ALTERATIONS IN SPEECH PRODUCED BY CEREBRAL STIMULATION AND EXCISION

by

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My debt to Professor Wilder Penfield cannot be expressed by the mere use of speech! His inspiration and direction, as well as the actual use of his cases, has made this work possible. It is almost impossible to think independently when closely associated with a man such as he. Nonetheless, an attempt has been made; and the author realizes that all of his conclusions probably will not be shared by his "chief".

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I. INTRODUCTION

The stimulation records of these five hundred and seventy-five patients have been made by Professor Wilder Penfield and his associates in a most meticulous way. The case records, however, leave much to be desired as regards the aphasic (or, if one desires, dysphasic) disturbances. The cases personally observed have been used to determine the type of disturbance; only whether any disturbance is present or not is noted in the others.

In 1946, Dr. Preston Robb summarized in his thesis the effect on speech of excising various cortical areas in some of these cases. He also began assisting Dr. Penfield in the operating room during the period of stimulation. The author took over this work in 1948.

The following represents an attempt to fulfill the requirement of "a clear statement of the author's claim of original work or contribution to knowledge". In his previous thesis (1949) the author presented the effects on speech of cortical stimulation. The only additions since that time are the production of misnaming without perseveration in the left Broca's and supplementary motor areas and an increased number of "aphasic types of responses" in the supplementary motor area during electrical arrest. The Rolandic regions of both hemispheres and the right supplementary motor area function

only for the motor control of speech organs. The left Broca's, parieto-temporal and supplementary motor areas all have the same function in relation to speech.

A subcortical area functions with Broca's, parieto-temporal and supplementary motor areas during the psychical act of speech. Limited excisions of any part of the left hemisphere may be performed without producing a permanent speech defect; the left hemisphere still functions during speech. When the left hemisphere is completely destroyed, relearning of speech may occur during activity of subcortical structures or of the right hemisphere; or the patient remains permanently aphasic.

The left hemisphere is dominant in practically all patients regardless of handedness. Defects in speech produced by lesions of the right hemisphere differ from those occurring with disease of the left hemisphere.

The well-known clinical syndromes of various aphasic difficulties occurring as a result of lesions in particular localities may be due not to the lesions themselves but to the discharging abnormal brain within or surrounding the involved cerebral tissue. This concept necessitates a slight modification of Jackson's concept of the positive and negative effects of cerebral lesions.

II. REVIEW OF LITERATURE

A. On Aphasia

In 1861 considerable argument waged between those who believed the brain functions as a whole and those who contended there is localization of function in the cerebrum. Gall (1810-1819) had done some excellent work on the anatomy of the brain but was criticized for his unscientific system of phrenology. Bouillaud (1825) maintained, on the basis of examination of brains of patients who had had loss of speech, that the cerebral control of movements necessary for speech resided in the frontal lobes, in support of Gall. Against the teachings of Flourens (1824) that all parts of the cerebrum were equipotential, he also pointed out that paresis of one part of the body as the result of a cerebral lesion could not occur were this true. At the time Broca presented his first case in 1861, Bouillaud was one of the outstanding physicians in Paris and head of the Charité.

It is true that Marc Dax had read a paper in Montpellier in 1836 stating that loss of speech was associated with right hemiplegia and therefore due to a lesion of the left hemisphere. However, this was unknown in Paris as the paper was not published by Dax's son until 1865. It should be emphasized that the discovery of the motor area in animals by Fritsch and Hitzig was not until 1870.

Paul Broca was secretary of the Société d'Anthropologie in 1861 when these heated discussions occurred. He was a surgeon and an excellent anatomist. He believed in the principle of localization chiefly based on the embryological and anatomical work of Gall, Gratiolet and himself.

Broca had a patient, Leborgne, who was to serve as a test case. This 51 year old man had had seizures since his youth. At the age of 30 he lost his speech (the circumstances of which were unknown), and was admitted to Bicêtre. He was only able to say "tan" and to curse "Sacré nom de D. . .". His companions detested him and even called him a thief. At the age of 40 he gradually developed paralysis of the right arm and leg and by the age of 44 became bedridden. Over the last ten years he had increasing difficulty in vision. His sheets were changed once a week and it was discovered that he had a diffuse cellulitis of the right leg; because of which he was transferred to the service of Broca.

On examination he had no movement of the right arm and leg. His left cheek was blown out more than the right on whistling. He had difficulty in swallowing. There was decreased sensation to pain over the right side. He could not write. He was able to indicate the length of time he had been in Bicêtre, could tell the time, and gave the order of appearance of his difficulties (pointed to mouth, then right arm and leg). Some of the things a normal person could have indicated by pantomime, he could not. His only speech was

"tan" and swearing.

The brain weighed 987 grams. The orbital and first frontal convolutions were atrophic, but there was no break in the surface of the cortex. A cystic cavity occupied the posterior part of the third frontal, with the adjacent part of the second frontal and precentral convolutions. The ascending parietal, angular, first temporal, and part of second temporal gyri, and the insula were also involved. Through a hole into the ventricle, accidently made by Broca, the corpus striatum was seen to be softened.

The second patient of Broca was an 84 year old man named Lelong. He was transferred to Broca's service because of a fracture of the left femur. Nine years and a half before, he had had loss of consciousness from which he recovered in a few days without paralysis but with "aphemie". He was admitted to Bicêtre eighteen months later with senile debility, feebleness, tremor, and inability to work or to write. His sight, hearing, motor power (except in fractured extremity) and sensation were normal. His only words were "Oui, non, tois (trois), toujour and Lelo (Lelong)." When asked if he knew how to write, he replied "Oui"; if he could write, "Non". When he tried, he was unable to manage the pen. He indicated that he had been in hospital eight years, that he had two sons and two daughters, that he was 84 years old, and that it was ten o'clock; but he always used the word "tois". He makes gestures of digging and planting to indicate his former occupation.

Lelong died 12 days after the fracture. His brain weighed 1,136 grams. There was a collection of fluid about the size of a franc over the posterior part of the third frontal convolution. This convolution was cut in half two centimeters from its posterior end, and loss of substance extended over 15 millimeters. The cortex of the second frontal convolution was only two millimeters thick. There was a separate lesion of softening at the junction of the anterior end of the corpus striatum with the white matter of the frontal lobe.

On the basis of these two cases Broca contended that the center for articulate speech is the third frontal convolution. He stated that anteriorly or posteriorly in the frontal lobe may not be important, but it is the third convolution. Pierre Marie (1926) has criticized these two cases by implying that Broca did not give the full anatomical descriptions of the surface lesions in the first case and that there was only the expected appearance of senility in the second. Neither of these criticisms is valid. The two most important criticisms are that there is no proof of Broca's supposition that the lesion of the third frontal convolution was the oldest in the first case and that neither brain has been cut so that any anatomical conclusion is unjustifiable.

At any rate these cases caused almost everyone interested in neurology to participate in the reporting of new material and to discuss localization. According to Broca (1888),

Charcot reported the next three cases and Gubler another of disease of the third frontal convolution with "aphemie". Charcot and then Trousseau found lesions of the parietal lobe with "aphemie", but Broca discovered a lesion of the third frontal gyrus in each. Then Charcot reported two more lesions of the third frontal convolution with speech disturbance. The preceding ten cases all involved the left hemisphere. Levy had a patient with a lesion of the same area on the right side without speech disturbance, and Charcot reported "aphemie" with a lesion of the left parietal lobe to which Broca agreed.

Broca stated that the fundamentals of speech consist of 1) an idea; 2) connection which convention has established between idea and word; 3) the art of combining movements of organs of articulation with the suitable words; and 4) the use of the organs of articulation. Loss of ideas is termed "alegia". Loss of conventional connections between idea and word is "amnésie verbale" of Lordat. Patients with this disorder use words which have no connection with the idea; they have forgotten the special memory of spoken and written words; but they still have memory as they recognize objects, places and persons. Loss of the art of combining movements of organs of articulation with the suitable words is "aphemie". These patients may have no words, few words - particularly curse words, strange words in no vocabulary, or a more extended vocabulary. Distinction between this patient and the previous

one is that he understands what is said to him. Damage to muscle, nerve or brain controlling nerve is "alalie mécanique". Broca criticized Trousseau's substitution of "aphasie" for "aphemie" in that "aphasie" meant without phases of the moon or brightness, or without ideas (Plato). According to Trousseau, the Greek meaning of "aphemie" in 1861 was infamy. Broca later suggested that the indefinite term "aphasie" be used for indefinite cases as M. Trousseau had used it with his inexact descriptions; and if the case be classifiable it would be one of the four preceding. However, Broca admitted that he had diagnosed "amnésie verbale" and found a lesion in the same place as for "aphemie".

Following the French school, the English and Germans took up the study of aphasia (the term to come into general use). In 1867, Ogle published a case of a man who could write things that he could not say (agraphia) and suggested that writing was separate from speech. Bastian began writing on aphasia in 1869 and continued for some 30 years. He was the first to describe "word-deafness" and "word-blindness". The former is supposed to be a condition in which the patient is not deaf but is unable to recognize a word as such, and the latter is a similar condition in which the patient is able to see but cannot recognize a word. Bastian believed that one thinks in words and that there are different specific centers with fiber connections: auditory and visual word centers,

"glosso-" and "cheiro-kinesthesic" centers. He stated that destruction of Broca's area produces loss of kinesthetic memory. He traced the development of speech in the child just as Broca had done (and numerous others since) and believed the auditory word center to be the most important.

Wernicke (1874) published a monograph of 72 pages in which he emphasized the work of Meynert in tracing sensory pathways, particularly visual, to the cortex, and the experiments of Fritsch and Hitzig. He believed that the anterior half of the brain is concerned with the concept of movement and the posterior (including the temporal lobe) with sensory impressions; the cells of the cortex are neither motor nor sensory but depend on their connections to determine their function. He separated the general auditory from the auditory speech area and located the latter in the first temporal convolution. A lesion in the auditory speech area would produce loss of understanding of speech; difficulty in naming and speaking as one could not understand in order to correct the mistakes; as well as inability to read and write due to the learning process of hearing words while reading and writing (though an educated person might be able to read silently though not aloud). There are various degrees of difficulty in understanding; there might be loss of "Klangbilder" or just loss of "Bindewörter" for sentence formation. He drew a diagram with the centers located: auditory speech in first temporal; Broca's,third frontal and writing, second frontal gyrus. Wernicke proceeded to give ten cases, only three of which had autopsies and these showed diffuse lesions; however, he was

satisfied that the auditory word center is in the first temporal convolution!

Kussmaul (1877) desired to make word-deafness and word-blindness separate entities. He accepted the work of Finkelnburg (1870) who pointed out that patients with cerebral lesions may have disorders not directly connected with word formation: "asymboly" is the inability to express ideas by means of signs together with lack of understanding of their significance. Kussmaul, therefore, thought that speech could not be located in one or another particular convolution. Nonetheless he proceeded with a very complicated diagram. This diagram was not received as well as that of Broadbent (1878) with its naming and propositionizing centers as well as visual, tactile, auditory and speech centers, or that of Lichtheim (1885) with its visual, auditory, writing, motor and multiple concept centers. The cases, however, could not be fitted into any of these schemata.

Hughlings Jackson (1931) stressed the fact that speech is a psychical act; and warned against classifications which are partly anatomical and physiological and partly psychological. "These mixed classifications lead to the use of such expressions as that an <u>idea</u> of a word produces an articulatory <u>movement</u>; whereas a psychical state, an 'idea of a word' (or simply 'a word') cannot produce an articulatory movement, a physical state".* "To coin the word verbalising to include all ways in which words serve, I would assert that both halves of the brain

* p. 156

are alike in that each serves in verbalising. That the left half is evident because damage of it makes a man speechless. That the right does is inferrible, because the speechless man understands all I say to him in ordinary matters". (p. 132) "When we consider more fully the duality of the Verbalising process, of which the second 'half' is speech, we shall try to show that there is a duality also in the revival of the images symbolised; that perception is the termination of a stage beginning by the unconscious or subconscious revival of images which are in effect 'image-symbols'; that we think not only by aid of those symbols, ordinarily so-called (words), but by aid of symbol-images. It is, I think, because speech and perception are preceded by an unconscious or subconscious reproduction of words and images, that we seem to have 'faculties' of speech and of perception, as it were, above and independent of the rest of ourselves". (pp. 167-168) "I think that the left is the side for the automatic revival of images and the right the side for their voluntary revival - for recognition." (p. 142) "Thus, very sudden and very extensive damage to any part of the left cerebral hemisphere would produce some amount of defect of speech, and I believe that similar damage to any part of the right hemisphere might produce some defect of recognition". (p. 142)

Jackson believed that the destruction of Broca's area produces aphasia but he did not localize speech in any particular part. He thought the nervous arrangements of

Broca's region represented movements of tongue, palate, lips, larynx and pharynx.

He stressed the fact that the aphasic has lost propositional speech but may have emotional speech, recurrent utterances and, rarely, propositions. He believed that these are mediated through the right hemisphere as well as "jargon", which is the survival of the fittest under the circumstances. Again Jackson stated that a lesion does not produce positive symptoms but the activity of a lower level released from control of the higher level gives the positive effects. The negative condition consists of inability to speak, to write (he is able to copy and frequently sign his name), to read; and pantomime is defective. The patient's positive symptoms are ability to understand what is said or read to him; to move his articulatory organs well in eating, drinking and in such utterances as remain possible; to use his vocal organs; and to use emotional language.

Jackson described the first case of partial imperception in a patient who at times did not recognize objects, persons, or places and who put her clothes on backwards. She had several tumors in the right temporo-occipital region.

Certainly Jackson's contributions to the understanding of aphasia were great but they are difficult to evaluate because he rarely presented cases for the reader to analyze, but illustrated his views with excerpts from cases; and because his thoughts were so influenced by Spencer.

In 1873, Ferrier (1886) localized the auditory center in animals in the temporal lobe. Munk (1877) determined the visual cortex to be in the occipital region of animals and demonstrated "mind-blindness".* These animal experiments had profound effects upon clinical interpretations.

In 1881, Dejerine (1914) stated that word-blindness is due to a lesion of the angular gyrus and later maintained that a lesion of the angular gyrus produces word-blindness, total agraphia and paraphasia. At the same time Exner maintained that the second frontal gyrus is the writing center in agreement with Wernicke. Mills (1895) placed a naming center in the third temporal convolution. All of these contentions were based on totally inadequate materials.

The interest in aphasia decreased at the beginning of this century - probably because of the difficulty of fitting the individual case to the various schemata - until Pierre Marie (1926) wrote: "La troisième circonvolution frontal gauche ne joue aucun rôle spécial dans la function du langage." **

*As Lashley (1948) pointed out Loeb denied the interpretation that vision was intact in Munk's animals and considered the visual field to be narrowed, and this was confirmed by the experiments of Hitzig.

**"The left third frontal convolution does not play any special rôle in the function of language".

Dejerine was the leader of the opposition. Marie's basic criticisms were that the anatomical material was not adequate to allow the conclusions drawn and that the clinical testing of the patients had been insufficient. He maintained that all aphasics have some defect in comprehension; they may be able to respond adequately to simple questions but fail on the more complicated ones (e.g. test of three papers). In addition he stated that general intelligence is lowered; the patient is by no means demented but he is unable to do some things not directly related to speech: for example, solving simple arithmetic problems or cooking an egg by a "chef". He correctly emphasized the fact that the patients Broca reported were not able to understand everything and were unable to write (ability to read was not stated in Broca's first two accounts). Marie maintained that Wernicke's aphasia is the true aphasia; the patient comprehends speech insufficiently, speaks poorly with paraphasia and jargon, is unable to read and write, and presents a particular intellectual deficit. He defined anarthria as not only a difficulty in articulation due to a disturbance in movement of the anatomical parts concerned in speech, but also a loss of control of those acts directly necessary for the production of speech; and stated it is equivalent to the subcortical motor aphasia of Pitres and is due to a lesion of the "lenticular zone" of either hemisphere. Broca's aphasia is therefore Wernicke's aphasia

plus anarthria. Marie was able to present a case of a right-handed man who was blind from glaucoma and was violent and demented but who presented no difficulty in speech; the lesion at autopsy destroyed the posterior part of the third frontal convolution.

In the "Discussion sur l'aphasie" at the meetings of the Neurological Society of Paris (1908) Madame Dejerine showed that the lenticular zone of Marie contains fibers from Broca's area. The discussions centered around Marie's concept of anarthria and the function of the third frontal convolution; and they failed to emphasize the more important criticisms of Marie of the nature of aphasia and the inability to localize the pure psychical images necessary for speech.

