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Electroencephalographic Changes Induced by Dimethyl-Tryptamine in Normal Adults

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Dimethyl-tryptamine (DMT) is a hallucinogenic agent having in man an action partially similar to that caused by d-lysergic acid diethylamide–25 (LSD) or mescaline [8]. The electrophysiological investigations of the possible mechanisms of the psychotonogenic drug action have provided some important results. Therefore it was hoped to observe some changes in the electroencephalograms which might help to recognize the alterations in the functional activity of the central nervous system caused by DMT.

Method

Five normal volunteers (four physicians and one chemist) aged 25–33 were subjected to EEG observations before and after injection of DMT in a room shaded slightly. Electrodes were placed symmetrically in the frontal, central, parietal, occipital, posterior and mid-temporal regions, further in the nasopharynx. Responses of the alpha activity to sensory stimuli such as light (opening and closing the eyes), sound (loud speech), proptioceptive impulses (the person's own movements) and to emotional states were especially analysed. In two persons the amount and amplitudes of the 8–12 cps. spindles were measured in millimeters throughout the total recording and diagrammatically summarized every minute. DMT was administered intramuscularly in doses ranging from 0.7 to 1.1 mg./kg. body weight.

Results

Prior to injection of DMT, four persons showed numerous spindles of 8–10 cps, well modulated in the temporo-occipito-parietal region with some preponderance of the one side, in the resting state with the

eyes closed. Opening of the eyes and intellectual stimulation, however caused immediately complete alpha blocking. One person did not have alpha activity at all, even after closing the eyes, but only an alert type of electroencephalogram. Abnormal rhythms were never seen. It was possible to analyse the effects of different grades of the DMT action.

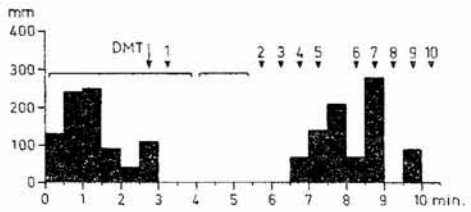

Fig. 1. The total length of alpha spindles expressed in millimeters in every half minute is shown. Spindles with peak-to-peak amplitude of less than two millimeters are not included (calibration: 10 mm. = 50 uV.). Horizontal lines on top indicate closing eyes.

Before injection of DMT well modulated, responsive alpha spindles of 8–9 cps. Following administration of DMT, there develops a two-stage pattern of the EEG, firstly immediate disappearance of the spindles; later on, alpha activity returns gradually, although eyes are open. This synchronisation coincides witht intense hallucinations. The most serious hallucinations were noted in this case.

Text related to numbers contains the most characteristic psychical events of the half minute designated, in the person's own words. – (1) (3rd minute after injection) dizziness, feeling of collapse (about one min. stop in recording because of manipulations with injection). (2) Visual hallucinations are rapidly growing: "It is frightening since I can not terminate it" (namely through opening the eyes). – (3) "How unpleasant!" – (4) "Oh how bad", she records her hallucinations. Spindles begin to appear with an initial frequency of 10–12 cps; eyes are permanently open. – (5) "It would be better to fall down in a faint... will it endure still for one hour?" Sometimes signs of tension or even excitement are visible; number, voltage and modulation of alpha spindles are further increasing. – (6) Excitement is rising, person supplicates or demands: "Give me somewhat so that I shall die quickly, it would be better to die." Alpha activity is much reduced by excitement. – (7) Person sinks down in lethargy, lies motionless, speaks little in a despondent tone: I should like to die... oh my God how good it would be to die." Alpha activity is more intense than before DMT, although eyes are open. – (8) Suddenly, she becomes very excited: "Oh how sick I am feeling"; she calls very indignantly upon Dr. *Szára* who produced DMT to account for experimentation with this drug. The hyperemotional states evokes full desynchronisation. – (9) Person again speaks about death: "I am not afraid of death... that is very unpleasant... I shall die." She is obviously hopeless, despondent; alpha spindles reappear while person is speaking. – (10) Person shows a pronounced anxiety and cries: "Kill me... how were you capable to do such?..."; she tries to get up and go away necessitating to end the recording; the spindles disappear.

