FUNCTIONAL REPRESENTATION IN THE TEMPORAL LOBE OF MAN

(A STUDY OF RESPONSE TO ELECTRICAL STIMULATION)

by

Maitland Baldwin, M.D.

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I. INTRODUCTION

The particular form of epilepsy which often follows a focal lesion in the temporal lobe is characterized by various combinations of abnormal experience and unusual behaviour. The clinical significance of these subtle feelings, crude sensations and unusual actions has been known for some time. If we agree that focal lesions in the human temporal lobe may produce paroxysms characterized by subtle changes in perception, hallucinations and dreams, or unreasoning behaviour which is apparently automatic, it becomes obvious that this region must have important functional representation.

An alteration in perception, or a perceptual illusion, of the type that occurs in temporal epilepsy, is a brief radical change in appreciation of present experience, while the hallucinations or dreams are vivid little complexes of imagery and sound in the symbols of past experience. The unusual behaviour which occurs in some of these temporal seizures is an apparently unnecessary and purposeless panoply of random actions. Self manipulation, self inspection, continuation of routine actions and procedures to the point of absurdity characterize this dimming of consciousness.

Focal epileptogenic lesions in the temporal lobe produce these bizarre changes. Surely we may presume that functional representation here is of a higher order, either intrinsically or because of intimate connections, than the sensory areas of olfaction, audiovestibular reception and vision, which lie on its boundaries. These clinical observations indicate that function here may be related to perceptual judg-

ment and acquired patterns or records of past experience. These are in a sense psychical functions and it is somewhat difficult to make accurate analogies concerning them from animal experimentation. However further investigation has been made possible by direct electrical stimulation of the human temporal lobe in conscious patients.

This stimulation is an essential step in surgical treatment of temporal lobe seizures as it often leads to reproduction of the aura and production of after-discharge in abnormally active areas, thus assisting in localization of the epileptogenic focus which must be excised. In the present technique, verbal responses to the stimulation follow carefully controlled interrogation and have been accurately recorded. Since most of the direct responses to electrical stimulation of the temporal lobe are within the mental experience of the patient, and cannot be seen by the objective observer, it follows that the verbal expression of these responses is of primary importance. The interpretation of these responses forms the basis of the present study. In so far as possible this has been directed towards a further understanding of the functional significance of the areas stimulated.

The responses fall into certain categories which the previous clinical observations have predicted. These categories have been discussed separately and in combination so as to develop certain theoretical conclusions. Reasonable evidence has already been presented for functional localization in the neighbouring sensory areas of olfaction, audiovestibular representation and vision, and this has not been reviewed here. There is a cortical representation of speech in the posterior temporal region of the dominant hemisphere which has been re-

cently studied in some detail by Roberts. The actual evidence concerning it is not presented in this report. Similarly, a discussion of the evidence for automatic behaviour following stimulation of the inferior and mesial parts of the temporal lobe has not been presented, since Feindel has just completed a study of this phenomena. The author is not aware of the conclusions reached in the latter study and some independent material has been included here for discussion purposes.

We are primarily concerned with an analysis of those verbal responses which afford a random glimpse into the memory records, hallucinations, and brief psychical illusions of the conscious co-operative patient following stimulation of his temporal lobe. These describe involuntary psychical experiences presented for the patient's conscious inspection after stimulation by a weak electrical current. This analysis is followed by a theoretical discussion which attempts an interpretation and integration of the data presented in terms of cerebral function.

II. MATERIAL AND METHOD OF ANALYSIS

The basic material for this analysis has been collected from the records of 157 temporal lobectomies. Each operative procedure was performed for the relief of seizures arising in the temporal lobe. The patient was conscious and usually alert during the electrical stimulation which preceded excision in each case. One hundred of these patients had focal non-neoplastic lesions confined to the first temporal, uncus, hippocampus and hippocampal gyrus. Most of the present evidence has been drawn from this last group. This selection was necessary and natural because the majority of positive responses to electrical stimulation of the temporal lobe came from the cases in which the essential lesion was focal and non-neoplastic. Statistically, this group formed 60.3% of the present series and on this basis alone would be expected to provide more responses to electrical stimulation. However, it is interesting to speculate that this type of objective abnormality may produce a local epileptogenic process which somehow facilitates response to stimulation, but does not greatly interfere with the intrinsic functions of the temporal lobe. Thus the epileptogenic process highlights or distorts a particular function or functional representation. This distortion of function often is recognized clinically in the initial phenomena of the seizure pattern and serves as an early guide to localization of the lesion. At operation the entire temporal lobe is available to electrical stimulation and exploration in the search for the localized lesion. Perhaps the focal nature of these lesions leaves much of the normal temporal function intact, but somehow facilitates their explor-

ation with the stimulating current. In large infiltrating or other destructive lesions, widespread damage may radically alter function so as to render its study by electrical stimulation fruitless.

The records of these stimulations and responses have been made at the time of operation. The conditions of stimulation and interrogation have been carefully controlled and approximate the standards of physiological experiment. The answers and other verbal responses are recorded verbatim in chronological order. The detail and general principles of this excellent technique are the results of the work of Professor Wilder Penfield and have been described by him in conjunction with Erickson, and later with Rasmussen. The entire system will be discussed in an authoritative treatise soon to be published by Professors Penfield and Jasper, and therefore it need not be discussed in great detail here.

In the present report the location of these stimulation points on the temporal lobe has been illustrated by the use of a part of a brain chart. This chart is a projection of the various contours of the cerebral hemisphere on a plane surface. It is designed to unfold at the upper and lower banks of the Sylvian fissure, thus exposing a further projection of the insular and superior temporal surfaces which have been hidden by the surrounding parietal and frontal operculae. If properly folded along the Sylvian banks and at the level of the frontal operculum, it will graphically demonstrate the close relationship of the uncus and part of the superior temporal surface to the insula. We have called this region which lies close to the brain stem and insula, the peri-insular grey. It is the most fre-

quent site of the focal lesions described above and a frequent source of interesting stimulation responses. The mesial and inferior surface as well as an internal or peri-insular view of the opercular regions have been diagrammed on the reverse side of this projection. We have also used the inferior surface diagrams as illustrations. The segment of this chart which is most frequently used in illustrations is shown by the interrupted lines in Fig. 1.

This chart was developed in response to a definite need for graphic representation of the various contours of the cortical surface in the temporal region. The need for accurate graphic representation has been paralleled by an equal necessity for more accurate description of these surfaces and contours. Because description by name of contour or structure is misleading and often vague, we avoid it and have come to refer to locations in terms of general surfaces. Thus we speak of the lateral surface instead of first, second or third temporal convolutions and in similar fashion of the superior, inferior and mesial surfaces. There must be a smaller division of these surfaces or we cannot precisely locate points within their boundaries. This division has been accomplished by means of arbitrary measurements, which the operating surgeon can make during the surgical procedure, and accurately transfer to the chart. The most practical of these measurements is on the lateral surface.

Thus we use an axis of measurement which begins at the temporal tip and follows the curvature of the lateral surface posteriorly in a plane midway between the inferior lip of the Sylvian fissure and the lateral edge of the third temporal convolution where it curves towards

the floor of the middle fossa. This axis is divided in centimetres and by this division we can say that a point is, for example, 4 cm. posterior on the lateral surface of the temporal lobe. Now we would also like to record its relative location in the vertical plane. This is done by measuring downwards from the inferior lip of the Sylvian fissure to the point. It is possible to combine these two measurements in the form of co-ordinates. Thus L 4-2 indicates a position 4 cm. posterior on the lateral axis and 2 cm. inferior to the Sylvian fissure. We know it is on the lateral surface by the letter "L". The lateral axis is shown in Fig. 2. Similarly we measure the location of points on the other surfaces. These measurements are of less practical interest to the operating surgeon but serve a useful purpose in our present illustrations. On these surfaces we measure posteriorly from the anterior limit of the bony temporal fossa in a plane midway between the edges of the surface. Thus the plane of measurement on the superior surface lies midway between the inferior lip of the Sylvian fissure and the peri-insular border of the superior surface. The plane of measurement for the inferior surface lies midway between the lateral and mesial edges.

We may measure inward from the lip of the Sylvian fissure on the superior surface and outward from the tentorial edge on the inferior surface, thus adding a second co-ordinate in each plane.

This report includes tabulations which describe the locations of the various stimulation points by means of these co-ordinates. It is often impractical to attempt accurate measurements of the mesial surface and the structures which compose its contours are therefore des-

scribed by name when used as references to point location. The combination of tables will provide the reader with opportunity to correlate the verbal response with the locations of the stimulations which preceded them.

The voltage is listed as a matter of interest but no attempt has been made to discuss its significance in detail.

The introduction of a coated electrode into the depths of the temporal lobe has proved a useful adjunct to surface stimulation. The present method of deep stimulation requires an electrode which is marked off in cm. divisions so that the depth of stimulation may be calculated. The direction of this deep stimulation is easy and almost any structure within the contents of the temporal lobe can be reached. The description of this direction for record purposes is not so easy, and it is often very difficult to make an accurate estimation in post-operative study of the brain chart and stimulation records. This is unfortunate because some of the most significant responses have been obtained by this method of electrical stimulation, and we cannot accurately evaluate their functional significance in terms of precise location without some additional method of measurement or observation. The skilled surgeon, long-practised in this method, finds individual use of deep stimulation and assessment of its direction easy, but this is not true for the surgeon who would acquire this technique nor for the worker who wishes to make careful evaluation of the location of stimulation points after operation.

To this end, we have included the description of a new electrode holder. This device is intended to facilitate accurate estimation

of the depth and direction of deep stimulation in terms of surface landmarks. Since this is not a technical report the only justification for such an inclusion is the extent to which the material reported depends on the frequent use of deep stimulation. The consciousness of a need for more accurate estimation of point localization in this type of stimulation has grown out of the study of this material.

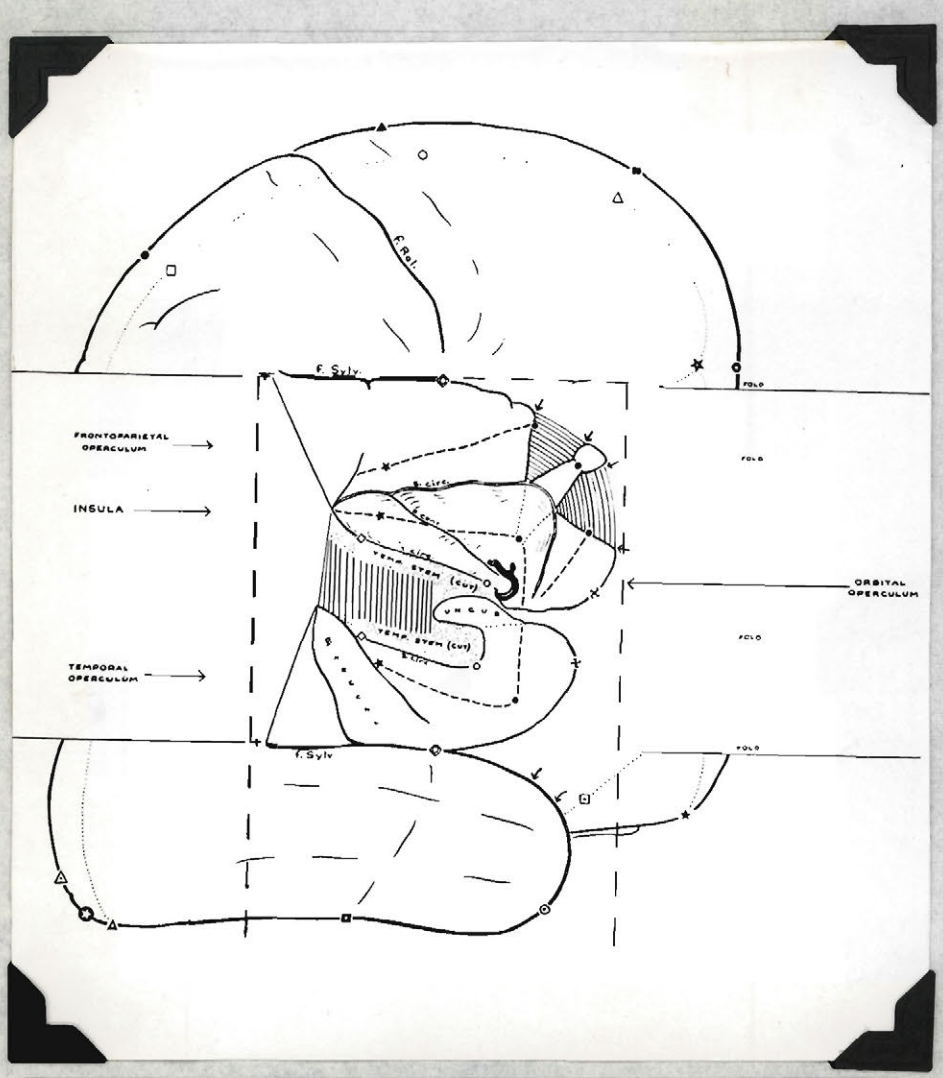


Fig. 1

Brain Chart Projection
with Illustrated Area
Outlined.

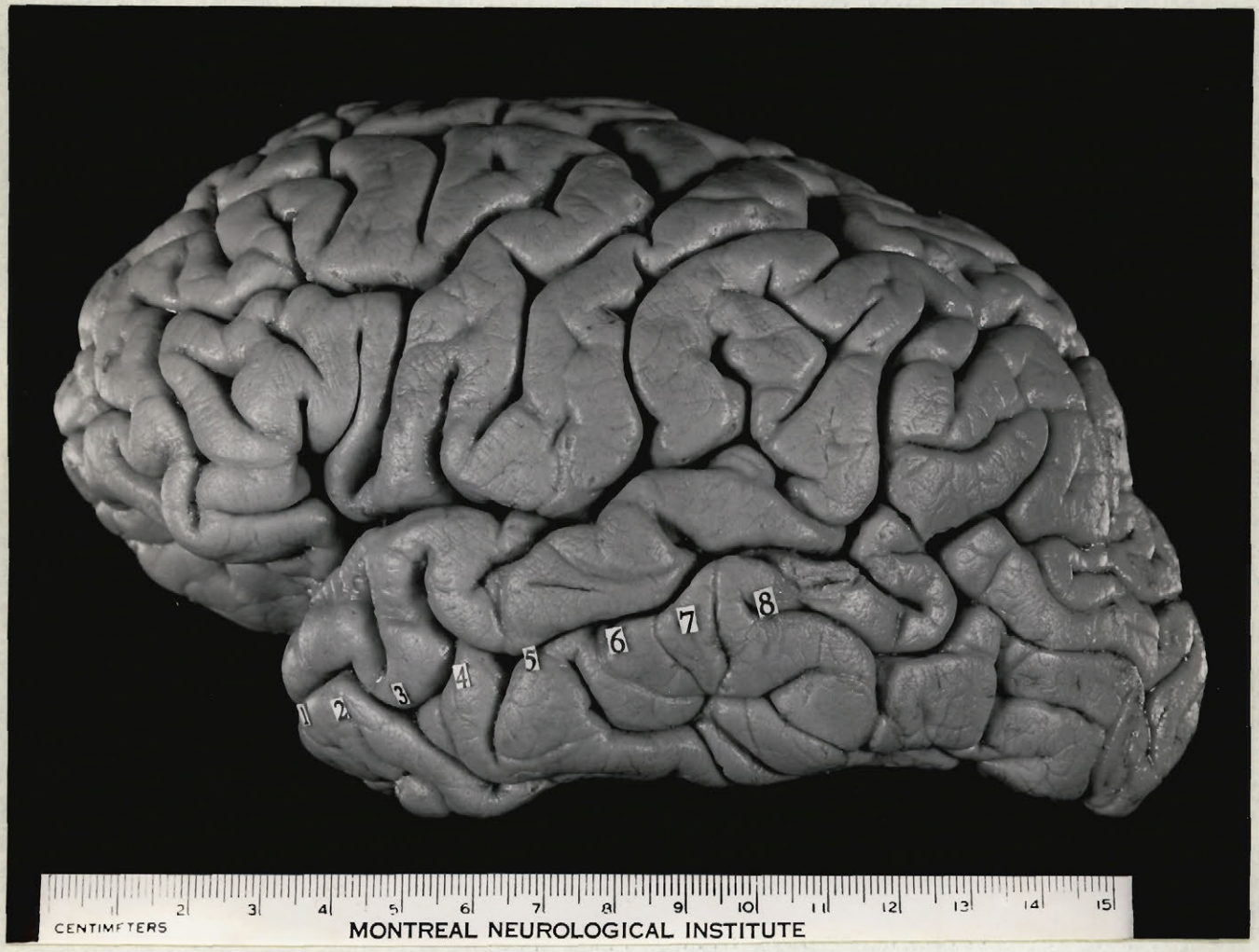


Fig. 2. Lateral Axis Measurement in Cm.

III. REVIEW OF THE LITERATURE

We may now examine some of the clinical observations which provide the basis for our previous statement concerning the functional significance of the unusual behaviour and bizarre mental experiences which often follow an epileptogenic process in the human temporal lobe. In these observations we can note the particular qualities of the symptoms which may be useful in future conclusions. It will also be interesting to know if these phenomena can arise from either temporal lobe, and if there is any apparent relationship to normal processes.

Hughlings Jackson in 1888 reported the case of a physician who for some years had been troubled with paroxysmal feelings of familiarity. The patient himself was able to relate these feelings to his usual appreciation of normal recollection. In this comparison he says that the paroxysmal feelings had no relationship to the external environment and that they were overpowering. Objects, people or general surroundings which he had never seen before suddenly seemed intensely familiar. His memory was poor throughout his life and he was subject to sudden episodes of nonsensical behaviour of which he seemed to have no recollection. At post mortem examination he had what was called a softening of his left uncinate gyrus.

This is a case with a proven objective lesion in the left temporal lobe. There were sudden bizarre mental experiences in which the patient was aware of a sense of recollection without apparent cause or suddenly became unaware of his surroundings and performed senseless repetitive acts. Jackson described these mental experiences as "dreamy states"and said

that they were the result of a partial dissolution of a highest level of activity in the brain due to an epileptic discharge.

From a group of fifty similar cases he summarized the patients' impressions of some of these feelings: "Old scenes revert..... I feel in some strange place .... In a strange country ..... A dreamy state .. ... A panorama of something familiar and yet something strange ....." Foster Kennedy described these phenomena in a group of nine cases of tumour of the temporal lobe which he reported in 1909. He says, "This is defective objective and increased subjective consciousness and a sense of reminiscence."

In 1893 MacEwen described the case of a young man with the signs of an expanding lesion in the right cerebral hemisphere. On exploration this lesion proved to be a right temporal abscess. On admission to hospital the patient was a little drowsy, but seemed quite alert mentally and answered questions in a clear accurate fashion. He was never at any time critically ill, nor did he lose consciousness. The next day, after the abscess had been drained, he was unable to remember coming to hospital and did not recall any of the previous examinations or questions even though he did not seem confused. His memory had been declining before operation and for about one month he had difficulty remembering recent events. Perhaps his ability to record present experience had been altered by the presence of the lesion in his temporal lobe. There was never any sign of a disturbance of consciousness.

In 1934 German reported a careful study of a case with symptoms of recent memory loss and some euphoria. This patient proved to have a

glioblastoma of the left temporal lobe. In the postoperative period his memory difficulty was marked and he was somewhat euphoric. These are two case reports, widely separated in time, which associate objective lesions of the temporal lobe with memory defects.

In 1889 Hughlings Jackson described the case of a woman who had a tumour of the right temporosphenoidal lobe. Her memory was poor. She frequently had a vision in which a little woman dressed all in black flitted to and fro across her kitchen. The patient knew this was a vision and was greatly concerned over it. She knew that the little woman was not in the external environment and was able to relate her dream or hallucination to reality by conscious comparison of its contents with the data of her immediate environment.

Contemporaries of Hughlings Jackson considered that complex visual hallucinations were due to lesions of the occipital lobe and the visual pathway. Henschen in 1890 presented the view that these arose as the result of a lesion in one occipital cortex and were always present in the opposite visual field. Jolly in 1902 and Pick in 1904 concluded that these visions or dreams were due to lesions of the optic pathway. Foster Kennedy in 1909 described the case of a woman who had a tumour of the right temporal lobe. (This was from a series of nine cases of temporal tumour, seven of which showed psychical phenomena) She had a recurrent vision (in her left visual field) of a woman dressed in blue. He concluded that this was the effect of the tumour in the right temporal lobe and not due to specific involvement of the visual pathway.