Monakow (1897-1914) introduced the concept of diaschisis to explain the temporary effects of a cerebral lesion. This constitutes the lowering or abolition of activity of those cells in uninjured areas which are in direct anatomical and physiological connection with the local area of injury. This is not the generalized effect of shock but a specific localized condition. In recovery, the effects of shock and edema first pass off, then those of diaschisis (over a period of weeks or months); the oldest most organized activities return before the more complex. With this concept, Monakow localized areas the destruction of which produces definite clinical syndromes but insisted there are no centers.

Henschen (1920-1922) became the foremost proponent of cerebral localization. He reviewed the literature on aphasia which consisted of about 1350 cases. He deplored the lack of clinical and anatomical data but, nonetheless, drew the most extravagant conclusions from these same cases. His contribution was great though in making available the summaries of all these cases.

Pick (1913) and Head (1926) emphasized the importance of Hughlings Jackson's contributions to the study of aphasia. Head maintained that a cerebral lesion produces more than a disorder of speech (in those cases where speech is affected) and designated "symbolic formulation and expression" to be what suffer in these cases. He insisted that the word is not the unit of speech. "Not only is it impossible to break up a word into auditory and visual elements, but disease does not analyse a sentence into its verbal or grammatical constituents. We cannot assume that a sentence is strickly a unit of speech. Speech, like walking, is an act of progression." (vol. 1, p. 120)

Head divided aphasia into four groups: verbal, syntactical, nominal, and semantic. The most original of these was the semantic aphasia, which he defined as follows: "These defects are characterised by lack of

recognition of the full significance of words and phrases apart from their immediate verbal meaning. The patient fails to comprehend the final aim or goal of an action initiated spontaneously or imposed upon him from without. He cannot formulate accurately, either to himself or to others, a general conception of what he has been told, has read to himself, or has seen in a picture, although he is able to enumerate most of the details. Such patients understand what is said, can read and can write, but the result tends to be inaccurate and confused. Counting is possible and the relative value of coins may be recognized, but arithmetical operations are affected and the patient is commonly confused by the monetary transactions of daily life. Drawing even from a model is usually defective and in most instances construction of a simple ground-plan is impossible. Orientation is definitely disturbed. The patient finds considerable difficulty in laying the table, putting together portions of some object he has constructed, or in planning an operation he desires to perform. This interferes seriously with his activities in daily life and renders him useless for any but the simplest employment; and yet his memory and intelligence may remain on a comparatively high general level." (vol. 2, pp. xix and xx) Head found these various disturbances in several patients, but they may occur separately and it is difficult to determine why he called these psychical disorders a type of aphasia. As he pointed out they may occur with damage to the right hemisphere.

Head's work would have been more valuable if he had not felt it necessary to indicate the site of the lesion which would give the different types of aphasia he described. He based this classification on only 11 cases. All were gunshot or shrapnel wounds except one with a compound skull fracture from the kick of a horse. The accuracy of the localization without the benefit of autopsy or cortical stimulation is extremely doubtful. Subsequent authors have not agreed with this classification.

Wilson (1926) gave a clear, concise exposition on aphasia which embodied the theory of association areas with only cortical connections. Aphasia is, physiologically, a disorder of transcortical mechanisms (Jackson's highest level) which play on those of the cortical projection class (Jackson's middle level). Actually it seems that Wilson was accepting most of the old concepts of thinking with words alone and of localization.

Goldstein (1948) began writing on aphasia shortly after the turn of the century and continued for over forty years. He applied the principles of Gestalt psychology to the study of brain lesions. He stressed the loss of the abstract with retention of the concrete, and the avoidance of catastrophic conditions in the aphasic. Von Kuenburg (1930) demonstrated in her testing of classification of colors and of objects that normal behavior is not controlled always by "categorical principle". Myers (1948) found no statistical difference in

the ability to solve a multiple choice problem between patients with receptive aphasia, those with lesions of the non-dominant hemisphere and those with lesions outside the brain. It does not seem that the problems of aphasia have been solved by Gestalt psychology. Also Goldstein's (1948) eight cases with autopsy had such diffuse lesions that they are of little value in anatomical localization.

Weisenberg and McBride (1935) criticized some of Head's (1926) tests on the basis that they cannot be done by all normal subjects. They presented an excellently controlled study. Aphasia is divided into four groups: predominantly expressive, predominantly receptive, expressive-receptive and amnesic. Gross or diffuse lesions were present in their cases.

Nielsen (1936-1947) is the current champion of the precise localization school.

Schiller (1947) summarized a study of 46 convalescent cases of penetrating missile wounds. He listed articulation, inflection, bradyphasia, paraphasia, jargon, telegram, syntax, perseveration, nominal, auditory comprehension, visual comprehension, spelling, construction, calculation, and apraxia; and stated that disorders of the former half give place to those of the latter half as the site of the wound becomes more posterior. Nominal aphasia was present in almost all cases, regardless of location of injury. He suggested a classification as frontal, fronto-temporal, etc., types of aphasia.

Guttman (1942) pointed out that aphasia does occur in children. Critchley (1938) reported "aphasia" in a partial deaf-mute and demonstrated the deficiency in the use of sign language.

Before considering the literature on agnosia and apraxia it should be concluded that there is no consensus as to the nature or cause of aphasia or the site of lesion in different types of aphasia (or, if one prefers, dysphasia).

Because the author does not believe anything fundamentally different has been presented by them, he is only going to mention the following: Hammond (1871), Cross (1872), Barlow (1877), Ball (1881), Heilly and Chantemese (1883), Bernard (1885), Hartmand (1889), Starr (1889), Freud (1891), Gowers (1893), Shaw (1893), Elder (1897), Bramwell (1898), Bernheim (1900), Bianchi (1910), Smith (1917-18), Kleist (1934), Zucker (1934), Kennedy and Wolf (1936), Klein (1937), Lhermitte (1937), Austregesilo (1940), Cobb (1943), Teitelbaum (1943), Alajuanine (1948), Alford (1948), Ajuriaguerra and Hécaen (1949) and Zeigler (1952).

B. On Agnosia and Apraxia

In 1876, Hughlings Jackson described a 59 year old woman who two months before admission to hospital suddenly lost her way and was unable to get home from the nearby park. When she returned home she seemed as usual. But from then on she would do odd things, such as to put sugar in her tea two or three times or put her clothes on backwards. Three weeks later she was unconscious for 48 hours. It was then noticed that her left arm and leg were paralyzed. She gradually improved, but mistook the people about her. She was unable to read Snellen's chart, but started at the right lower corner, and read " 'The name colony' and 'name' again". At the end of the line she did not know where to go; at last pointed to the and said "That's 'the' and to me they look all 'the's, the's, the's' ". She named familiar objects. A fortnight later no mental imperfection could be demonstrated. Then she suddenly became unresponsive and died the same day. Autopsy showed multiple gliomatous tumors of the right temporo-occipital region. This condition Jackson called partial imperception.

In 1883 Charcot (1890; vol. 3, pp. 178-193) described a patient with loss of visual memory of objects and persons and of certain letters (which he recognized only after tracing them himself). As previously noted, Bastian had already described word-blindness and word-deafness. According to Brain (1941a), Lissauer in 1889 considered that perception

is divided into first, conscious perception of sensory impressions - apperception; and second, linkage of content of perception with other images - association. Freud (1891) introduced the term agnosia to apply to loss of association (second stage of Lissauer).

Goldstein and Gelb (1918) reported in great detail the visual disturbances in one patient; they considered the patient to have apperceptive mind blindness which was not due to the loss of memory images in the association field but to loss of figure-ground relationship or visual Gestalten. Brain (1941a) stated Poppelreuter considered that they had not shown the vision to be normal in the remaining fields.

Jackson (1931) was the first to mention visual disorientation. Non-agnostic visual disturbances of color vision, of depth perception, of attention, etc., are not related directly to our problem, but are mentioned because they may occur in addition to other disturbances.

The term agnosia has had a number of different meanings by various authors. Visual verbal agnosia is considered to be the same as in word-blindness. Dejerine (1914) maintained that pure word-blindness is caused by a lesion of the angular gyrus. The literature has been reviewed to determine if such a condition can be found. No case in the literature meets these requirements. There is one case with a temporo-occipital lesion which should be noted. The author has not been able to review the original by Henshelwood but takes the summary from

Weisenberg and McBride (p.66) and Henschen (case 155). This 58 year old teacher of the French and German languages was reported to have had no difficulty in speaking, understanding speech, naming, or writing. He had a right homonymous hemianopsia and inability to read words and French letters (Henschen); but he retained ability to read numbers. A year later the patient complained of defective memory, particularly in remembering proper names, and spelling errors in writing were noted. Henschen stated that he had "wordblindness, also of learned letters" but no agraphia six years after the original difficulty. At autopsy three years later there was a lesion of the occipital lobe limited superiorly by the calcarine fissure, extending almost to the occipital pole, and involving the lower margin of the cuneus and the posterior part of the third temporal gyrus. Even Nielsen (1947) did not present cases to prove his statement that visual verbal (or literal or numerical) agnosia is produced by a lesion of the angular gyrus.

As previously mentioned Bastian first used the term word-deafness, and this is equivalent to auditory verbal agnosia. Nielsen (1947) considered that one hears sounds and stores up memory pictures (develops engrams) of certain words (utilizes the function of auditory verbal agnosia). Physiologically speaking there are two levels of integration:

primary perception and eugnosia. Destruction of the first results in deafness, of the second, in agnosia, acoustic or auditory agnosia if complete, acoustic verbal agnosia if recognition of words only is lost . . . A patient may become sound deaf so that he does not hear anything; he then has lost primary perception. He may, however, retain ability to hear sounds but lose the ability to recognize that he had heard them before. Or he may retain memory of having heard general sounds before but not the memory of having heard sounds of words before. The anatomic site of formation of engrams of words is therefore different from that of other sounds." (p. 25) Also Nielsen then stated that the first transverse gyri of Heschl on both sides serve in hearing; Wernicke's area (posterior half of the first and part of the second temporal convolutions) is the center of auditory recognition. Lesions which produce auditory verbal agnosia have to interrupt the fiber tracts from both hearing centers to Wernicke's center or destroy the latter on the dominant side.*

The preceding is the elaborate schema adopted by most strict localizationists. Henschen (1920-1922) went even farther to state that there is also a word meaning center in the temporal lobe; Nielsen (1946) did not agree (?)(p.26), but

* Why this does not produce, logically, general auditory agnosia is not stated.

later stated that the language formulation area (chiefly area 37 of Brodmann) is identical with it (p. 121).

In reviewing the cases of "word deafness", one is unable to find a single case with an isolated defect. There are cases in which comprehension of speech is the most involved but none of these cases show conclusively that hearing is intact. Miller (1950) has found no case of "congenital auditory imperception" as repeated audiometric tests have shown considerable partial deafness in all. "In some of them the failure of understanding speech seems disproportionate to degree of hearing deficit which in other subjects is not accompanied by such a pronounced failure of understanding but this is a far cry from attributing the defect wholly to a specific agnosia of cortical origin."

In the case of Henschen (No. 3) to which Nielsen lay great stress there was complete involvement of Wernicke's zone bilaterally without producing complete loss of understanding speech. The lesions which have produced the difficulty in understanding involved the temporal region usually the first and second temporal, and Heschl's convolutions - Shaw (Mills, 1891), Mills (1891), Pick (1892), Barrett (1910) Kahler and Pick (Henschen, Case 417), Wernicke and Friedlander (Mills, 1891), and Anton (Henschen, Case 369), and Seppilli (Henschen, Case 465).

Again Jackson (1931) was first to describe the inability of a patient to put out his tongue upon request, even though he knew what was desired and later would stick it out automatically to lick his lips. This has come to be known as apraxia of the tongue. Although Steinthal and Gogol used the term apraxia, Leipmann in 1900 made a comprehensive analysis of apraxia and clearly distinguished this condition from agnosia (Ajuriaguerra and Hécaen, 1949). Various types of apraxia (kinesthetic, ideo-kinesthetic, ideational, constructional, etc.) have been described; but let us consider only the concept held by Wilson (1926), Nielsen (1947) and others that motor aphasia is an apraxia of speech and that of Neilsen (1948) contending that motor aphasia (apraxia of speech) and agraphia (apraxia of writing) are produced by lesions of the posterior parts of the third and second frontal convolutions, respectively. Of the 43 cases, Nielsen (1947) presented to support the contention that the destruction of Broca's area produces motor aphasia, there is not a single case which is acceptable; either the case was incompletely reported clinically or pathologically, or the clincial and pathological findings were incongruous (e.g., hemiplegia with only a lesion of the third frontal convolution) or there was no aphasia. The case of Scheinker and Kuhr (1948) is unsatisfactory because of the acuteness of the lesion. There is one case reported by Banti (Bastian, 1898, and Henschen, Case 727) of a 36 year old man who had a right

hemiparesis and loss of speech. The hemiparesis disappeared quickly but he was completely mute though able to write correctly and rapidly and to understand oral and written directions. A little over four years later it was stated that he had almost completely recovered speech by reeducation though when this happened was not given. At autopsy there was a lesion limited to the posterior part of the left third frontal convolution. Of all the cases reported in the literature here is one that seems to fit the criteria!

There is also one case to support the thesis of a "writing center" in the second frontal convolution. Gordinier (1899) reported a 37 year old woman who for three months had had headaches, vomiting and failing vision. She had papilledema and weakness of the right hand, though fine movements were present, and a right sixth cranial nerve paresis. She could speak, read, name and understand speech. She was unable to write with either hand - however, from the samples given some letters are easily recognizable. Over the next six weeks, she became slow in speech though not aphasic; and she tended to fall to the right. Trepanation was carried out and no tumor seen. She died two days later. There was a glioma two centimeters in length at the foot of the second frontal convolution extending to the ventricle and invading the white matter of the first frontal gyrus. The cerebral hernia which followed the operation involved the precentral gyrus.

The concepts of eugnosia and eupraxia with their anatomical localizations as given by Nielsen (1946) are inadequate. It seems to the author quite necessary that we return to studying what the patient can and cannot do and omit the use of words such as apraxia and agnosia which no two authors seem to define the same.

C. On Cerebral Dominance

The concept that the right cerebral hemisphere is dominant in left-handed people in the same manner that the left cerebral hemisphere is dominant in the right-handed is credited to Broca (1888). The basis for this concept seems to have been the following case: A 47 year old left-handed woman had had weakness of the right arm and leg, and epilepsy since infancy. At no time did she have any aphasia. At autopsy there was demonstrated destruction of the left third frontal, inferior parietal and first temporal convolutions. Broca stated that because the right hemisphere took over the function of the left in infancy there was no "aphemie". He went on to claim that because an individual becomes right-handed the left hemisphere becomes dominant.

Monakow (1914) mentioned that the theory of cerebral dominance was created by the "localizationists" and needed to be reviewed. Why some people are left-handed remains unknown (Blau, 1946). Even in Biblical times, they were present: "All these people, even seven hundred chosen men were left-handed; everyone could sling stones at a hair-breadth and not miss" (Judges 20). Blau (1946), Brain (1945), Chesher (1936), Eustis (1949), Kennedy (1916), Ludwig (1938), and Wepmann (1951), among others, have written on this problem. There is no proof that left-handedness follows mendelian laws. The suggestion of Blau (1946) that left-handedness is due to negativism would seem to explain only a few cases, at most. Our interest, however, is in cerebral dominance; but one thing should be pointed out, namely, the more tests used to determine handedness the fewer becomes the number of entirely left- or right-handed individuals until they are the exceptions (Blau, 1946). Kennedy (1916) proposed that the handedness of the family must be considered to explain "crossed-aphasias" - right-handed with lesions of the right hemisphere and aphasia, etc.

Bastian (1897) cited, without reference, Seguin's report of aphasia in 266 patients, 243 of whom had right hemiparesis and 17, left hemiparesis. Ludwig (1938) stated that out of 880 right-handed patients with injury to the right hemisphere, 100 had aphasia. Excluding such reports, the writer finds in the literature that following disease of the left

hemisphere, aphasia was present in 7 left-handed patients[1] and 13 "ambidextrous"[2] and no aphasia in 6 left-handed[3]. Following disease of the right cerebral hemisphere aphasia has been noted in 75 patients, as follows: right-handed, 24[4]; left-handed, 19[5]; "ambidextrous", 11[6]; and no handedness given, 21[7]. Two left-handed and one "ambidextrous" patient, reported by Kennedy (1916), had no aphasia after involvement of the expected speech areas of the right hemisphere.

[1] Cases of Henschen (1920-22) Nos. 414, 427, 1029; Liepmann (Ludwig, 1938); Nielsen, 1937; Wepmann (1951) - 2 cases.

[2] Cases of Bramwell (1899); Dickson (Bramwell, 1899); Chesher (1936) - 5 cases; Kennedy (1916); Moutier (1908) - 4 cases Nos. 127, 256, 322, 343; Weissenberg and McBride (1935).

[3] Cases of Henschen (1920-22) No. 1262; Moreau (Broca, 1888), Bucy and Case (1937); Chesher (1936); Gardner (1941) and Nielsen (1947, p. 212, No. 23).

