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PLEASURE AND BRAIN ACTIVITY IN MAN

DEEP AND SURFACE ELECTROENCEPHALOGRAMS DURING ORGASM

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Deep and surface electroencephalograms were recorded during sexual arousal culminating in orgasm in 2 patients, 1 undergoing treatment for severe mental illness and the other for intractable epilepsy. Such recordings were obtained on two occasions in 1 patient and on 12 occasions in the other. Recording changes concomitant with the behavioral response were significant and consistent; most striking was the appearance of spike and slow-wave with superimposed fast activity in electroencephalograms from the septal region during sexual orgasm. In one patient distinct, but less dramatic, changes also occurred in the amygdalae, thalamic nuclei, and deep cerebellar nuclei. The other brain sites in which changes occurred are anatomically connected to the septal region and have previously been shown to be important sites in the pathways for emotional expression.

These data substantiate previously reported data, gathered through other procedures, of a consistent correlation between activity in the septal region and the pleasure response.

Studies in severely ill patients prepared with stereotaxically implanted deep and cortical brain electrodes, as part of a therapeutic program begun in the Tulane Department of Psychiatry and Neurology in 1950, have invariably pointed to the septal region [as defined by the Tulane researchers (4)] as the brain site most consistently implicated in the pleasure response (1, 6, 13, 14). In some of the 60 patients studied thus far by these techniques, the pleasure response has also been found to affect the septal region's main pathway of outflow, the medial forebrain bundle, through the lateral hypothalamus to the interpeduncular nuclei of the brain stem. The techniques used in these studies and the data obtained were first described at a meeting in 1952, and the first major report was published in 1954 (13).

As techniques have been refined, we have been able to leave the electrodes in place for as long as 3 years for long range study of patients with schizophrenia and various other neurological disorders, as well as for some with intractable pain but no classical neuropsychiatric disorders.

This report concerns the electroencephalographic (EEG) data obtained from 2 patients during intense sexual arousal. In patient B-19, a man, EEG's were obtained on two occasions when this arousal culminated in orgasm: once, as a consequence of masturbation and once through heterosexual intercourse. Recordings during orgasm were obtained on 12 occasions in patient B-5, a woman, in response to introduction of acetylcholine (10 occasions) and levarterenol bitartrate (2 occasions) into her septal region. These data corroborate previously reported evidence gathered under

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different circumstances and involving other types of pleasurable states that physiological activity of the septal region of man's brain is consistently correlated with the pleasure response (1, 5, 6, 8, 11, 13, 14).

HISTORIES OF PATIENTS

PATIENT B-19

This man, who was 24 years old when these studies were conducted in 1970, had a diagnosis of temporal lobe epilepsy. He had had a 5-year history of overt homosexuality and a 3-year history of drug abuse. He was considered a chronic suicidal risk who had repeatedly remarked, "I live with the idea of suicide daily" and had made several abortive suicidal attempts. Chronic depression, characterized by inability to experience pleasure, was persistent. Ingestion of drugs had offered fleeting relief of his persistent anxiety and depression and had led to habituation to sedatives and stimulants, as well as to chronic use of marijuana and *d*-LSD. All of his relationships (with family members, acquaintances, physicians, and supporting hospital personnel) have been characterized by coercion, manipulation, and demand.

The patient's parents are both 55 years of age. His father was an officer in the United States Army who retired when the patient was 18 years old. He has one sibling, a sister of 19.

The patient's educational history (characterized by repetition of grades, need for frequent discipline by teachers and principals) was chaotic—beyond that which could be expected by the frequent moves of the family, which included three tours of duty outside the United States. He dropped out of high school after 3½ years and later held a variety of jobs (stock clerk, janitor) for brief periods. One month of military service, when he was 19 years old, was terminated by medical discharge because of "homosexual tendencies." For about 3 years before his hospitalization for the procedures described in this report, he led the life of a vagrant, experimenting with drugs, engaging in numerous homosexual relationships, and being supported financially by his homosexual partners.

The patient's experimentation with drugs began when he was 21, with ingestion of vanilla extract. He became habituated to amphetamines, and he used a variety of other sedative and hallucinogenic chemicals (marijuana regularly, nutmeg frequently, *d*-LSD sporadically, as well as inhalants such as glues, paints, and thinners, and sedatives). He still faces charges of possession of marijuana for which he is now out on bail.

Because of his poor adjustment to high school, the patient first saw a psychiatrist when he was 17. He was hospitalized in a state psychiatric institution in August, 1968; discharge diagnosis 5 months later was "depressive reaction." In July, 1969, he was admitted to the psychiatric service of a Veterans Administration Hospital, and this 4 months' hospitalization was typified by uncooperativeness and coercion of hospital personnel. His condition at discharge was essentially unchanged; diagnoses were 1) personality disorder with homosexual behavior and drug experimentation; and 2) temporal lobe dysfunction (based on EEG findings). The patient's hospitalization for the studies described herein began 5 months before the elective brain surgery.

The patient's 5-year history of homosexuality was characterized by anal intercourse. Before the study reported here, the subject had never engaged in heterosexual intercourse.

PATIENT B-5

This woman, of borderline defective intelligence, was 34 years old at the time of these studies in 1960 to 1961. The second of nine siblings, her birth was apparently normal except that the mother had a severe case of mumps 3 months before delivery and "fell" 2 months before delivery. The patient's development was reportedly normal until age 11, when she developed petit mal epilepsy. Spells varied in frequency from once a week to several times a day. By the mother's estimate, it was a few years later that the patient began having psychomotor seizures, during which she was dazed, sometimes screamed, and became overactive, and occasionally beat her head against the wall; she was subsequently confused and amnesic about the episode. These seizures occurred several times a week. At about 20 years of age, she also began having grand mal seizures.

After an initial work-up when the diagnosis was made of psychomotor and grand mal epilepsy in a woman of borderline defective intelligence, the patient was observed and medically treated for about 8 years before she was hospitalized for the procedures described herein. During this interim, she was poorly controlled with a range of anticonvulsant medications, continuing to have an average of 7 to 10 seizures each week.