In a series of fifty-nine proven tumours of the temporal lobe which he reported in 1921, Cushing noted that twenty-four had attacks characte-

rized by "dreamy states". In thirteen of these there were complex visual hallucinations. He states, " One would naturally expect visual hallucinations to be a feature of occipital rather than temporal lobe tumours, but the former are far less common in my series (of occipital lobe tumours) and though they have not been thoroughly studied with this point in view it is my impression that they are less prone to have petit mal attacks and that subjective visual phenomena, if any, are much more likely to be of colours and lights than of pictured scenes." We will later present evidence on this point from the present series.

Horrax in 1923 reviewed the problem of visual hallucinations. He quotes the views of Jackson, Henschen, Pick, Jolly and Cushing, and then presents a series of seventeen patients with visual hallucinations, all of whom had tumours of the temporal lobe. Six of the tumours were demonstrated at post-mortem examination and eleven at operation. Thirteen of the total also had feelings of familiarity and other "dreamy states" which have the qualities of psychical illusions.

Horrax stresses the complexity of these hallucinations and gives as an example the case of a young boy of 16 who had a glioma of the left temporal lobe. This boy's memory for recent events was poor. On many occasions he 'saw' distinctly a crowd of men 'playing cards and having a good time'. They were usually acquaintances of his playing euchre, and the game inevitably ended in an altercation among the participants. This hallucination which preceded his attacks has many elements of the boy's past experience in it. It did not always present itself as completely as cited, but the basic elements were always the same. For our future discussion, it is interesting that Horrax notes,

"As to the mental attitude of the patients toward these phenomena, it has been recorded in some instances in our own histories and in the cases elsewhere that the patients were quite aware that these were hallucinations." It would seem that these bizarre experiences are subject to conscious inspection, and that the patient voluntarily makes a comparison with immediate external experience, concluding that they are unreal.

Frazier in 1934 recorded one case of auditory hallucinations and three 'dreamy states' following tumours of the temporal lobe. In 1941, Penfield reported the case of a young minister who had a tumour of the right temporal lobe. This man had no unusual neurological signs and had complained only of occasional generalized seizures during the preceding eighteen months. These attacks were nocturnal and usually followed a dream in which he found himself in a room which seemed familiar. This was actually a dream about a room in his own house. Several times when awake he walked into that very room and had "a little feeling of a dream". Here is a fascinating example of a dream which preceded major convulsions. The content of the dream was based on past experience and in it he was quite aware of a feeling of recollection. The elements of past experience and the feeling of reminiscence suggest that the epileptic discharge was using a pattern of pathways in which a record of past experience was stored.

In 1946 Penfield also reported that: "Elaborate hallucinations, like dreams, constitute a moderately common manifestation of a seizure. The localization of ictal hallucinations is in the cortex of one temporal lobe. The experience may be entirely visual such as a scene from the

distant past. There is usually some doubling of consciousness so that the patient recognizes the significance and unreality of the state. It may be a vivid past experience, such as that of a woman who saw herself giving birth to a child. It may repeat the formula of a familiar childhood dream, but usually it is a simple experience with no childhood significance and the elements are chiefly visual and auditory. Music as a hallucination may be a simple air or it may be a symphony. It seems to arise in the anterior pole of one temporal lobe." He is implying that these phenomena may arise after epileptic discharge in either of the two temporal lobes and he states clearly that the patients are usually aware that the experience is not in the external environment. Also there is evidence that these experiences are drawn from records of the past. In the same report Penfield also emphasizes that illusions of perception may occur during epileptic discharge in one or the other temporal lobe.

Penfield and Kristiansen summarized their evidence regarding psychical seizures in 1950. Out of 222 cases with epileptic attacks, 29 presented some psychical phenomena. There were five cases of hallucinations, nine of perceptual illusions and one with fear, all with an epileptogenic focus in the temporal lobe. These authors point out that the hallucinations were complex and were usually made up from the material of past experience. Including both sounds and sights, they were not similar to the simple visions of coloured lights which follows cortical lesions in the occipital lobe. The illusions which they call psychical are described as illusions of perception or interpretation of past experience. They are distortions of judgment concerning present

environmental experience. Both the hallucinations and the illusions are related to the individual's experience, either in his interpretation of it, or to his past experience.

We can summarize briefly the clinical evidence thus far presented. Focal epileptogenic lesions of one or the other temporal lobe can produce, as part of the seizure pattern arising with their discharge, attacks which are characterized by psychical phenomena. These are hallucinations, illusions and occasionally automatic behaviour. The hallucinations are vivid complexes of image and sound, drawn from the elements of past experience of the individual. The patient is aware that these hallucinations are unreal and can compare them with present experience in a "doubling of consciousness". The illusions are distortions of interpretation of present experience. They may convey a false sense of recollection or reminiscence which is stronger than, but similar to the normal feeling of reminiscence or familiarity. Or they may involve distorted perception of sensory data from the immediate environment. Objects may seem nearer or farther away. Automatic behaviour involves apparently nonsensical repetitive acts or the repetition of otherwise sensible routine procedures to the point of absurdity. The individual is unaware of these actions afterwards. Here an alteration of consciousness accompanies behaviour, which suggests the individual is completely at a loss to make the simplest of judgments concerning his immediate environment and present experience.

Among the cases reviewed above memory for recent events was disturbed in four reported by Jackson, MacEwen, Horrax and German respectively. Three of these had lesions in the left temporal lobe, one in the right. Memory patterns or records formed an important part of

many of the hallucinatory experiences described in the preceding reports. (It should be noted here that Penfield and Rasmussen report no significant memory disturbance following temporal lobectomy. This is in accord with more complete studies of the problem.) We may conclude that focal disturbance of the temporal lobe without regard to side can produce abnormal interpretation of present experience, involuntary recollection of past experience, perhaps inability to record a present experience, and a dimming of consciousness in which there is both complete loss of ability to interpret the present environment and record from experiences in it. Since this clinical evidence seems to show that abnormality in either temporal lobe can produce these changes, perhaps we may assume that interpretation of present experience and recording of past experience occurs in both temporal lobes.

Involuntary distortion of interpretation of present experience and recollection of past experience have been produced from either temporal lobe by disease, and Penfield and Rasmussen in 1950 reported that they had produced these phenomena from either temporal lobe by electrical stimulation and noted that the temporal lobes must be of equal functional value. The ablation of one, whether dominant, or non-dominant, was not followed by marked memory loss or impairment of perceptual interpretation. We have already stated that these involuntary alterations of judgment and recollection of past experience seem to be available for conscious inspection and if necessary, voluntary comparison. This is certainly true in the cases of electrical stimulation of the human temporal lobe reviewed by Penfield and Rasmussen. Then if the temporal lobes have equal value in these functions of

judgment and recollection, there must be some coordinating mechanism to allow for synchrony and coordinate action. The fact that the involuntary phenomena are available for conscious inspection suggests that this coordinating agency may be related to the maintenance of a conscious state. There is clinical evidence for the existence of a central agency concerned with the mechanism of consciousness in the reports of Fulton and Bailey, and Cairns, Oldfield, Pennybacker and Whitteridge. These authors show that an isolated lesion related to the higher brain stem may produce profound disturbances of consciousness without other remarkable phenomena. Meyer has summarized this evidence. Penfield and Jasper in 1947 have pointed out that epileptic discharge arising in the upper brain stem is associated with an immediate alteration of consciousness and that this is the most characteristic clinical expression. There is experimental evidence for this as well in the work of Jasper and Fortuyn.

The temporal lobes are bilateral, symmetrical in form, and apparently in function (with the exception of the cortical area for speech discussed by Roberts in 1950, which lies in the posterior part of one lobe). Therefore we may presume some coordination of two bilaterally symmetrical functional areas and it seems reasonable to suggest that this coordination be central in location.

In direct application to the present hypothesis, Marsan and Stoll have shown functional relationships of each anterior temporal pole to the pulvinar-nucleus lateralis posterior complex of the thalamus; septal area-fornix system; hypothalamus; basal ganglion system; thalamic reticular system; (centrum medianum reuniens). They suggest that

these are subcortical structures connecting the two anterior temporal regions by means of functional pathways, and show how it is theoretically possible for impulses originating in the central system to affect either temporal lobe singly or both temporal lobes simultaneously. Further information concerned with the possible connection of a central coordinating mechanism was presented in 1951 by Starzl, Taylor and Magoun from an experimental work on the brains of cats. They concluded that there was an ascending reticular activating system which receives connections from afferent paths and exerts generalized influence on the cerebral cortex. Penfield and Rasmussen (1950) conclude after a review of pertinent evidence that " it is clear that the most important means of coordinating the function of cortical areas is not the association mechanisms within the cortex. Such coordination is provided largely by the integrating action of subcortical centres which must lie within the mesencephalon and the diencephalon. Therefore, if the term 'seat of consciousness' is to be used at all it must be applied to the old brain, for the diencephalon is 'that nervous centre to which the most heterogeneous impressions are brought'. From it must go out effector neuronal impulses that are capable of summoning a memory, of causing the lips to speak or an arm to move." They conclude further that: "Through these interconnections (meaning connections of the cortex with subcortical higher central structures) memories are stored in neurone patterns within the temporal cortex and the frontal cortex is utilized in the elaboration of thought."

We may digress for a moment and ask how memories might be stored in neuronal patterns. Obviously, as shown by Penfield and Rasmussen, memory records have been reproduced in little sequences suggesting the

possibility of a neuronal pattern. How may this be formed ? Perhaps the work of Eccles and McIntyre on the plasticity of monosynaptic reflexes in experimental animals may be applicable to this process of recording. They suggest in their paper that some such process forms the neuronal background for both learning and memory.

All this evidence from the results of human cortical stimulation or temporal lobectomies, and from clinical observations on patients with focal temporal lesions, points to the conclusion that the temporal lobe in man may be concerned with interpretation of present experience and the recollection of past experience. It seems possible that each temporal lobe in man has equal functional value and that they may be coordinated in action by means of a centrally placed integrating system which is within the confine of the upper brain stem.

We may return for a moment to the temporal lobe itself without reference to its possible connections and review other experimental evidence for localization of function within its limits. In 1939 Kluver and Bucy reported unusual behaviour in monkeys following temporal lobectomy. They called this behaviour "psychic blindness". Apparently, the animals would pick up any or all objects without regard to kind, and place them in their mouths. They had lost at least, to some extent, their ability to interpret their immediate environmental experience. When previously, these monkeys had shown evidence of fear reactions to snakes, following temporal lobectomy they no longer reacted in the usual manner when shown a snake and in fact it is reported that some of the animals attempted to eat the snakes.

We might assume that in the bilateral ablation of their temporal lobes they had lost the experience records, comparison with which might have permitted a satisfactory judgment or interpretation of the immediate experience with snakes.

It is doubtful that the ablation included a representation of fear or other emotion. This seems reasonable because it is difficult to conclude that there is a precise cortical representation for fear in these areas. Bard, 1939, was unable to find significant cortical representation for fear in cats, and concluded that this must be subcortical or hypothalamic in origin. This is in contradiction to the Papez theory of general emotion (1937), which assigns the hippocampus, hippocampal gyrus and cingulate gyrus important roles in the basic emotions. Clinically, fear has been associated by Penfield and Kristiansen,(1950) with epileptic patterns arising in the intermediate, frontal and posterior Sylvian regions of the cortex, but they could not draw a conclusion as to localization from these cases. Penfield and Rasmussen (1950) noted the association of fear responses to epigastric sensations following electrical stimulation of the insula in conscious human patients. Bailey and Gibbs, (1951) correlate rage tantrums and psychotic behaviour associated with emotional disturbances with electrographic evidence of abnormality in one or other human temporal lobe. They consider that the hippocampus and uncus have some essential relationship to emotional behaviour and avoid excising this area in the surgical treatment of temporal lobe epilepsy. Their ideas are thus in accord with the Papez theory of general emotion, as discussed by MacLean in 1949. It is difficult to conclude from this information that the temporal lobe in man has any specific representation

for fear or other crude emotions. Our present evidence summarized in this report permits further conclusion relative to this problem.

RESULTS - A

1. INVOLUNTARY RECOLLECTION

In some patients from the present series electrical stimulation of the temporal cortex has been followed by a brief recollection of past experience. These recollections have been involuntary and may consist of a snatch of song, familiar voices, a childhood scene or neighbourhood noises. These are fragments from the records of experience, both recent and past, which have been summoned for conscious examination by an artificial stimulation.

Twenty-nine responses fall directly within the category of memory records and have been derived in eleven cases. Eighteen responses are from the right side; eleven from the left. Some hallucinations and dreams following other stimulations are so closely related to the elements of past experience as to be almost indistinguishable from memory responses. These we will discuss in a separate section.

The surface areas from which involuntary recollection has been evoked are shown in Fig. 3. The numbers illustrated are from the stimulation sequences of the various cases and have no relationship to each other. Table I is a tabulation of these responses in which we may compare verbal context with point localization.

We may examine the general characteristics of these responses within the particular qualities of the individual case. This examination will provide the evidence for further conclusion.

T.S. is a boy of 19 who had seizures for two years. These originated in the right temporal lobe, and usually occurred while he was

listening to music. He would experience a sensation of warmth and a tingling in his right hand. This was often followed by a generalized seizure. At operation his right temporal lobe was grossly abnormal along its mesial surface and electrographic abnormality was recorded from the temporal tip at Points A and B in Fig. 4.

Point 14 was stimulated 9 times with a current of 5 volts. This voltage is higher than the voltage threshold for the post-central gyrus. During the first three of these stimulations he said he felt as if he were going into an attack or answered, "Nothing". In the second and third there was an electrographic abnormality as noted above. In the fourth there was a "flattening" of the electrographic record, and after about ten seconds the patient,said, "I feel as though I was in the bathroom at school". He had not been warned that stimulation was in progress. During the fifth stimulation he said, "Nothing", then added, "Slight blurring on the street corner". When asked where, he said, "South Bend, Indiana - Jacob and Washington". When asked about it, he said he seemed to be looking at himself at a younger age. The sixth time he said, "Nothing". This was his first response at the stimulation, but it was quickly followed by the statement, "I feel as though I am going into an attack". When asked why, he said, "That music from the stage hit, 'Guys and Dolls'". When asked to name the song, he was unable to name it. He added that it was more like it was "when I was listening to it". It was an orchestration. "I seemed to be there". The eighth and ninth stimulations were negative.

This boy had been in South Bend, Indiana, and had recently seen

the musical comedy, "Guys and Dolls". The music and the scene are familiar to him. He is aware of their familiarity. This feeling of reminiscence is accompanied by a sense of participation. Thus he recognizes the music and the scene in South Bend as fragments of past experience. At the same time he is conscious and knows that he has not voluntarily summoned these memories to the foreground of his consciousness. The stimulating current has done this for him. Apparently the pathway stimulated is also available to voluntary interpretation, because he knows that both the song and the scene are being played only for him and are not in the immediate external environment.

This patient's attacks were most likely to occur when he tried to identify a musical melody and found identification difficult. Attempt at voluntary recollection seemed to activate the epileptogenic focus. Electrographically, this focus was localised in the anterior temporal cortex. It is therefore not unreasonable to assume that these memory records lie here also.

This involuntary recollection of past experience has followed electrical stimulation in others. Let us examine the case of G.F. This 45-year-old housewife had seizures for eight years before radical treatment. Her attacks began with a feeling of fear, followed by lip-smacking and swallowing. Her behaviour was often automatic. At operation electrocorticogram showed a spike focus over the tip of the right temporal lobe and there was gross abnormality in the first temporal convolution, uncus and hippocampus. Fig. 5 diagrams the location of point 17. Here the patient was stimulated with a current of 5 volts. (This is three times the voltage necessary to produce

response from the post-central gyrus). She responded, " I just heard one of my children speaking". When asked, she said it was the older one, Frank. When asked what he said, she said, "I could not get that. There was some other noise at the same time," and when asked what it was, she said, "Neighbourhood noise". This stimulation was repeated without warning. She said she heard the noise but not her boy's voice.

This is not the comparatively simple response of the post-central gyrus, as in Point 4. Here on stimulation with only 1 volt, the patient said that she "had a stiffness in her face - more on the right". This is a simple sensory response, the pattern for which is not acquired. Another type of sensory response (auditory) is illustrated by that evoked at Point 15 with 1.5 volts. Here she heard a "humming", a characteristic response for the auditory area. Repetition of this stimulus yields the same result. On the other hand, repetition of 17 at 3 volts (the same as the first voltage) caused the patient to say she heard only the "noise" - meaning the street noise - and not her boy's voice. This differs from the simple sensory response which is relatively constant in repetition. At Point 17 stimulation has evoked a complex response. Its complexity suggests that we have activated a multi-synaptic pathway. The context of the response describes a past experience. We have evoked a part of the acquired pattern which forms its record.

This woman was able to discuss her response at Point 17 some days later. She said that it had been her habit to listen for her son Frankie, (whose voice she had heard under stimulation) while he was playing in the street, as she feared he might have an accident. Here

we have the record of a real experience evoked by the stimulus. Later she can recall its relationship to her home life and at the same time tell us that the recollection in the operating room seemed "more real" than a voluntary memory. She is intelligent and this is valuable introspection. At the time of stimulation, she has made a comparison between voluntary and involuntary recollection and concludes that the latter seems more real. Obviously she knew that she was in the operating room at the time of stimulation and that she was not at home listening for her son in the street outside. In the brief instant following artificial recollection she has apparently made a comparative judgment concerning this experience. To make this judgment, voluntary and involuntary recollections had to be coordinated. This implies a coordinating agency or mechanism.

Now the right temporal lobe was stimulated and involuntary recollection occurred. After stimulation it was excised, yet voluntary recollection of both the stimulation experience and the original street scene is still possible. This is significant, because it suggests coordination of an acquired pattern in the right temporal lobe with another area of memory records. Consider again the judgment she has made concerning her artificial experience. The sights, sounds and perhaps smells of the operating room must be quickly recorded. These form the sensory information from the immediate environment and this information is somehow compared with the involuntary recollection of her neighbourhood. The comparative analysis results in a judgment concerning her whereabouts and the unreal character of the involuntary recollection. This certainly seems to require the existence of a higher centre which can coordinate a variety of sensory impressions

with records of past experience. Here recollection has been quickly correlated with judgment, and a record of the conclusion established.

Another case in which involuntary recollection followed stimulation is that of D.F. This lady was twenty years old. Her attacks began at about the age of six years. A substernal sensation gave her warning of their onset. This was followed by puckering of her lips and swallowing. The attacks often became generalized. Her right temporal lobe was exposed at operation. There was objective abnormality along the inferior and mesial surface. The entire temporal lobe at first showed delta activity and an electrographic seizure was produced by stimulation of the insula anteriorly. The cortex of the first temporal convolution close to the Island of Reil was stimulated at Points 23 and 24 with 4 volts. This reproduced her aura. (The post-central threshold was 1½ volts). These points are shown in Fig. 6. When 23 was repeated the patient said, "I hear music". When it was repeated without warning the patient said, "I hear the music". The third time point 23 was stimulated, the patient said, "I heard the music again .... It is the radio". She had not been warned. When asked what tune was being played, she said she did not know, but it was familiar. Again stimulation caused her to say, "I hear it". She was able to hum the tune. Three further stimulations followed, and the patient was able to hum the tune with such accuracy that it was quickly recognized as "Marching Along Together". These stimulations were all on the inferior bank of the fissure of Sylvius close to the Island of Reil. Notice that she first experienced her aura, then simply "music", knowing only the melody was familiar. As the stimulation was repeated the melody became clear, and she could reproduce it for the operating

room staff. It is interesting that she heard the tune, not as if the original were being played inside her head, but as if she were then hearing it as broadcast from a radio. She had previously heard it on a radio program.

Here perhaps we have evoked her recollection, not only of the melody but of some of the circumstances in which she heard it in real life. As the stimulator is applied she says that she hears the music, describes it as best she can, concludes that it is familiar and says that it sounds as if it came from a radio. She is not quite certain that the tune is not being played in the operating room. Eighteen days after operation she said that we had turned on a radio or phonograph in the operating room. She was convinced of this because the stimulation machine looked like a radio and it was turned on and off. Despite this false idea she could still hum the tune as in the operating room, although not as completely. It is interesting that she remembers the "music", but does not recall the aura which preceded it. It is important that she could think about her experience at the time of stimulation and recall it later, regardless of her false interpretation of the immediate origin. Her conclusion is not fantastic, because she had actually heard the tune on the radio before operation and "it sounded to her as if from a radio" at stimulation.

These results are somewhat similar to those in the case of J.T., a young man of twenty-two whose attacks originated in the right temporal lobe. He had a cephalic aura often followed by automatic behaviour. At operation the depth of his first temporal convolution was

stimulated at Point 7_3 (Fig. 7 & 7a) by a 3-volt current. On the third stimulation in this region, he exclaimed, "Yes, Doctor, Yes, Doctor, now I hear people laughing - my friends in South Africa." He was asked if he could recognize who they were, and he said, " Yes, they are two cousins, Bessie and Ann. They are both girls." The patient did not know what they were laughing at, but thinks they must have been joking.