[4] Cases of Henschen (1920-22) Nos. 28, 29 and 432; Moutier (1908) Nos. 330, 345, 346, 347 and 348; Chesher (1936); Dimitri (1933); Kennedy (1916) 2; Lovell et al (1932); Preobrashenski 2 (Weber, 1904); Weisenberg and McBride (1935); Wilson (1926); Ludwig (1938); and Joffroy, Lewandowski, Mendel, Marinesco et al; Stauffenberg, and von Monakow - all from Ludwig (1938).

[5] Cases of Henschen (1920-22) Nos. 313, 329, 482, 1101 and 1109; Chesher (1936) 2 cases; Head (1926); Jackson (1914) - 2 cases; Ogle (Kussmaul, 1877); Smith, (Kussmaul, 1877); Moutier (1908) Nos. 320, 324, 334 (335 is same case), 336, 337, 338; and Weisenberg and McBride (1935).

[6] Cases of Chesher (1936) 3 cases; Moutier (1908) Nos. 318, 321, 323, 333, 340 and 342; Weisenberg and McBride (1935); Nielsen (1937).

[7] Cases of Henschen (1920-22) Nos. 133, 282, 579, 627, 750, 755, 880 and 978; Trousseau (1865); Charcot (3), Vulpian (1) and Kirks (1) - all Trousseau (1865); and Moutier (1908) Nos. 325, 327, 329 and 331; and Jackson (1914) 3 cases.

No attempt has been made to determine the number of right-handed patients who have had aphasia following disease of the left hemisphere. It should be mentioned that handedness was frequently not mentioned in the literature - in more than half of the patients reported by Henschen, it was not recorded. Also, 399 cases recorded by Henschen are useless because one does not know from the clinical data whether or not any type of aphasia was present, or there were bilateral lesions without clear clinical evidence as to which hemisphere should be incriminated.

Nonetheless it is difficult to state that the right hemisphere is dominant in left-handed people on the basis of these figures. This statement is another generalization handed down in medical literature without satisfactory proof (as Wepmann (1951) has noted).

Jackson (1914 and 1931) maintained that the emotional speech and occasional utterances of patients with aphasia due to lesions of the left hemisphere accompany activity of the right hemisphere. Bastian (1897) claimed that after destruction of the left auditory word center the right one takes over its function.

Henschen (1926) maintained that the right hemisphere is less able to take over for the left in writing than reading; it is more able to do so in understanding and speaking, but still is defective. Nielsen (1947) believed that the right hemisphere is able to assume the various functions of the left, but in the three cases with autopsies presented there is no

proof that this was true. Usually the type of material that is presented is similar to the case of Barlow (1877). Six months before death a boy, aged ten years, suffered with right hemiparesis and aphasia. One month later he seemed quite recovered. Two months before death he had left hemiplegia and loss of speech. He could not protrude his tongue and had difficulty swallowing and chewing. He could write and make signs for what he wanted. At autopsy there were bilateral lesions of the lower precentral region and posterior parts of the second and third frontal convolutions. It seems obvious that this child had pseudobulbar palsy. Nielsen (1946, p. 107) stated: "This case is crucial in that the patient recovered his speech by the use of the right hemisphere only to lose it again when the new lesion affected the side which had taken up the function". No case is found in the literature which would satisfy scientifically the preceding statement.

D. On Localization

No discrete localization of lesions producing various forms of agnosia and apraxia have been found. It seems as Jackson (1931) stated that any acute lesion to any gross part of the left hemisphere* will produce some disturbance in speech. It should be mentioned that this includes disease of

*In rare incidences involvement of the right hemisphere will give the same clinical picture.

the anterior (Critchley, 1930) and posterior cerebral (Brown-Séquard, 1877) arteries as well as the middle cerebral. Critchley (1930) and Ethelberg (1951) have demonstrated speech disturbances, predominantly of difficulty in articulation - which Ethelberg (1951) attributes to a general "disorder of rapid and complex movements" - from occlusion of the anterior cerebral circulation. Cushing and Eisenhardt (1938) found aphasia associated with parasagittal and postcoronal meningeomas. The speech areas of practically all authors include the postero-inferior part of the frontal lobe, the posterior half of the first and second temporal gyri, the angular gyrus and the no man's land of the temporo-parieto-occipital junction.

From the studies on frontal lobectomies and lobotomies it is quite clear that all of the frontal lobe anterior to Broca's area may be removed without permanent aphasia. Burkhardt (1891) claimed that he removed part of Broca's area without aphasia. Mettler (1949) stated that all of Broca's area may be removed bilaterally without aphasia. As the motor cortex was not outlined by stimulation and as no case has been reported with autopsy performed, this statement is doubtful. Burkhardt (1891) had also removed the posterior parts of the first and second left temporal convolutions without permanent aphasia. As Nielsen (1948) pointed out there are a number of cases in the literature with destruction of the left Broca's area without aphasia. Nielsen (1948, p. 571) stated: "There is no case on record of bilateral destruction

of Broca's convolution (as defined by Nielsen (1948) to be limited posteriorly by the precentral gyrus, anteriorly by the pars triangularis, and superiorly by the second frontal gyrus - the inferior limits are not given*) with retained ability to speak". However, there is such a case. This case (41 of Moutier (1908)) is a 75 year old woman who had right hemiplegia and aphasia at the age of 73. Speech returned, and at the age of 75 she had another stroke with left hemiplegia. Prior to death she was definitely able to speak. There was bilateral destruction of the posterior part of the third frontal convolution, exclusive of other lesions. There is another case (Moutier No. 260) in which the entire left Broca's region was destroyed but the small postero-superior part of the right third frontal convolution was intact, however.

Bilateral destruction of the lenticular nucleus was reported without difficulty in speech (Nielsen, 1946). It is unknown as to whether lesions of the thalamus are accompanied by aphasia. Brown-Séquard (1877) stated that aphasia (not just a motor disturbance) was noted with pontine lesions; but he did not present the material on which this opinion was based.

The localization of lesions producing different types of aphasia and the mechanism of speech remain challenging problems. Perhaps the best suggested classification of the disorders is that of Schiller (1947) on an anatomical basis.

* Nielsen limits Broca's area to the one gyrus anterior to the precentral face area.

A few words about retraining - Singer and Low (1933) have demonstrated that rehabilitation may be accomplished after several years of useless aphasic life. The progress made following both World Wars demonstrates that no case should be considered as hopeless (Wepmann, 1951).

E. On Stimulation

Other than the grunts and groans produced during stimulation of the Rolandic region by Foerster (1936), and the repetition of words and syllables during stimulation of the intermediate precentral region by Brickner (1940), the effects of stimulation have been observed by Dr. Wilder Penfield and coworkers (as the entire series of Dr. Penfield's cases is to be presented in this thesis, the previous reports will not be reviewed - see Roberts, 1949).

III. STIMULATION

A. Types of Stimulation and Method of Analysis

While the patient is under local anesthesia, the cerebral cortex has been stimulated to determine where and how speech might be affected. Two types of stimulators have been used - the thyratron (used before 1945) and a modified Rahm stimulator. Both deliver a condenser discharge wave. The pulse duration produced by the thyratron stimulator is constant at 0.072 msec. The frequency used has been 55 to 65 per second; and the voltage has varied from 10 to 70 volts. The thyratron stimulator has been used for a number of stimulations within the Rolandic area but for few outside of it.

The modified Rahm stimulator has been used for most stimulations. The usual frequency employed has been 60 per second, at which frequency the pulse duration is 8 msec. Occasionally the frequency has been 30 per second with a pulse duration of 15 msec. The peak voltage has varied between 3 and 24 volts, with most of the stimulations being between 6 and 12 volts. Bipolar electrodes have been used with both stimulators; only rarely a unipolar electrode has been employed.

After the cortex is exposed, it is stimulated and the precentral and postcentral gyri are outlined. Each point of stimulation is marked by a small ticket. The operator marks a prepared brain map to show the location of the points of

stimulation. All other places of stimulation are marked in relation to the fissure of Rolando. The outline of the cortical excision is drawn by the operator also in relation to the fissure of Rolando. Photographs are taken of the brain showing the tickets and the excision; they are used for confirmation of the operator's drawing. Admittedly there is a source of error in this localization. But it is assumed to be comparatively small. All operations have been performed by Dr. Wilder Penfield, or under his direction.

Stimulation has been performed while the patient is silent or while he is counting or naming. Originally objects were shown to the patient and he was asked to name them. Small pictures have been used more recently, and the patient has preceded the name of the picture by the words "that is a . . .". The patient was shown these pictures prior to stimulation and any picture which was not named correctly and immediately was discarded. It is therefore assumed that without stimulation the picture would have been named correctly. If during the latter part of the operation the patient had difficulty naming without stimulation, the immediately preceding stimulations which affected speech have been discarded.

All stimulations which affected speech have been discarded if the patient had his habitual aura or a seizure during stimulation; if the difficulty continued after withdrawal of the stimulating electrodes; if upon stimulation of the same point

no effect was produced; or if any after-discharge was noted in the electrocorticogram. These criteria reduce considerably the total number of electrical arrests of speech but are considered necessary for purposes of localization.

B. Results

Stimulation has produced two effects on speech: 1) positive or vocalization; and 2) negative or inability to vocalize or to use words properly. No intelligible word has been induced while the patient is silent. Vocalization is a sustained or interrupted vowel cry, which at times may have a consonant component. It is produced by stimulation of the motor areas called by Penfield and Rasmussen (1950) Rolandic and supplementary (see Fig. 1 and Fig. 2). For vocalization the Rolandic area includes the precentral and postcentral gyri for lips, jaw and tongue and the supplementary area includes the superior and medial aspects of the intermediate precentral region of Campbell (1905). Three stimulations are anterior to the precentral gyrus in Broca's area; two are on the left and one on the right. Vocalization has been induced from the right Rolandic region in 26 patients at 39 places, from the left Rolandic in 47 patients at 68 places, and from the right supplementary motor area in 3 patients at 5 points and from the left in 12 patients at 15 points.

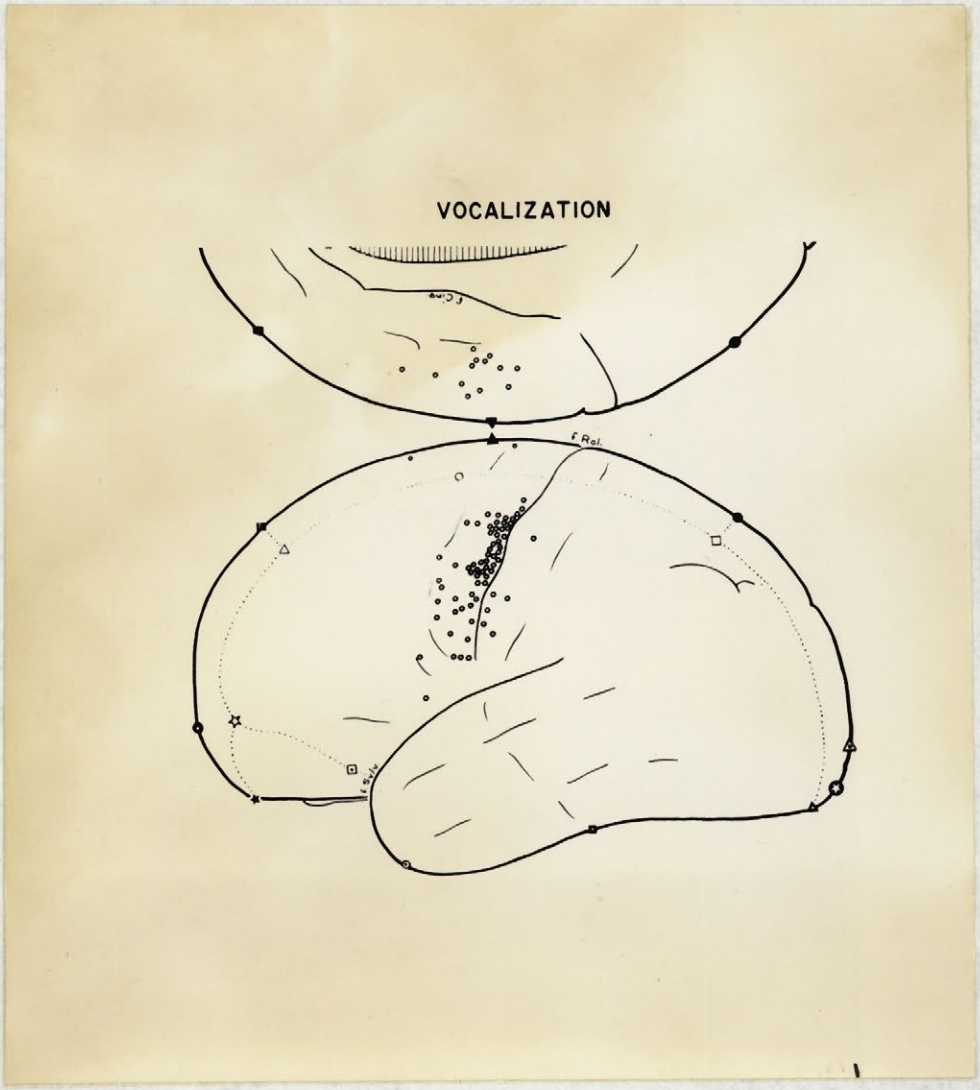


Figure 1

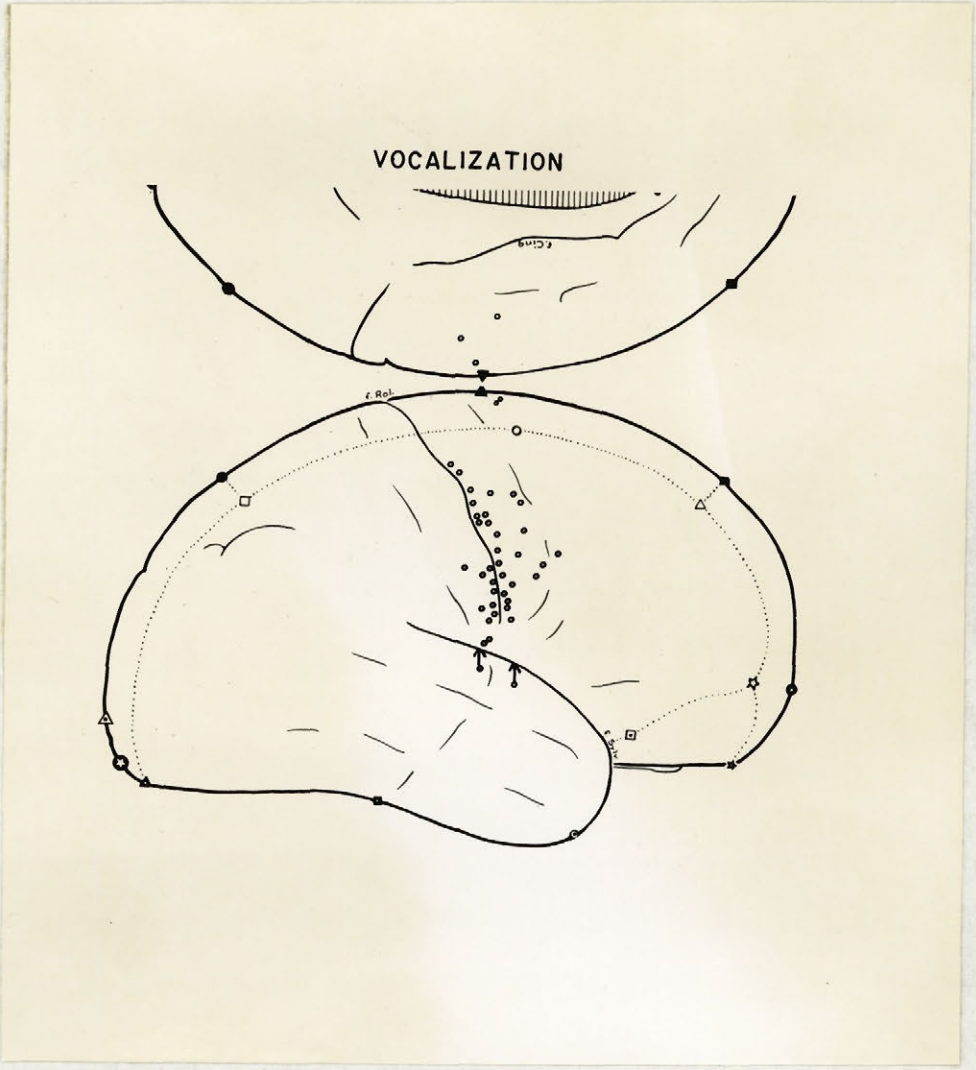


Figure 2

The negative effects of stimulation are classified, arbitrarily, into various types of responses. The first effect of electrical arrest involving the left hemisphere is inability to vocalize spontaneously or total arrest of speech (Fig. 3). The second effect is hesitation and slurring of speech (Fig. 4). The third and fourth effects are distortion and repetition of words and syllables, grouped together in Figure 5. Distortion differs from slurring in that the distorted word is actually not a word but an unintelligible sound. The unintelligible sound has been repeated. Repetition of numbers while counting, and repetition of other words and syllables have occurred.

