up the target behaviors were self-instruction (area of daily self-care), role-play (social skills, especially those which concern the interaction with his mother), treaties and token economy. *In vivo* exposures should train him to practice the strategy learned during psychophysiological training in critical situations (for instance, choosing postcards in a shop, sitting down in the car and relaxing only gradually).

Data Analysis

SCP Data

Due to a large number of artifacts four sessions were discarded. Twenty-two sessions from the first phase of therapy and 17 sessions from the second phase were analyzed. In addition to the on-line artifact correction described above, the exact correction of artifacts was carried out off-line. Small blinks permitted by the on-line program were corrected using the algorithm of Gratton et al. (1983). Further, all trials containing intervals of zero activity, or EEG amplitudes $> 150 \mu V$ (after blink correction), or differences between mean amplitudes on consecutive seconds $> 100 \mu V$, were discarded. After this preprocedure, the area under the SCP curve was measured during three consecutive 2-s intervals: early in the trial (3rd and 4th s), in the middle (5th and 6th s), and at the end of the trial (7th and 8th s). Trials were averaged, within each session, separately for Feedback and Transfer conditions as well as for Negativity and Positivity tasks. For the first and the second training course separately, three-way repeated-measures ANOVAs were conducted with factors Task (two levels), Feedback (two levels: Feedback vs. Transfer), and Time (three levels corresponding to the three 2-s intervals within a trial). Training sessions were regarded as repetitions. For the factor Time and its interactions, nonsphericity correction was performed using Greenhouse-Geisser epsilon. When significant effects were obtained using these ANOVAs, they were localized and rechecked by means of a two-tailed Wilcoxon test. Using the nonparametric technique served to reassure that the ANOVA results were not affected by possible violations of normality.

Seizures

The source of seizure data was the diary kept by the patient's mother. Number of seizures per week was calculated for four nearly equal periods of time: 12 weeks before the beginning of training (first period), 14 weeks during training (second period), and two consecutive periods after the end of training (third and fourth), each lasting for 10 weeks. Since seizure data usually do not have normal distribution, a χ^2 (Kruskal-Wallis) test was used for checking the null-hypothesis that seizure frequency did not change across time.

RESULTS

Neuropsychological Data

The Wechsler Memory Scale (WMS; Wechsler, 1987) and the Life Satisfaction Inventory (FLL; Kraak & Rüdiger, 1989), were administered twice: before the first training phase and after the end of therapy. As regards WMS (logical memory), no substantial change in the patient's scores for immediate and delayed reproduction was obtained. As regards FLL, a shift toward less satisfaction with various areas of daily life (such as *work*, *leisure time*) after training should be noted. The largest changes toward less satisfaction were observed in areas *financial security* and *health*. Within the *health* area, the most clear shift toward discontent was found for items *physical ability* and *relaxation/balance*. The satisfaction score in the area *family life* (in only one) substantially increased at the end of training.

Biofeedback Learning

In order to convey the biofeedback procedure, UB had first to learn to sit without moving during an 8-s trial, to concentrate on the screen, to minimize blinks during trials, and to follow the instruction. He had to decide and clearly signal the therapist whenever he wanted to make a break or to go on. Therefore the first part of training served not only to learn how to produce the required EEG shifts but also to improve UB's concentration and social skills as well. All these aspects, seemingly trivial in training of patients with normal cognitive abilities, demanded particular attention in the present case.

Prior to the ninth session, only few transfer trials were made. Thus for the first training phase, the Task effect (positivity vs. negativity) was tested across all 22 sessions, and then, this effect together with the Feedback effect (feedback vs. transfer) and their interaction were tested across the 14 sessions in which large blocks of transfer trials were conducted. In the second analysis, a significant effect of Task ($F_{1,13} = 4.80$, $p = .05$) indicated that SCP amplitudes were, generally, more negative in the negativity condition (mean = $-3.2 \mu V$) than in the positivity condition (mean = $-1.5 \mu V$). The Wilcoxon test failed, however, to confirm this effect ($p > .20$). A further analysis revealed that the patient could significantly differentiate between the two tasks only in the feedback condition ($Z = 2.84$, $p < .005$, Wilcoxon test), but not in the transfer condition, resulting in a significant Task \times Feedback interaction: $F_{1,13} = 7.26$, $p < .02$. Further, the successful differentiation was limited by the end phase of the trial (Task \times Time interaction: $F_{2,26} = 4.65$, $p < .05$, $\epsilon = .64$). The difference between the required positivity and the required negativity was, on average,