Some time after the operation, he described this experience for us. He said that this was a fragment from a childhood scene in which he had gone across a meadow on a visit, and his two cousins, laughing happily, had come halfway to meet him. He thought the scene was reproduced at operation incomplete in imagery and sound, but he did not think it was like a dream.

Here again the patient remembers the stimulation experience after excision of the area from which it was evoked. Also he can compare the substance of the involuntary recollection with voluntary recollection just as he did at operation.

In summary, the most simple of these responses are of an auditory nature and lie close to the auditory area. (E.g., "A voice calling my husband's name, Jimmy, Jimmy ...." in R.L. See Fig. 8) The more anterior or more mesial the origin, the more complex the response. Thus J.T. and G.F. cited above are on the superior surface anteriorly, and T.S. is anterior on the lateral surface. These memories are admixtures of sights and sounds when complex. They occasionally carry with them (in recollection) the emotional colouring of the original experience. They are not reproduced early in stimulation and in some cases

several stimuli with other responses in or about the same point have preceded the single memory response. Whatever the memory recalled for the patient, each part is an entity which may be followed in a gradually developing sequence by related scenes. The entity may itself be a small part of a larger panorama, but the individual presentation is complete.

In these cases stimulation has been followed by recollection of past experience. This is involuntary recollection and the patient is aware that it is involuntary. The patient knows that the scene or song appears for him alone and is not in the immediate environment. In each case the substance of the recollection has been available to voluntary inspection, interpretation, and comparison with present experience.

These recollections are records of past experience. The records are therefore acquired patterns within the temporal cortex. Each memory pattern is available to the stimulus of voluntary recollection as well as to that of the electrical current. The area containing the patterns evoked by stimulation has been excised and after excision voluntary recollection seems to reproduce the same memory patterns. An area of memory has been excised and yet memory remains elsewhere. Perhaps these memory patterns have been acquired in the opposite temporal cortex as well. We know that stimulation has evoked eighteen memory patterns from the right temporal lobe, and eleven from the left, therefore this representation may occur on either side. Since we have never evoked involuntary recollection except in the temporal lobe, it

seems reasonable to conclude that these remaining memory patterns lie in the opposite temporal cortex. Both the patterns evoked by stimulation and those remaining after excision are available for voluntary recollection, conscious inspection, comparison with present experience and finally, interpretation. This is significant because it may imply a central coordinating mechanism connecting the two temporal lobes. Coordination by this mechanism includes both memory areas and involves comparative action, comparative analysis with present sensory data and the existence of a state of consciousness.

INVOLUNTARY RECOLLECTION RESPONSES (Table I)

Initial	Stim.No.	Coordinate	SF No.	Side	Summary	Voltage
					Lateral Surface	
A.B.	18	L 1-0	446	Rt.	Patient said it made her try to imagine a familiar song. It is not that she hears the music.	3 v.
A.B.	24	L 1-1	446	Rt.	Patient said "no", then said "it reminded me of a song, but I do not know what song it was". Repeated: "Right there". When asked what she meant, she said it reminded her of a song.	3 v.
T.S.	14	L 1.5-0	649	Rt.	"Slight blurring on the street corner". When asked where, he said "South Bend, Indiana..... Jacob and Washington." When asked about it, he said he seemed to be looking at himself at a younger age. Repeated:"I feel as though I am going into an attack". When asked why, he said, "That music from the stage hit, 'Guys and Dolls'..." When asked which song in this play he said he did not remember. When asked whether he remembered it he said it was more like an orchestration. When asked whether he seemed to be there or was remembering it, he said, "I seemed to be there."	5 v.
N.C.	23	L 2-0	657	Lt.	"It made me think of a baby song, I cannot think of the words." Repeated: "I had a little pain in my head. I again thought of the song." When asked what song, she said, "That baby song - The War March of the Priests." Repeated without warning: After withdrawal, the operator said, "You don't notice anything, do you ?" and she said, "Yes, I was trying to identify the song." When asked if she would like me to stimulate again, she said "Yes". Stimulus was applied, and after a time, she began to hum and hummed an air quite accurately and then she said, "It is the War March of the Priests". Repeated: Patient was asked if she heard the air and she said she heard another one which sounded very much like "War March of the Priests". She added that it was not a baby song after all. She thinks the first song she heard was a baby song.	2 v.

Initial	Stim.No.	Coordinate	SF No.	Side	Summary	Voltage
N.C.	23	L 2-0	657	Lt.	(Continued) As a final test the patient is asked to let me know when she hears the song. After some delay Point 23 was stimulated. When asked what it was she said all she could think of was the "War March of the Priests". She says she has the Hallelujah Chorus on a record at home and this is on the other side of it. When asked what it is she hears, she says it is just an arrangement of the orchestra and no voice. She is only able to hum it part way and she added that she does not know the words.	2 v.
S.B.	17	L 3-0	590	Rt.	"Something I have heard of, but I cannot remember it ....."	2 v.
N.C.	20	L 3-2	657	Lt.	"I feel like a sick spell". Stimulus was withdrawn. She then added "Mother is talking to me". Repeated: Patient laughed. When asked what had happened she said, "Well, it is kind of a long story, but I will tell you." Stimulus was withdrawn. She went on to explain a rather complicated situation and then said she said to her mother, "Don't forget the fabulous feeling". When asked if that was something she said to her mother, she said yes. When asked what her mother said, she said her mother mocked her. When asked whether it was a dream or something she remembered, she exclaimed "No". Then she said, "I took my arm and brought it down on the plate and broke the plate all to pieces." When asked where it was, she said in her home in Richland, Washington.	
S.B.	16	L 3.5-0	590	Rt.	Patient described the following during continuation of stimulation: "Something brings back a memory .... I could see Seven Up Bottling Company ..... Harris Bakeries....."	2 v.
R.L.	14	L 4-0	545	Rt.	"It sounded like a voice saying words ..... 'Jimmy....Jimmy.....Jimmy'" When asked she said it was her husband's name and what she calls him. She recognized the voice of her husband.	4 v.
R.W.	30	L 5-0	594	Rt.	"I heard someone speaking .... my mother telling one of my aunts to come up tonight.	3 v.
R.W.	32	L 6-0	594	Rt.	"My mother is telling my brother he has got his coat on backwards. I can just hear them...."	3 v.

Initial	Stim.No.	Coordinate	SF No.	Side	Summary (Continued)	Voltage
R.W.	32	L 6-0	594	Rt.	When asked if he remembered it, he said,"Oh yes, just before I came here ...." When asked if he thought these things were like dreams, he said, "No".	3 v.
R.W.	31	L 7-0	594	Rt.	"Same as before..... my mother telling my aunt over the telephone to come up and visit us."	3 v.
M.N.	12	L 7-0	667	Lt.	Patient said "Oh yes, there is something". A little later she said, "It is like music in the background". Warning without stimulation. Nothing. Warning with stimulation. Music she thinks is like an orchestra. Stimulation along the first temporal convolution from before backwards produced nothing until Point 12 is reached, and then she said, "There, I hear the music". Electrode was kept in place. She was asked to let us know when it had stopped. Very shortly after withdrawal she said it had stopped. When asked, she said it was either an orchestra or an organ.	3 v.
M.N.	12	L 7-0	667	Lt.	Re-stimulated: Patient said "Oh, it is music". There was after-discharge. She was asked to say when it stopped and she said "No" and at this moment the after-discharge had disappeared at electrode 3. When asked, the patient said she heard the music.	3 v.
					Repeated: Patient said, "No". Then she said "Oh". After a little time, she said "Music, too far away to be able to name". When asked she said it was like the music she has been hearing with her attacks since coming to hospital.	3 v.
					Repeated: Patient said, "No, nothing" and then she said, "Oh no, it is music, but it is too far away". There was a flattening of the record from the electrode adjacent to Point 12.	3 v.
					While stimulus was continued, patient said,"Oh, so many things are happening away from you completely." When asked afterwards what she said, she thought she heard something but she could not say for sure now what it is. Repeated again without warning, patient said, "I cannot hear words, but I can hear..... I cannot say the word." Re-stimulation now produces nothing.	3 v. 4 v.
C.F.	J.	L 8-0	203	Rt.	"Familiar sight danced into my mind and away again".	Thy. 2

Initial	Stim. No.	Coordinate	SF No.	Side	Summary	Voltage
					Superior Surface	
D.F.	23	Sup. Surf. 3-1.5	491	Rt.	Repeated: "I hear some music". Repeated without warning. "I hear the music". Repeated without warning. "I hear the music again. It is like the radio." Repeated without warning. "I hear it." She was asked to tell us about it, and hummed the tune. When asked, she said she never noticed that before an attack.	4 v.
D.F.	24	Sup. Surf. 3-1.5	491	Rt.	Repeated without warning. Patient said "A funny sensation...." On enquiring, patient said it was not a question of being made to think about it, but that she actually hears it. This humming is carried out in time with the music which she hears.	4 v.
J.T.	24	Sup. Surf. 3.1 -1.5	546	Rt.	He exclaimed, "Yes, Doctor, Yes, Doctor, now I hear people laughing - my friends in South Africa." He was asked if he could recognize who they were, and he said, "Yes, they are two cousins, Bessie and Ann. They are both girls."	3 v.
G.F.	17	Sup. Surf. 4-1	601	Rt.	"I just heard one of my children speaking." When asked, she said it was the older one, Frank. When asked what he said, she replied, "I could not get that." "There was some other noise at the same time,"and when asked what it was, she said, "Neighbourhood noise".	3 v.

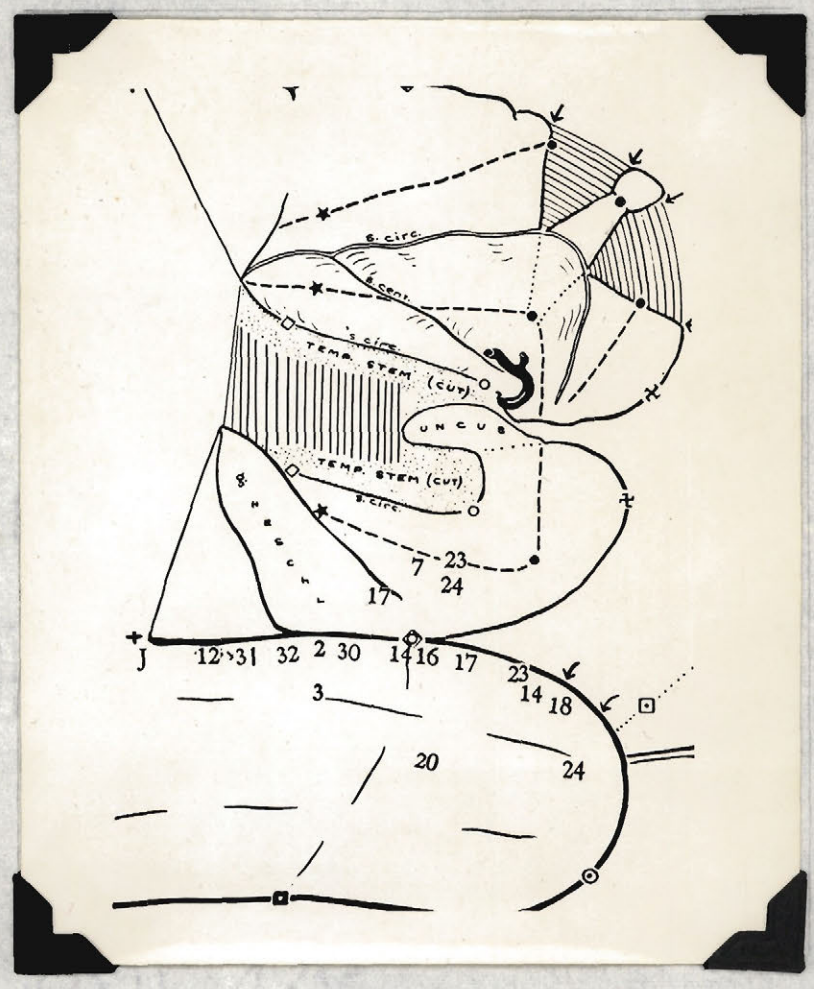


Fig. 3

Involuntary Recollection Responses

Case, T.S. No 649 (Fig. 4) : Stimulation evoking involuntary recollection. "Slight blurring on the street corner..... South Bend, Indiana.....that music from the stage hit, 'Guys and Dolls'....."

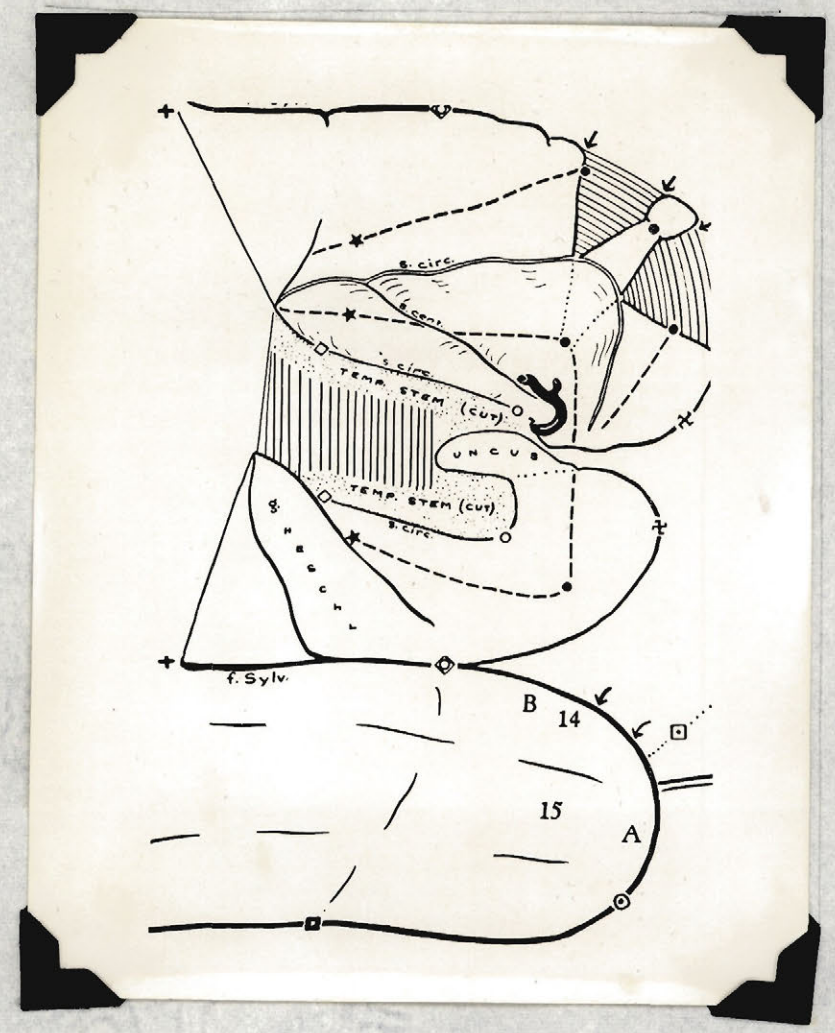
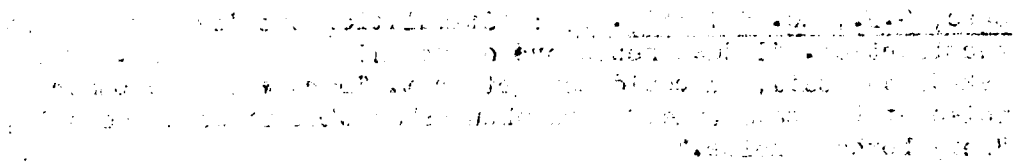

s. circ.
s. cent.
s. circ.
TEMP. STEM (cut)
UNCUS
TEMP. STEM (cut)
s. circ.
s. HIPPOCAMPAL
f. Sylv.
B
14
15
A

Fig. 4 - Case, T.S.



Case, G.F., No. 601 (Fig. 5) : Stimulation evoking involuntary recollection. "I just heard one of my children speaking." When asked, she said, "I could not get that. There was some other noise at the same time," and when asked what it was, she said, "Neighborhood noise."

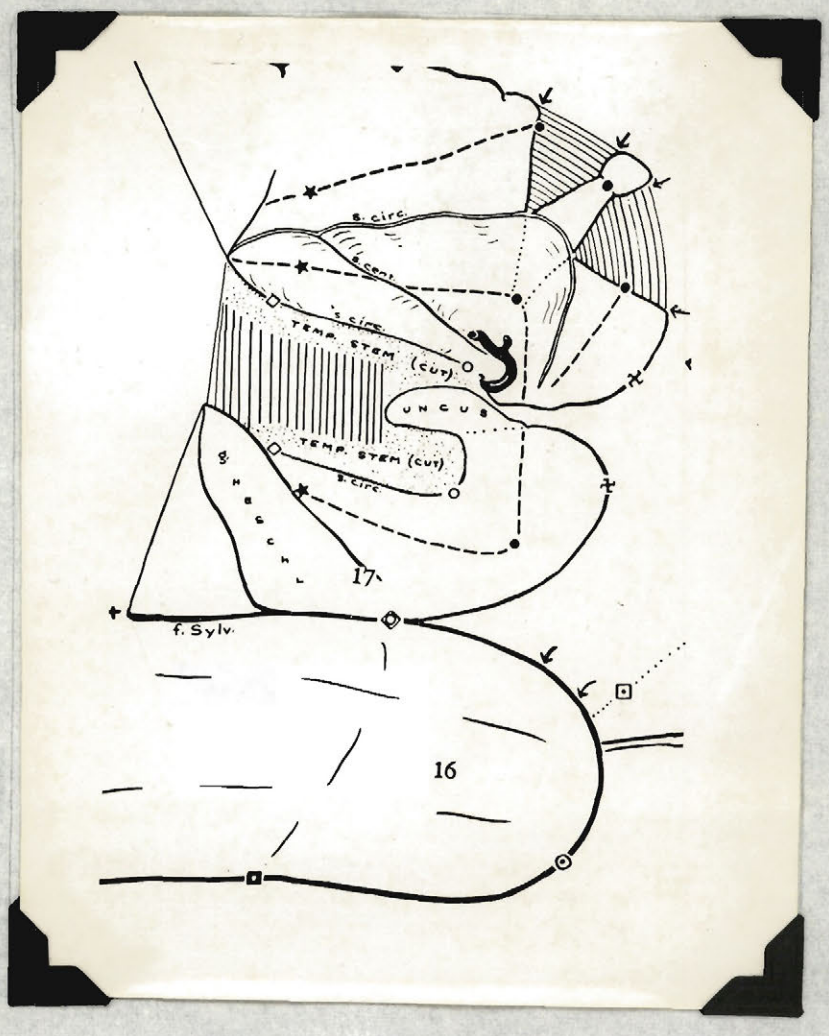

s. circ.
s. cent.
s. circ.
TEMP. STEM (cut)
UNCUS
TEMP. STEM (cut)
s. circ.
s. HIPPOCAMPAL
17
f. Sylv.
16

Fig. 5 - Case, G.F.

Case, D.F. No. 491 (Fig. 6) : "I hear the music.....I hear the music again.....It is the radio...".The patient was able to hum the tune with such accuracy that it was quickly recognized as "Marching Along Together.