The fifth effect is confusion of numbers while counting (Fig. 6). This is illustrated by the patient jumping from 6 to 20 then back to 9. Inability to name with retained ability to speak is the sixth effect (Fig. 7). An example is "that is a . . . I know. That is a . . .". When the current was removed the patient named the picture correctly. Another example is "Oh, I know what it is. That is what you put in your shoes." After withdrawal of the stimulating electrodes, the patient immediately said "foot". Some of the effects of stimulations placed in the preceding and subsequent categories could also be put in this category, but none has been duplicated in this manner.

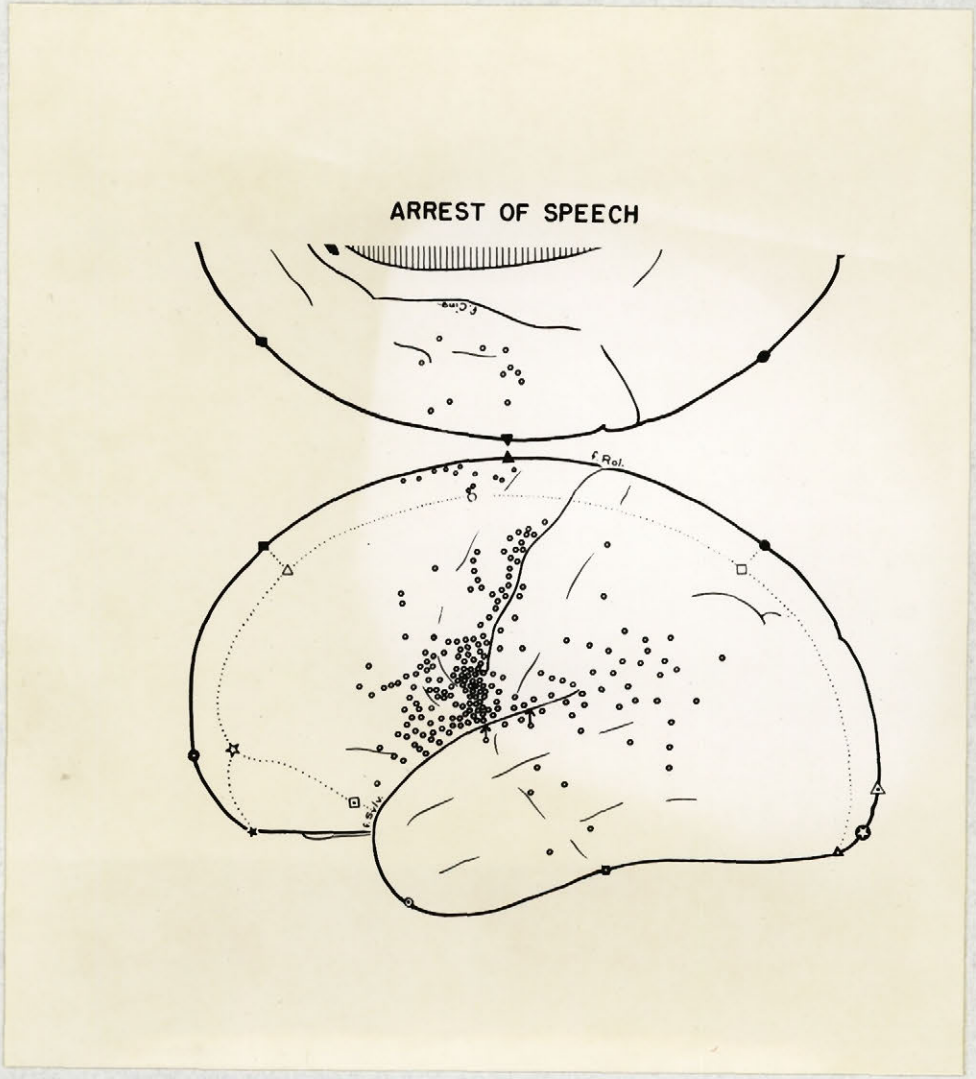


Figure 3

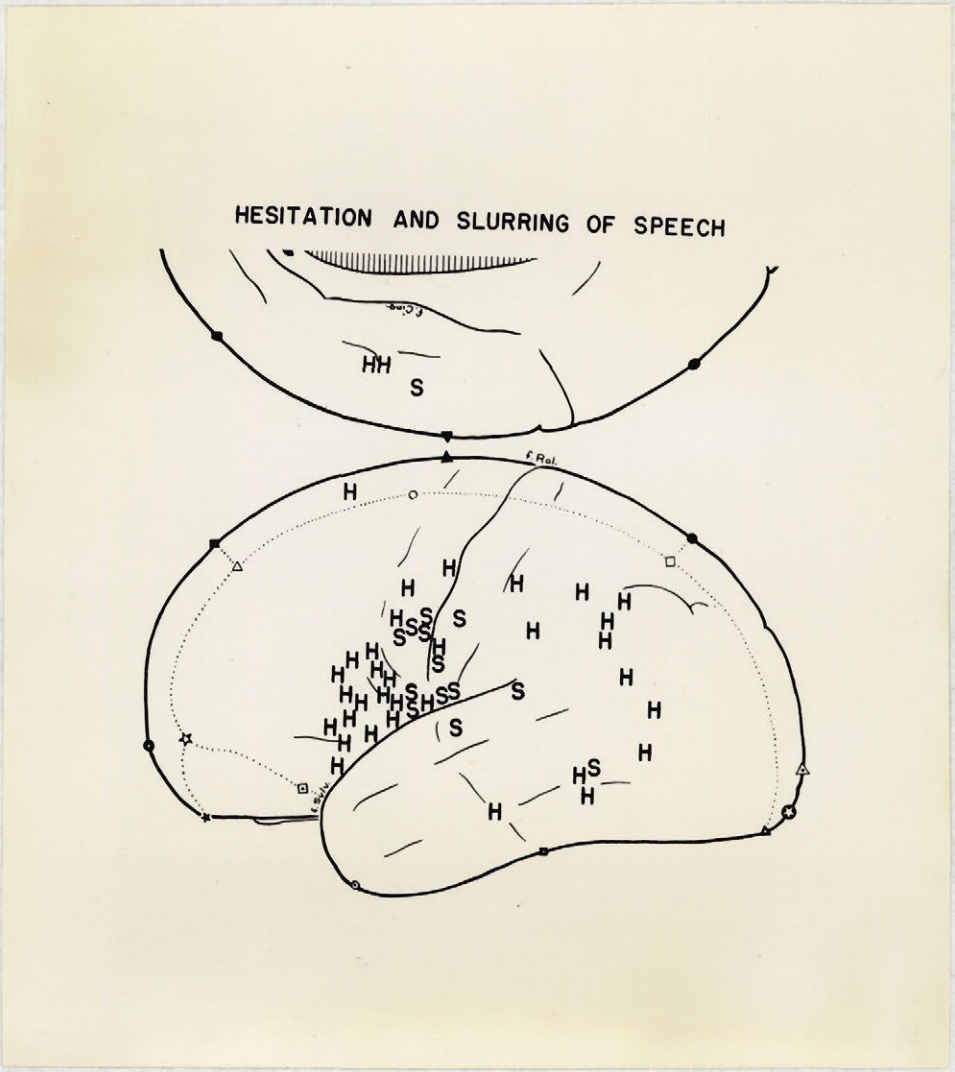


Figure 4

DISTORTION AND REPETITION OF WORDS AND SYLLABLES

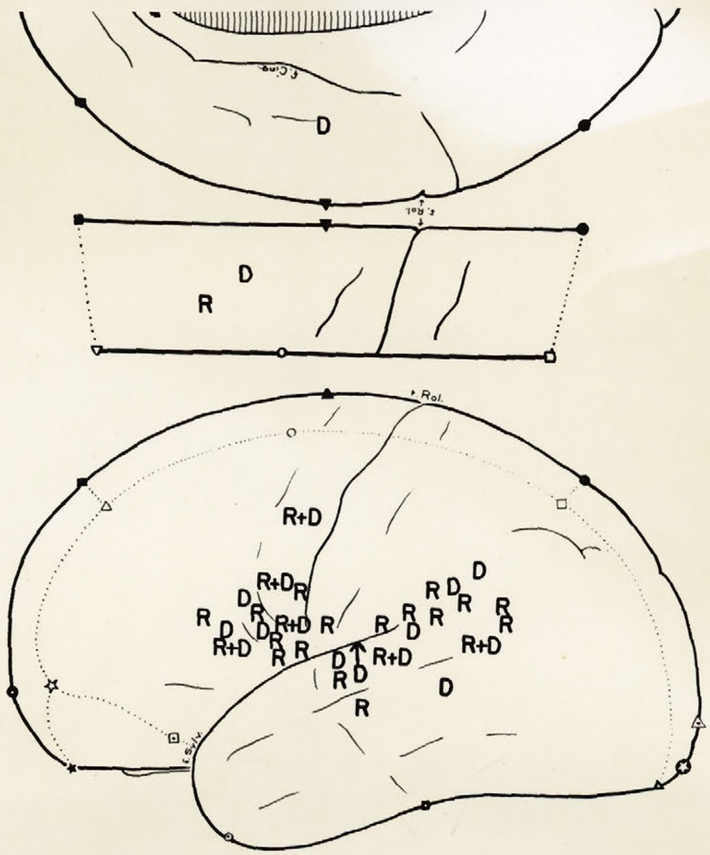
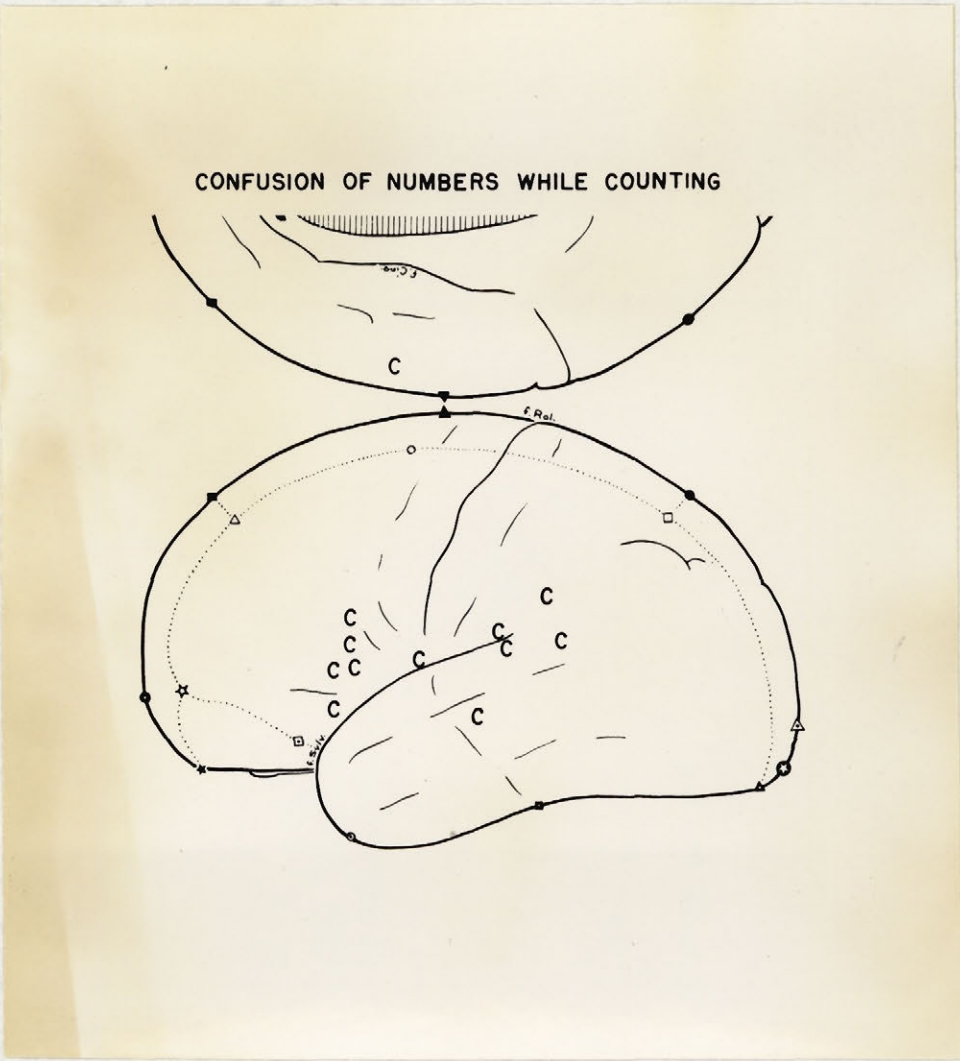


Figure 5


CONFUSION OF NUMBERS WHILE COUNTING
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C
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C
C
C
C
F.Sylv.

Figure 6

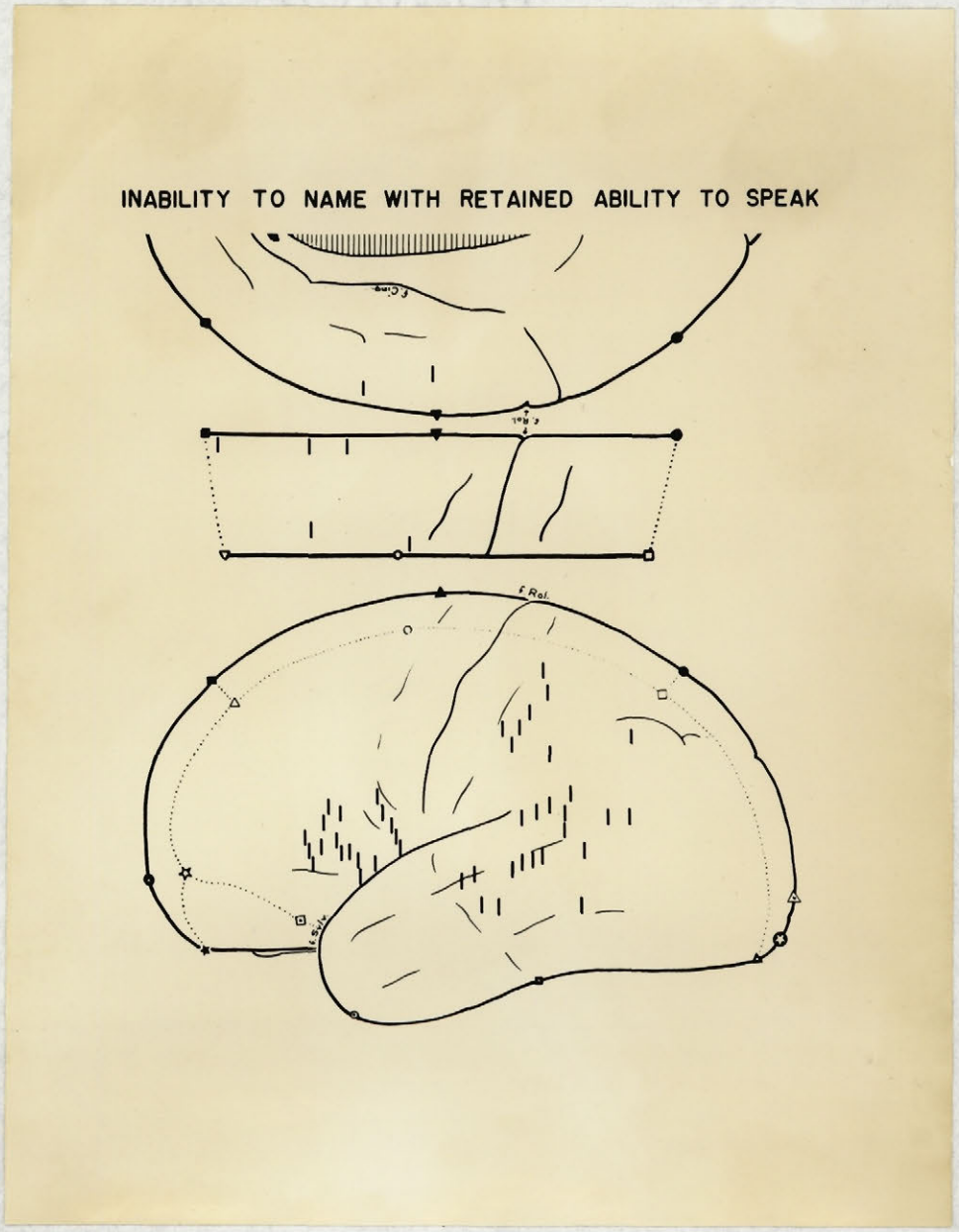

Figure 7

Misnaming with evidence of perseveration (Fig. 8) occurs when the patient names a "butterfly" as the stimulating electrode is applied, then calls a "table" a "butterfly"; after the current is removed, he names the picture correctly.