The patient's education stopped at the sixth grade after yearly failures, beginning with the onset of petit mal. She had had three marriages and two divorces. Her present husband, father of her only child (who was reportedly developing satisfactorily), was an unemployed, disabled veteran supported by a government pension. Family history otherwise was noncontributory.

PREOPERATIVE EXAMINATIONS

PATIENT B-19

Physical and neurological examinations were within normal limits. Results of urinalyses and blood chemical determinations were normal. Preoperative conventional scalp EEG's repeatedly showed an abnormality characterized by bilateral temporal slow-wave activity maximal on the left. With Chlorolose activation, paroxysmal delta activity also appeared over the right temporal region, and this was further exaggerated by hyperventilation. Psychological testing showed a verbal intelligence level of 124 and a performance level of 108.

PATIENT B-5

Numerous physical examinations were within normal limits. Carotid angiograms were normal. Results of blood and urine analyses were within normal range. Preoperative conventional scalp EEG's showed an almost continuously discharging focus over the right anterior temporal leads with a lesser degree of focal abnormality over the left anterior temporal region. Psychological testing confirmed the clinical impression of borderline defective intelligence.

ELECTRODE PLACEMENTS

The operative procedure was carried out with the patient under general anesthesia and with visualization of the ventricular system by air and pantopaque. Electrodes were stereotaxically implanted into a variety of deep sites and over the cortex of the brain by techniques previously described (14). Each patient was also prepared with intracerebral cannulas (9, 10).

PATIENT B-19

Stainless steel Teflon-insulated electrodes, .003 inch in diameter, each with 3 to 6 leads separated by 2 mm, were implanted into the following brain regions: right midseptal region, right hippocampus, left and right amygdalae, right anterior hypothalamus, right posterior ventral lateral thalamus, left caudate nucleus, and at two subcortical sites within the left lobe of the cerebellum.[2] Cortical leads were placed under the dura at sites in the left and right frontal regions, left and right parietal areas, and right temporal region. Triple-lead silver ball polyvinyl chloride acetate-insu-

[2] The electrodes here were intended for the fastigius and dentate nuclei and are so labeled on recordings (Figures 2–6). Final X-rays, however, revealed them to be in the cerebellar cortex and subcortical white matter.

lated electrodes were implanted into the left anterior and left posterior septal region. The silver ball contact points were .5 mm in diameter, each 2 mm apart. Intracerebral cannulas (used for studies to be described in another report) were implanted into the septal region bilaterally (about 2 mm rostal to the anterior commissure on the left and at the level of the anterior commissure on the right) and into the hippocampus.

PATIENT B-5

All electrodes used for this patient were the silver ball type. Placements were into the left anterior and left posterior septal region, the right anterior and right posterior septal region, left anterior and left posterior hippocampus, right posterior hippocampus, left and right amygdalae, left caudate nucleus, and right anterior and right posterior hypothalamus. Cortical leads were placed under the dura at four sites over the left temporal cortex, at five sites over the right temporal cortex, and also over the left frontal cortex, the left parietal cortex, and the left and right occipital cortex. Intracerebral cannulas were implanted into the septal regions bilaterally and into the hippocampi bilaterally.

ELECTROENCEPHALOGRAMS

In both patients, EEG's from various brain sites had stabilized, that is, all artifacts due to anesthesia and the brain trauma incurred at operation had disappeared by 3 weeks after operation.

In patient B-19, recordings were obtained on two Grass Model VI EEG's, one, 12-channels and one, 8-channels. The two machines were synchronized by use of a time code generator. One channel recorded the electrocardiogram.

In patient B-5, recordings were obtained on a Grass Model III-D and a Grass Model IV EEG, synchronized by simultaneous recording of temporal leads on both machines.

POSTOPERATIVE PROCEDURES

PATIENT B-19

Numerous techniques were used within the total treatment program of this patient, but only those pertinent to the present report will be included herein.

Beginning about 3 weeks after operation, the patient's responses to passive[3] electrical stimuli delivered to all deep brain sites where electrodes had been implanted were carefully examined. He responded with pleasure only when electrical stimulation was applied to the septal region, responses to stimuli to other sites being neutral or adversive.

As another study-treatment phase, the patient was equipped with a three-button self-stimulating transistorized device previously used in other patients in this series and described in detail elsewhere (1, 5, 6). The design of this apparatus was based on the technique introduced by Olds and Milner (16) in 1954 to demonstrate the pleasure response in animals. The three buttons of the Tulane unit were attached to electrodes in the various deep sites, and the patient was free to stimulate any of these three sites as he chose. A counter for each button automatically registered each push of the button, which delivered a 1-second stimulus. The patient explored the effects achieved by pushing each button, but it was the septal region that he stimulated repeatedly. He was permitted to wear the device for 3 hours at a time: on one occasion he stimulated his septal region 1,200 times, on another occasion 1,500 times, and on a third occasion 900 times. He protested each time the unit was taken from him, pleading to self-stimulate just a few more times. The buttons attached to other brain sites were never used more than a few times during each 3-hour period.

With both passive electrical stimulation

[3] Stimulus delivered by the treating physician, in contrast to self-stimulation.

and self-stimulation to the septal region, the patient reported feelings of pleasure, alertness, and warmth (goodwill); he had feelings of sexual arousal and described a compulsion to masturbate. Figure 1 shows the placement of the electrodes where stimulation induced the most consistent and intense pleasure response.[4]

One aspect of the total treatment program for this patient was to explore the possibility of altering his sexual orientation through electrical stimulation of pleasure sites of the brain. As indicated in the history, his interests, contacts, and fantasies were exclusively homosexual; heterosexual activities were repugnant to him. The programming and outcome of this phase of the patient's treatment program will be presented in another paper,[5] but a few aspects of that study are pertinent to the results presented here.