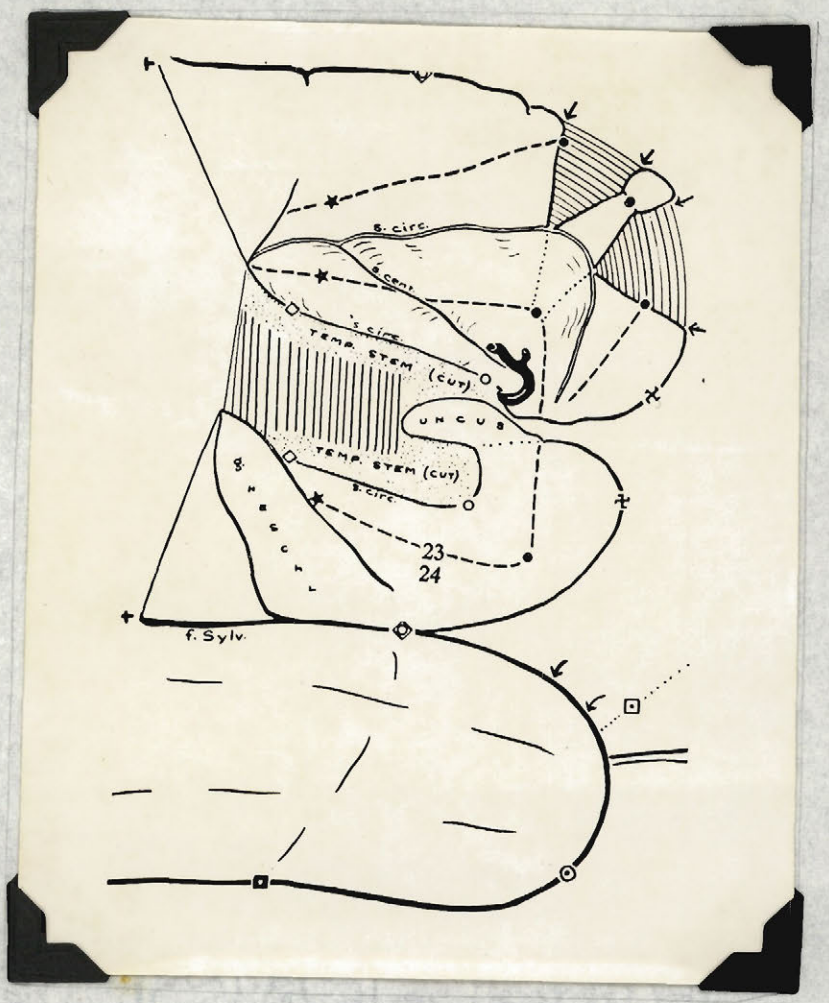

s. circ.
s. cent.
s. circ.
TEMP. STEM (cut)
UNCUS
TEMP. STEM (cut)
s. circ.
s. HIPPOCAMPAL
23
24
f. Sylv.

Fig. 6 - Case, D.F.

Case, J.T., No. 546 (Fig. 7) : Stimulation provoking an involuntary recollection. This patient had experienced attacks beginning with a sensation in the forehead and eyes, before operation. A right osteoplastic craniotomy was carried out, and a grayish, avascular neoplasm was discovered in the posterior temporal region. After stimulation at Point 7 with 3 volts, using the Rahm Stimulator, the patient explained, "Yes, doctor.....yes, doctor....now I hear people laughing.....my friends in South Africa...." He was asked if he could recognize who these friends were, and he said, "Yes, they were two cousins, Bessie and Ann. They are both girls." He did not know what they were laughing at, but thinks they must have been joking.

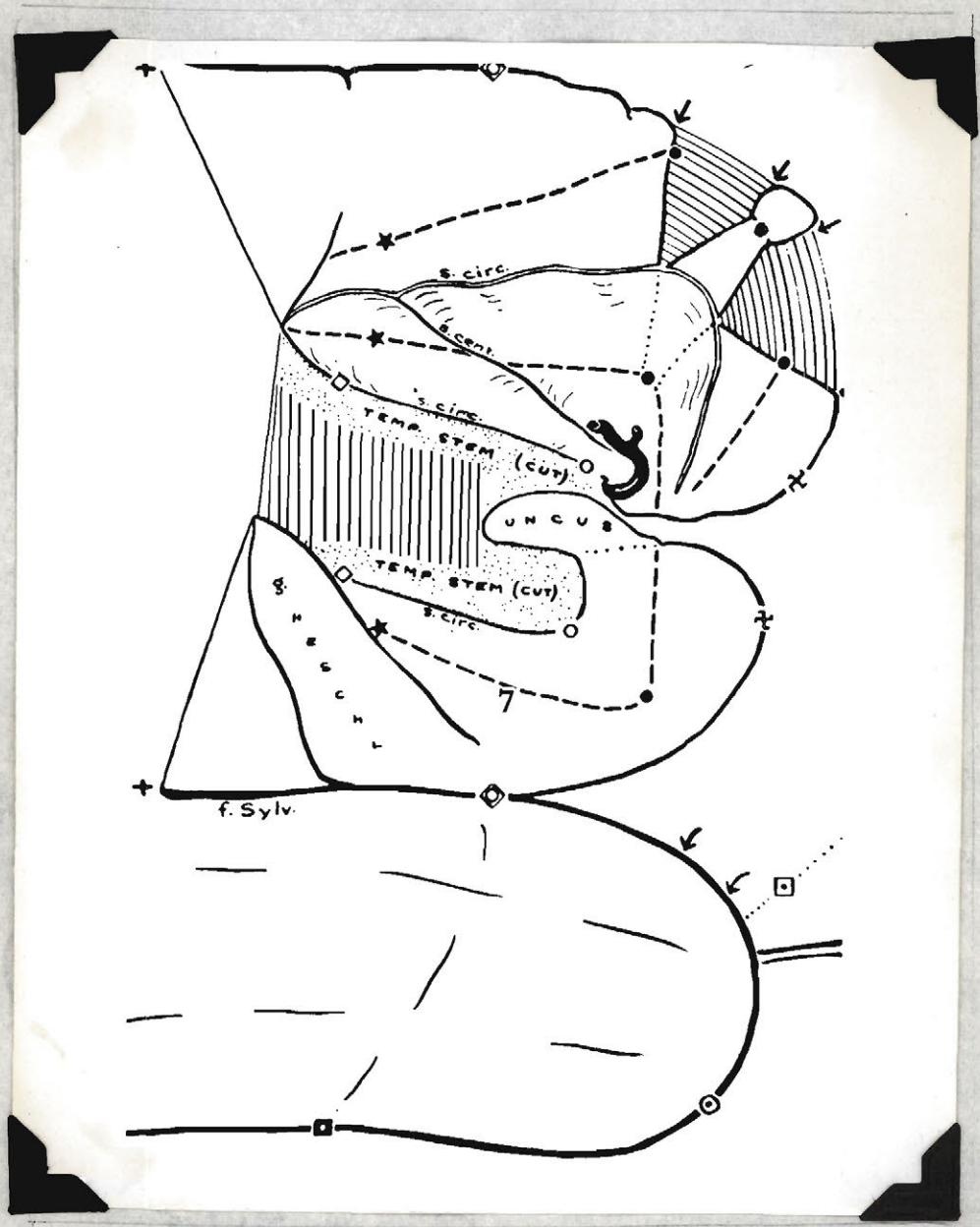

s. circ.
s. cent.
s. circ.
TEMP. STEM (CUT)
UNCUS
TEMP. STEM (CUT)
s. circ.
s. Hippocampal
7
f. Sylv.

Fig. 7 - Case, J.T.

Fig. 7a

Operative Photograph.
Stimulation producing involuntary recollection.

Case R.L., No. 549 (Fig. 8) : Stimulation producing involuntary recollection. After exposure in a right osteoplastic craniotomy, stimulation at 14 with 2 volts caused the patient to say, "It sounded like a voice saying words.....Jimmy.....Jimmy..... Jimmy...." When asked, she said it was her husband's name, and what she calls him. She recognized this as the voice of her husband.

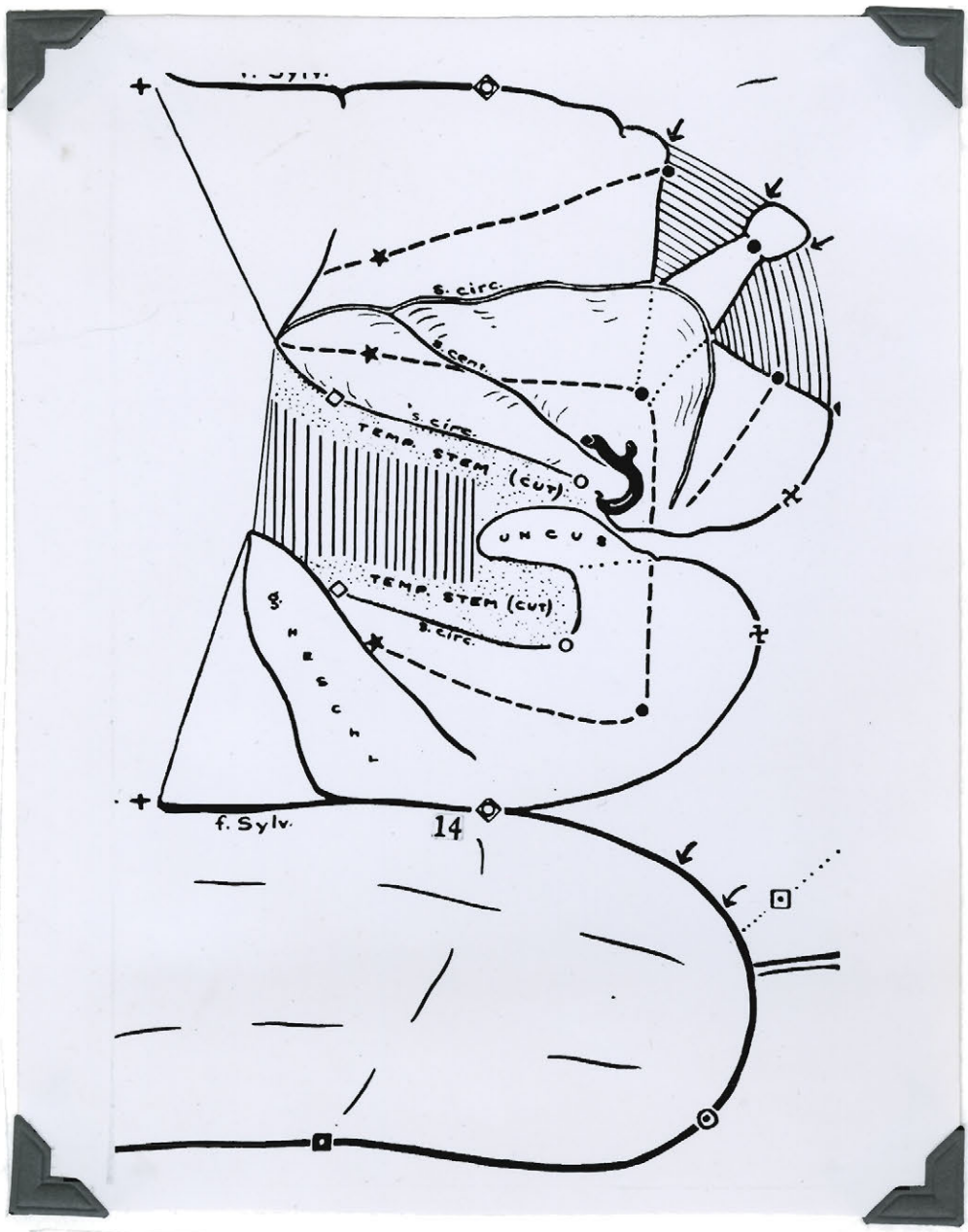

s. circ.
s. cent.
s. circ.
TEMP. STEM (CUT)
UNCUS
TEMP. STEM (CUT)
s. circ.
GYRUS HIPPOCAMPI
f. Sylv.
14

Fig. 8 - Case, R.L.

2. ILLUSIONS

When after a long separation, we see again the face of an old friend, or revisit the scenes of childhood, we know at once what is familiar and what is not. Minutes before the encounter it is doubtful if many of us could give an accurate account of the friend's face or the original childhood scene. Yet the changes seem obvious to us. It is not the individual feature such as the nose or the church door which seems strikingly familiar, but the composite picture. This entity we quickly compare with our old memory record and without apparent effort produce a judgment that the friend is well preserved or the old town changed. The friend's face and the town square have served as adequate stimuli to an area of memory records. Our recollection of these people and places has been stirred by a more natural stimulus than the electrical current described in the preceding section, to bring fragments of the memory record to the surface of consciousness.

It does not seem unusual that a chance encounter with old friends or childhood scenes should convey a sense of familiarity, but it is important that this occurs concerning features which we could not voluntarily recall. This is of particular interest in regard to our discussion on memory mechanisms since it seems to provide evidence that some memory records exist beyond the scope of voluntary recall and within the range of an adequate external stimulus. It is also evidence of a mechanism for comparative analysis of past and present experience. The sense of familiarity signals this function in sub-

jective experience.

We are here directly interested in the sense of familiarity which often accompanies and sometimes precedes these recollections. The face of a passer-by on the street may seem familiar, but we are unable to develop the impression beyond the sense of familiarity. Later, the passing face proves an adequate stimulus to recollection. The sense of familiarity, however, signals this action. It is not at first directed to the nose or eyes or a single part of wearing apparel. We simply say, "That man looks familiar". In so doing a normal judgment has been made. However, the sense of familiarity sometimes occurs without logical stimulus. When this occurrence is without apparent cause and is frequent, we say it is abnormal. It has come to be recognized as an aberration of judgment, a distortion of the normal and may be a warning of an epileptic process within the temporal lobe. In its abnormal form, it was described by Jackson as the "deja vu" sensation.

By means of electrical stimulation of the temporal lobe, we have produced a "feeling of familiarity" four times in three patients. In one of these it was called a "feeling of repetition". In an additional case, the patient (L.G.) had a feeling of reminiscence concerning a thought which "entered his head" during stimulation. We have recognized this feeling of familiarity in other cases as part of an epileptic pattern arising in the temporal lobe. The stimulations which were followed by a "feeling of familiarity" are diagrammed as to location in the temporal lobe in Fig. 9.

Let us examine a case in point to provide evidence and perhaps material for further discussion. E.L. is a young man of twenty-seven. He had a difficult birth and began to have attacks at the age of eighteen years. He described his frequent minor attacks as beginning with a feeling that things he looked at were suddenly familiar. These things occasionally seemed larger to him. His behaviour then became automatic. There was a great deal of electrographic abnormality over the right temporal lobe with a maximum over the inferior anterior surface. At operation his right temporal lobe was exposed. Stimulation at 2 volts through Point 19_4 on the lateral surface of the second temporal convolution (Fig. 10) and into the third convolution, at a depth of 1 cm., caused the patient to say, "Nothing". He explained afterward that it was as if he were having an attack. When asked why, he said, "Because things seemed familiar, as though I had been through this before." The stimulation itself must have been deep in the third temporal convolution near the floor. This was close to a previous stimulation at the same voltage. Again, when stimulated with 2 volts, on the lateral surface of the uncus, he had the "feeling like before an attack", and repetition produced the same result. By this he meant "the feeling of familiarity".

It is clear that this patient had not been in our operating room before, nor was there anything in his previous experience comparable to craniotomy and cortical stimulation. However, following application of a 2 volt current to his uncus and third temporal convolution, he had made a false judgment concerning his present experience. Somehow

a most unfamiliar scene had for a brief instant seemed completely familiar. This illusion was not directed at any single object or person but included the entire panorama of present experience. Afterwards he described it as "overpowering" but at the time he knew the judgment was false. That is, while we activated one part of a mechanism and provoked it to a false conclusion, another part acted normally and provided information that the "feeling of familiarity", although "overpowering" was false. There must have been an integration of these mechanisms so complex as to arrange for simultaneous action and consequent appreciation that the judgment was false.

How does this abnormal feeling of familiarity compare with the normal feeling of familiarity that comes with recollection after adequate external stimulus ? It is not focused directly on a particular object or objects in the immediate environment, and is, as he said later, "overpowering". The normal sense of familiarity is not overpowering. It follows an encounter with elements in the present environment on which one has focused conscious attention in the past. Both the normal and abnormal sense of familiarity convey an awareness of recollection. Actual recollection follows the normal sense of familiarity but does not occur following the abnormal. In the normal a sense of familiarity signals the comparison of present experience with similar past experience. In the abnormal, the feeling of familiarity occurs without subsequent comparison of present experience with similar past experience. Apparently, comparison is attempted, since the individual knows at once that the feeling of familiarity is false. The signal hoist affirms a function which cannot occur. It seems important to report that both feelings are somehow related to the mecha-

nism of recollection.

In the case of E.L. cited above, another stimulus evoked a different type of abnormal experience. This preceded the sense of familiarity which we have just described. The stimulator was introduced at 19_3 on the second temporal convolution and directed to a depth of 2 cm. reaching the third convolution. After stimulation here with 2 volts, he said, "Feels like an attack coming on". When asked why, he said, "Because everything looks funny". When this was repeated he said, "There we go again..... Things looked as if they were sideways a little". He understands that there is no actual distortion of his external environment and is aware of an involuntary false conclusion concerning its appearance. The sensory data derived from the environment has been misinterpreted. This misinterpretation has been subject to conscious inspection and voluntary correction. We have evoked a misinterpretation of present experience from one temporal lobe and yet there has been a simultaneous voluntary correct interpretation. Perhaps this indicates that he is making the correct judgment with the opposite temporal mechanism and the two are therefore coordinated by means of a higher agency which is central in location.

In the case of A.H., a man of twenty-six, whose attacks began in the right temporal lobe, stimulation at Point 12 on the inferior surface with 1.5 volts (Fig. 11) caused him to say, "Yes, in my mind I had a feeling as though I were standing up and dropping over towards the floor." When he was asked if this could possibly have been like an attack, he replied that he had a feeling of familiarity as though he had done it, although he does not remember doing anything like this.

The surgeon noted that the point is directly over the petrous ridge and slightly anterior.

In this patient stimulation has evoked a false sense of reminiscence in association with a false interpretation of immediate experience. The patient feels that his position is changing in relation to the external environment, and this false sense of bodily displacement seems briefly familiar. Despite this compounding of illusion, he knows that the experience is not familiar and that he is not falling.

A sense of familiarity was again produced in the case of R.S., whose first temporal gyrus was stimulated in the region close below the lower end of the central fissure at Points 24 and 25 with a current of 3 volts (Fig. 9). After stimulation he said, "A slight feeling of familiarity ....." Point 25 produced the same result with the same current. Here the feeling of familiarity is not directed toward any particular object, action or scene. The patient again understood that there was nothing actually familiar in the environment.

In these cases we have provided examples of illusions in which the patient felt the immediate situation or environment was familiar. In the case of A.H. an illusion of position accompanied the sense of familiarity. E.L. thought that objects in his environment "looked sideways" as well.

Sometimes stimulation has produced a sense of individual dislocation with regard to the environment. As for example in the case

of G.A., on stimulation of her first temporal convolution close to the lower end of the central fissure, " I have a queer sensation as if I were not there...." Again, in the case of D.A., who felt as if he were "..... out of this world". This was produced at a point on the second temporal convolution with 2 volts and later from the peri-insular grey in the stump of the amputated temporal lobe with 4 volts.

Each of these three individuals has made a statement concerning his relationship to his immediate environment. In their own words, these people described a sense of separation from the immediate surroundings. This misinterpretation of the individual's environmental relationship is coincident with an accurate understanding of its falsehood. It may be similar to the "mental diplopia" described by H. Jackson. Perhaps this is evidence of a mechanism which in the normal is continually interpreting the individual's relationship to present experience.

Another type of illusion followed stimulation in the case of R.W., who had attacks arising in the right temporal lobe characterized by a sense of "increased awareness" preceded by a rising epigastric sensation. He felt more aware of elements in the immediate environment. At operation, stimulation of his right temporal lobe at Point 11 with 2 volts was followed by a sensation in his right foot. He asked that this be repeated because he felt the increased awareness which he associated with his attacks. Point 11 was within the first temporal convolution anteriorly. After stimulation deep to Point 12, which lay on the second temporal convolution posteriorly, he thought

things seemed more distinct.

By saying "Things seemed more distinct" this man meant that he was more acutely aware of objects within his environment. These did not change size, seem nearer or farther away. He was simply more conscious of their presence. There is no implication that his visual, auditory, olfactory or other sensory faculties became selectively or generally more acute. The sensory information presented by these faculties for conscious inspection seems more distinct in his mind. In some of his attacks he became more aware of certain objects, such as the corner of a desk or the pressure of a seat cushion in a car, but no particular sensory mechanism was selected. We may say that he is interpreting sensory data from his environment in a usual fashion, but that he is more acutely aware of that interpretation. His comparative analysis of present experience is normal, but he is abnormally aware of this analysis. The abnormal interpretation follows stimulation and is involuntary, but it is voluntarily corrected by normal interpretation.

Stimulation about the auditory area in the temporal cortex has often caused the patient to misinterpret the quality of sound in the environment. In the case of W.W., stimulation at Point 14 on the left temporal lobe, with 3 volts, caused the patient to say, "My voice sounds as though it were in a space where it might echo". This was repeated, and the patient said, "Yes, an enclosed sound". Point 15 close to 14 was stimulated with the same current and the patient said, "Yes, definitely, an enclosed sound". These points are on the lateral surface near Heschel's convolution. His response is similar to that of

others who have said that the voices of those in the operating room sound more distinct, louder, or often merely "different". All of them, including this patient, knew that the voices had not actually changed. They understand that they are somehow misinterpreting the sensory data.