The eighth type of response is the most unusual (Fig. 9). In misnaming without perseveration, the patient may use words somewhat closely related in sound, such as "camel" for "comb". Or he may use a synonym, such as "cutters" for "scissors", "hay" for "bed" and "moth" for "butterfly". Or an entirely unrelated word, such as "rink" for "scissors" or "cone" for "hammer", has been used. Sometimes there has been evidence of general confusion occurring only during stimulation: for example, "You are climbing", "That is trying to comb the power", and "It is horrible . . . (something about) lettuce".*

The locations of the points of stimulation of the left hemisphere producing the eight different types of responses are seen in the various figures. The last six types are classified as aphasic types of responses in Figure 10. All are summarized as interference with speech (Fig. 11). Arrest, slurring, distortion and repetition of words occur during stimulation of all five areas - Rolandic, supplementary motor,

* This type of general confusion in speech has been noted rather frequently during and after seizures produced from stimulation of either temporal region; but these stimulations have been excluded because of the seizure.

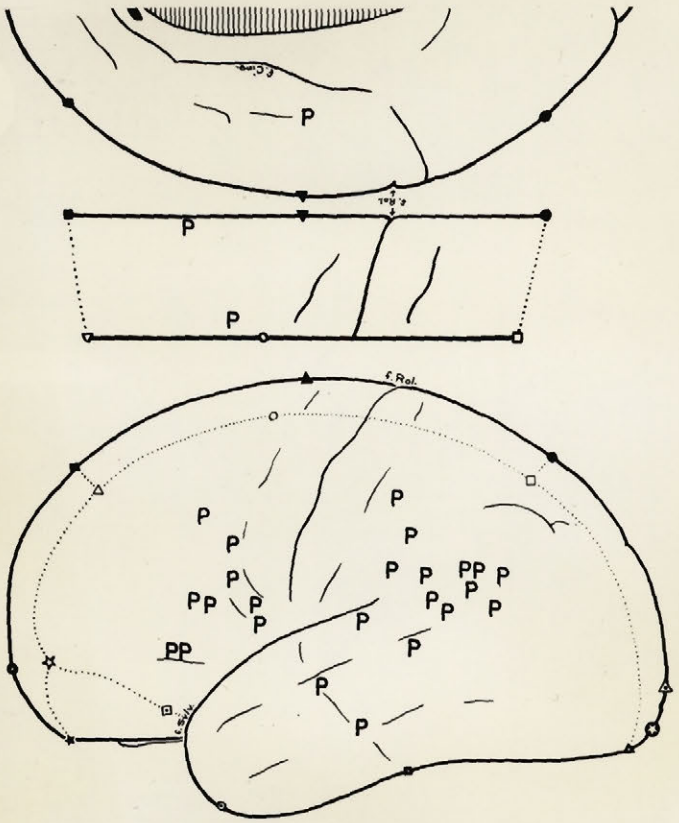

Figure 8

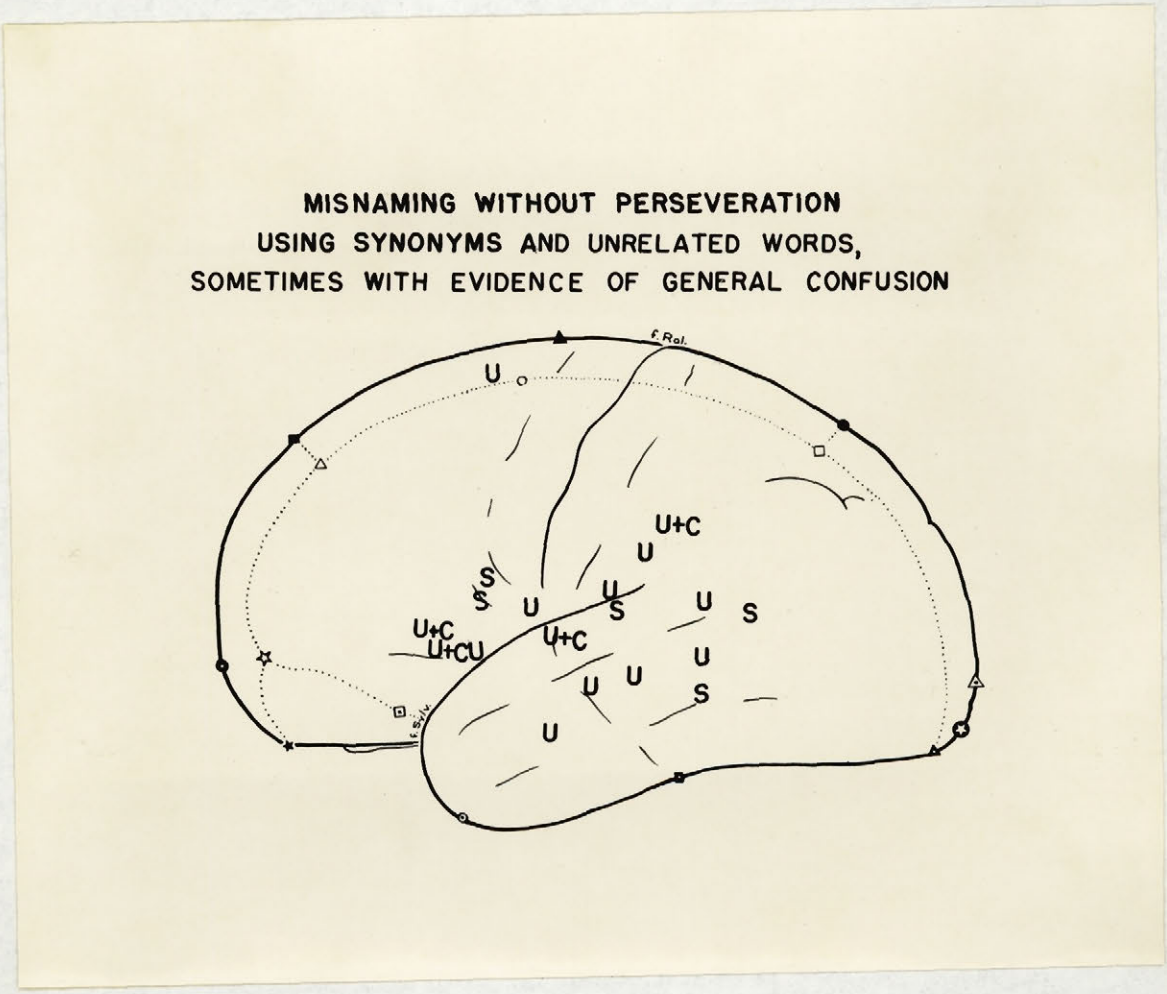
MISNAMING WITHOUT PERSEVERATION
USING SYNONYMS AND UNRELATED WORDS,
SOMETIMES WITH EVIDENCE OF GENERAL CONFUSION
f. Rol.
U
U+C
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Figure 9

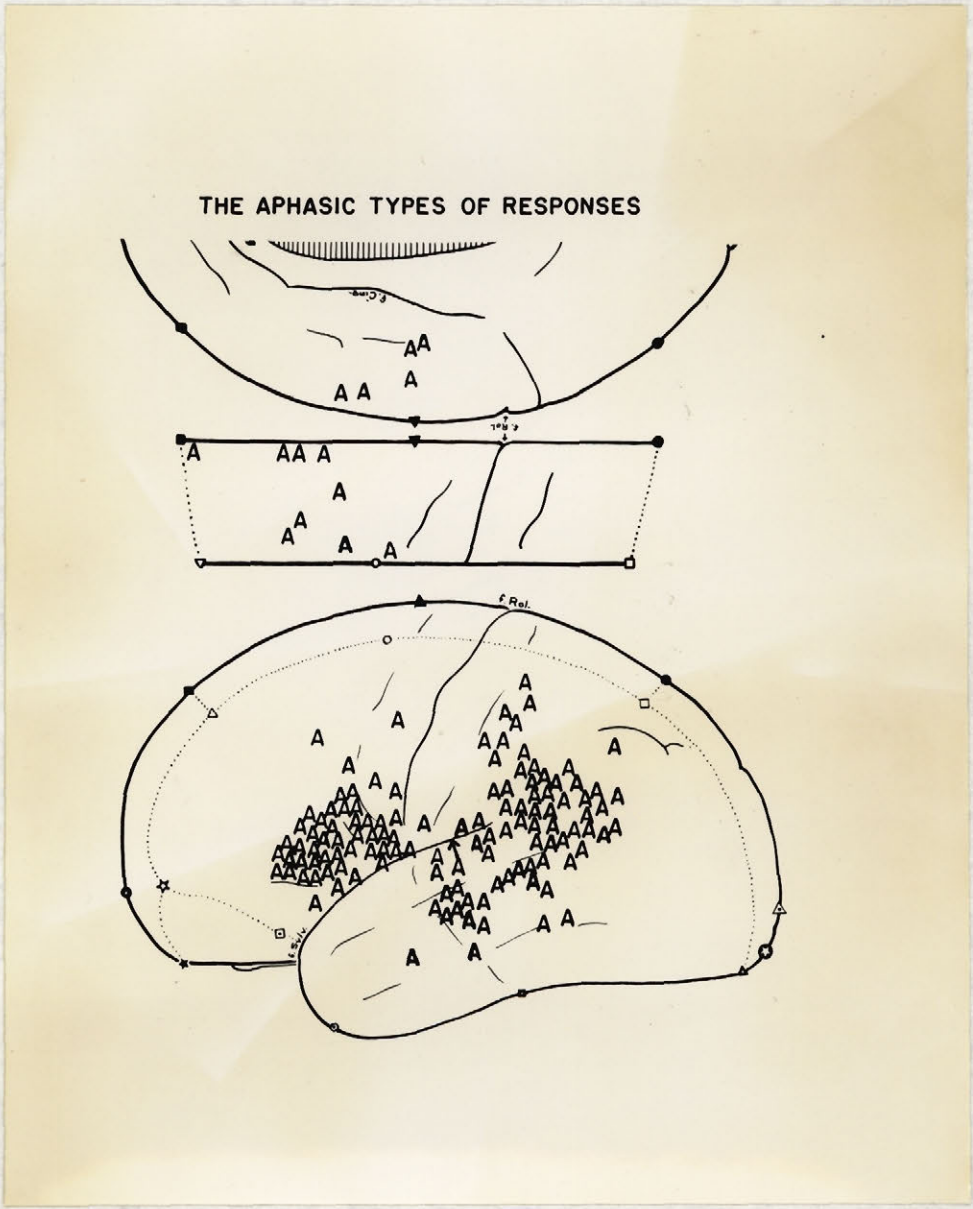

Figure 10

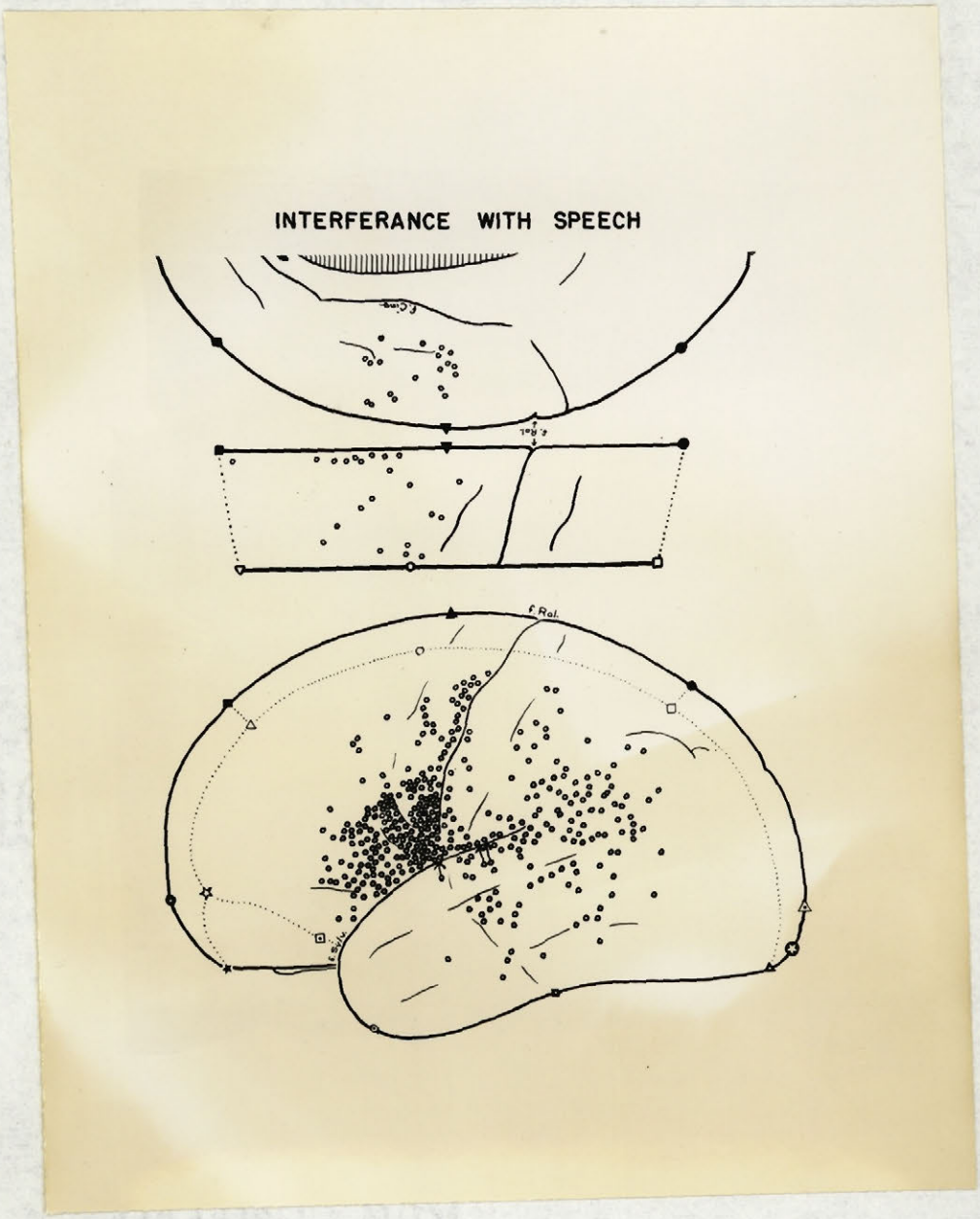

Figure 11

Broca's, inferior parietal and posterior temporal regions. The last four effects are obtained rarely from the Rolandic region (only five times).

Electrical interference involving the right cerebral hemisphere has produced the first four effects (Fig. 12 and Fig. 13). Most of these stimulations are in the Rolandic and supplementary motor areas. Electrical interference of the right side has not produced confusion of numbers while counting, inability to name with retained ability to speak, or misnaming with or without perseveration.

Of the 595 patients reported in the next section, 114 (94 and 20 involving the left and right hemispheres, respectively) have had stimulations of Broca's and/or inferior parietal, and/or posterior temporal regions to determine if speech might be disturbed. These and other patients have had stimulations of the Rolandic and supplementary motor areas, but the number of stimulations producing no effect from these areas is not recorded; therefore they are excluded from the following analysis. Also the various other areas of both hemispheres have been stimulated to determine if speech might be affected. No effect has been noted; however, the location and number of stimulations is not accurately recorded.