After electrode implantation, but before stimulation of pleasure sites of the brain, an 8-mm silent film (the type shown at stag parties) displaying heterosexual foreplay and intercourse was shown to the patient in the laboratory. He responded with revulsion to the film, registering angry protests. Ten days later, however, during the treatment phase when the patient was using the self-stimulating transistorized device and reporting feelings of pleasure and of sexual arousal with a compulsion to masturbate, as well as showing increasing interest in female ward personnel, he was again shown a "stag" motion picture film displaying overt heterosexual activity. During the film showing, EEG recordings were obtained. The patient was provided with a buzzer, which sounded in the recording room and marked the EEG electronically, and he was instructed to signal with the buzzer if he responded orgastically to the film. As the film was shown, he became increasingly aroused, had an erection, and masturbated to orgasm. The EEG changes that occurred were at the same sites as those shown in Figures 4 to 6 and were similar, but less dramatic in character.

During the next 7 days, the patient's conversation was preoccupied with sex; a continually growing interest in women culminated in his expressed wish for heterosexual activity. A twenty-one-year-old female prostitute agreed, after being told the circumstances, to spend time with the patient in a specially prepared laboratory. The laboratory was modified to permit complete privacy, and an extension cord was inserted between the plugs in the patient's hand and the jack box to the recording room to give him adequate mobility.

On the afternoon of this study, the patient was again permitted to use the transistorized self-stimulation unit for 3 hours. Five hours later the patient's electrodes were attached to the EEG and recordings were obtained for about 45 minutes, with a 5-minute interruption for delivery of passive electrical stimulation to the septal region which lasted 3 minutes. He was then introduced to the prostitute, and EEG's were obtained throughout his relationship with her.

In separate interviews after the study, both the patient and the young woman related his anxiety and reluctance when they were left alone, although his apprehension gradually subsided. He reported, and she later verified in her account of the experience, that as he started to be aroused, he felt the need to confess his homosexuality and generally presented himself negatively, seemingly as a defense against progressing further. During this phase, which lasted about 20 minutes, she continually reassured him. Later, the patient began active participation and achieved successful penetration, which culminated in a highly satisfactory orgastic response, despite the milieu and the

[4] Representative audio-visual tapes were made of this patient (and another patient as well) showing the pleasure response to septal stimulation.

[5] Moan, C. E. and Heath, R. G. Septal stimulation and initiation of heterosexual behavior in a homosexual male. Submitted for publication in *J. Behav. Ther. Exp. Psychiat.*

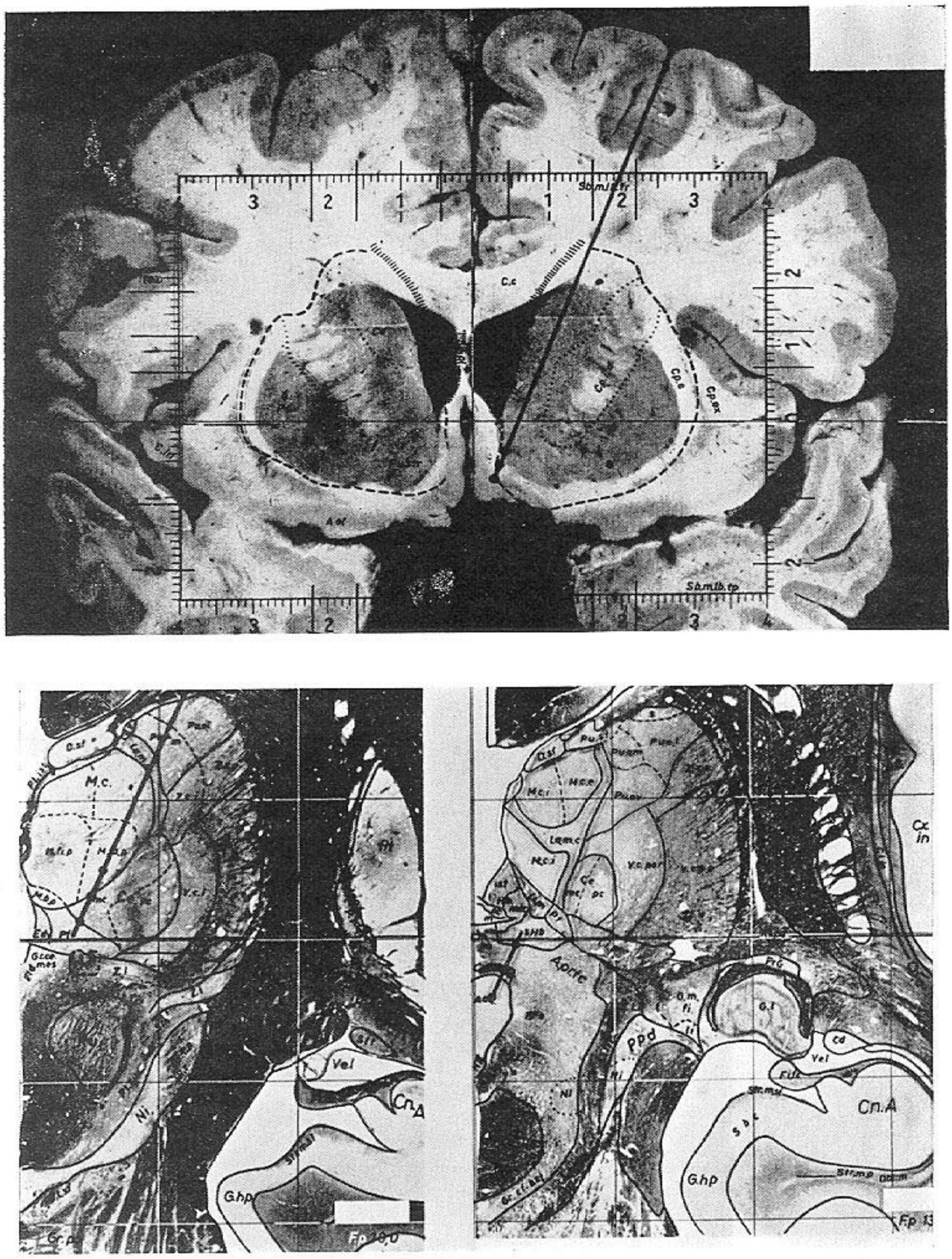

FIG. 1. Electrode placements in the brain of patient B-19. (Diagrams modified from *Introduction to Stereotaxis with an Atlas of the Human Brain,* ed. by Schaltenbrand, G., and Bailey, P. New York, Grune & Stratton, 1959.) Placements are shown in the left anterior septal region (part A) and right central nuclei of the thalamus (includes the centro median) (part B), brain sites from which the most pronounced changes were recorded during orgasm. The bottom 3 leads of the 6-lead electrode (right half of part B) are on a separate diagram because the angle of implantation differed from the orientation of the Atlas.

encumbrances of the lead wires to the electrodes.