In summary, we have evoked by electrical stimulation 21 psychical illusions in 17 patients; 8 from the left and 13 from the right. These illusions (Fig. 9) of familiarity, bodily displacement, individual dislocation, increased awareness, and changes in the appearance and sounds of the immediate environment, are all misinterpretations of present experience. They are subject to conscious inspection and simultaneous correction. In each case the individual understands that an involuntary misinterpretation has occurred and simultaneously makes a voluntary correct interpretation. This might suggest that we have activated an area concerned with judgment or comparative analysis of immediate sensory data, distorted its function and caused a false judgment. Meanwhile, another area with similar function has evolved a correct judgment or interpretation. The valid interpretation may have resulted from normal activity in the opposite temporal lobe. This assumption is not unreasonable, since we have evoked 8 illusions from the left and 13 from the right temporal lobe, thus showing that misinterpretation of present experience can be produced on either side. There must have been rapid coordination of the normal and abnormal judgments since the individual is aware of both the correct and incorrect interpretations at the same time. This coordination must include incoming sensory data because it forms the raw material for perceptual judgmentor interpretation of present

sensory experience. Here, then, we have postulated the existence of a mechanism which coordinates the two temporal lobes with incoming sensory data from the immediate external environment. Surely this must be central in location and function on a high physiological level.

PSYCHICAL ILLUSIONS (Table II)

Initial	Stim. No.	Coordinate	SF No.	Side	Summary	Voltage
					Lateral Surface	
S.L.	14	L 1-.5	588	Lt.	"A feeling of quiet all around my body". When asked for an explanation he said, "Your voice is quiet and I have a feeling all around my body as though waiting for something to happen."	3 v.
D.A.	14	L 1-1.5	358	Rt.	Repeated: "Out of this world". No significant after-discharge.	2 v.
R.W.	11	L 1.5-.5-1d	518	Rt.	Repeated: with the electrode probably in the first temporal convolution, produced sensation in the right foot. Patient then asked if it could be repeated because he felt as he does in an attack, an increased 'awareness'.	2 v.
H.D.	14	L 2 - 1.5	353	Lt.	"As if I wasn't here".	1¼v.
R.S.	24	L 2.5-0	507	Rt.	"Slight feeling of familiarity".	3 v.
B. McK.	28	L 2.5-0	470	Rt.	"There is a funny sensation which has been coming over me, as though I were fading from this room".	3 v.
E.L.	19_3	L 3-2-2d	560	Rt.	At a depth of 2 cm. same thing. "Feels like an attack coming on." When asked why, he said, "Because everything looks funny". When asked what he meant, he said the machine looked funny, just like in one of his attacks.	2 v.
E.L.	19_4	L 3-2-1d	560	Rt.	At a depth of 1 cm., patient said abruptly "nothing". He explained afterwards that it was as though he was having an attack. There was an activation of many isolated spikes. Direction from Point 19 was a little downward. This last stimulation must have been deep in the third temporal convolution where first stimulus was, near the floor. When asked about the previous stimulation he said it felt like an attack and when asked why, he said because things seemed familiar, "as though I had been through this before."	2 v.
H.D.	13	L 3.5-0	353	Lt.	He felt queer....."All sounds seemed to be distant".	1½v.
A.B.	15	L 3.5-3	446	Rt.	"I felt as though my system were apart from my mind".	3 v.
R.S.	25	L 4.5-0	507	Rt.	"..... a feeling of familiarity".	3 v.

Initial	Stim. No.	Coordinate	SF No.	Side	Summary	Voltage
G.A.	0	L 4.5-0	128	Rt.	Patient said "I have a queer sensation as if I am not here". Then a little later, "As though I were half and half here." This lasted about 30 sec. Says she never had that feeling before.	Thyratron
R.W.	12	L 4.5-2.5 2.5d	518	Rt.	When asked whether things looked different he said he could not say but thought they did.	2 v.
T.R.	14	L 5-3 1.5d	651	Rt.	Patient said "Ah" and then "I just got the taste I get before my attack." Stimulation continued and then withdrawn. After withdrawal, he said "I had the feeling of repetition too." When asked to explain he said, "It is a feeling that comes over me as though the 'whole set-up' had occurred before."	5 v.
G.A.	3	L 5.5-0	128	Rt.	"I feel like I am going away again". Continued a few seconds after stimulation.	Thyratron
G.A.	1	L 6-0	128	Rt.	"I feel queer". Feels as though she were floating away. Feels as though arm were moving. With this feeling, Dr. Santha reports a choreiform, athetotic movement, left arm. Patient said, "Am I here ?"	Thyratron
T.E.	21	L 7.5-0	272	Lt.	Repeated:"I felt as though I were staring into space. I could see everything, but my mind was different altogether.	Thyratron
A.G.	23	L 8-0	432	Lt.	"Things are distant". When asked whether it was a sound or what she saw, she said,"Your voice."	2 v.
P.B.	24	L 8-1	332	Lt.	"Something strange and unnatural in my thoughts".	3 v.
L.G.	13	L 8.5-1.5	443	Lt.	A thought entered his head which he seemed to have had before.	2 v.

Initial	Stim. No.	Coordinate	SF No.	Side	Summary	Voltage
					Superior Surface	
E.L.	15_2	S .5-1	552	Rt.	"Things seem far away"	3 v.
R.S.	30	S 1-.5	507	Rt.	Feeling of familiarity.	4 v.
R.S.	31	S 1-1	507	Rt.	A feeling of familiarity and it made him a little sick.	4 v.
					Inferior Surface	
A.H.	12	I 5-4	348	Rt.	"Yes, in my mind. I had a feeling as though I were standing up and dropping over toward the floor." When asked whether this could possibly have been like an attack, he replied that he had a familiar feeling making him feel as though he had done it, although he does not remember ever doing anything like this. He explained that this might happen during an attack and he would not remember it. This point is directly over the petrous ridge and slightly anterior. It could be on what corresponds to the 3rd or 4th convolution. Repeated: Patient said," I seem to be falling again".	$1\frac{1}{2}$v.
					Uncus	
E.L.	20	Uncus	560	Rt.	Lateral surface of uncus or anterior to it. Patient had feeling like before an attack. Repeated once, the same. He apparently means the feeling of familiarity.	2 v.

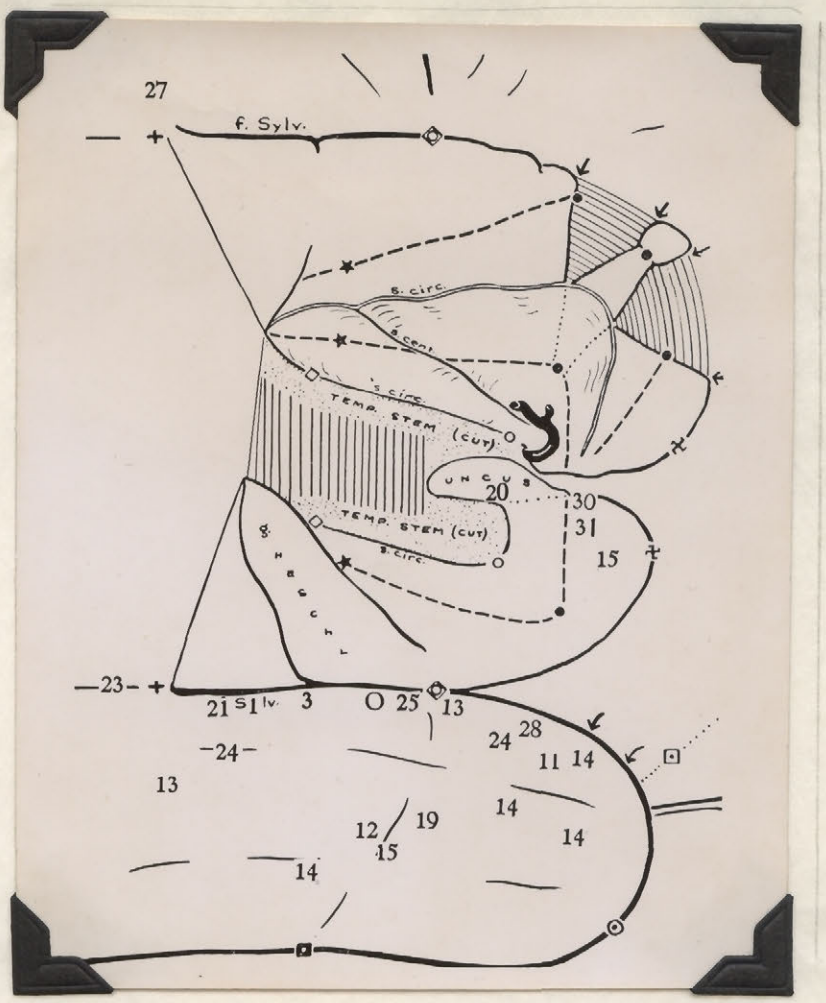
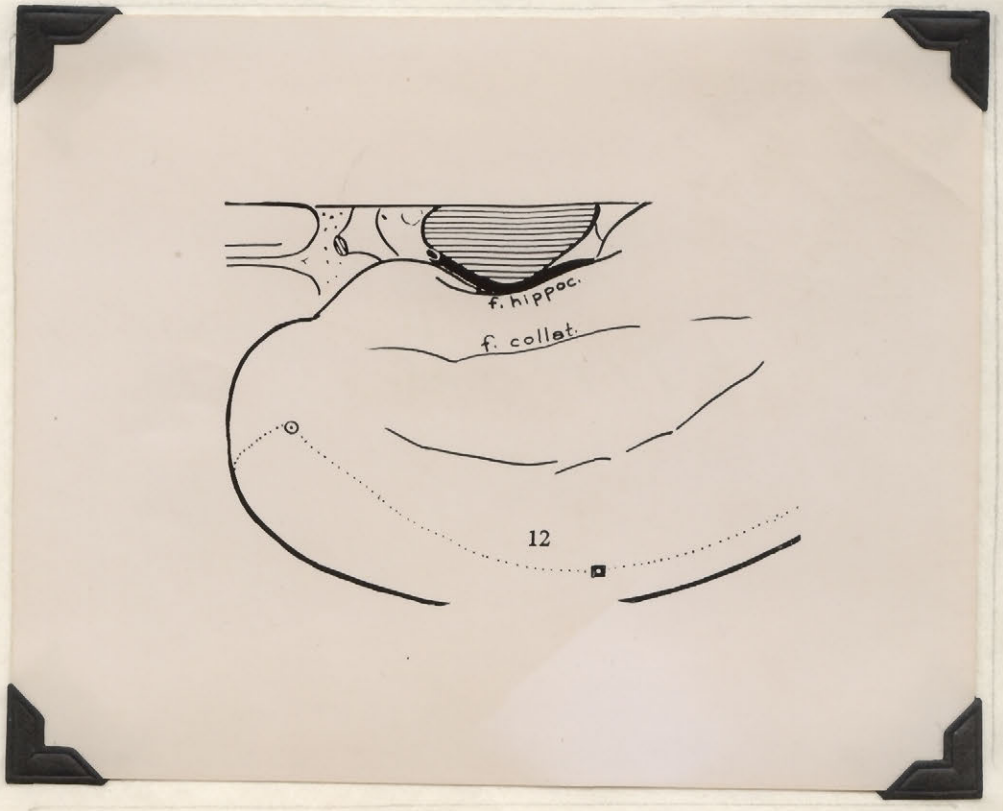


Fig. 9 - Psychical Illusions



Case, E.L., No. 560 (Fig. 10) : He explained afterward that it was as if he were having an attack. When asked why, he said, "Because things seemed familiar, as though I had been through this before."

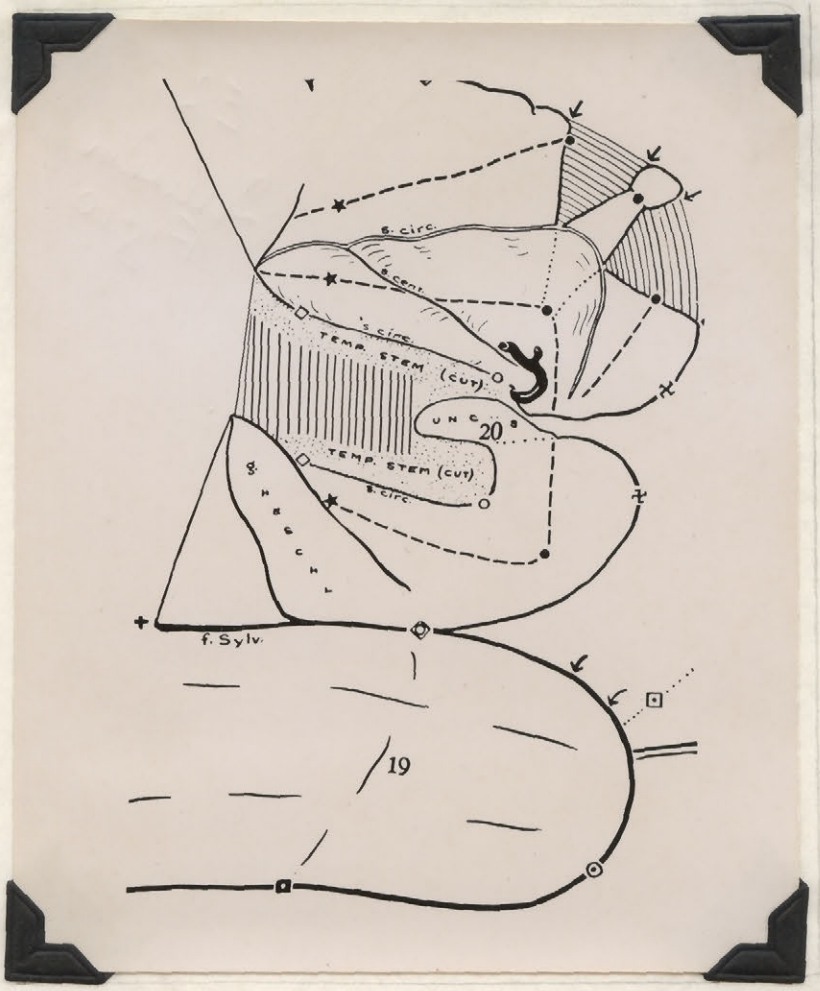


Fig. 10 - Case, E.L.

Case A.H., No. 348 (Fig. 11) : "Yes, in my mind I had a feeling as though I were standing up and dropping over towards the floor." When asked if this could possibly have been like an attack, he replied that he had a feeling of familiarity, as though he had done it, although he does not remember doing anything like this.

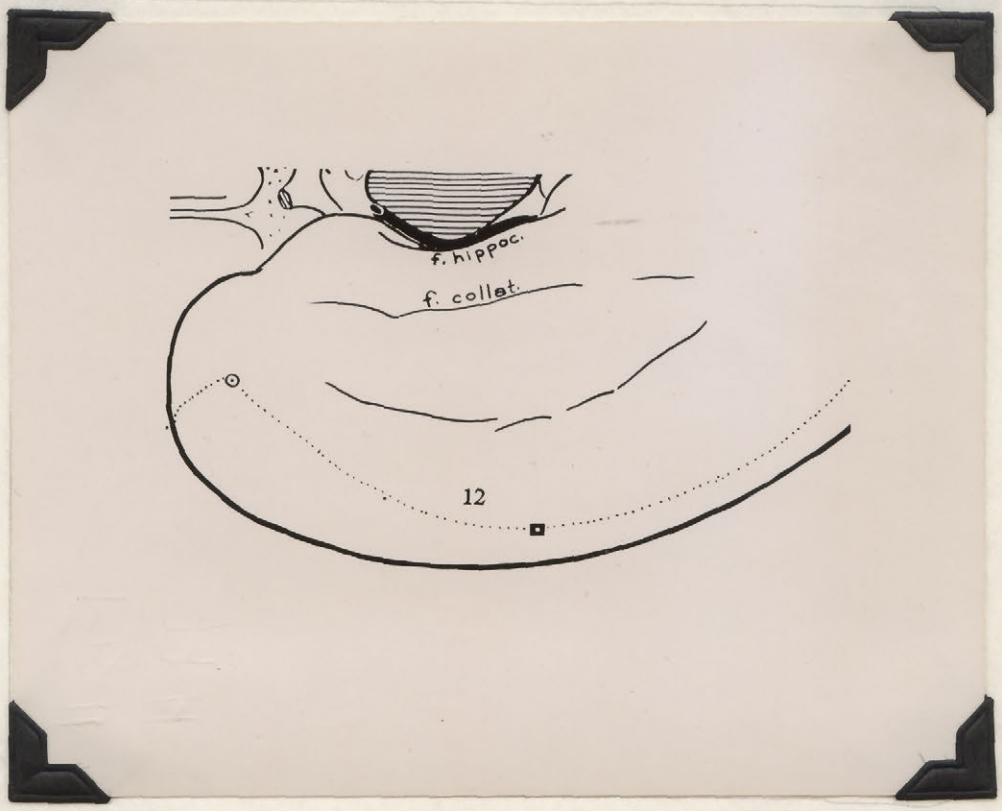


Fig. 11 - Case, A.H.

3. PSYCHICAL HALLUCINATIONS

The preceding sections provide examples of involuntary recollection of past experience and unusual interpretations of present experience which have followed electrical stimulation of the human temporal lobe. The same type of stimulation has been followed by descriptions of other bizarre experiences. In these, temporal stimulation may evoke the description of a small scene or perhaps a voice calling. Neither elements of the scene nor the origin of the voice are in the external environment. The patient may say that he has "seen" a man sitting on a chair, people talking in a room, or a man walking with a dog. He uses the word "seen" but both he and the observers know that the vision is within the mirrors of his mind and not in the world outside. The voices may be "heard", but the hearing and the origin of the voices are internal. The sounds are never simple tonal repetition such as one encounters after stimulation of the auditory areas. The images of such scenes are drawn from every-day life, and their source is in his ordinary activities, or else from his reading or the various forms of dramatic art to which he is exposed. For example, a small boy saw "robbers" during stimulation. The scene did not terrify him, and perhaps if real in origin it might have. However, "robbers" are vividly described in many forms in stories and comic books. These hallucinations are complex constructions built with symbols from the records of past experience.

The case of S.B. will serve as an individual example for study of these generalizations. We may compare it with others of similar type and test them for relationship to the cases presented in the other

sections. S.B. was twenty-five years old at the time he underwent craniotomy and cortical excision for seizures arising in his right temporal lobe. He had had attacks for six years. At first these were characterized by vertigo and by the sound of a voice calling his name. Later they began with an epigastric sensation. Seizures often followed unusual or prolonged voluntary recollection. He might try to remember if a face was familiar and as the conscious effort of recollection progressed, an attack would begin. He once saw a light in the hospital ward which seemed familiar, and as an attack began he realized that he had been trying to substantiate the feeling of familiarity with recollection. Electrographic abnormality was maximal in the right temporal lobe. This was exposed at operation and the first temporal convolution stimulated with 2 volts at Point 18. Fig. 12 illustrates the stimulation points in the case of S.B. It should be noted that he was a good witness and did not attempt to elaborate on the sensory responses as from the post-central gyrus at Point 4 in the face area, he simply said, "Numbness in left upper lip" when stimulated with 1 volt.

After stimulation at Point 18 he was asked what he noticed. He had not been warned. He said he was a little drowsy and not sure. "Someone was there in front of me, right where the nurse is sitting or someone." Point 19, more posterior on the first temporal convolution and closer to the auditory area was stimulated with the same voltage. He said, "I am trying to find the name of a song. There was a piano there and someone was playing. I could hear the song, you know. It is a song I have sung before, but I cannot find out quite what the title of the song is. That was what I was trying to do when you finished

stimulation." Notice that he has been able to attempt voluntary comparison of the imagery and sound in the hallucination with past experience during stimulation.

It may be important that the tune is one that he has heard before, but he does not see himself playing it on the piano nor does he have a sense of having participated in the scene. Yet all the elements are common to his experience and as he studies them he understands their unreality as compared with his true surroundings.

Stimulation at 19 was repeated with the same voltage and without warning. The patient was not asked a question. At the end of stimulation he said, "Someone speaking to another and he mentioned a name, but I could not understand it." These are not simple sounds, or simply a disembodied voice, but the voice of a person speaking. He is not frightened and the experience carries no emotional colour to him. When asked whether he saw the person talking, he said it was just like a dream. When asked if the person was there, he said, "Yes, sir, about where the nurse with the eyeglasses is sitting." When 19 was repeated again, without warning, the patient said, " Yes..... Oh Marie....Oh Marie...someone is singing...." When asked who it was, he said, "I don't know, doctor, I cannot recognize the voice". Further repetition at the same point with the same current produced nothing. The fourth time Point 19 was stimulated without change of current,he observed during the stimulation, "Oh Marie...Oh Marie..." When asked what this meant, he said it was the theme song on a radio programme. "The Life of Luigi is the radio programme". There followed a discussion of the song with a member of the surgical team and the patient

then sang the refrain, "Oh Marie....Oh Marie.." which the surgeons recognized.