As previously noted a number of stimulations have been discarded. If the remaining stimulations produced effects upon speech which were not confirmed by repeated stimulation, that case is classified as having had no effect upon speech

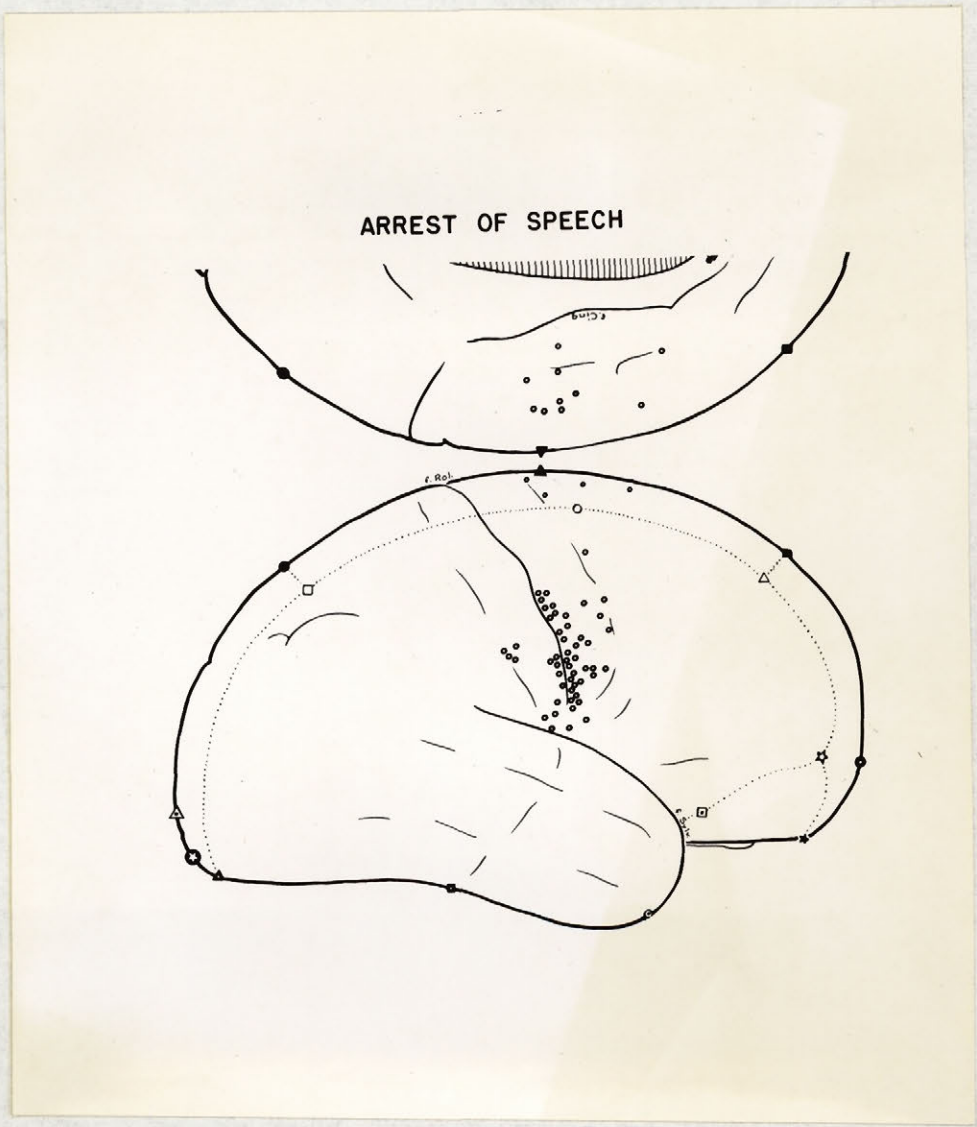

Figure 12

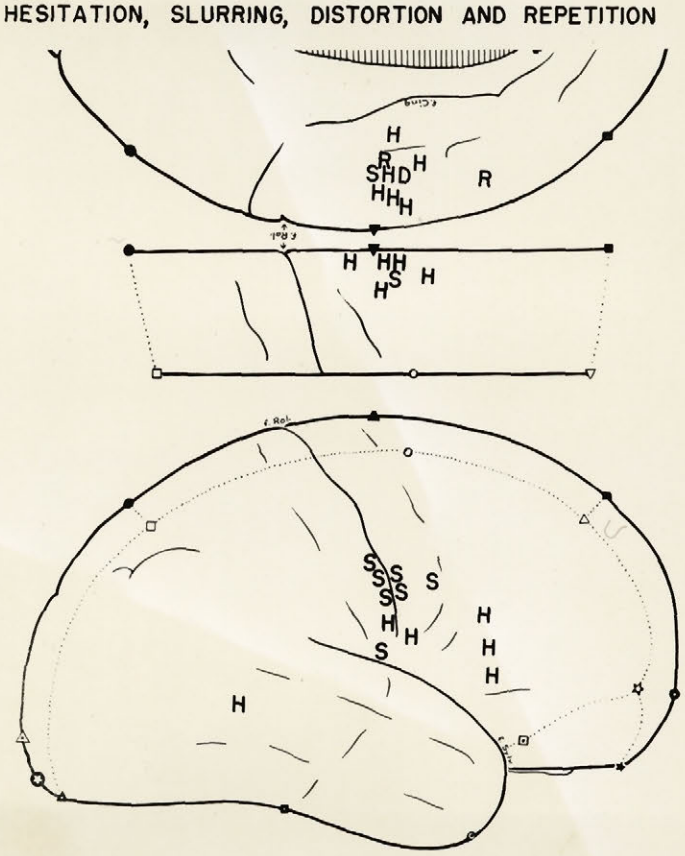

Figure 13

produced by electrical arrest.

Ninety-four patients had stimulations of the left Broca's, and/or inferior parietal and/or posterior temporal regions. Four are excluded in some of the subsequent calculations; one had electrical arrest which interfered with speech during one operation and stimulations which did not disrupt speech at another operation; one had interference in speech from stimulation during both operations and had aphasia after one but not the other; two others classed as left-handed had been right-handed before the age of three years. Fifty-four of 65 right-handed patients having aphasia after operation had stimulations affecting speech from one or more of these three areas (see Table 1). Ten of 15 right-handed patients having no aphasia after operation had electrical arrests which affected speech. Four of five (or two of three if those who changed from right-to left-handed are excluded) left-handed patients had stimulations affecting speech, and aphasia after operation. Seven other left-handed patients had no stimulations which caused alterations in speech and no aphasia after surgery.

One left-handed patient had electrical arrests affecting speech in the right inferior parietal region but not in Broca's area, and had aphasia after operation (see Table 2). Five left-handed patients had stimulations of the right hemisphere which did not affect speech and they had no aphasia after operation. One of fourteen right-handed patients who had no aphasia after operation had stimulations affecting speech.

TABLE I

STIMULATION OF THE LEFT HEMISPHERE

	Broca		Inferior Parietal		Posterior Temporal		Total	
	+[1]	-[2]	+	-	+	-	+	-
Right-Handed								
Aphasia	46	10	21	13	31	6	54	11
No Aphasia	6	6	3	3	6	1	10	5
Left-Handed								
Aphasia	2	1	1	0	1	1	2	1
No Aphasia	0	5	0	5	0	6	0	7

STIMULATION OF THE LEFT HEMISPHERE

EXCLUDING THOSE PATIENTS WITH INJURY BEFORE TWO YEARS

Right-Handed								
Aphasia	39	9	17	12	27	5	47	10
No Aphasia	5	5	3	2	5	1	8	5
Left-Handed								
Aphasia	2	1	1	0	1	1	2	1
No Aphasia	0	0	0	0	0	0	0	0

---

1 " + " indicates the number of patients who had stimulations affecting speech.

2 " - " indicates the number of patients who had stimulations not affecting speech.

TABLE 2

STIMULATION OF THE RIGHT HEMISPHERE

	Broca		Inferior Parietal		Posterior Temporal		Total	
	+[1]	-[2]	+	-	+	-	+	-
Left-Handed								
Aphasia	0	1	1	0	-	-	1	0
No Aphasia	0	2	0	3	0	4	0	5
Right-Handed								
No Aphasia	1	11	0	5	1	4	1	13
Aphasia	-	-	-	-	-	-	-	-

STIMULATION OF THE RIGHT HEMISPHERE

EXCLUDING THOSE PATIENTS WITH INJURY BEFORE TWO YEARS

Left-Handed								
Aphasia	0	1	1	0	-	-	1	0
No Aphasia	0	2	0	3	0	3	0	4
Right-Handed								
No Aphasia	1	10	0	4	1	3	1	12

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1 " + " indicates the number of patients who had stimulations affecting speech.

2 " - " indicates the number of patients who had stimulations not affecting speech.

There is a statistically significant difference in the percentage of all patients who have alterations in speech during electrical arrest of the left Broca's, parietal and temporal regions as compared with those of the right side (see Table 3). This is also true when comparing the percentage of right-handed patients who have electrical interference of the left hemisphere with that of left-handed patients who have electrical arrest of the right hemisphere. There is no statistical difference in the left-handed with stimulation of the right and left hemispheres. If those with injury early in life are excluded, the percentage having alterations in speech during electrical interference in the left hemisphere is raised in the left-handed (66.7%). However, as there are only three patients in all, this is not significantly different from the percentage (20%) of left-handed having electrical arrest of the right hemisphere. Nor is there any significant difference in the percentage of left-handed (20%) and right-handed (7.7%) with alterations in speech during electrical interference of the right hemisphere(Table 4).

On the basis of the number of patients, the total number of stimulations which affected speech are shown in Tables 5 and 6. Electrical interference in any of the three areas of the left hemisphere causes disturbances in speech about one-half the time.

TABLE 3

DIFFERENCE IN NUMBER OF PATIENTS WITH ELECTRICAL ARREST PRODUCING ALTERATIONS IN SPEECH FROM LEFT AND RIGHT HEMISPHERES

Area	No. with Effects	Total No.	% of Total	Critical Ratio [1]	Significance [2] of Difference
* Broca, Lt.	55	77	71.5	4.67	< .001
* Broca, Rt.	1	15	6.7		
* Parietal, Lt.	26	47	55.3	2.36	< .050
* Parietal, Rt.	1	9	11.1		
* Temporal, Lt.	39	53	73.6	3.63	< .001
* Temporal, Rt.	1	9	11.1		
Total, Lt.	68	92	73.9	5.56	< .001
Total, Rt.	2	20	10.0		
Total, Lt. Rt.-handed	64	80	80.6	3.51	< .001
Total, Rt. Lt.-handed	1	6	16.7		
Total, Lt. Lt.-handed	2	10	20.0	0.02	Not significant
Total, Rt. Lt.-handed	1	6	16.7		

* Regardless of handedness.

1. $SD_p = \sqrt{\frac{pxq}{N_1} \quad \frac{pxq}{N_2}}$ 2 $\quad P_1 - P_2$

2. C.R. of 1.96 is significant at .05 level
   C.R. of 2.58 " " " .01 "
   C.R. of 3.29 " " " .001 "

TABLE 4

NUMBER OF PATIENTS WITH ALTERATIONS IN SPEECH DURING ELECTRICAL INTERFERENCE, EXCLUDING THOSE WITH INJURIES EARLY IN LIFE.

Left Hemisphere		Right Hemisphere	
Right-Handed	Left-Handed	Right-Handed	Left-Handed
55/70, 78.6%	2/3, 66.7%	1/13, 7.7%	1/5, 20%

TABLE 5

STIMULATION OF THE LEFT HEMISPHERE[1]

	Broca		Inferior Parietal		Posterior Temporal		Total	
	+[2]	-[3]	+	-	+	-	+	-
Right-Handed								
Aphasia	118	127	44	73	82	120	244	320
No Aphasia	22	35	8	6	27	22	57	63
Left-Handed								
Aphasia	6	8	2	2	2	8	10	18
No Aphasia	2	14	0	11	0	11	2	36

STIMULATION OF THE LEFT HEMISPHERE

EXCLUDING THOSE PATIENTS WITH INJURY BEFORE TWO YEARS

Right-Handed								
Aphasia	89	103	37	60	65	92	191	255
No Aphasia	21	28	5	4	25	10	51	42
Left-Handed								
Aphasia	6	8	2	2	2	8	10	18
No Aphasia	0	0	0	0	0	0	0	0

---

[1] Number of patients is the same as in Table 1.

[2] " + " indicates the number of stimulations which affected speech.

[3] " - " indicates the number of stimulations which did not affect speech.

TABLE 6

STIMULATION OF THE RIGHT HEMISPHERE[1]

	Broca		Inferior Parietal		Posterior Temporal		Total	
	+[2]	-[3]	+	-	+	-	+	-
Left-Handed								
Aphasia	0	2	1	0	-	-	1	2
No Aphasia	0	6	0	13	0	16	0	35
Right-Handed								
Aphasia	-	-	-	-	-	-	-	-
No Aphasia	4	26	0	10	1	16	5	52

STIMULATION OF THE RIGHT HEMISPHERE

EXCLUDING THOSE PATIENTS WITH INJURY BEFORE TWO YEARS

Left-Handed								
Aphasia	0	2	1	0	-	-	1	2
No Aphasia	0	6	0	13	0	14	0	33
Right-Handed								
Aphasia	-	-	-	-	-	-	-	-
No Aphasia	4	25	0	8	1	13	5	46

[1] Number of patients is the same as in Table 2.

[2] " + " indicates the number of stimulations which affected speech.

[3] " - " indicates the number of stimulations which did not affect speech.

TABLE 7

DIFFERENCE IN NUMBER OF STIMULATIONS WHICH PRODUCE ALTERATIONS IN SPEECH FROM LEFT AND RIGHT HEMISPHERES[1]

Area	No. with Effects	Total No.	% of Total	Critical Ratio	Significance of Difference
Broca, Lt.	153	340	45.0	3.73	$<.001$
Broca, Rt.	4	34	11.8		
Parietal, Lt.	64	164	39.0	3.27	$<.010$
Parietal, Rt.	1	23	4.3		
Temporal, Lt.	120	294	40.8	4.19	$<.001$
Temporal, Rt.	1	32	3.1		
Total, Lt.	337	798	42.2	6.65	$<.001$
Total, Rt.	6	89	6.3		
Total, Lt. Rt.-handed	301	684	43.8	4.96	$<.001$
Total, Rt. Lt.-handed	1	38	2.6		
Total, Lt. Lt.-handed	12	66	18.2	2.36	$<.050$
Total, Rt. Lt.-handed	1	38	2.6		

[1] The same notations as in Table 3 apply to this table.

The significance of the difference in the various groups is about the same with both methods (Tables 3 and 7). If those with injury prior to two years are excluded, electrical interference produces disturbances in speech in the left-handed 10 times out of 28 (35.7%) in the left hemisphere and once out of 36 (2.8%) in the right hemisphere; this difference is significant at the .001 level.

IV. EXCISION

A. All Patients

1. Method of Analysis

The case records of all patients included in the files of Dr. Penfield have been reviewed for evidence of aphasia before and after operation. Most of these patients had epilepsy. Some had tumor without seizures, and a few had cortical excisions for abnormal movements or pain; all had cortical stimulation. Two other cases did not have cortical stimulations.

The handedness of the patient is considered as that hand used more just prior to operation. Usually this has been the hand used more since infancy; if not, this is noted. In most incidences the record states that one or the other hand was used; sometimes it is noted that both hands could be used, but one was preferred. If the preferred hand were left, then the patient is considered as left-right-handed. As far as could be determined one hand was preferred, even though only slightly, in all "ambidextrous" patients. In some cases the handedness is not noted in the chart.

The age and sex of the patient has been recorded. The chief complaints and results of neurological examination on admission have been noted. The location of the excision as determined by the operator's drawing at operation has been given in terms of lobes only; for example, an excision

involving the lower posterior frontal, anterior parietal and adjacent temporal regions is called a fronto-parieto-temporal excision (or FPT). More exact localization has been determined and will be given when indicated. The method is described under "stimulation".

The presence or absence of aphasia or speech disturbance has been determined for all patients. Aphasia is defined as that psychical condition in which one has difficulty in speech, comprehension of speech, naming, reading and writing, or any one or more of them, and associated with misuse and/or perseveration of words; and not due to disturbance in the mechanisms of articulation as in pseudobulbar palsy, or involvement of peripheral nerves, and not due to mental insufficiency. Speech disturbance is 1) aphasia, and 2) a disturbance in articulation without difficulty in naming, reading or writing except an articulatory one. In the subsequent results the number of patients with articulatory disturbances only is determined by subtracting the number with aphasia from the total with alteration in speech. A patient is said to have had aphasia or disturbance in speech only if it occurred as a result of operation. In other words if a patient had some sort of aphasia or speech disturbance prior to surgery and no change as a result of operation, it is considered that the operation itself had no effect upon speech.

The cases in this section are considered from the standpoint of presence or absence of speech disturbance. The patients personally examined are included.

Many patients have had more than one operation. Where the courses after operation as regards language functions are the same (speech disturbance or not), only the number of patients is given; where the courses are different (aphasia after one operation and no aphasia after the second operation), the patient is omitted and the operations are considered in a separate account. Where the patient had aphasia (or had no aphasia) after both operations, the location of the excision is that of the first operation.

2. Results

Five hundred and seventy five patients had 669 operations. Two hundred and ninety six had 341 operations involving the right hemisphere; 283 had 316 operations involving the left hemisphere. In eight patients in the latter group different effects upon speech occurred after a second operation than had occurred after the first operation. These eight are not included in the subsequent tables. Ten had operations first on one hemisphere then the other, and are considered in both groups. Eleven patients had 12 operations involving both hemispheres at the same time and five of them had other operations on a single side.

The data presented in Tables 8 through 11 are self-explanatory. Emphasis is placed upon the fact that if those with injury early in life are excluded, the percentage of the left-handed and the right-handed having aphasia after operation on the left hemisphere is almost exactly the same; and this percentage is significantly greater than the left-handed having aphasia following operations on the right hemisphere. If those left-handed patients who had been right-handed are excluded in the various comparisons, these general statements still hold true. The left-handed had aphasia after operations on the right hemisphere more frequently than the right-handed (13.0% and 0.8%) and this difference is significant.