Following injection of DMT, two subjects displayed serious visual hallucinations associated with hyperemotional states and confusion that necessitated to interrupt the recording. Two others had hallucinations of medium intensity without psychomotor excitement; in one person, DMT resulted only in a moderate psychic effect with weak hallucination. The observation comprised in these last three subjects the whole period of hallucination. DMT induced in the four persons with resting alpha activity obvious changes of varying degree in the EEG depending on the intensity of the psychic processes.

(a) The *first stage* of DMT effect was characterized by reduction and eventually *complete disappearance of the alpha band* even during the closing of the eyes. In two persons the drug administration was

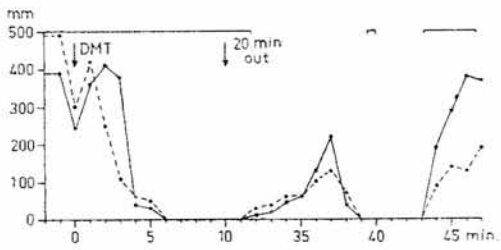

Fig. 2 demonstrates measurements of electrographic changes caused by DMT in a person who experienced hallucinations of medium intensity without excitement. – Horizontal lines on top denote eyes closed.

Broken lines indicate relations between average voltage and average length of alpha spindles based upon the formula $\frac{At \times Lt}{100}$ where At= amount of the 10 highest amplitudes measured peak-to-peak and Lt= sum of lengths of the 10 longest spindles obtained in millimeters in every minute. Continuous line expresses relation between total number and total length of alpha spindles counted in millimeters by means of the formula $\frac{Ns \times Ls}{100}$ where Ns = number of spindles, Ls= length of spindles summarized in every minute. – In the fully resting state with eyes closed, the first relation gives a higher value than the latter one because the spindles are high and long.

One can recognize the gradual development of the two-stage effect of DMT and the recovery. Desynchronisation is recognizable in the 2nd and 3rd minutes already, by fall of the value of voltage-length relation following diminution of amplitudes. Returning of alpha rhythms (synchronisation) begins much later and reaches a lower level with eyes open than in Fig. 1, in the first person. – *Recovery* (restitution of normal alpha activity) is not yet completed at the end of recording, five minutes after cessation of visual experiences as shown by the low values of voltagelength relation.

followed immediately by generalized flattening the activity (Fig. 1); it is probable that here the pricking pain and attention helped the desynchronisation, at least initially. In a third person, the alpha spindles showed a gradual diminution in number, voltage, and length associated with shifting to some faster, 10–12 cps frequencies; in such a manner, alpha activity disappeared entirely within six minutes (Fig. 2). In the fourth one, this process required fourteen minutes; desynchronisation was completed concurrently with the first hallucinations, when random coloured spots appeared; the hallucination was very mild and of short duration, therefore the recording was ended at the seventeenth minute.

(b) The *second stage* was heralded by a few short runs of 11–12 cps waves in the low-voltage fast groundactivity. Gradually, *alpha spindles returned*, notwithstanding that no somnolence was noted during this new synchronisation, moreover the hallucinations culminated at that time. The spindles of the second stage arose some five minutes after the injection of DMT in the subject who displayed the most striking psychic effect of the drug (Fig. 1). Alpha activity reached here somewhat greater intensity than before DMT. Such a phase of alpha synchronisation developed also in two other cases although more slowly, and it showed a less advanced state (Fig. 2).

Sensory stimulation evoked quite different responses during the second stage as compared to those before DMT administration. *Opening the eyes*, even keeping them permanently open *did not reduce* at all the alpha activity in one person with the heaviest hallucinations. However, light stimuli elicited partial desynchronisation in two other persons. The person's own speech and movements as well as environmental events did not cause a fast flat EEG during certain periods of the second stage, although they did it regularly before DMT administration. Alpha spindles appeared almost invariably while the subjects were lying with the eyes open, looking at their hallucinated experiences and reporting them spontaneously, making movements and forced smiling. In one case, a *paradoxical appearance of alpha runs* was observed in response to opening of the eyes during the transition from the first stage of the drug action to the second one and from the second stage to the recovery.