Here four hallucinations and one negative response have been produced at one stimulation point with the same current. Each is a complete entity. He does not see or hear the parts being assembled, but only the final product. They are brief and often end before the stimulator has been removed. All are subject to his conscious judgment, in which he concludes that they are false, e.g., not within the external environment. At first, he "sees" someone sitting, then a man playing a tune he can almost recognize. By simultaneous voluntary recollection he is able to focus his memory mechanisms on this internal experience in the brief interval of its appearance. The theme song of the radio programme is obviously stored within his recollection records. It is interesting to theorize that he has opened these to the stimulating current by voluntary control, since the appearance of the song follows close on his voluntary attempt at recognition of the piano tune. At any rate it seems that we have had access to multisynaptic pathways and that more have become available to stimulation as it progressed. These patterns are also available to comparison by recollection and thus to the mechanisms concerned in comparative analysis of present and past experience.

How do these responses differ from those we have classified as involuntary recollections ? An important difference is that there is no immediate sense of familiarity about them. The patient does not relate the piano player to his previous experience. Later he relates his description of the radio programme to past experience, but at the

time of stimulation he does not say, "I was sitting listening to a man playing the piano", or "I saw myself sitting listening ....etc." Rather he sees the man playing as if for the first time. However, he has heard the radio theme song before, and this is an example of an involuntary recollection related in origin to a psychical hallucination.

In the same patient stimulation at Point 16 with 2 volts was followed by a description, "Something brinks back a memory .... I could see Seven-Up Bottling Company and Harris Bakery ..." Here the patient was aware of a sense of familiarity or reminiscence, and this response must fall into our category of involuntary recollection. We may conclude that this sense of personal participation is another factor which seems to differentiate involuntary recollection response from psychical hallucination. Both recollections and hallucinations use the same symbols - the words and figures, the meanings and images of the individual's past experience. We would not expect to evoke a hallucination of a Roman chariot in an individual who had no knowledge of chariots.

Are these hallucinations comparable to anything in normal experience ? Perhaps they are related to the processes of imagination and day-dreaming. It is perfectly possible for a normal person to "imagine" a man playing a piano. Here what we call "imagination" makes an abstract of the records of the individual's past experience with regard to men playing pianos. The abstract is somewhat vague and lacks the clearer imagery of voluntary recollection, e.g., of a specific man playing a piano in a specific environment upon which the

individual has focused his conscious attention in the past. Involuntary recollection may be even "more real" as in the case of G.F. above.

Similarly the psychical hallucination evoked by stimulation in the case of S.B. is abstract and somewhat vague. He sees a man sitting, any man, not one related or identifiable. Later a man is playing a piano. Now the scene becomes more specific. The patient can almost recognize the tune as one he has heard. This scene becomes almost an involuntary recollection. After the next stimulation he does have an involuntary recollection. He "hears" a song which is at once familiar. Further stimulation at Point 16 develops a clear memory pattern concerning a familiar advertising sign. This scene is specifically related in his own consciousness to past experience. Thus it may be, perhaps, that involuntary imagination, if prolonged, may be followed by involuntary recollection. Similarly, in the normal, perhaps if voluntary imagination is prolonged by continued effort, it results in some form of specific voluntary recollection.

We suggest that in these hallucinations there has been selection of individual symbols from several acquired patterns. These are grouped for conscious inspection. Continuation of the process of selection of one or all of these separate elements may focus conscious attention on an entire acquired pattern of which the element is only a part.

In this patient (S.B) the hallucinations did not bring with them any emotional colouring. He was not afraid, angry or depressed.

In general, the hallucinations which followed stimulation were not accompanied by fear or other emotion. However, fear may accompany involuntary recollection if it was part of the original past experience. Penfield and Rasmussen cite the case of J.V., a young girl, whose epileptic pattern seemed to lie in the right temporo-parietal region. She had had a terrifying experience earlier in childhood. The neuronal pattern forming the recollection records for this experience had become involved in the epileptogenic process. Stimulation here evoked an involuntary recollection of parts of this experience and she was conscious of its terrifying qualities and of her previous participation. As we will see later, emotion can be evoked from the temporal lobe following stimulation, but when related to involuntary recollection or involuntary imagination, it must have been present in the original experience record.

The case of L.G. serves as a further example. He was fourteen years old at the time of operation for focal cerebral seizures arising in the left temporal lobe. His attacks started in his sixth year. The minor attacks occurred only when he closed his eyes. He would then see a room in which he might have been, although he could not see himself. The room then became distant as if he were looking at it through the wrong end of field glasses. There was maximum electrographic abnormality in the left temporal region with some conduction to the right.

At operation (see Fig. 13 & 13a), with his left temporal-parietal cortex exposed, Point 17 was stimulated with 2 volts. This was approximately 7 cm. posterior on the temporal lobe and in the

plane of the first temporal convolution. He said, "Un homme battu". When asked if it were someone he knew, he said, "No, a stranger". When asked with whom he was fighting, he said he could not distinguish very much. Point 17 was repeated with 3 volts. Patient said, "Yes, a man ....." He then explained he saw a man walking. When asked whether the man was in town or country he said he could see only a man and a dog. Point 19, more anterior than 17 and closer to the auditory area, was stimulated with 3 volts. The patient did not at first respond. On renewal of stimulation he said, "Chante un chanson". He explained it was a song he had heard before. When asked whether it was someone singing or an orchestra, he said he seemed to hear it. When stimulation was repeated with 4 volts, a hallucination followed. The patient said a little boy was playing with another one, but he does not know what they were doing. When asked if he heard a song, he said, "Yes".

This boy understood that the man fighting and the boys playing were not in his external environment. These are hallucinations, not involuntary recollections but all the images and sounds fall within the range of past experience. We should note that these occur far posterior on the temporal lobe and their location should be compared with those of the significant points in the case of S.B.

Further comparison as to location of stimulation point and response evoked can be made in the case of H.P., a young girl of fifteen years. Her problem has been reported at length by Penfield in 1947 and by Penfield and Rasmussen in 1950. The case is reported here to emphasize the anterior-posterior extent over which psychical

hallucinations may be evoked. Following a stimulation at Point 18 with $2\frac{1}{2}$ volts she said, "I am seeing somebody". When asked, she said it was the same sort of thing she sees in her dream, meaning the dream which characterizes her attacks. This was repeated without warning. Patient said after a few seconds, "It is coming again". When asked if she saw somebody she said, "Sure, a boy". She does not know where he was. With 3 volts at Point 22 she said she felt dizzy, and said, "Dream is starting.....there are a lot of people". When asked if they were speaking, she said she did not know. When asked where they were she said, "In the living-room". When asked if she recognized them, she said, "I think one of them is mother".

All these points are in the anterior portion of the lateral surface. They are illustrated in Fig. 14. If H.P. is compared with the case of R.W. who saw "robbers" after stimulation of Point 24 close to the temporo-occipital junction we may appreciate the wide antero-posterior extent over which these hallucinations may be evoked.

Also we must illustrate the difference between responses evoked from the occipital cortex in which the patient sees coloured lights and the more complex phenomena cited above. This difference is important because the coloured lights have been called hallucinations by some writers.

In the case of A.B., a housewife of thirty-two, we can compare a simple visual hallucination produced by stimulation of the occipital cortex with the examples of more complex voluntary imagination which have been cited above. The patient had her first major seizures nine

months before operation and two months previously had begun hallucinating. She showed electrographic evidence of a destructive lesion in the right posterior temporal and occipital regions. At operation, stimulation of Point 22 with 4 volts caused her to see red, white and orange colours off to the left. This point is on the lateral surface of the right occipital cortex just above the level of the calcarine fissure. Stimulation at Point 23 on the first temporal convolution with 3 volts caused her to say, "The play .... the men were talking..." When asked who they were, she said she did not know. This point is close to the auditory area. Stimulation at Point 18 on the same convolution with the same current preceded this. She said, "White Christmas". She meant she heard an orchestra playing the popular melody of that name. These examples serve to differentiate the simple visual hallucination such as coloured lights from the more complex psychical hallucinations composed of imagery and sound.

Fifteen cases cited in this section provide examples of psychical hallucinations. There were nineteen responses of this type, twelve from the right side, seven from the left. These are small complexes of imagery and sound summoned for conscious inspection by artificial electrical stimulation. The complexity suggests that they are represented in neuronal patterns. They are involuntary in origin but the patient can and does exercise voluntary comparative judgment concerning their content and relationship to his immediate external environment. The symbols and images are those of his past experience, and each hallucination is therefore in an acquired pattern. We have

discussed one case in which a patient has compared the hallucination with past experience by voluntary recollection.

The imagery of these hallucinations is involuntary in production, but somewhat similar to the scenes and symbols of voluntary imagination. This type of response might be called involuntary imagination.

PSYCHICAL HALLUCINATIONS (Table III)

Initial	Stim.No.	Coordinate	SF No.	Side	Summary	Voltage
					Lateral Surface	
H.P.	15	L 0-1	308	Rt.	"Had that dream...."	1½ v.
H.P.	23	L 1-2	308	Rt.	"That feeling again." When asked what had happened, and if there were people in the room, she said she did not know.	1½ v.
H.P.	22	L 2-1	308	Rt.	"Dream is starting...there are a lot of people in the living-room.....I think one of them is my mother....."	1½ v.
H.P.	18	L 3-1	308	Rt.	"I am seeing somebody." When asked if it was the same sort of thing she sees in the dream, she said yes.	1½ v.
H.P.	24	L 3-1	308	Rt.	"I felt that feeling again....somebody is in the room....."	1½ v.
Y.N.	25	L 3.5-0	615	Lt.	Repeated. "There was talking or murmuring, but I cannot understand it." Apparently they resemble the voices she has heard before her attack.	2 v.
A.B.	17	L 3.5-0	446	Rt.	"I seemed to hear a song, sort of familiar-like, on the radio."	3 v.
E.C.	X	L 4-0	430	Lt.	Patient was naming things and named one object. Then he said suddenly, "There he is". When asked what he said, he said, "Like a spell. He was doing that thing, grabbing something from somebody.....It was somebody else doing the grabbing." When asked what he was grabbing, he said, "A stick or something." When asked where he was, he said, "Up the street." He said that was like an attack - "Doing that thing....."	3 v.
S.B.	18	L 4-1	590	Rt.	"Someone was there in front of me...right where the nurse is sitting, or someone....."	2 v.

Initial	Stim. No.	Coordinate	SF No.	Side	Summary	Voltage
G.L.	15b	L 4-1-2d	577	Lt.	Anterior at a depth of 2 cm. Patient did not respond. After withdrawal, she said,"Something coming to me from something." "A dream". When asked whether it was like an attack, she said "Yes" (There was some 4 sec. activity near electrode 5 - HJ)	2 v.
					Repeated without warning. Dr. Roberts switched on the current and then spoke to the patient during the stimulation and she did not reply. After cessation of the stimulation she was silent for a time and then when asked if she noticed what Dr. Roberts did, she said, "I don't know what you did, I was trying to see what they were doing." "The scenery seemed to be different from the one just before". She said, "I think there were people there, but I could not swear to it. That is what I call an attack". There was after-discharge at electrodes 5 and 6, a series of spikes about 2-3 sec. spike and wave form at electrode 5. Electrode 5 is marked C and Electrode 6 is marked D. Dr. Roberts thought that following this induced attack there was a slight degree of aphasia. During the attack Dr. Roberts made gestures with his hand. When asked about it, she said yes, she saw his hand. - "I see the people in this world and in that other world too at the same time". This stimulation may be in first or second convolution but is definitely anterior.	2 v.
G.L.	15c	L 4-1-2d	577	Lt.	"Something flashed over me .....something I dreamt"	2 v.
L.G.	17	L 5.5-1.5	443	Lt.	"Un homme battu..." When asked if it were someone he knew, he said, "No, a stranger." When asked with whom he was fighting, he said he could not distinguish very much. Repeated: "Yes, a man". He then explained he saw a man and a dog walking. When asked whether the man was in town or in country, he said he could only see a man and a dog.	2 v.
S.B.	19	L 6-0	590	Rt.	"Someone is speaking to another and he mentions a name, but I could not understand it ....I am trying to find the name of a song.....There was a name there and someone was playing....I could hear the song, you know.... It is a song I have sung before, but I cannot find out quite what the title of the song is."	2 v.
L.G.	14	L 6-0	443	Lt.	He then explained there were two men sitting in chairs singing. He doesn't think it is the same song he heard before.	4 v.

Initial	Stim. No.	Coordinate	SF No.	Side	Summary	Voltage
R.W.	23	L 7-4	594	Rt.	"Pain in my forehead and there were robbers." "He wasn't in front, he was off to the left side." There was after-discharge at electrode 2 and between electrodes 6 and 7. Electrode 2 is posterior to the stimulation. Electrodes 6 and 7 are about 3 cm. above it.	2 v.
C.F.	J	L 8-5	203	Rt.	"Familiar sight danced into my mind and away again." Repeated without warning. Patient saw nothing. When asked, said yes, three or four things danced before his memory.	Thyratron 2
G.P.	15	L 8.5-1	626	Rt.	Patient said, "Oui, là, là, là" and he began to struggle. Stimulus was withdrawn. When Dr. Pasquet enquired after the struggling was over, he said, "It was he, he came, that fool....."	3 v.
M.G.	1	L 9-.5	144	Rt.	"It's a dream. There are a lot of people - I don't know the rest." When asked whether she hears or sees people, she says, "I don't seem to see them - I hear them. I don't hear them talking. I just hear their feet."	Thyratron 10
					Superior Surface - Uncus	
G.L.	18	Uncus	577	Lt.	"I keep seeing things.....dreaming of things"	2 v.

Case, S.B., No. 590, Fig. 12 : (Point 18) "Someone was there in front of me, right where the nurse is sitting, or someone." (Point 19) "I am trying to find the name of a song. There was a piano there and someone was playing. I could hear the song, you know. It is a song I have sung before, but I cannot find out quite what the title of the song is."

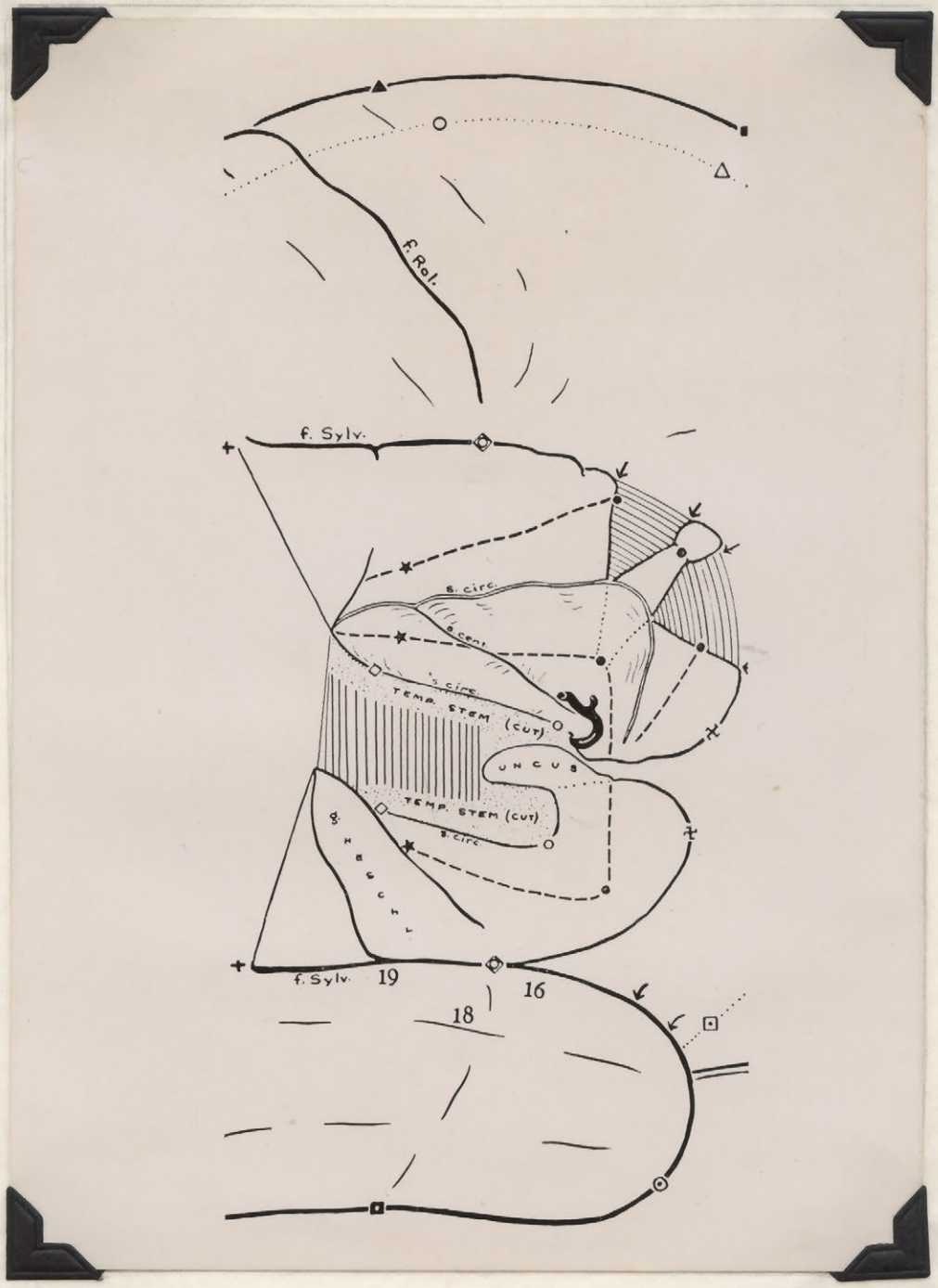


Fig. 12 - Case, S.B.

Case, L.G., No. 443 (Fig. 13) : Stimulation producing an hallucination. At exposure in a left craniotomy, this boy's temporal lobe was seen to be rather yellow and tough, particularly on the under surface. Stimulation at Point 17 with 2 volts, using the Rahm Stimulator, caused the patient to say, "Un homme battu....." When asked if it were someone he knew, he said, "No, a stranger." When asked with whom he was fighting, he said he could not distinguish very much. Stimulation at Point 19 with 3 volts and the same stimulator : the patient said at first, "Chante un chanson." He explained that it was a song he had heard before. When asked whether it was someone singing or an orchestra he said he seemed to hear it. This was repeated at 4 volts. The patient then explained a little boy was playing with the other one, but he does not know what they were doing. When asked if he heard a song, he said, "Yes."

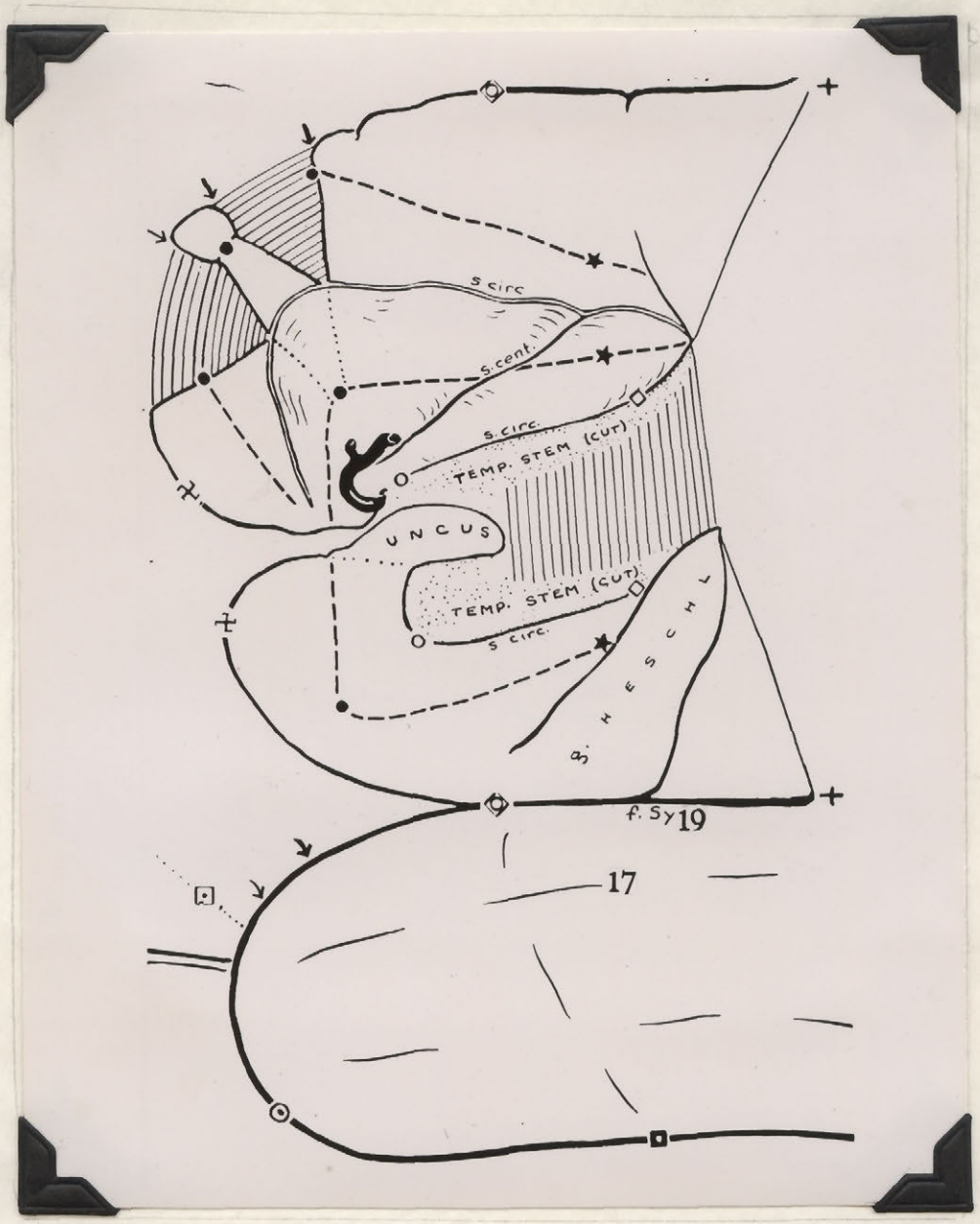


Fig. 13 - Case, L.G.