Though the percentage are higher in the various categories for disturbance in speech than for aphasia, the comparisons are not statistically different.

Eighty-six patients had initial injuries after the age of two years and subsequent operations involving the left hemisphere.

TABLE 12

After Operation	After Injury Aphasia	No Aphasia	Unknown	Total
Aphasia	16	6	30	52
No Aphasia	8	7	19	34

TABLE 8

DIFFERENCE IN PERCENTAGE OF PATIENTS WITH APHASIA

AFTER OPERATION ON LEFT AND RIGHT HEMISPHERE

Hand	Left Hemisphere Total No.	Left Hemisphere No. with Aphasia	Left Hemisphere %	Right Hemisphere Total No.	Right Hemisphere No. with Aphasia	Right Hemisphere %	Critical Ratio	Significance of Difference
Right	175[3]	121[3]	69.8	253	2	0.8	15.54	< .001
R.-L.[1]	4	4		2	0			
Left	48[5]	10[6]	28.3	12	2	13.0	1.47	Not significant
L.-R.[2]	19	9		11	1			
Unknown	29	16	55.2	18	0			
Total	275	160	57.8	296	5	1.7	15.17	< .001

[1] Greater use of right hand. [2] Greater use of left hand.

[3] Eight other patients had more than one operation with aphasia after one and not another.

[4] One had a second operation without subsequent aphasia.

[5] Five patients had been right-handed. [6] Three patients had been right-handed.

TABLE 9

PATIENTS WITH INJURY BEFORE THE AGE OF TWO YEARS AND APHASIA AFTER OPERATION

Hand	Left Hemisphere		Right Hemisphere	
	No. with Aphasia	No. without Aphasia	No. with Aphasia	No. without Aphasia
Right	9	12	0	57[1]
R.-L.	1	0	0	1
Left	3[2]	36[3]	1	3
L.-R.	3	7	0	3[4]
Unknown	4	1	0	2
Total	20	56	1	66

[1] One had a disturbance in articulation.

[2] One had been right-handed.

[3] One had a disturbance in articulation.

[4] Two had a disturbance in articulation.

TABLE 10

DIFFERENCE IN PERCENTAGE OF PATIENTS WITHOUT INJURY BEFORE TWO YEARS OF AGE AND WITH APHASIA AFTER OPERATION ON THE LEFT AND RIGHT HEMISPHERE

Hand	Left Hemisphere Total No.	Left Hemisphere No. with Aphasia	Left Hemisphere %	Right Hemisphere Total No.	Right Hemisphere No. with Aphasia	Right Hemisphere %	Critical Ratio	Significance of Difference
Right[1]	157	115	73.2	197	2	1.0	14.40	$<.001$
Left [2]	18	13	72.2	16	2	12.5	3.49	$<.010$
Unknown	24	12	50.0	16	0	0	3.38	$<.010$
Total	199	140	70.4	229	4	1.7	16.36	$<.001$

[1] Including right-left.

[2] Including left-right.

TABLE 11

PATIENTS WITH DISTURBANCE IN SPEECH AFTER OPERATION[1]

Hand	Left Hemisphere	Right Hemisphere
Right	123	9[2]
R.-L.	4	0
Left	11	3
L.-R.	10[3]	4[4]
Unknown	16	1
Total	164	17

[1] Total number of patients and footnotes of Table 8 apply to this one.

[2] Three patients had other operations without disturbance in speech.

[3] One patient had a preceding operation without disturbance in speech.

[4] One patient had a subsequent operation without disturbance in speech.

Aphasia after operation is more frequent in patients without injury than those with injury (see Table 13). However if those five patients who continued to be aphasic but had no change in their condition after operation are excluded, the difference is not significant at the one per cent level.

If those patients having birth injury or tumor are excluded, aphasia followed operations on the various lobes of the left hemisphere, as shown in Table 14. In this table all operations after the first are included.

Edema of the brain frequently accompanies cerebral trauma, tumor and operation, and generally manifests itself in a definite time course. Following operations with prolonged cortical exposure and stimulation, evidence of edema in the form of motor or sensory disturbances, aphasia, seizures, etc. is frequently first noted several days after operation. Because of this time course, the adjective neuroparalytic is used to describe the edema, and it includes aphasia as a symptom of edema. Neuroparalytic edema occurred after 131 of the 178 operations on the left hemisphere after which patients were aphasic, and only after 17 of the 138 operations after which patients were not aphasic. Following operation on the right hemisphere, neuroparalytic edema occurred after 3 of 5 operations after which the patient was aphasic and occurred after 104 of 336

TABLE 13

DIFFERENCE IN PERCENTAGE OF PATIENTS WITH APHASIA AFTER OPERATION ON THE LEFT HEMISPHERE WITH VARIOUS INITIAL PATHOLOGICAL PROCESSES

	Aphasia After Operation				
	No. with Aphasia	Total No.	%	Critical Ratio	Significance of Difference
A. Injury before the age of two years	20	76	26.3 (A + B)	4.38	$< .001$
B. Injury after the age of two years	52	86	60.5 (B + C)	2.80	$< .010$
C. No injury	71	89	79.8 (C + A)	6.86	$< .001$

TABLE 14

HANDEDNESS

Area	Right-Handed			All		
	No. with Aphasia	Total	%	No. with Aphasia	Total	%
Frontal	15	35	43	20	46	43
Pole	0	10	0	3	17	18
Other	15	25	60	17	29	59
F.-P.	5	6	83	6	7	86
F.-P.-T.	1	1	100	1	1	100
F.-T.	2	3	67	2	3	67
Parietal	8	9	89	9	11	82
P.-T.	5	9	56	5	10	50
Temporal	30	36	83	33	42	79
T.-O.	1	2	50	1	2	50
Occipital	-	-	-	1	1	100
Exploration	24	35	69	31	46	67
Total	91	136	67	109	169	64

operations after which the patient was not aphasic.

Aphasia occurred immediately after operation in 22 of the 160 patients having aphasia after operation on the left hemisphere and did not occur immediately after surgery involving the right hemisphere. Thirteen of those having immediate aphasia did not have a tumor and 9 had a tumor. Of the former group four had frontal excisions of the area superior to Broca's region; one had a removal of the Rolandic face area and possibly Broca's area; one had an excision of the area just anterior to Broca's area as well as the tip of the temporal lobe; five had excisions of the tip of the temporal lobe; one had an excision of the posterior inferior temporal region; and the last had frontal and temporal biopsies without cortical removal. It is believed that the reasons for the immediate aphasia are seizures in four, fatigue in three (no difficulty in speech shortly after surgery) vascular occlusion in one (see page 92) and unknown in five. Only three of these thirteen patients had permanent aphasia. One had the removal of the Rolandic face area and possibly part or all of Broca's area. Two years later he still had definite slowness and mispronunciation according to his letter: "Je parle avec beaucoup de difficulter; trés lentement et prononce pas trés franc mes mots." He is having an occasional seizure. The one with the vascular occlusion had moderate difficulty on examination two months

after operation and still had difficulty eleven months later according to his letter. He is having occasional seizures. The third patient had only slight difficulty three weeks after operation. Another patient (supplementary motor area removal) died six days after operation. The other nine patients had no permanent aphasia.

Five of the nine patients with tumor who had immediate aphasia had excisions of the frontal lobe superior to Broca's area (possibly involving it in one); two had excisions of the Rolandic face area; one had an excision of the postcentral arm area and the gyrus posterior; and the last had the tip of the temporal lobe removed. Seizure with subsequent hemiplegia and aphasia was the cause of the immediate aphasia in two; one had gross brain swelling and another had fatigue (no difficulty shortly after operation). The latter patient and one with an excision of a meningeal fibroblastoma with underlying cortex in the frontal region had no permanent aphasia. The others had permanent aphasia and three have died.

Besides the three patients already mentioned permanent disturbance in speech occurred in 15 others who had operations on the left hemisphere for lesions other than tumor. Four of them (one frontal, two parieto-temporal and one exploration only) had aphasia after their original injury, still had definite difficulty before operation for relief of seizures,

had increased aphasia after operation and residual difficulty approximately equal to that before surgery. All had continuing seizures. Another patient (parieto-temporal) had a similar course except that he had no change in speech immediately after operation and nine months later showed definite improvement and had had no seizures.

Four patients personally examined (frontal, parietal and two temporal) showed only slight difficulty on discharge. Two others (frontal and exploration) had moderate aphasia on discharge and follow-up has not been complete, but both have had seizures. Two had no difficulty on discharge; yet when one (fronto-parietal) returned to the clinic four years later his chief complaint was marked difficulty in speech and inability to read and write; the other (parietal) had his wife write twelve years later stating he had been unable to read or write since operation. Both have had seizures.

Another patient with a frontal lobe removal and a second operation performed without excision of Broca's area for fear of permanent aphasia still has frequent seizures with postictal aphasia. Still another patient had an exploration with transient secondary aphasia. Fourteen years later at the age of 22 she had the tip of the temporal lobe removed. Before this operation she had slight difficulty in spelling, but otherwise showed no striking difficulty in language though

she appeared mentally retarded. After operation she had a secondary profound aphasia for the second time. She improved before discharge so that she was approximately the same as on admission. The seizures continured and four years later she had marked difficulty with all tests except that spontaneous speech was not of the aphasic type at other times than immediately after a seizure. She had a third operation with removal of the posterior inferior temporal and adjacent anterior occipital region. She showed no appreciable change in language functions after this procedure and is therefore included in the negative group in the next section, though, of course, she still has marked language difficulties.

Two patients having operations on the right hemisphere have had permanent speech disturbances. Neither are included in the five patients classed as aphasic. One (left-handed) had a severe accident with evidence of bilateral cerebral damage. When first admitted, he appeared mentally deficient. He had two operations three years apart with excisions of the parieto-temporal region and the precentral face and Broca's areas. No change in speech was noted after either procedure. The other patient (right-handed) had had a birth injury with left hemiparesis and he stuttered. Following a right fronto-parieto-temporal excision, his wound was reopened for a post-operative hemorrhage which was controlled. He had a decerebrate posture for two weeks and was unconscious for six weeks.

He has had marked speech difficulty since operation but is improving with therapy.

The five patients who are classified as having aphasia with involvement of the right cerebral hemisphere should be briefly mentioned. One is presented in detail (page 148). The second was a 32 year old man who had a gunshot wound in the right frontal region at the age of 28. The right eye was enucleated and he had complete anosmia. At operation for seizures about 2½ cm. of the tip of the temporal lobe and a large part of the frontal lobe, which included the entire third frontal convolution, were excised. On the fifth day after operation, it was noted that he had difficulty in naming objects though he thought he named them correctly, and that there were no motor or sensory disturbances. He had no difficulty naming several days later according to the record.

The third patient was a fifteen year old right-handed boy who had seizures beginning with inability to speak, write, or understand though he remained conscious of his environment. At operation there were adhesions over the lower posterior frontal and adjacent temporal regions; and the gyrus anterior to the motor face area was yellowish-grey and atrophic - it was removed. Between the fourth and sixth days after operation he is reported to have "nominal aphasia and inability to write". This cleared completely. He continued to have seizures and

four years later the temporal lobe was excised back to a level 3 cm. posterior to the central fissure if it were extended downwards. He had no speech disturbance but died three days later as a result of kidney damage from a transfusion reaction.

The fourth patient was a 22 year old man who wrote with his right hand but did many other things with his left hand. He was struck by a golf ball in the right parietal region but continued to play for another two and one half hours. At that time he became disoriented as to place and had difficulty in speech. On examination an hour later he had very little difficulty in spontaneous speech, he had difficulty understanding requests, he was unable to point to all objects named by a word on a card, or to write at all well and did not seem to be able to use a pen. He also had a left homonymous hemianopsia and slight left hemiparesis. Several days later a right parietal craniotomy was performed and blood aspirated from beneath the cortex. At discharge six weeks later he had a great deal of difficulty with writing, both misspelling and misusing words, but no other defect. His writing returned to normal.

The last patient was a 50 year old right-handed man who had had progressive left hemiparesis, speech disturbance and headaches for three weeks prior to admission. On examination he had hemiparesis, hemianopsia, and sensory disturbances on the left. He had marked disturbance in all language functions. There was no

papilledema. A right parietal abscess was removed and he made a gradual complete recovery.

B. Patients Personally Examined

1. Methods of Examination

All patients reported in this section have been examined before operation (except two) and periodically thereafter. Complete testing is carried out before operation and as soon as it is thought feasible afterwards. In the immediate period after operation, limited testing is done; the amount will be given in the subsequent paragraphs. Practically all patients can be described as acutely ill with headaches, elevated temperature and so forth for the first several days to several weeks after surgery. Feasibility of complete testing is determined by the general condition of the patient.

At the beginning of this work, methods had not been established. Some patients were operated upon or discharged without complete testing. More than thirty patients have been omitted from the subsequent detailed analysis because of incompleteness of examination. The 71 patients are divided into four groups, as follows: operations on the left cerebral hemisphere 1) with language disturbances (26), and 2) without language disturbances (19); and operations on the right cerebral hemisphere 3) with language disturbances (1) and 4) without language disturbances (26).

The tests will be described and then the results obtained in each of the four groups given.

Spontaneous speech is the ability to carry on a conversation. This involves the ability to understand and to reply. No patient was completely speechless or showed evidence that he understood nothing. The deficit has been judged subjectively by the author as he knew of no way to be objective. The words questionable, slight, moderate, marked and very marked, or the numerical representations 1, 2, 3, 4 and 5 have been used to describe the various degrees of increasing disturbance in spontaneous speech, as well as difficulty in the following categories of perseveration, naming, etc.

Perseveration is used to include the uncontrolled repetition of words or nonsense sounds occurring in spontaneous speech as well as in naming. Perseveration also has been judged subjectively.

Naming includes the naming of 12 objects (key, pencil, match, scissors, comb, spoon, safety pin, thumb tack, paper clip, quarter, dime and nickel), eight miniature objects (chair, stove, pipe, boot, watch, cat, telephone and spoon), and 21 small pictures (bird, comb, knife, horse, bed, tree, drum, apple, house, butterfly, table, top, hat, foot, clock, fish, glove, scissors, cow, hammer, and flag). Some patients fail to name one or more of the preceding before operation; the thumb tack, paper clip, coins (by foreigners), boot, butterfly, or top were the objects missed. Frequently the

patient could describe rather accurately the use of the object but could not put the concrete name to it; or he might call the boot, a shoe, or the butterfly, a moth. Failure to name one or two of these objects is classified as a questionable defect. Failure to name one-fourth of them is slight difficulty; one-half, moderate difficulty; three-fourths,marked difficulty; and more than three-fourths is classified as very marked difficulty in naming. Immediately and for the first few days after operation, the patient was asked to name only about ten objects (usually the first ten small pictures); as soon as feasible all objects were used again.

Repetition includes the repeating of "Methodist Episcopal", "British Constitution", " The Third Riding Artillery Brigade" and "Around the rugged rock the ragged rascal ran". Also the patient is asked to repeat key, pencil, match, scissors, comb and spoon as a unit. If he cannot do the preceding, he is classed as having marked difficulty in repetition and is requested to repeat individual words.

Oral commands consist of asking the patient to put his right second finger on his left ear, or his left third finger on his right eyebrow, etc. If the patient can do none of these commands he is said to have very marked difficulty in obeying commands, and is given simpler ones. If he obeys some of these commands, he is given two then three of

the preceding simultaneously. If the patient fails on the three simultaneous commands and executes the others, he is classified as having slight difficulty. If he obeys one-half of the two simultaneous commands, he has moderate difficulty and if he obeys none of them but obeys the single commands he has marked difficulty.

Written commands consist of the same type as the oral - "Put your left third finger on your right eyebrow". Only two commands similar to the preceding are given and if not obeyed the patient has slight difficulty obeying written commands. If he obeyed none of the single commands he has marked difficulty and is given commands such as "show me your teeth", or "show me your right second finger". If these are not obeyed he has very marked difficulty obeying written commands.

Spelling is judged by both oral and written ability; and as the writing (see under "spontaneous writing") varies considerably, difficulty in spelling is classified slight, moderate, marked and very marked on a subjective basis.

Reading aloud involves the reading of letters, numbers, words and simple sentences. As practically all patients before operation read these correctly, this scoring is based on reading the following three sentences aloud: 1) The test is applicable to individuals above the 8 or 9 year level. 2) In explaining each test to the patient use only the phrases given above the form. 3) Repeat each test three times and in the same sequence. In the immediate period after

operation only the simple sentences are given and difficulty charted on the basis of the percentage of the whole missed. At times there is a difference in ability to read numbers as compared with letters or words and this is noted. As soon as feasible the more difficult reading is given.