A variety of *emotional states* occurred in every subject, at least to some extent, inducing changes in the EEG. Tension, indignation, protestation, apprehension, anxiety, excitement exerted always a desynchronising effect. On the contrary, relaxation, expression of

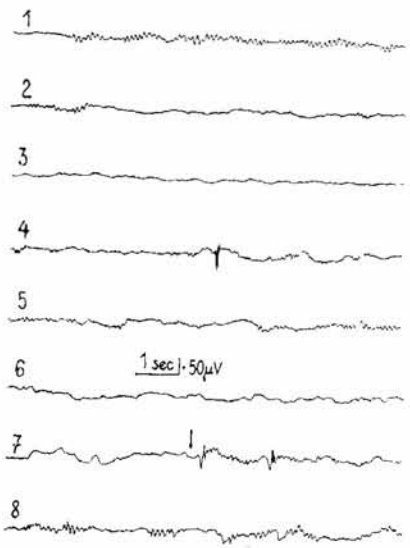

Fig. 3. Effect of DMT upon alpha activity from left temporo-occipital region of the same person.

Strip 1: Before DMT: almost continuous alpha activity (eyes closed). – (2) 5th min. after injection of DMT, eyes closed; rare and low alpha spindles (incomplete desynchronisation). – (3) 10th min.; no spindles, complete desynchronisation either with eyes closed or opened; first stage of action of DMT fully developed. – (4) 35th min., person lies smiling with eyes opened just answering the question of observer: "Why are you smiling?" with the words: "I am compelled... it is a forced smiling"; alpha synchronisation despite of light and sound stimuli, impairment of alpha blocking; second stage of the effect of DMT. – (5) 10 seconds later, he lies smiling and relaxed in silence with eyes opened; synchronisation is somewhat reinforced following relaxation and discontinuation of speaking. – (6) 38th min., person shows some tension: "May I speak?... I should like to speak because EEG seems to be endless"; desynchronisation caused by emotion of tension type. – (7) 40th min., stage of synchronisation is almost finished, effect of DMT is decreasing; prior to arrow desynchronisation with eyes closed, while repeated opening of eyes (marked by arrow) is followed by a run of an alpha rhythm (paradoxical alpha response) at the transition phase from resynchronisation to desynchronisation. – (8) 46th min. eyes closed; hallucination does not occur any more; alpha activity is steadily growing, its blocking is restituted; recovery of electrogenesis is nearly completed.

hopelessness, lust for death and lethargy were followed mostly by the appearance or increase of the alpha activity. This difference in the EEG response was particularly observable when opposing hyper-emotional states such as excitement and lethargy followed each the

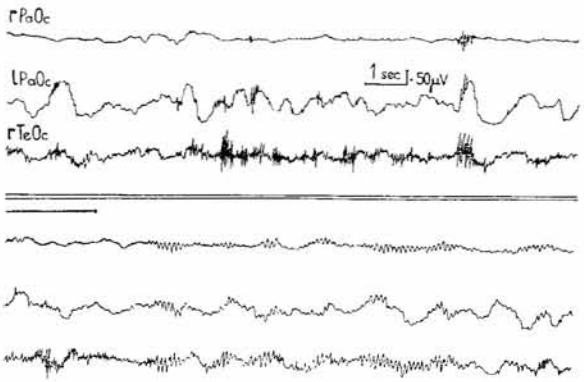

Fig. 4. Effect of changing hyperemotional states upon the EEG during very intense hallucinations, in the second stage of action of DMT in the subject presented in Fig. 1.

In the record's upper half muscle artifacts (speech and head's movements) continuing also to the lower half. Person's speech expresses despair, desire of death: "It would be better to die... I am desiring to die... oh my God, how good it would be to die." The emotional charge of the speech induces direct desynchronisation which, however, turns into vigorous alpha synchronisation after end of speech, during the subsequent lethargy.

other rapidly. In such a case the complete desynchronisation was replaced without transition by well modulated alpha spindling (Fig. 4). In the second stage of the drug action, the subject's own movements and speech as well as conversation with him evoked desynchronisation only if associated with emotion of the tension type.