Fig. 13a - Case L.G.

Operative Photograph.

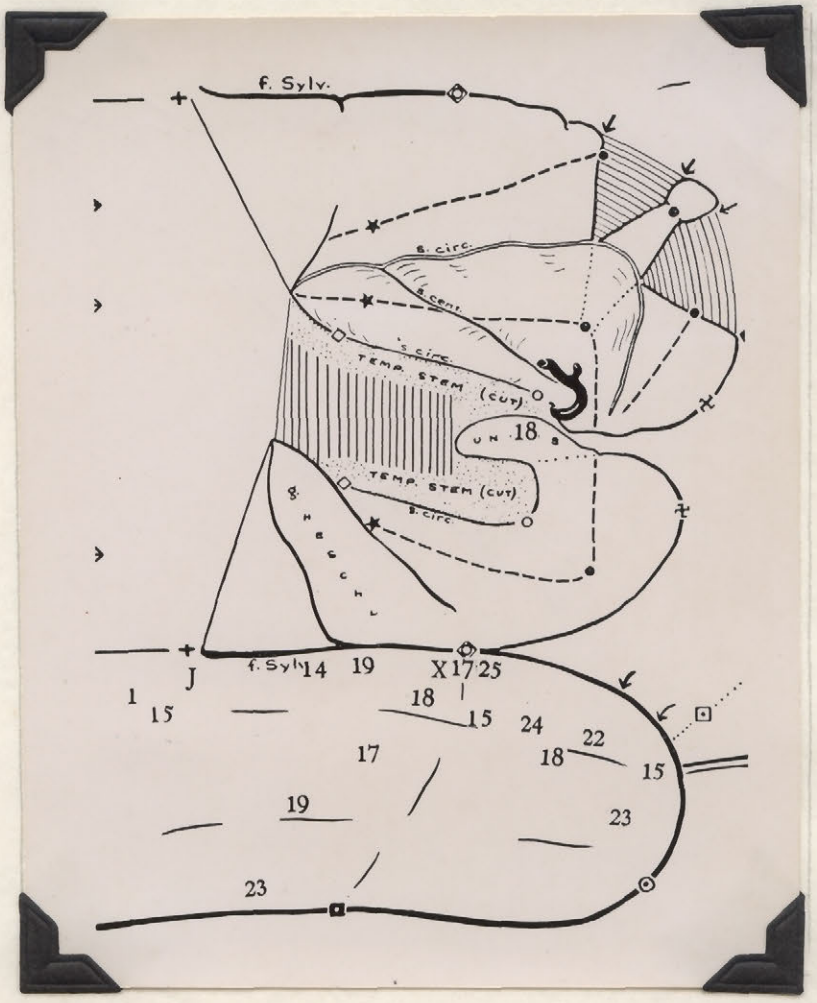


Fig. 14 - Psychical Hallucinations.

4. EMOTION

There has been an emotional response following stimulation of the temporal lobe in six patients. (see Fig. 15) Four of these responses were evoked from the left side and two from the right. All the responses consisted of descriptions of fear or fear with lonesomeness or sadness. There have been no responses to electrical stimulation which suggest rage, happiness or joy. In each of the six cases of fear, the feeling occurred as part of the seizure pattern. Perhaps it is significant that in our experience, emotion associated with epileptic seizures has always been described by the patient in terms which suggest that it is unpleasant. It is not fear of the seizure, but rather a separate fear or sense of fear, or in the words of one patient, " a fear which was independent of myself".

A feeling of fear may follow interpretation of present experience in terms of past experience or in recollection of a fearful past experience or perhaps without apparent cause. Some of the 157 patients composing the entire series have expressed varying degrees of fear during the stimulation which follows craniotomy and perhaps this is natural, although the number is surprisingly small among patients young and old, male or female, of varied background and personalities. However, this type of fear reaction is usually completely identified by the patient and critical observers as related to the fancied perils of the moment. Again, some other patients have had a sense of fear associated with the particular experience

record evoked by stimulation (as in the case of J.V., cited above). This is also apparent in origin to the observers and occasionally to the patient himself. G.F. in another stimulation than the one cited in the discussion on "Involuntary Recollection", was conscious of an apprehension or a slight feeling of fear, when the street scene appeared to her as an involuntary recollection. She had been apprehensive in the original experience of which this is a record, because she felt her child might be hurt in the street traffic. In the original situation this sense of fear was the result of the rapid comparison of this experience with the record of her past experience of busy streets. This apprehension based on comparative analysis was different from the fear which she ordinarily experienced in her seizures and also from the feeling of fear which she noted following deep stimulation through Point 16 on the lateral surface of the temporal lobe. The difference is essentially one of degree in that the sense of fear which precedes an attack or which followed the stimulation just cited is more intense. Further, it is not associated with the context of a particular experience or situation.

It is interesting to speculate concerning the nature of this apprehension which occurs in some involuntary recollections following stimulation. Its existence might imply that there is not only a recording of the simple images and sounds as small sequences from past experience, but also the comparative judgments made at the time of the past experience.

However, in the six examples of fear following electrical stimu-

lation which we are presenting in this section, none are associated with recollection. The case of B.S. will serve as an example. She was a young woman of thirty-five years at the time of craniotomy. When she was seven years old she began to have attacks associated with fear. It is interesting that she had what she called "frights" from the age of three to seven years and that her first attack began after she had been frightened. At operation her left temporal lobe was exposed. Stimulation with 2 volts at a depth of 1½ cm. to Point 20 on the lateral surface anteriorly caused the patient to say, "..... like the feeling before an attack ..... stronger than most of them ...." When asked to describe what she meant, she said she thinks the feeling is in her head and is a frightened feeling. She amplifies this by saying it is a disconnection ....." You are thinking along, then there is a sudden gap". When asked, she said, "This is not a feeling of fear because I am going to have an attack, it is a feeling of fear which is independent of myself."

In another case, R.W., stimulation with 3 volts on the superior surface on the left caused the patient to have an attack characterized by staring, lip-smacking, swallowing and stiffening of the arms and legs. He was confused afterwards for a few seconds and then was able to say that he had had a scared, "lonesome feeling" before the attack began. This was quite similar to that which occurred in his spontaneous seizures.

These patients and the other four in the series were afraid without reasonable cause. They understood that there was no reasonable cause for the fear. We may say that they had illusions of fear.

These are not the feelings of fear which follow insular stimulation, where the patient has a definite epigastric or thoracic sensation as in the case of N.K., who when stimulated on the anterior portion of the left Island of Reil with 4 volts said she felt the fear " in her chest". It is easy to understand a patient associating epigastric, abdominal and precordial sensation with fear. The normal individual who has been startled frequently feels a quick epigastric sense of movement. However, in the normal person, this sensation does not rise to the throat as it may following an epileptic discharge spreading from insula to the upper bank of the fissure of Sylvius.

The fear responses which we are considering in this section are not associated with any definite physical sensation or sensations. They are within the patient's mind and he knows the "feeling of fear" is false. This may be as much a false interpretation of present experience as a feeling of falling forwards and therefore it may be called an illusion of fear. Each"feeling of fear" evoked has been the same as that which occurred in the patient's spontaneous seizures.

EMOTION RESPONSES (Table IV)

Initial	Stim. No.	Coordinate	SF No.	Side	Summary	Voltage
					Lateral Surface	
P.G.	11	L 1-0	542	Rt.	He added further that he was afraid he was going to die and he explained that he felt that way during an attack.	
B.S.	20	L 1-2	585	Lt.	Stimulation at a depth of 1½cm. straight in, a short stimulus. Patient said "Yes". When asked what she meant, she said, "Like the feeling before an attack, stronger than most of them." When asked to describe what she meant, she said she thinks the feeling is in her head and is a frightened feeling. She amplifies this by saying there is a disconnection... "You are thinking along, then there is a sudden gap." When asked, she said, "This is not a feeling of fear because I am going to have an attack, it is a feeling of fear which is independent of myself."	2 v.
G.F.	16_6	L 2.5 -2	601	Rt.	Electrode introduced slowly from outside, stimulating all the way. Patient said at first, "Nothing". Then she failed to respond. Stimulus was turned off. She then said "She was dressed differently". When asked about this she said, "The nurse who was standing behind Dr. Everett seemed to be dressed differently, as though her dress was tight like a sheet." Then she said, "That is what is hard to put into words, that is what I notice in my attacks, the last thing that I notice." She then explained that that is the last thing that she remembers when she wakes up after an attack. Then she added that the fear goes with it. When asked if she felt it that time, she said "Yes". There was a marked depression in the electrographic activity observed in the electrocorticogram following this stimulus.	1½v.
L.R.	8	L 6-1	535	Lt.	The patient says that at the time of the last stimulation she became frightened. She had a feeling in her head and in her face. She was unable to speak and she thought this was very similar to her own habitual attack.	

Initial	Stim. No.	Coordinate	SF No.	Side	Summary	Voltage
					Fusiform gyrus	
G.P.	X	Fusiform gyrus	336	Lt.	Stimulation on the fusiform gyrus on one occasion produced a feeling of fright. She says she has felt it before, but does not think it was with attacks, and once again said she could not talk.	
					Superior Surface	
R.W.	11	Sup. Surf. 2-1.5	528	Lt.	On being asked, he said he had the scared, lonesome feeling. This obviously came at the beginning of stimulation.	3 v.

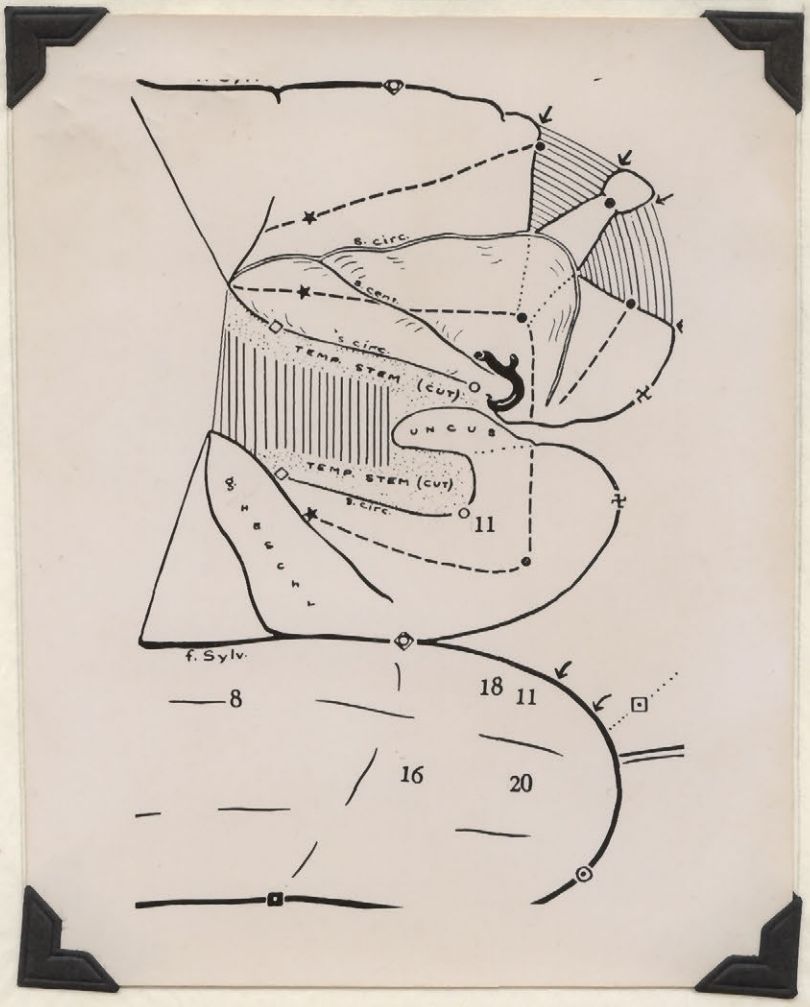
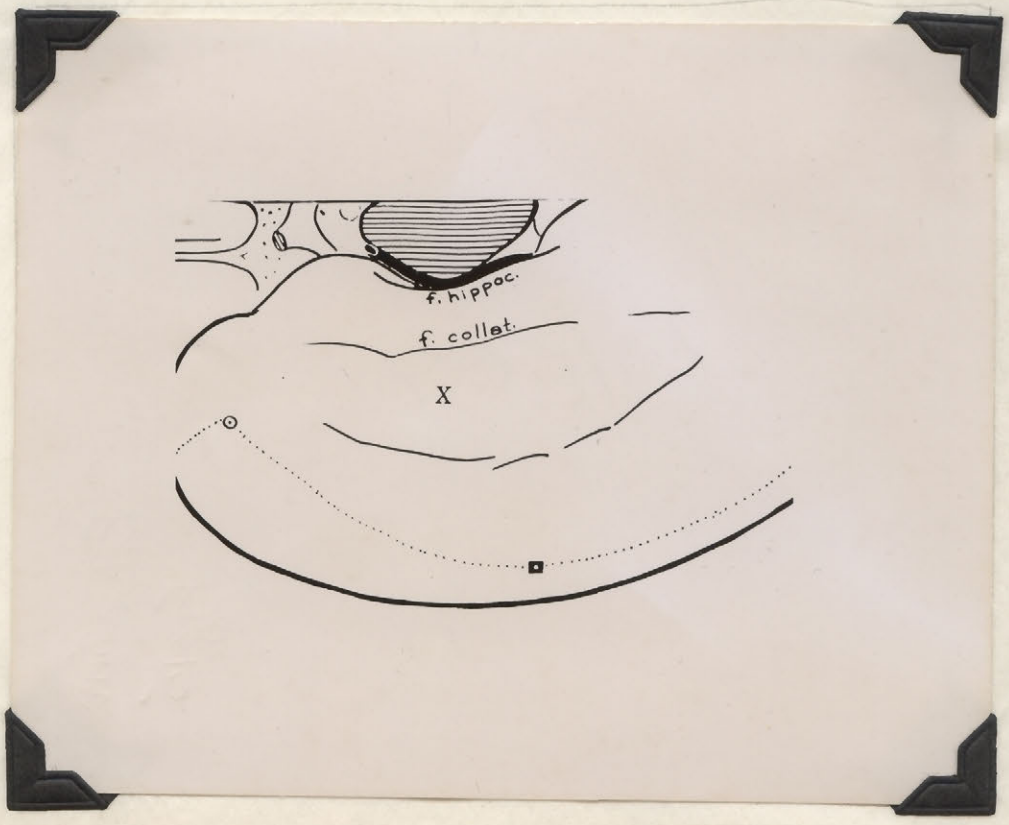


Fig. 15 - Emotion Responses.



RESULTS - B

A TECHNIQUE OF DEEP ELECTRICAL STIMULATION IN THE HUMAN TEMPORAL LOBE

In preceding sections we have presented the need for additional methods of deep stimulation and for other purposes outlined significant responses which have followed its use. Here we present an idea which may assist us in accurate determination of the location of the electrode point with reference to surface landmarks.

In the present technique a coated electrode marked off in cm. is held in the operator's hand and introduced through the lateral temporal surface to a desired depth. The direction of the electrode towards deep structure must be estimated at the time of insertion. Only long practice makes accurate stimulation possible, and it is difficult to describe these positions in accurate terms after operation. Also, it is difficult to calculate the position of the point in depth with regard to the entering direction, since the shape of the temporal lobe in cross section is roughly triangular, with the apex mesial and the base lateral. Therefore, if the electrode is inserted at right angles to the lateral surface it may enter the Sylvian fissure and stimulate middle cerebral vessels causing pain, or stimulate the insula and upper bank, producing a response outside the temporal lobe.

Likewise an insertion in the third temporal convolution may place the tip of the electrode on the floor of the middle fossa and cause sensation in the face from stimulation of the fifth nerve. These difficulties can always be avoided with practice but the

method is still not entirely suitable to accurate description for record purposes.

To provide a solution to these problems we suggest the use of a small electrode holder which slides on a thin, light scale calibrated in centimetres. Both holder and scale are held in position by a curved arm which can be fixed to the bony edge of the anterior temporal fossa with an adjustable clamp. The arm is curved in two planes and connects with the clamp and scale by means of rotating joints. The double joints provide mobility of the scale and the curved arm elevates it above the temporal cortex. A point has been placed on the anterior end of the scale. The purpose of this point is to fix the anterior limits of the scale at the anterior limits of the bony fossa. The long axis of the scale is then adjusted to a position which corresponds to our lateral measurement axis.

If the present model proves useful, it may be advantageous to curve this scale in direct correspondence with this lateral axis so that all measurements begin at the temporal tip. In that case the centimetre divisions would have to be altered proportionately.

For the present it seems practical to try a flat scale which can be held above the lateral surface at any desired height within the limits of the arm and joints. The artist has shown some of these features in Fig. 16. This drawing does not attempt to detail the actual electrode holder ring. This must have a universal joint connecting it with the slide which rides along the scale in order to permit free movement of the electrode in an angular direction. This

direction can be measured by means of a small angular scale divided in degrees. Our present electrode could be redesigned with a smaller shaft but it must retain the division of the shaft in cms. or other suitable measurement.

Thus we have an instrument which can be placed in a fixed position over the lateral surface of the exposed temporal lobe. If this position is calculated in terms of our lateral axis of measurement we can measure the position of the electrode in terms of this axis and then read the angle of insertion from the small scale in the electrode holder. The depth of insertion will be shown as before by the markings in the shaft of the electrode.

We must have some other means of charting the deep structures in terms of surface landmarks if we wish to use this instrument intelligently. This can be accomplished by making drawings of the temporal lobe as if it had been cut into cm. sections at the points of measurement along our lateral axis. Thus if we refer again to Fig. 2 which shows this axis, we will understand that it is possible to divide the lobe into sections making each cut at right angles to the axis across one of the cm. divisions. This provides a small sectional atlas of the temporal lobe in cm. sections. Each section is related to a measurement on the lateral surface.

If we consider the electrode holder as placed over an individual section, for example, the one cut at the 5 cm. point, we can see how it is possible to measure the depth and angular direction of the electrode point in terms of the known contents of this section. If these

sections are diagrammed as small individual charts, appropriately numbered as to level on the lateral axis, we then have a ready means of charting the position of our electrode point in that particular section. Sample drawings of these sections are shown in Fig. 17. The numbers on each drawing indicate the position on the lateral axis at which the corresponding section has been cut. The position of the electrode tip within each individual section can be estimated by the angle of the electrode shaft. The antero-posterior depth of each section is only 1 cm. and while this depth provides a slight source of error, this should not be too great.

Perhaps an instrument similar to that described will prove useful in deep stimulation of the temporal lobe. It should be particularly applicable to point stimulation of the amygdaloid nucleus, uncus and hippocampus from the lateral surface and might also be used in stimulation of the anterior visual fibers as they cross the ventricle.