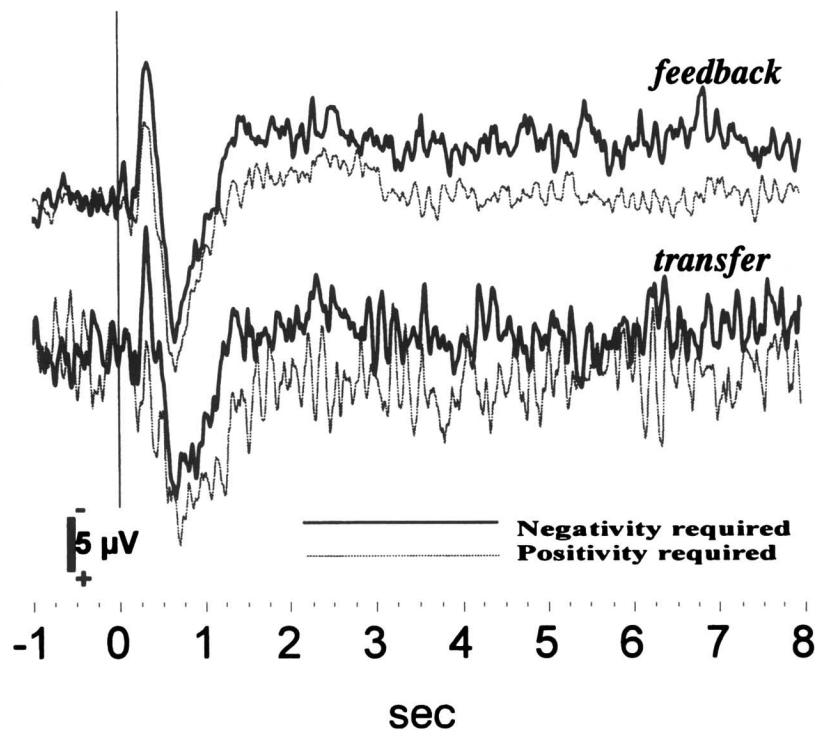


Fig. 1. SCP averaged across the second biofeedback training phase (17 sessions). Solid line: Negativity task. Dotted line: Positivity task. The discriminative signal was presented at 0 s and disappeared at 8 s. Note larger amplitudes of alpha-oscillations in transfer trials than in feedback trials, which may be due to more intensive visual stimulation (moving object) in the latter case.

0.8 μV (n.s.), 1.6 μV (n.s.), and 2.6 μV ($Z = 2.86$, $p < .005$, Wilcoxon test), for the beginning, the middle and the end of the trials, respectively.

In the second training phase, as can be seen in Fig. 1, the differentiation between conditions of required positivity versus required negativity was significant ($F_{1,16} = 10.26$, $p < .01$), while the Task \times Feedback interaction was not ($F_{1,16} = 4.04$, $p < .10$). Thus the patient was able to differentiate between conditions not only in feedback trials (on the average, $-6.04 \mu\text{V}$ versus $-1.02 \mu\text{V}$; $Z = 3.48$, $p < .001$), but in transfer trials as well ($-2.23 \mu\text{V}$ versus $2.64 \mu\text{V}$; $Z = 2.53$, $p < .02$).

The ANOVA in the second training phase revealed two further task-related interactions, namely, that of Task \times Time ($F_{2,32} = 9.31$, $p < .005$, $\epsilon = .69$), and a triple interaction between Feedback, Task, and Time ($F_{2,32} = 7.69$, $p < .005$, $\epsilon = .81$). As can be seen in Fig. 2, the SCP values with positivity task were slightly negative on feedback trials, and clearly positive on transfer trials. This difference between the feedback and transfer conditions was very large (5.5 μV , $Z = 2.91$, $p < .005$) at the beginning of the trial, but smaller in the middle part (3.0 μV , $Z = 2.53$, $p < .02$), and yet smaller at the end of the trial (2.4 μV , $Z = 1.92$, $p < .10$).