A *diminution of hearing* accompanied the hallucinations. One person experiencing only hallucinations of medium degree without agitation reported spontaneously, nine minutes after DMT administration tha the voices diminished, and later on, that he could not hear the buzzing of the EEG machine's motor. Good hearing returned some four minutes prior to the abating of the hallucination.

(c) *Recovery* form the action of DMT was traced in two subjects only. The subsiding of hallucinations was followed by a step to step restitution of normal electrogenesis. Regular alpha responses developed again and the amount of the resting alpha activity approached a level similar to that before the experiment. The ability to desynchronise returned for visual stimuli in less time than for voices, the individual's own speech and movements.

Discussion

Dimethyl-tryptamine induced definite alterations in the electroencephalogram which were composed of two stages. The first stage exhibited only the pattern of enduring electrographic alertness. Although desynchronisation seemed to be a sudden process in certain persons such as occurs in visual or mental stimulation, in others it proved to be the result of a progressive reduction of the alpha activity. Displacement of the alpha pattern was first not connected with the hallucinations since it preceded the outbreak of the visual events. Thus one may suppose that the desynchronisation caused by DMT is, at least partially, related to some stimulatory drug action exerted directly upon subcortical activating structures resposible for the electrical alertness.

The second stage showed new patterns: lesion of the alpha blocking mechanism and sometimes paradoxical alpha response, further appearance of well organised alpha activity in spite of the opening of the eyes. Deficiency of the alpha blocking is probably caused in part by depression of some sensory systems presumably of the auditory and proprioceptive ones or by inhibition of sensory collaterals at the synapses to the meso-diencephalic reticular formation. This depression seems to be a direct action of DMT; however, focusing of attention on the visual sphere during hallucinations may contribute to a diminution of acoustic functions, since a similar type of inhibition of acoustic responses to click stimuli caused by shifting of attention to visual events is known from animal experiments [2].

Reappearance of the alpha spindles is possibly caused by various factors. Defective alpha blocking, relaxation in consequence of pleasure during hallucinations or emotional collapse following psychomotor excitement (Fig. 4) may account for the appearance of bursts of alpha waves. Perhaps spindling may express a certain protective, inhibitory function of normal slow rhythms [3, 9] against the pathological excitatory state of optic neuronal chains. Spindling is not explainable by transitory interruptions in the hallucinations because such interruptions were never noted during the phase of intense hallucinations.

The two-stage response of the EEG to administration of DMT suggests that this drug induces a dual effect. Initially (in lower concentration) it causes an excitation (facilitation) which, if progress-

ing (at higher concentration), may subsequently turn into its opposite and inhibit certain alerting and sensory structures.

These conclusions were drawn from our EEG and clinical observations made during the model psychosis precipitated by DMT.

Our findings are similar to those reported in the literature under effect of LSD and 5–HT (serotonin) both substances being chemically related to DMT. However, DMT seems to produce a more complete EEG effect comprising most of the bioelectrical changes caused by LSD and 5–HT; namely, DMT evokes a two-stage pattern of the EEG: an initial desynchronisation and a return to alpha synchronisation, with impairment of the alpha blocking mechanism. Such a chronological succession of the bioelectrical events was infrequently observed in the numerous experiments on the hallucinogenic drugs.

There are data indicating that hallucinogens display facilitatory or inhibitory effects at certain kinds of the cerebral synapses. LSD, mescaline and 5–HT are capable to depress functions of the cortico-cortical (transcallosal) synapses [4]. Furthermore, LSD has an inhibitory action also on nonspecific systems having mostly synapses of axodendritic type similar to the cortico-cortical ones. However, LSD facilitates the specific afferent systems possibly at their axo-somatic synapses [5, 6]. It seems probable that these synaptic actions have some role in the hallucinogenic effect of the aforementioned drugs, including per analogiam also DMT.