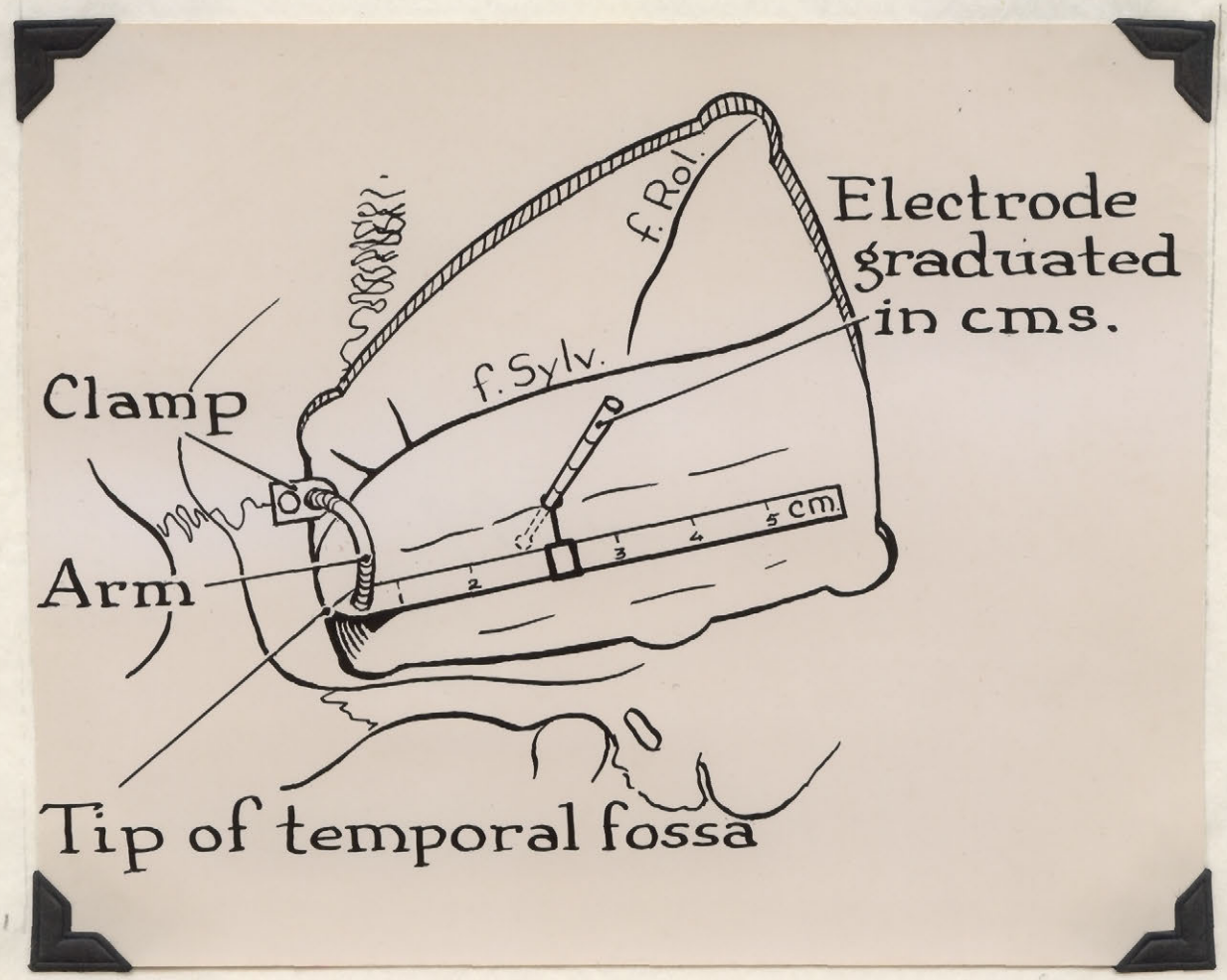


Fig. 16 - Electrode Holder to be used in Deep Stimulation.

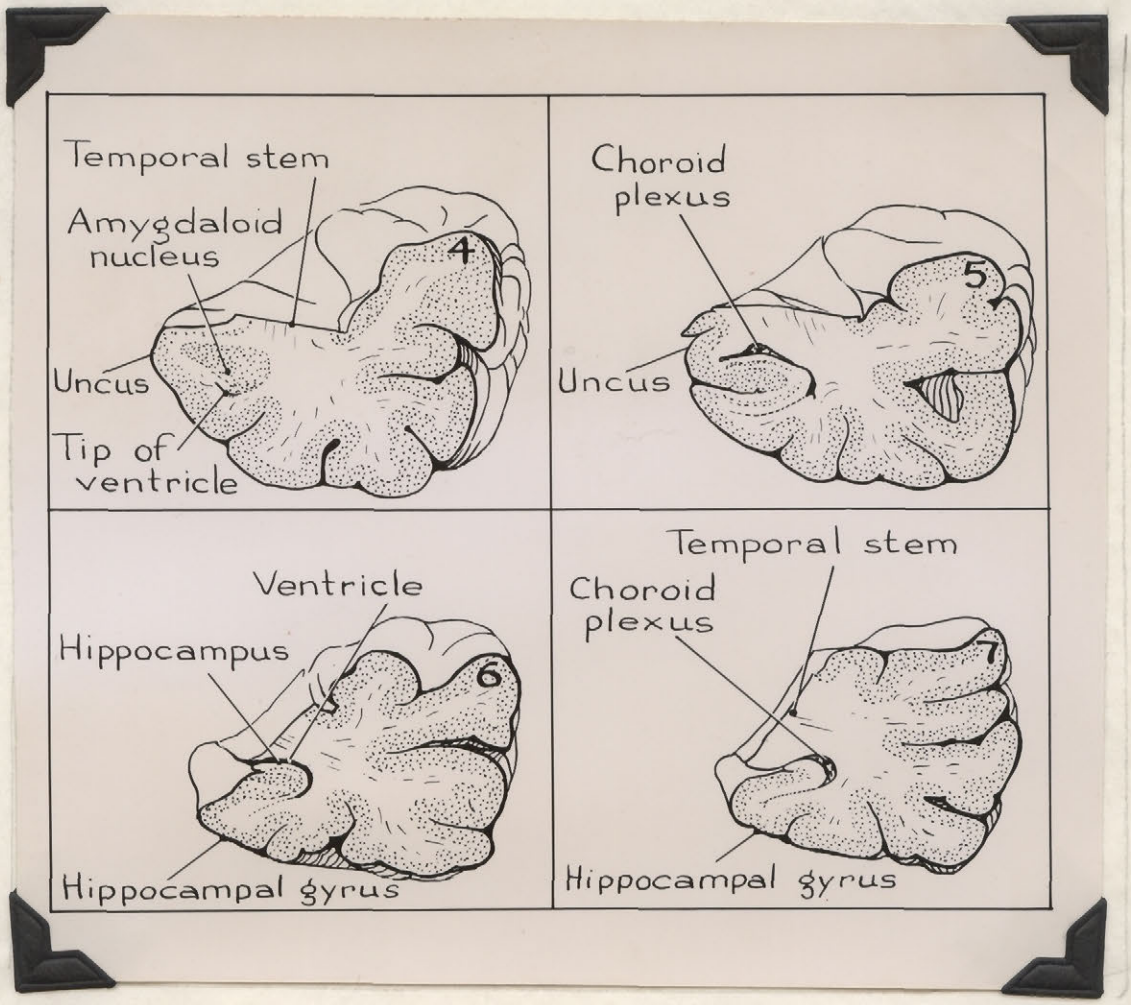


Fig. 17 - Temporal Lobe Cut into Sections at Points of Measurement Along Lateral Axis.

V. DISCUSSION

It seems clear that focal epileptogenic lesions in the human temporal lobe may produce seizures characterized by psychical illusions, psychical hallucinations and unusual behaviour. These lesions may occur in either temporal lobe and yet the seizures produced, whether their origin is in the right or left side, seem remarkably similar. We might say that this is presumptive clinical evidence that the temporal lobes are of equal functional value insofar as the functions distorted in these seizure patterns are concerned. What are these functions or functional representations whose distorted images we often see through the clouded lenses of disease ? In order to answer this question we must look once more at the qualities and characteristics of the illusions, hallucinations and unusual behaviour which clinicians include in their descriptions of temporal epilepsy.

Jackson has illustrated feelings of reminiscence, changes in the appearance of objects and feelings of strangeness and fear as part of the complicated pattern of the temporal lobe seizure. No matter how seemingly insignificant, transient or brief these mental experiences may be, they usually represent a disturbance in cerebral function caused by an epileptogenic discharge. Penfield has said that the illusions are psychical and are in fact brief alterations in the interpretation of present experience. Horrax emphasizes that the hallucinations which characterize temporal seizures are complex, both visual and auditory in content and that the patient understands that they are unusual. Clinically, then, they are complexes of imagery and sound which the patient examines in conscious inspection and classi-

fies as unreal. The content of the hallucinations is drawn from the past experience of the patient. This is emphasized by Jackson, Horrax and Penfield. The selection of the content which parades before consciousness is involuntary and results from the action of the epileptogenic discharge. So these are involuntary panoramas of images from the records of past experience, appearing briefly in the focus of consciousness.

This briefly reviews the evidence obtained from clinical studies of temporal lobe epilepsy. We can now recall the previous information derived from electrical stimulation of the human temporal lobe. Penfield and Rasmussen have reported a series of cases in which both involuntary misinterpretation of present experience (psychical illusion) and involuntary imagination (psychical hallucination) followed electrical stimulation of the human temporal lobe. They have also shown that involuntary recollection of past experience follows electrical stimulation of the human temporal lobe. We have presented a further series of cases which demonstrate these phenomena. In both groups, these illusions, hallucinations and memory patterns have been evoked from both the right and left temporal lobes.

Following stimulation, images and sounds may appear before consciousness in a sequence suggesting that we have activated a neuronal pattern, or a multisynaptic pathway. These images and sounds are individually complete, but as the stimulation progresses they are related in almost cinematic sequence to others, which follow. The images and sounds are not simple in design or tone. They are the figures of people, the music of an orchestra, the melody of a song.

All are within the range of the patient's past experience.

Similarly, psychical illusions have been evoked from these areas. These are misinterpretations or misjudgments of present experience. Sometimes this is a false comparative judgment of present experience in terms of past experience. Such a false judgment appears in consciousness as a strong feeling of familiarity or reminiscence. The patient knows the scene is not familiar because no recollection record appears for his conscious inspection. The misinterpretation of present experience is available for voluntary correction and this occurs almost simultaneously.

In these illusions we have listed several types, e.g., familiarity, awareness, a sense of dislocation, of posture, sound, etc. These have been evoked from either temporal lobe. It is interesting to speculate on the relation of each to function. We have shown that an illusion of familiarity is related to the mechanism of recollection, as a signal of its occurrence. Perhaps a sense of "increased awareness" may be related to function as well. This illusion seems to imply increased awareness of everything in the immediate environment or in some cases increased awareness of a particular object, as a chair or the edge of a table. In this instance the particular object must be within the focus of immediate consciousness. Since it is doubtful if we record anything in a distinct memory pattern on which the conscious attention can or does not focus for a time, why isn't it possible that we have activated (with the stimulating current) a pathway which is concerned in recording present experience and thus emphasized this process in consciousness. In other words,

we have activated the peripheral or cortical side of an already functioning pathway between a central integrating system and the recording cortex. The central system can and perhaps has already selected this pathway for a record of immediate experience and we have emphasized the cortical recording in consciousness. This would explain the " doubling of consciousness" of Jackson or the increased subjective consciousness of Kennedy.

The illusions of dislocation or unreality suggest another theory. Perhaps here we have (with the aid of an epileptic process) actually interfered with the recording of immediate experience, making the subject less aware of his immediate surroundings. Since similar psychical illusions have been evoked (in another series) from the insula as well, we might speculate that the interference is directed more toward the central integrating system than the cortical periphery. If this interference is more central than peripheral, then this is a very minimal dissolution of consciousness at the highest level.

On the other hand, the illusions related to sound seem more simple, and as they are usually evoked close to the auditory area they may be accepted as perversions of auditory perception, produced by the stimulating current. Similarly we would like to relate the illusions of posture to a disturbance of vestibular perception, but this is difficult in view of some of the locations (as in A.H.).

One observation is pertinent to all these involuntary misinterpretations of present experience and perhaps to the various involuntary recollections of past experience as well. That is the speed with

which the individual recognizes that the judgments are false and the recollections involuntary and unrelated to present experience. In other words, to the observer at least, the patient seems to know the character of the experience as soon as it happens. This suggests a very direct pathway between the recording cortex and the central integrating mechanism. It makes one want to postulate a monosynaptic relay.

We have concluded that records of past experience lie in the temporal cortex. These are not always available for voluntary recollection, but when evoked by electrical stimulation are always available for conscious inspection. They have been evoked from either temporal lobe. Often a memory evoked from one temporal lobe has been available for voluntary recollection after excision of that lobe. If one can evoke these from either side and the same recollection pattern appears for voluntary recollection after its stimulation origin has been excised, it seems reasonable to suppose that records of past experience lie in both temporal lobes.

We have shown that involuntary misinterpretation of present experience, imagination and recollection of past experience have followed electrical stimulation of either temporal lobe. It seems that these bilateral representations are available to consciousness and are closely coordinated in their functions. Bailey and Fulton, Cairns, et al., as well as Penfield and Rasmussen, have presented clinical evidence which shows that central lesions, those in the upper brain stem, usually produce marked alterations in consciousness. Penfield and Jasper have shown that epileptic discharge arising here is always followed by an immediate loss of consciousness. This is the transient

dissolution of the highest level originally proposed by Jackson, Marsan, Stoll and Jasper have presented significant evidence for functional connections of the temporal lobes with the upper brain stem, and the work of Starzl, Taylor and Magoun substantiates this in showing the existence of a centrally placed integrating system which activates the cerebral cortex in various areas.

From all this and our present evidence we may conclude that the bilateral representation of the records of past experience and the mechanisms for interpretation of present experience which lie in the temporal lobes are connected. This connection is central, serving both sides and is intimately concerned in the mechanism of consciousness.

The interpretation of present experience must be based on the initial reception of a multitude of sensory data. This data must be integrated and some selection made so that the most essential facts are presented to consciousness. A pattern of appropriate past experience must also be selected and in turn compared with this data. It seems reasonable to infer that these selections are made by the central system since it is associated with maintenance of consciousness and is connected to each temporal lobe. Furthermore, it has sufficient cortical connections to permit reception of sensory data from widely separated areas.

This evidence suggests the existence of a functional system composed of the two temporal lobes, one on each side and a central mechanism between. The central mechanism is intimately concerned with the maintenance of consciousness and the reception of incoming sensory

data. It can also select record patterns from either temporal lobe for comparison with the data of present experience or open new pathways in the temporal cortex for the recording of experience within the immediate focus of consciousness. Once the latter records have been made, they in turn become available for future selection (by the central mechanism) and comparison with more immediate experience.

Conscious or voluntary selection by this mechanism may also involve elements from several separate acquired patterns. This selection permits comparison or integration of these elements in consciousness and leads to what we have called imagination. This differs from recollection in that it is more random and the images are less specific in detail. Also they do not recall a precise record of actual participation in past activities. If this more random selection is continued by voluntary effort or by artificial electrical stimulation of the cortex at one periphery of the system, actual recollection of a past experience related to the preceding images may occur. This continuation suggests that the scenes of imagination are in fact drawn from acquired patterns which record past experience and that one of these patterns has been entered by the stimulation or the circuit of central selection.

It has been necessary to emphasize the evidence for a central integrating system because we believe that this forms an essential element without which these temporal functions are impossible. However, we are not primarily concerned with the hypothesis of a 'highest level' here. This has been accurately presented by Penfield, and Penfield and Rasmussen, and constitutes one of their most important

contributions.

Here we are directly concerned with the functional role of the temporal lobe in this system. On the basis of our evidence drawn from the results of electrical stimulation we can state that the primary functional role is the recording of present experience. This implies that the grey matter of the covering mantle in this region has a peculiar property which enables it to establish acquired or new neuronal patterns. Undoubtedly there is transcortical connection between these systems because we have watched stimulation in which involuntary imagination preceded recollection of related but more specific data. However, the principle connection for purposes of selection and comparison is central and not transcortical.

These records extend over a wide cortical area stretching from the anterior temporal pole to the occipito-temporal junction. This implies that all this cortex has the property of establishing acquired patterns. Further, this cortical area is bilateral and of equal functional value (with the exception of speech skill in the dominant hemisphere) on either side.

These are cortical regions of high functional value, therefore we might expect significant changes following their removal. In our present series we cannot yet make a definitive conclusion concerning functional loss after ablation. However, we may say that many patients after unilateral temporal lobectomy show a transient memory defect and some have abnormal mental experiences which also seem transient. A physician who underwent temporal lobectomy for focal cerebral seizures described his mental experience after opera-

tion in some detail. He said that nothing in the immediate environment seemed real to him. Also he had great difficulty in remembering daily occurrences on the ward. He felt that this difficulty in remembering was due to his feeling that all these occurrences were slightly "unreal". Perhaps this is his subjective expression of a temporary inability to record present experience. It is also interesting to relate it to our previous discussion of illusions of individual dislocation or "unreality". In any case, it is significant that his difficulties were transient, since we might conclude that the opposite temporal lobe had taken up the full burden of function after a period of adjustment.

The information on functional deficits following temporal lobectomy in monkeys is more definite than that derived from present human studies. Kluver and Bucy said that monkeys had "psychical blindness" after bilateral temporal lobectomy. These monkeys ate or tried to eat objects which were inedible. Previous to lobectomy they had been extremely afraid of snakes, but afterwards fondled them and tried to eat them. We would say that this "psychical blindness" was really a loss of ability to interpret present experience in terms of past experience. The monkeys had lost their ability to make accurate comparative analysis of past and present experience. They lacked judgment. It is interesting that the only human whom we have observed after bilateral temporal lobectomy did not show this deficit to such a marked degree. Perhaps it may be necessary to remove all cortex with the special properties of establishing acquired patterns in the human, in order to produce so marked a deficit as followed lobectomy

in the monkeys. This was not done in the latter case. Further evidence after temporal ablation in monkeys may be found in the work of Blum, Chow and Pribram. These workers report that after temporal lobectomy the animals showed marked deficit in 'visual discriminative learning, patterned string problems, conditional reaction, and delayed reaction and changes in taste preference, in food selection and in tractability'. These animals could not interpret the immediate environment or present experience, and had lost the ability to compare past records of feeding preference with present feeding experience. Their comparative analysis of present experience with past was also deficient.

This state of "psychical blindness" is seen in a more acute and dramatic form in patients who exhibit automatic behaviour. In our experience this is most commonly the result of epileptic discharge arising in, or electrical stimulation of, the amygdaloid nucleus and surrounding structures. For present purposes it is useful to theorize on this mechanism. The patient who suddenly, stares, inspects his clothing in a random fashion, as if he had never seen it before, or picks up a knife and carefully sections a tablecloth which he then attempts to eat as if it were a sandwich, is said to show signs of automatic behaviour. These activities cease quickly and he does not remember them afterward. Perhaps we could argue that this is not only a partial dissolution of consciousness but also a temporary depression of the temporal system which records and interprets present experience. The epileptic discharge or electrical stimulation aided by the discharge has briefly paralysed the temporal circuits con-

cerned with comparative analysis of present experience. Of course it has also affected the central integrating system, but we are concerned here with its possible effect on the temporal lobe. At any rate it is reasonable to say that these patients are "psychically blind" for a brief period and that this psychical blindness may be due to a transient inability to interpret present experience, just as Kluver's monkeys had a permanent inability to make similar interpretations.

After consideration of our evidence and the related hypotheses, it is possible to reach final conclusions concerning the primary functions of the human temporal lobes. The primary function of these areas is that of comparative analysis of present and past experience. Perhaps we might call this comparative judgment, or simply, judgment. We may say that this is the place of dreams and memory, imagination and learning, but all this serves no useful purpose unless it is available in ready reference for comparison with the data of immediate experience, so that a critical and comparative judgment follows. An essential part of this mechanism lies in the temporal lobes and it is activated and controlled by a centrally placed integrating system.

VI. SUMMARY

We have shown that electrical stimulation of either temporal lobe in the conscious patient may be followed by involuntary recollection of past experience or involuntary misinterpretation of present experience. These phenomena have been discussed against the background of previous clinical and scientific work.

From this evidence we conclude that the primary function of the human temporal lobe is the comparative analysis of present experience in terms of the records of past experience. Each temporal lobe has equal value in this function and the two are coordinated by a centrally placed integrating system. The comparative analysis is rapid, and consists of comparison of material stored in acquired patterns (in the temporal cortex) with the sensory data of immediate environmental experience received and selected by the central system.

Comparative analysis of this type is a form of critical judgment of present environment based on the records of past experience.

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