The last significant effect was independent of the task (i.e., negativity versus positivity). In both phases, cortical potentials were generally more negative with feedback than without

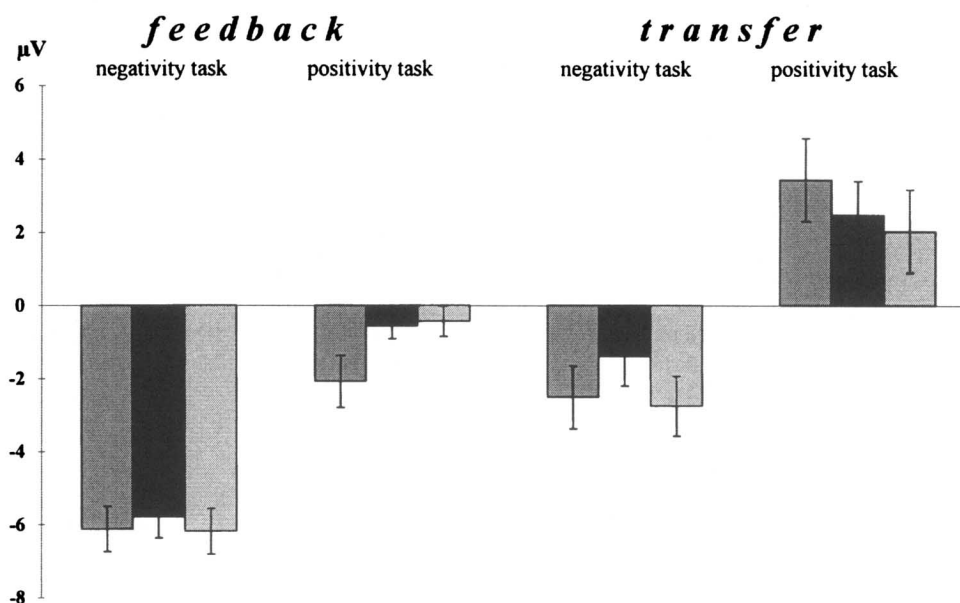


Fig. 2. Mean SCP amplitudes in the second training phase as a function of feedback condition (feedback vs. transfer) and task (negativity vs. positivity). Three adjacent bars stand for three subsequent 2-s time intervals at the beginning, in the middle, and at the end of the trial. Error bars indicate standard errors.

feedback (main Feedback effect: $F_{1,13} = 5.24$, $p < .05$; Wilcoxon $Z = 2.42$, $p < .05$; and $F_{1,16} = 10.06$, $p < .01$; $Z = 3.43$, $p < .001$, for the first and the second phase, respectively).

Other Changes in Behavior

As stated above, a token plan was developed to provide UB with several behaviors, some of them being directly related to seizures, others involving his overall independence in everyday life. By means of role playing and relaxation training UB learned to cope with *high-risk situations* and to avoid sudden drop of arousal level.

As regards seizure-related behaviors, UB practiced daily and accurately his self-regulation strategy and wore the helmet in the institute (100% tokens). Also he was accurate in taking drugs on the morning (100% tokens) and evening (80%). Behaviors involving gradual relaxation were practiced less regularly (20% tokens).

As regards independence-related behaviors, the patient was able to prepare his alarm-clock on his own (rather than being awakened by his mother as before), to distribute reminders over the flat, to make his bed and to turn over the clothes before being washed (100% tokens), as well as to make coffee and to choose things (e.g., postcards) in shops (70 to 80% tokens). Learning to develop more physical activity and to prepare dinner was not successful (less than 20% tokens).

In addition to the intended effects influenced by the token-economy and by self-instruction, some non-specific effects were observed. Thus there was a striking amelioration of social skills like initiating and maintaining visual contact, talking loudly and clearly. The frequency of smiling and making jokes increased. Posture while talking was controlled and,

Table II. Blood Serum Concentrations ($\mu\text{g/ml}$) of Medicaments and Their Metabolites Before the Beginning of the Intervention (A), at the End of Training (B), and After the End of the Follow-up Period (C)

Substance	A	B	C
Phenobarbital	27.1	23.4	28.5
Pirimidon	12.4	13.0	14.1
Carbamazepin	6.5	10.7	10.1
Epoxid	2.0	2.8	2.6

if necessary, corrected. The patient began to answer the therapist's questions, instead of to agree passively with his mother answering. He became able to talk about the relationship to his mother and about the death of his younger brother.