Figures 2 and 3 are typical EEG recordings obtained from this patient before the study when the stag film was shown. During the period of progressively increasing arousal (Figure 4), delta waves appeared in the septal leads associated with high-amplitude spindling in the amygdalae and in the thalamus (these recordings were similar to those obtained in the film study). In the immediate preorgastic stage, when the patient was about to begin orgasm, he momentarily withdrew so as to prolong his state of intense pleasure (reported separately by the two participants later), and, as prearranged, he signaled the researchers that he was immediately preorgastic. At that moment, just preceding withdrawal and when he was immediately preorgastic, striking changes occurred in recordings from the left anterior septal and right midseptal leads. The activity, focal at these sites, resembled an epileptiform discharge in that it was characterized by spike and slow-wave complexes at a frequency of 1½ to 2/second with considerable fast activity superimposed on the slow wave. It is notable that the stainless steel electrode in the right midseptal revealed more fast activity than the silver ball left anterior septal lead. These changes at the septal region were

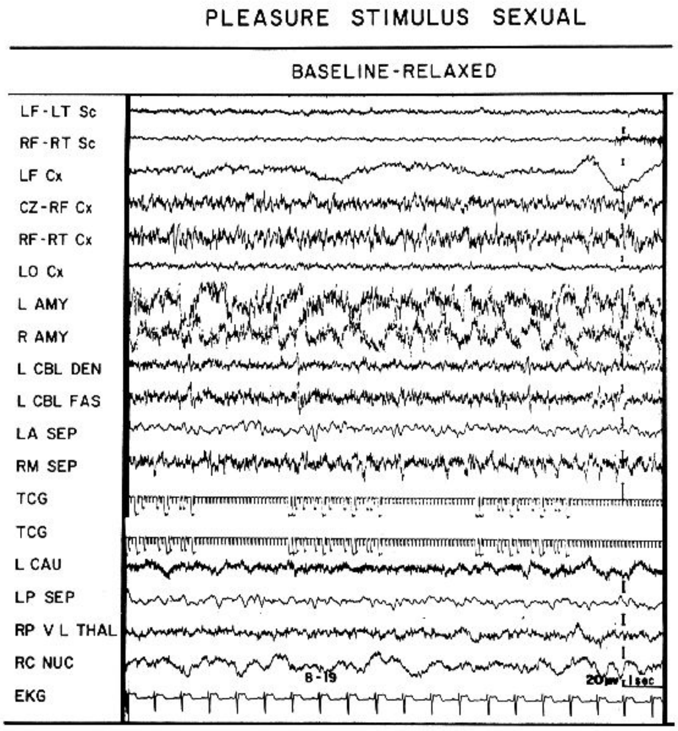

FIG. 2. Deep, cortical, and scalp electroencephalograms obtained from patient B-19 during a period of relaxation. LF-LT Sc, left frontal to left temporal scalp; RF-RT Sc, right frontal to right temporal scalp; LF Cx, left frontal cortex; CZ-RF Cx, central zero to right frontal cortex; RF-RT Cx, right front to right temporal cortex; LO Cx, left occipital cortex; L AMY, left amygdala; R AMY, right amygdala; L CBL DEN, left cerebellar dentate; L CBL FAS, left cerebellar fastigius; LA SEP, left anterior septal region; RM SEP, right midseptal region; TCG, time code, generator machine 1 and time code generator, machine 2; L CAU, left caudate nucleus; LP SEP, left posterior septal region; RP V L THAL, right posterior ventral lateral thalamus; RC NUC, right central nucleus; EKG, electrocardiogram.

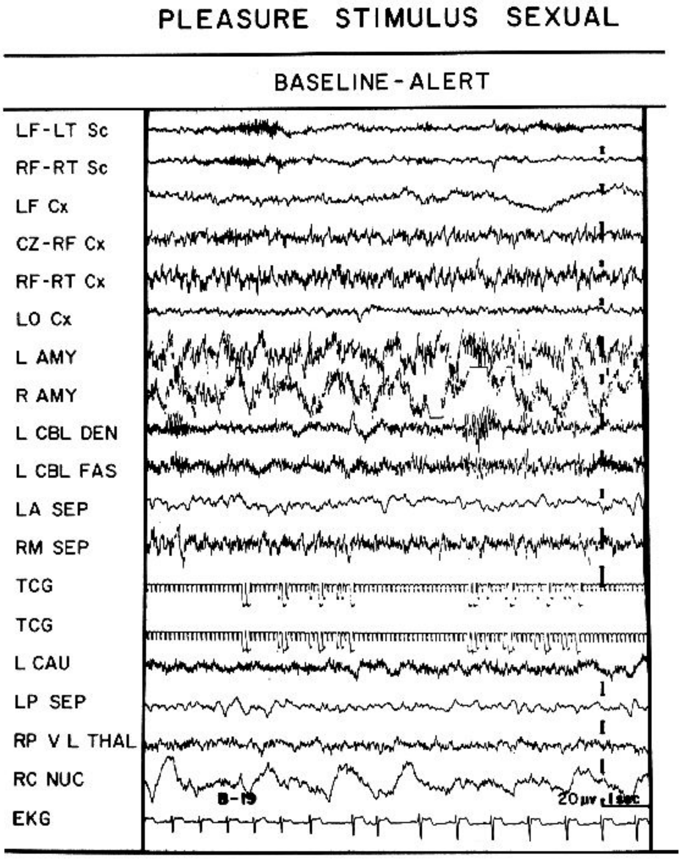

FIG. 3. Deep, cortical, and scalp electroencephalograms obtained from patient B-19 during a period of alert relaxation. (See key for leads under Figure 2.)