Considering the similarity between the electrophysiologic effects LSD [1, 7] and those of DMT we suppose that the hallucinogenic actions of both compounds are based upon some common processes, probably on differential facilitations and inhibitions at the synapses. But DMT acts more completely and quickly, in a few minutes, while LSD acts rather slowly; these facts indicates that DMT sets off the processes leading to hallucinations more directly than LSD.

Summary

Electroencephalograms were made during a model psychosis evoked by dimethyl-tryptamine (DMT) in five adults.

DMT given intramuscularly induced a two-stage EEG pattern depending on the psychic changes. In the first stage, alpha spindles were replaced by flat activity (desynchronisation) preceding the hallucinations. The second stage was characterized by the gradual developing of alpha activity (synchronisation); however, the alpha rhythm responded defectively, paradoxically or not at all to sensory stimuli.

This EEG pattern shows a great similarity to that seen under effect of LSD, but DMT acts quickly, apparently more directly, while LSD acts slowly, probably rather indirectly.

It is suggested that DMT exerts a dual effect: it facilitates certain alerting and sensory systems in low concentrations, while it causes differential inhibition at higher concentrations.

Zusammenfassung

EEG-Ableitungen wurden an fünf normalen Erwachsenen durchgeführt, die sich unter Einwirkung von Dimethyl-tryptamine (DMT), einem Psychoticum befanden. Die erste Phase der von DMT hervorgerufenen EEG-Veränderungen ist ein Abflachen (Desynchronisation), welches den Halluzinationen vorausgeht. Die zweite Phase ist durch stufenweise Entwicklung einer neuen Alpha-Synchronisation im Laufe der Halluzinationen gekennzeichnet; diese Alpha-Tätigkeit zeigt aber unvollständige, paradoxe, ja sogar fehlende Antworten auf sensorische Stimuli. Die Verfasser meinen, daß DMT eine zweifache Wirkung auf das zentrale Nervensystem ausübt: in kleinen Konzentrationen fördert es gewisse aktivierende und sensorische Systeme, in höheren Konzentrationen aber verursacht es differenzierende Hemmungen.

Résumé

Les auteurs ont pratiqué des examens électroencéphalographiques sur cinq adultes normaux chez qui une psychose artificielle avait été provoquée par l'administration de diméthyle-tryptamine (DMT). Par voie intramusculaire, le DMT produisit une image EEG en deux phases dépendant des modifications psychiques. Dans le premier stade, on constate un aplatissement ou même une disparition complète de la phase alpha (désynchronisation) précédant les hallucinations. Le deuxième stade se caractérisa par le retour graduel de l'activité alpha (synchronisation); cependant, ce rythme alpha répondit de façon anormale, paradoxale ou nulle aux stimuli sensoriels.

Le tracé EEG présente une grande similitude avec celui que l'on note sous l'action du LSD, mais le DMT agit rapidement, probablement de façon plus directe, tandis que le LSD a une action lente et vraisemblablement indirecte.

Les auteurs suggèrent que le DMT exerce une double action: à faibles concentrations il facilite certains systèmes sensoriels d'alerte, tandis qu'il provoque à hautes doses une inhibition différentielle.

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Buchbesprechungen - Book Reviews - Livres Nouveaux

Elrod, N.: **Zur Phänomenologie der Besserung in der Psychotherapie.** S. Karger, Basel/New York 1958. 196 p., 14 fig. sFr. 25.–. (Suppl. ad. Vol. 5, Acta Psychotherapeutica Psychosomatica et Orthopaedagogica.)

In an introductory chapter it is outlined what improvement in psychotherapy means to various psychiatrists. The main body of the monograph deals with the author's therapeutic experiences with a chronic schizophrenic who after 2½ years of therapy was able to live outside the institution in a state of "schizophrenic defect". Such careful and detailed records of psychotherapeutic experiences as presented in this monograph are rather rare in the literature, and their study should be highly rewarding to anyone interested in the phenomenology and dynamics of psychotherapy. *E. S.*