Blood Levels of Anticonvulsants

Mean serum concentrations of the anticonvulsive substances and their metabolites are presented in Table II. It can be seen that, with constant medication, these values were kept within the therapeutic range with only minor variations.

Seizures

Weekly seizure frequencies (means \pm standard errors) for periods before training, during training, and two consecutive 10-week periods after the end of training were 12.0 ± 0.95 , $9.29 \pm .76$, 7.30 ± 0.95 , and 7.71 ± 0.88 , respectively. The null-hypothesis that

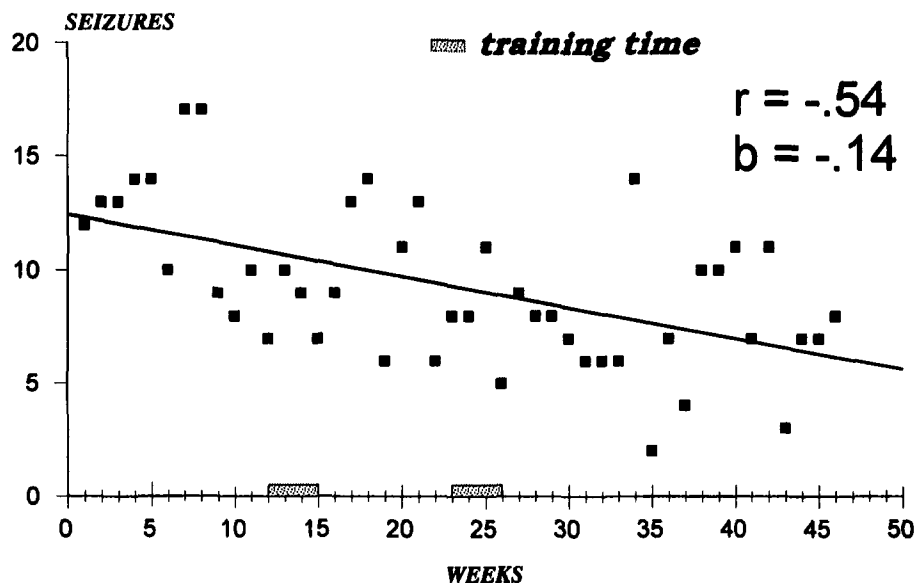


Fig. 3. Change of seizure frequency across weeks. Shaded bars on the time axis represent the two training periods.

seizure frequency did not change was clearly rejected ($\chi^2 = 11.86$, $df = 3$, $p = .008$). Post hoc Mann-Whitney comparisons indicated that seizure frequency tended to be lower during training than before training ($p = .047$). Further, the number of seizures significantly decreased after training as compared with the period before training ($p = .003$, and $p = .01$, for the first and the second post-training periods, respectively). The consistent decrease of seizure frequency across the time of observation was further confirmed by a highly significant linear regression of seizures on weeks ($b = -0.14 \pm 0.016$, $T = 2.71$, $p = .009$, see Fig. 3). The quadratic trend did not attain significance ($T = 1.71$, $p = .094$).

The baseline period began 5 weeks following the surgical treatment. We could not obtain exact data concerning these 5 weeks, nor detailed data about the patient's seizures during the time preceding surgery. We know only that the average seizure frequency was 12.1/week and 8.6/week just before and immediately after the surgical treatment, respectively. The former number is notably close to 12.0 during 3 months prior to behavior therapy. Without weekly data, the effect of surgery cannot be estimated, but if this effect took place immediately after the intervention, it was not longer detectable from the sixth week on.

DISCUSSION

The data obtained in the present study indicate, first, that behavioral intervention resulted in a significant decrement of patient's seizures. Second, SCP biofeedback training embedded in the behavioral treatment revealed the ability of the patient to self-generate reliable slow potential shifts in the positive or negative direction according to the required task. Third, the patient was able to realize the goals of treatment and to take responsibility for his bodily well-being. Changes of his behavior during therapeutic conversations, as well as the increasing dissatisfaction with his health status indicated growing ability for self-perception and self-control.