concomitant with high-amplitude delta waves in the left amygdala and some spiking intermingled with delta frequency activity in the right central nuclei (vicinity of the centromedian thalamus). Delta activity of lesser amplitude was seen in the right posterior ventral lateral thalamus. The very dramatic recording changes disappeared upon withdrawal, but reappeared when the patient again penetrated, and his almost immediate orgasm was accompanied by intensified delta activity in the amygdalae (more pronounced in the right than in the left) and similar delta activity in the left caudate nucleus (Figure 5). A gradual buildup of delta activity occurred in septal leads and in the right posterior ventral lateral thalamus and right central nucleus of the thalamus. With onset of orgasm, the septal and thalamic recordings evolved into spike and slow-wave activity with superimposed fast frequencies. Again, this activity was most pronounced in the septal leads. Scalp leads showed only artifact. Except for the appearance of some delta activity over the left occipital cortex, subdural cortical leads were unchanged. Shortly after onset of orgasm, the recordings were overwhelmed with movement artifact, and although the septal seizural activity seemed to endure throughout his orgastic response, it was impossible to separate meaningful activity from artifact. Acceleration of the patient's heart rate with onset of orgasm can be seen in the electrocardiogram. The patient's EEG recording at conclusion of orgasm sug-

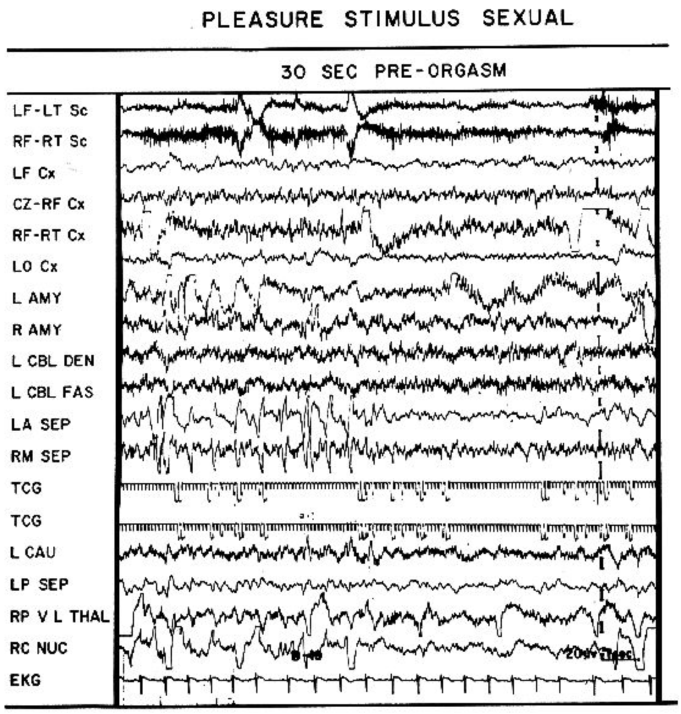

FIG. 4. Deep, cortical, and scalp electroencephalograms obtained from patient B-19 when he was immediately preorgastic. (See keys for leads under Figure 2.)

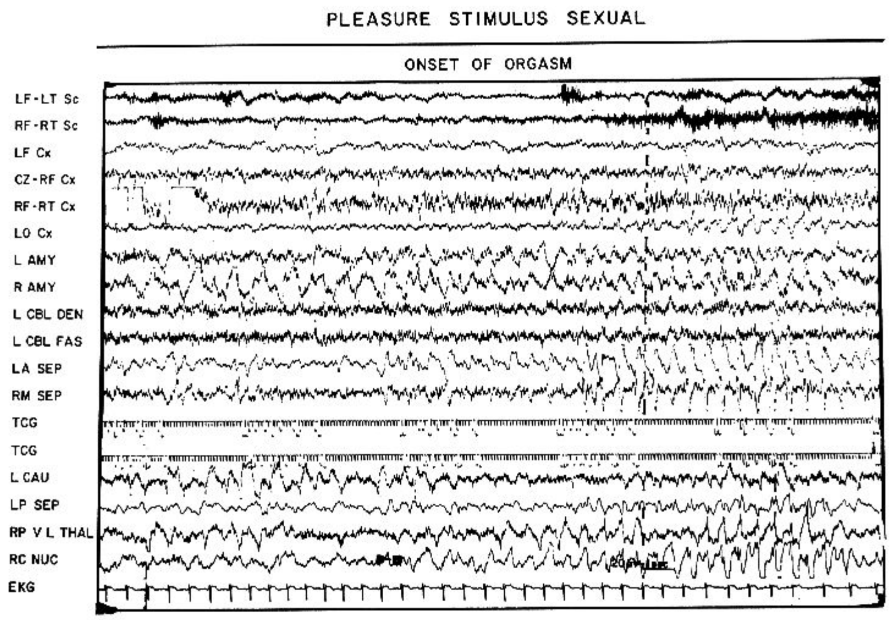

FIG. 5. Deep, cortical, and scalp electroencephalograms obtained from patient B-19 with onset of orgasm. (See key for leads under Figure 2.)

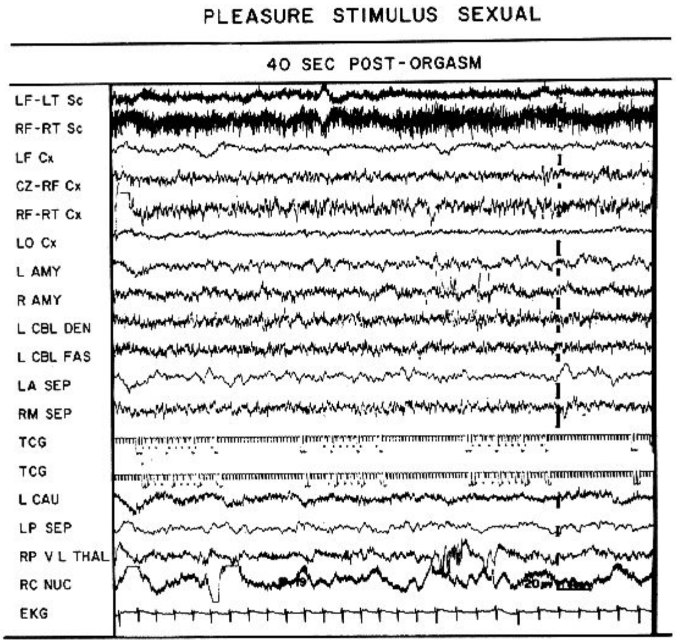

FIG. 6. Deep, cortical, and scalp electroencephalograms obtained from patient B-19 at conclusion of orgasm. (See key for leads under Figure 2.)

gested relaxation except for muscle activity at the scalp (Figure 6).

PATIENT B-5

This patient's treatment program was also extensive, involving numerous technics. Treatment pertinent to the present report involved introduction, by microsyringe, of minute amounts of acetylcholine and levarterenol bitartrate through the intracerebral cannulas (10) implanted into the septal region. These techniques have been described in several previously published articles (6, 12, 14). Acetylcholine (400 μg in 70 lambda) was introduced into the septal region on 12 occasions. Levarterenol bitartrate (140 μg in 70 lambda) was used on four occasions. Behavioral and EEG changes were induced 10 of the 12 times acetylcholine was used and two of the four times levarterenol was used.

When a response occurred with introduction of these compounds, it was essentially the same (behaviorally and electroencephalographically) regardless of which chemical was used. In 1 to 2 minutes after completion of the injection, the patient's mood would gradually begin to change. It consisted of gradual elevation of mood, culminating, within 10 to 15 minutes, in a state of mild euphoria accompanied by increased level of awareness. The degree of change was dependent on the patient's condition at the time the stimulus was given; if she had been in a low mood, the change was dramatic, whereas if she had already been feeling pleasant at the onset of treatment, the change was less profound. The patient became more attuned to her environment, answered questions more rapidly and accurately, and solved simple mathematical problems with more ease. The elevation in mood and heightened awareness involved development of a sexual motive state and in most instances, within another 5 to 10 minutes, this culminated in repetitive orgasms. Not only did the patient describe the response when questioned, but her sensuous appearance and movements offered confirmation.

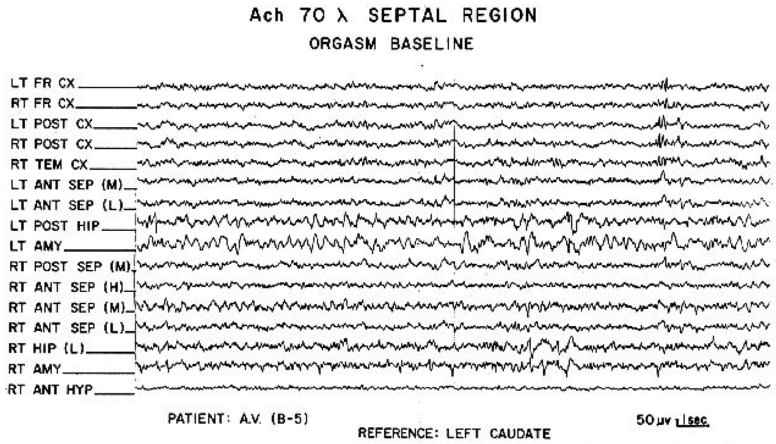

FIG. 7. Deep and surface electroencephalograms obtained from patient B-5 during a resting state. LT FR CX, left frontal cortex; RT FR CX, right frontal cortex; LT POST CX, left posterior cortex; RT POST CX, right posterior cortex; RT TEM CX, right temporal cortex; LT ANT SEP (M), left anterior septal region, middle lead of triple-lead silver ball electrode; LT ANT SEP (L), left anterior septal region, lowest lead of triple-lead silver ball electrode; LT POST HIP, left posterior hippocampus; LT AMY, left amygdala; RT POST SEP (M), right posterior septal region, middle lead of electrode; RT ANT SEP (H), right anterior septal region, highest lead of triple-lead electrode; RT ANT SEP (L), right anterior septal region, lowest lead of triple-lead electrode; RT HIP (L), right hippocampus, lowest lead of triple-lead electrode; RT AMY, right amygdala; RT ANT HYP, right anterior hypothalamus.

The resting EEG's of this patient were characteristic of the recordings we obtained from all epileptic patients in our series. The principal feature was an almost continuous spike discharge from sites in the amygdalae and hippocampi; seizural patterns occasionally appeared at these sites and there was generalized moderately slow (S-2) activity (Figure 7). On each occasion that the chemical stimulation was effective, changes in EEG recordings were concomitant with the behavioral phenomena. The changes were focal, appearing in the septal leads with occasional minor reflections in activity of the amygdalae. As elevation in mood began, increased amplitude spindling activity at a frequence of 12/second appeared in the septal leads in contrast to the base line low amplitude, fast activity. As elevation in mood progressed further, this same activity appeared in more leads in the septal region, increased in frequency, and then remained continuous for periods of 5 to 10 minutes before changing in character as the patient began to report onset of the orgastic response and to display mannerisms suggesting it. This usually began 10 to 15 minutes after injection. In association with the orgastic response, the EEG recordings began to show spike and slow-wave activity (Figure 8). Superimposed on the slow wave was suggestive low-voltage, fast-wave modulation. This activity would subside, only to reappear as the patient experienced another orgasm. Fast high-amplitude spindles appeared intermittently between the spike and slow wave plus superimposed fast recordings. Figure 9 illustrates the high-amplitude spindling activity which appeared during arousal preceding orgasm and also between orgasms. The behavioral and EEG responses persisted for varying periods with the different treatments, usually for 10 to 30 minutes. When the arousal and orgastic responses subsided, the EEG returned to base line.