The achieved improvement of clinical status, although significant, may appear rather moderate. However, it should be emphasized that the patient had previously tried many other anti-epileptic treatments, including brain surgery, but a substantial decrease of seizure frequency comparable with that obtained after the present behavioral treatment has never been observed before.

As mentioned above, we regard the use of EEG self-regulation and behavioral self-regulation learning as a single process, not as a combination of two different techniques. To be sure, this learning process has different aspects, but a single-case study is not a suitable tool to differentiate between these aspects. For this reason, only a preliminary and rather speculative discussion on possible therapeutic factors may be proposed. The basic idea of SCP self-regulation in epilepsy has been that the self-control skills acquired during training sessions to produce cortical positivity (or to suppress undesirable cortical negativity) can be applied in seizure-threatening situations in order to reduce the excitability of cortical neurons and their recruitability in the pathological network built around the epileptic focus (Birbaumer et al., 1991; Elbert et al., 1990). Since UB acquired the ability to suppress negative potential shifts (at least, in the second training phase), we may hypothesize that this mechanism could have played a part in the subsequent decrease of seizure frequency. However, as can be seen in Fig. 3, a trend toward fewer seizures appeared even prior to the point when significant self-control of SCP was obtained. Of course, the EEG recorded at Cz reflected only a minor part of complex processes in the patient's brain. It may therefore

be speculated that this early clinical improvement might have been due to some changes in brain function that occurred before they were measurable in the SCP at vertex. (This idea was suggested by J. Peter Rosenfeld.) Unfortunately, due to the multifocal nature of the patient's seizures, the choice of a better site for the EEG recording is very difficult.

From the very beginning of behavioral therapy, the patient was placed in a demanding, achievement-oriented environment, which differed dramatically from his habitual, permissive and over-protective environment. He was included in a number of activities, where his results were continuously evaluated. Involvement of "idle" neural circuits into goal-directed activities may have been another mechanism to decrease the recruitability of neurons toward whom the seizure spread is advancing, as suggested by Wolf (1996).

The effect observed during the first 20 weeks does not guarantee, of course, the ultimate stability of the attained clinical improvement. If the stimulating surrounding created by behavioral treatment was an efficient factor, this effect may be expected to decrease with patient's return to his habitual environment, where these demands are not maintained. It would not be a surprise if the patient, returning to his permissive environment, is not persistent enough to regularly practice his self-regulation skills. Thus, the second factor supposedly responsible for seizure decrement would also weaken with time.

Two alternative interpretations should be taken into consideration. First, as suggested by a reviewer, the seizure decrement might be interpreted as a delayed consequence of the callosotomy, with the improvement starting about 18 or 19 weeks following the surgery. In fact, this factor cannot be completely ruled out as we have not found data on how late after this surgical intervention the clinical effect can appear. Since, however, dramatic effects of corpus callosotomy were consistently observed immediately after or even during operation (Gates, 1992; Spencer et al., 1988; Torres & French, 1973), the hypothesis about effects appearing only after 4 months does not seem very probable.

Another hypothesis would be that the primary clinical change may have been caused by nonspecific factors. One of such factors usually considered in biofeedback studies is a placebo effect. However, it is implausible that simply the status of a patient in a study and the attention of the therapists played a major role, since the patient had previously had much experience as an object of investigation during his 23-year seizure history including many hospitalizations in different neurological and neurosurgical institutions. Moreover, his subjective satisfaction with his life and health status *decreased* following treatment, which is not consistent with the placebo hypothesis.

The present results indicate that behavior therapy entailing cortical self-regulation can be employed in patients with organic brain dysfunction and mental retardation. Possible limitations may be in maintainance of the effect. Self-control needs a certain level of self-consciousness and reflexiveness, which implies preserved internal feedback loops. Even nonhandicapped patients require extensive training before new behavior is established and transferred to everyday life. Therefore, booster sessions, which will embrace both psychophysiological and behavioral training, are necessary.

ACKNOWLEDGMENTS

The study was supported by the German Research Society (DFG, SFB 307). The authors thank J. Peter Rosenfeld and A. P. Rudell for their very helpful comments on earlier versions of the manuscript.

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