Treatments were spaced at intervals of 1/week. When either acetylcholine or levarterenol bitartrate was used, it was always

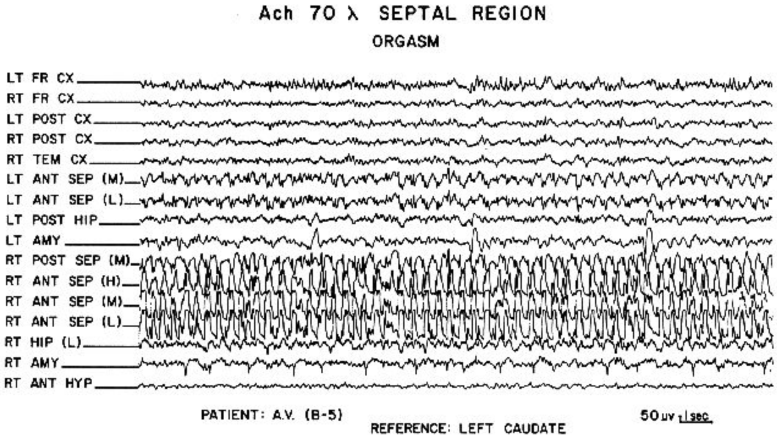

FIG. 8. Deep and surface electroencephalograms obtained from patient B-5 in association with orgasm after intracerebral injection of acetylcholine (400 μg in 70 lambda). When this recording was obtained, spike and slow-wave bursts were more prominent in the right septal leads. However, this pattern sometimes migrated and became more pronounced on the left. (See key for leads under Figure 7.)

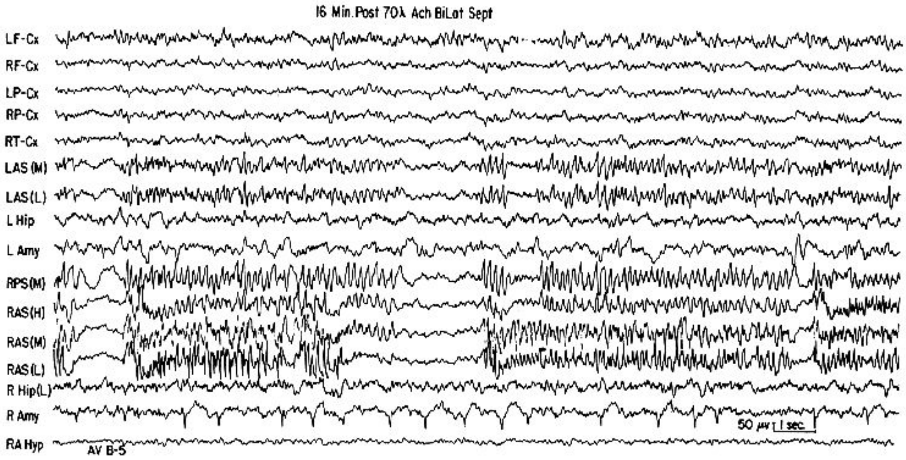

FIG. 9. Deep and surface electroencephalograms obtained from patient B-5 after administration of acetylcholine. Activity is typical of the high-amplitude spindling which appeared during arousal preceding orgasm and also between orgasms.

introduced into both sides of the septal region.

On numerous occasions before beginning this treatment program, recordings were obtained from the patient during clinical seizures, both grand mal and psychomotor. The spread of activity was similar to that which we have reported for other patients (2, 3). Although those brain structures activated during the pleasure response were also involved just before inception of the epileptic seizure, the pattern of discharge was different and with onset of the clinical seizure the abnormal electrical activity encompassed the entire cortex. This patient did not have a clinical seizure during the 4 months that she was being treated with the intracerebral injections that induced activation of the septal region, and immediately thereafter.

Patient B-5 was studied 10 years earlier than patient B-19, when sites of electrode placements were more restricted. The first patient did not have electrodes implanted into the thalamus, where dramatic recording changes occurred in patient B-19 in association with his sexual arousal and orgasm, or into the cerebellum, where only minimal changes were noted in the latter patient.

DISCUSSION

In the 2 patients from whom we have been able to record electrical activity from numerous deep and surface sites of the brain in association with repeated sexual orgasms, we found that both patients displayed the same EEG pattern with each orgasm. Further, the brain activity at these times was similar in the 2 patients. In both patients, the most striking and consistent changes were recorded from the septal region, with characteristic spike and large slow-wave with superimposed fast activity. This EEG activity was similar to that recorded on scalp EEG's of patients during epileptic seizures. But in the patients described here, where these outbursts were restricted to specific subcortical sites, no clinical manifestations of epilepsy were evident.

One other patient in our current series of 60, B-10, a man with temporal lobe EEG abnormality, displayed changes in recordings from the septal region with introduction of acetylcholine into that site of his brain. This treatment induced strong pleasure feelings and a sexual motive state but it did not culminate in orgasm. The recordings during this arousal were characterized by fast, high-amplitude spindling focal in the septal region. They were similar to the EEG's obtained from patient B-5 when she was aroused preceding orgasm. These recordings from patient B-10 did not show the spike and slow-wave activity with superimposed fast frequencies that patients B-5 and B-19 showed during orgastic response. [Samples of the recordings obtained from patient B-10 with acetylcholine treatment have been published elsewhere (6, 12)]. The kind of recording obtained from this patient with administration of acetylcholine was strikingly different than his spontaneous epileptiform activity; it was localized to the septal region and different in form. Likewise, concomitant behavioral changes were unique. The patient said he had never before experienced such intense feelings of pleasure, which were in sharp contrast to his dysphoria during spontaneous epileptiform discharges.

These consistencies in recordings would indicate that EEG changes in the deep subcortical regions of the brain that are not reflected on the surface are indeed true correlates of the orgastic response. The findings in these studies of little or no change in scalp recordings substantiate most earlier reports that there are no correlates between the sexual orgasm and activity recorded with conventional scalp EEG's; in fact, such scalp EEG's are inevitably contaminated with muscle artifact, as were the scalp EEG's obtained in these studies. One report in the literature, however, describes "slowing of electrical activity with increased voltage until there are paroxysmal 3-per-second waves mixed with alternating rhythmic muscular discharges . . ." in 4 of 6 patients during orgasm (15, p. 218). While this finding is difficult to interpret because of the reference to muscular discharges in the recordings, it is possible that this activity was a reflection of the delta activity that we have observed in recordings from some sites of the amygdala. Our failure to note changes in scalp recordings associated with the explosive manifestations at deep sites suggests that scalp changes are insignificant. However, since subdural leads over the occipital cortex did show some delta activity, the possibility remains that scalp recordings at some sites might show changes reflecting the stormy activity at deep sites if the usual complicating and overwhelming muscle artifact could be eliminated.

The findings reported herein are consistent with other data obtained in our depth electrode studies in man which indicate a correlation between activity of the septal region and the pleasure response. This correlation has been demonstrated by six approaches: 1) induction of pleasure by external sensory stimuli (visual, through sexual movie films, and physical contact through sexual intercourse), as described here; 2) the psychiatric interview—recordings obtained while the patient is freely associating during a pleasurable motive state; 3) direct delivery of chemicals to the septal region with use of the intracerebral cannula; 4) programmed electrical self-stimulation with use of the transistorized unit; 5) passive electrical stimulation of the septal region; 6) administration of pleasure-inducing or euphorizing drugs (oral, hypodermic, intravenous).

With each approach, induction of the behavioral pleasure response has been accompanied by changes in electrical activity in the septal region or demonstrably interconnected sites, or both. In our depth electrode studies in man, we have consistently observed that development of intense emotion, pleasurable or painful, while the patient freely associated during the psychiatric interview, corresponded with appearance of high-amplitude spindling focal at specific subcortical sites in the pathways for emotional expression (11). When painful emotions (fear and rage) prevailed, the spindling was usually most prominent in deep nuclear masses of the temporal lobe (amygdala and hippocampus). With pleasurable emotions, spindling was most consistently recorded from the septal region and occasionally from sites in the amygdala as well (6, 7, 11, 12, 13). We have also previously described EEG changes at sites within the pathways for emotional expression in association with various pleasure-inducing drugs (6).[6] Further substantiation of this relationship is forthcoming from studies of persons exhibiting deficiencies in their pleasure mechanism (anhedonia). These patients have consistently shown abnormal septal recordings (spike or slow-wave, or both); this aberration has been described in association with psychotic behavior by the Tulane researchers (8, 13) and by investigators at the Brain Research Institute of the University of California at Los Angeles (18). The correlation of septal spiking and psychotic behavior is consistent regardless of the basic etiology of the psychotic state. Aberrant recordings sometimes appear at other brain sites as well but, if the septal region is not involved, psychotic behavior will not be evident.

At first glance it seems paradoxical that seemingly similar recordings are obtained from the septal region in association with the dysphoric, psychotic state, and the intensely pleasurable orgastic state. The similarities, however, may be more apparent than real. Although there are features in common between the spike and/or slow-wave recording of the psychotic patient and the recording during orgasm described here, there are also distinct differences. The recording during orgasm contained significant fast activity, as suggested by the saw-tooth activity superimposed on the slow-wave. Moreover, the spiking seen with the orgasm is characteristically more rhythmic and continuous than the irregular spiking of the psychotic recording. The recording of the seriously ill psychotic patient may show as many as two or three spikes in a single 10-second page, whereas there may be intervals of a minute or more between spikes when the same patient is less symptomatic. We have previously described the characteristics of the spikes recorded from psychotic patients (2, 8, 12, 13). Their form varies considerably from a rather spread-out sharp wave of moderate amplitude to a high-amplitude, very sharp spike—in contrast to the uniform wave associated with the orgasm. It is possible that the seeming simi-

[6] Heath, R. G. Manuscript in preparation.

larities in the recordings are caused by limitations of the ink-writer instrument with its considerable lag time. This issue will be clarified when it becomes possible to record the data on magnetic tape for accurate computer analysis.

The fabrication and use of a self-stimulating transistorized device in our patients was inspired by the experiments of Olds et al. (16, 17) with small animals. Our unit has provided an objective estimate of relative pleasurable or adversive effects of stimulation to different sites deep in the brain of man. The fact that patients most consistently choose to stimulate the septal region with this device concurs with their verbal reporting that a pleasurable response is most often elicited at this site. This technique has helped to demarcate the pleasure areas of the human brain (the medial forebrain bundle and interpeduncular nuclei of the mesencephalon), roughly corresponding to pleasure areas of brains of animals (17).

The Tulane group previously reported that septal stimulation induced a sexual motive state, whereas stimulation of other pleasure sites (the vicinity of the medial forebrain bundle and interpeduncular nuclei), while creating pleasant feelings, failed to induce the sexual motive state (5, 6). The anatomical connections between the septal region and other nuclear sites within the pathways of emotional expression, together with demonstration of the functional inter-relationship among sites within these pathways, has been described.[7] These studies indicated that principal sites involved in emotional expression were the septal region (defined by the author to include the nucleus acumbens septi and the nucleus of the diagonal band of Brocha (4), the hippocampi, the amygdalae, the orbital cortex, and specific sensory relay nuclei (posterior ventral lateral thalamic nucleus and the deep nuclei of the cerebellum).

[7] Heath, R. G. Physiologic basis of emotional expression: Electroencephalographic, evoked potential, and mirror foci studies in isolation- and feral-raised rhesus monkeys. Manuscript submitted for publication in the *Biol. Psychiat. J.*

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