Silent reading consists of reading and repeating the following three sentences: 1) Do not help the patient out. 2) Be sure to record verbatim all hesitations and incorrect responses. 3) A pause is to be judged as such depending on the mental activity of the patient. Scoring is made on the following basis: Each sentence counts thirty-three and one-third per cent with the actual words counting one-half and the meaning one-half. If the meaning is not clear to the examiner, questions are asked and both questions and answers recorded. No time limit is set. If the patient cannot repeat anything, three simpler sentences are used: 1) Snow is cold. 2) Bread is good to eat. 3) The man and his dog went for a walk in the woods.

Spontaneous writing consists of what the patient writes when asked to write a page on a subject of his own choosing. There is considerable variation and the scoring is on a subjective basis.

Writing to dictation includes writing of the words and sentences which are the same as those used in repetition.

Copying consists only of copying words.

Oral calculation consists of the following problems: 8 plus 4; 29 plus 36; 100 minus 18 from 34; 8 times 4; 9 times 7; 13 times 13; 8 divided by 4; 36 divided by 6; 96 divided by 6; and 256 divided by 16. If the simpler problem in each category is not answered correctly, others even simpler are given. This test is not repeated until it is thought feasible after operation.

Written calculation includes the following problems: 863 + 136; 987, 864 + 958; 986 - 121; 988 - 889; 4567 - 5456; 94 x 37; 9.08 x 95; 48048 ÷ 24; and 68064 ÷ 32. Simpler problems are given if required.

The preceding tests have been given by the author; the subsequent examinations have been done partly by members of the staff of the Montreal Neurological Institute and partly by the author. For example, if there is no defect in muscular power and coordination recorded in the clinical examination, this datum is used. If there is weakness the author also evaluated its extent. No detailed examinations of the motor or sensory systems have been made, so that minor defects may not have been detected. Evaluation of motor and somato-sensory disturbances are made on a subjective basis.

Most of the patients with temporal excisions have visual field examinations before operation and before discharge by means of the perimeter and tangent screen. Examination of

these patients during the immediate period after operation and examination of the other patients has been done in a gross manner and includes simultaneous movements within both visual fields.

Only routine deep and superficial reflexes have been tested. Seizures are recorded on the basis of the patient's and observer's statements. The electroencephalograms are reported by Dr. Herbert Jasper. Cerebrospinal fluid pressure is recorded whenever a lumbar puncture is done.

2. Operations Involving the Left Hemisphere

a. Twenty-Five Patients with Aphasia

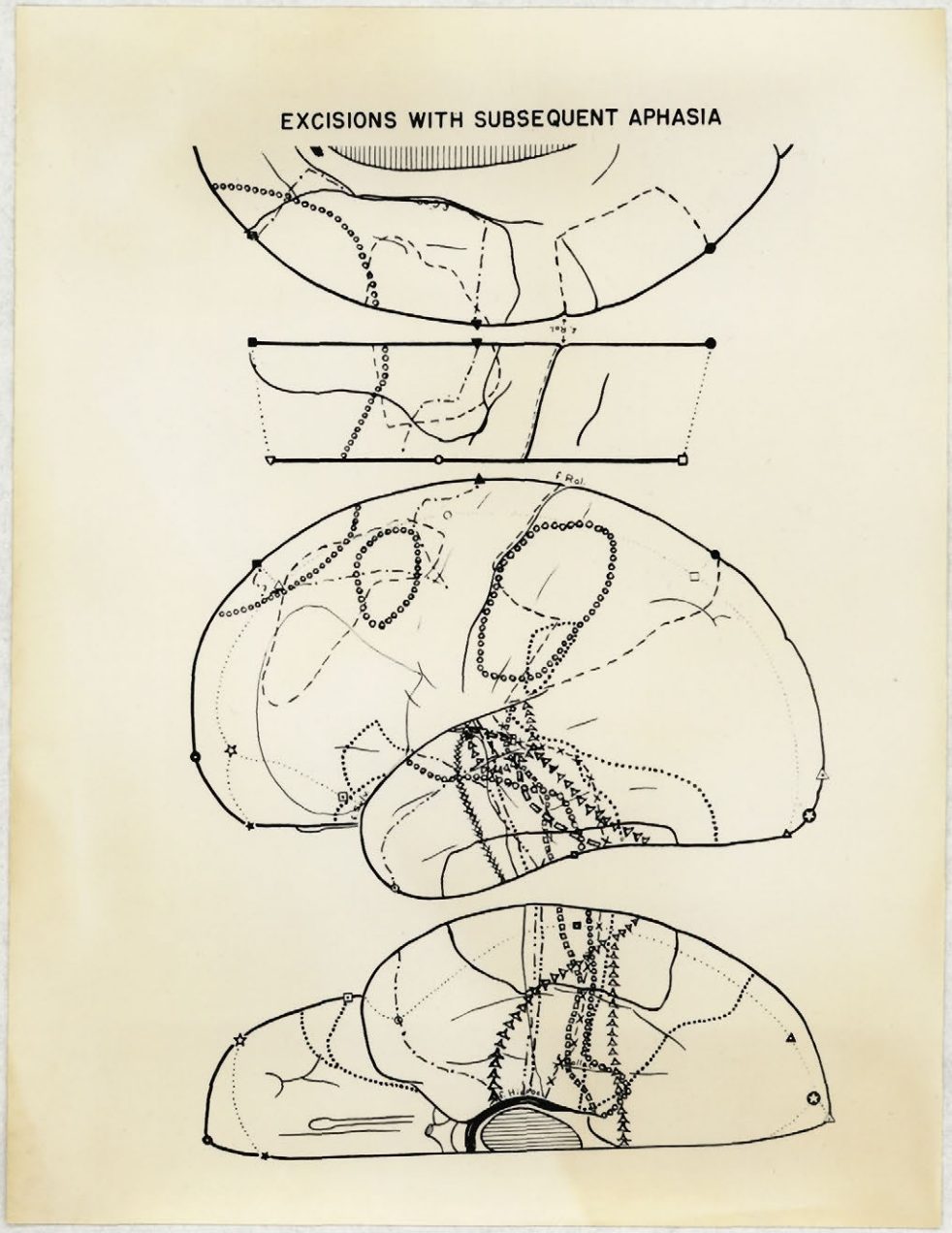

Figure 14

Spontaneous Speech

Frontal lobe excisions.

The five patients with cortical excisions showed no defect in spontaneous speech before operation with the exception of one who was born in Germany, spoke with a foreign accent and made grammatical errors in English. One had no difficulty after operation; one talked practically not at all for the first few days after surgery but thereafter spoke well. The other three had difficulty in spontaneous speech beginning on the first, second and fourth days after operation. The defect was very marked in two and there was a questionable defect one month later. The other patient had only a slight defect and it disappeared.

Two of the three patients with frontal lobe tumors had slight difficulty in spontaneous speech before operation and the other's speech was slow and slurred. One had three seizures during the operation and became almost speechless. She showed slight improvement the next day but still had moderate difficulty on discharge three weeks later.

The second case had no increase in speech difficulty immediately after operation but the next day it was marked. On discharge four weeks later he still had a moderate defect. Considerable brain swelling occurred in the slow-speaking patient, and closure of the dura was possible only after spinal

fluid drainage. During which time, he had slight difficulty in speech. This became very marked on the second day and was still moderate three weeks later.

Fronto-temporal.

This patient tended to repeat phrases and sentences but otherwise spoke normally. During the excision in the region of the insula or frontal operculum she developed a moderate right hemiparesis with slurring and slight difficulty in spontaneous speech. The difficulty cleared in two days but she continued to slur. Following the second operation she had slight difficulty for several days beginning on the fourth day. On discharge three weeks after the second operation she continued to repeat sentences and to slur her words.

Parietal.

These three patients had no difficulty in spontaneous speech before operation. One with cortical excision had slight difficulty four days after operation, then very marked difficulty and on discharge only questionable trouble. A year later he spoke normally. One with excision of a vascular anomaly and surrounding cortex first had difficulty speaking the day after operation, then marked difficulty, and only questionable difficulty on discharge. The patient with tumor had a questionable defect immediately, which became very

marked the next day and was moderately severe three weeks later.

Temporal.

The twelve patients in this group had no difficulty in spontaneous speech prior to operation. During the removal of tissue by suction in the region of the free edge of the tentorium, one patient had a sudden onset of marked right hemiparesis and almost complete speechlessness. At the time of discharge two months later there was still moderate speech disturbance. Two other patients had slight difficulty in spontaneous speech immediately. One recovered completely and the other suffered a slight disturbance four weeks later. The onset of speech difficulty in the nine remaining patients varied from one to eight days. Two had slight disturbance 25 days later; one (the only tumor case) had moderate difficulty after 12 days.

Exploration.

A slight speech disturbance was first noted in this man 5 days after operation. It cleared in 3 days but recurred post-ictally on the tenth day.

Summary.

Only one of the twenty patients with cortical excisions - adjacent to Broca's area - failed to show any definite evidence of interference with spontaneous speech. Three patients - all temporal lobe excisions (T*) - had disturbance in spontaneous speech immediately. The explanation of the one with almost complete speechlessness seems to be either damage to the cerebral peduncle which is close, or the temporal stem (isthmus) or vascular occlusion. Vascular occlusion seems the most likely because of simultaneous aphasia, hemiparesis and homonymous hemianopsia. The reason for the immediate slight speech disturbance in the other two cases could be the frequent minor seizures during operation.

Two patients - temporal lobe excisions - had slight difficulty in spontaneous speech four weeks after operation. It is suggested that this slow recovery is related to continuation of seizures and abnormally functioning brain. The man with the almost complete speechlessness still had moderate difficulty two months later. This is attributed again to the vascular lesion.

Two of the tumor cases - frontal - had slight difficulty before surgery. All five had moderate difficulty on discharge.

* For conservation of space the first letter of the lobe involved will be used, thus T stands for temporal lobe excision; FPT stands for an excision involving the frontal, parietal and temporal lobes; and E stands for exploration without any excision.

Perseveration

In general evidence of perseveration parallels defects in spontaneous speech - the greater the difficulty in speech, the more perseveration. Only one patient - frontal lobe tumor - perseverated slightly before operation; the following comments refer to evidence of perseveration after surgery.

Frontal.

One patient had marked speech difficulty with slight perseveration on the fifth day after operation. By the tenth day his speech was moderately affected but he perseverated more; about half of what he said showed perseveration. None had perseveration on discharge. The patient with the tumor who had very marked speech difficulty immediately following surgery perseverated in everything she said. The next day though her speech was only slightly improved she did not perseverate. However, several days later she again showed evidence of perseveration. The other two tumor cases perseverated more the more spontaneous speech was involved.

Fronto-temporal.

This patient had slight perseveration after both operations.

Parietal.

The three cases showed only slight perseveration even during the time when speech was very markedly affected; and there was no perseveration on discharge.

Temporal.

All the patients showed perseveration except the one patient with a tumor. In three cases there was only slight to moderate perseveration with marked speech disturbance.

Exploration.

This patient showed no perseveration.

Summary.

The amount of perseveration usually coincided with the degree of involvement of spontaneous speech. Three of the temporal lobe cases had very slight perseveration on discharge and two of the frontal lobe tumor cases had slight perseveration.

Naming

Frontal.

None of the excision group had difficulty naming prior to operation. The patient who had no difficulty in speech also had none in naming. Two patients had moderate difficulty in naming with marked and very marked difficulty in speech.

One had marked difficulty naming with only slight disturbance in speech. All named correctly on discharge.

One of the tumor cases had very slight trouble naming before operation. After surgery he was unable to name any object on the fifth day, then returned to his preoperative status. Another could not name immediately after operation; named all objects on the first day; had marked difficulty by the fifth day and slight trouble on discharge. The third patient had no trouble immediately but was unable to name on the first day and still had moderate difficulty on discharge.

Fronto-temporal.

This patient did not know the names of a few objects before operation, but there was no change after either operation.

Parietal.

The patient with the vascular anomaly did not know the name of two objects before operation. She was unable to name on the first day after; by discharge she had regained her previous ability. The other excision case showed no deficit in naming until three days after surgery. It was very marked on the fifth day, slight on discharge, and not present a year later. The patient with a tumor had some difficulty naming immediately, marked disturbance in twenty-four hours and slight difficulty three weeks later.

Temporal.

All patients named correctly before operation except for one who did not know the names of three objects in English though he did in his native Spanish. Four patients had difficulty immediately - two moderate and two very marked. The disability increased to very marked by the first day in the former two. One had slight trouble and three very slight difficulty naming on discharge. The one patient seen two months later showed no disturbance.

The seven other cases with cortical excisions had difficulty in naming, usually in the same proportion as the disturbance in spontaneous speech. One had slight difficulty in speech on the day after operation though no trouble naming. However, he later had very marked difficulty which was slight on discharge but non-existent seven months after operation. Only one other patient had slight difficulty on discharge (also slight disturbance in speech).

The tumor case showed marked disturbance from the third to the ninth day and very slight difficulty on the twelfth day though his spontaneous speech was moderately affected.

Exploration.

This patient had very slight difficulty naming immediately. This did not increase and disappeared by the eleventh day.

Summary.

Three patients without tumor (FT, P, and T) and one with tumor (F) had very slight difficulty naming before operation. Five patients with excisions (one F and four T) had trouble naming immediately after operation. Three with tumor (two F, and one P) also had difficulty naming immediately after surgery. Three patients without tumor (T) had slight difficulty naming on discharge and the one seen seven months later had no difficulty. Excluding those with very slight difficulty on admission, four (one P and three T) had very slight difficulty on discharge; the two examined some months later showed no difficulty. Three individuals with tumor (F, P, and T) had slight difficulty naming and one (F) moderate difficulty on discharge.

Repetition

As this test was not given routinely at each period after operation, only the testing prior to surgery and the last test afterwards will be summarized. From the tests given during the first few days after operation, it can be stated that the reduction in ability to repeat the test phrases usually was in proportion to the disturbance in spontaneous speech.

Frontal.

The patient born in Germany had slight difficulty in repetition prior to operation and three weeks afterwards. None of the other patients in the excision group had any trouble with this test before surgery or three weeks later.

One of the tumor patients had slight difficulty before and moderate difficulty 4 weeks after operation. The other two had no disturbance initially and slight and marked difficulty three weeks after operation.

Fronto-temporal.

This French patient had no trouble repeating six names before or three weeks after the first operation or two weeks after the second procedure.

Pariétal.

The two patients with cortical excisions had no difficulty before operation; one had slight difficulty seven weeks after operation. The tumor case showed no disturbance before and slight difficulty three weeks after operation.

Temporal.

Four patients had very slight difficulty in repetition initially. One of them had no difficulty on discharge; one, very slight; one, moderate at four weeks; and the fourth (the one with the probable vascular occlusion) had moderate difficulty after two months. Three of the other seven patients

with no trouble before operation had slight difficulty four weeks after surgery.

The patient with a tumor had very slight difficulty prior to operation and moderate difficulty twelve days after operation.

Exploration.

This patient had very slight difficulty before and eleven days after operation.

Summary.

One patient (F) had slight difficulty in repeating before and after operation. Four (T) had very slight difficulty before operation. At discharge one had no difficulty, one very slight difficulty and two moderate difficulty. Three others (T) had slight difficulty at discharge.

Two patients with tumor (F and T) had very slight difficulty before operation, and moderate difficulty at discharge. Two (F and P) had very slight difficulty at discharge and one (F) marked difficulty.

Oral Commands

Frontal.

One patient had no difficulty with oral commands before operation, three had very slight difficulty and one moderate. The patient with no difficulty had no trouble on the fifth and tenth days after operation. The three with very slight difficulty had marked difficulty after operation. One continued to have marked difficulty one month later, and the other two had a very slight deficit. The patient with moderate difficulty prior to operation had only slight difficulty about two weeks later (the test was not repeated prior to thirteen days).

Two of the three tumor-cases had moderate difficulty in obeying oral commands and the other very slight difficulty before operation. The former two had marked difficulty and the latter moderate difficulty on discharge.

Fronto-temporal.

This patient had marked difficulty before and after both operations.

Parietal.

One patient had no difficulty before surgery. The patient with the vascular anomaly and the one with the tumor had moderate difficulty before operation.

After operation all three had marked trouble obeying oral commands. The one without deficit before operation had

slight difficulty 14 days afterwards and very slight difficulty a year later; the other two continued to have marked difficulty.

Temporal.

Four patients executed oral commands correctly prior to operation. Two had very slight difficulty, two slight difficulty and three moderate difficulty. The tumor case showed slight difficulty. Those who were tested shortly after operation showed a drop in ability to follow oral commands.

Two of the four without previous difficulty had no difficulty after some weeks following operation; the third (the one with the vascular occlusion) had slight difficulty two months later; the fourth showed marked difficulty three weeks after surgery. The two with very slight difficulty had no difficulty three weeks afterwards. One of those with slight difficulty initially had moderate difficulty twenty-five days later and the other had marked difficulty five days after his second operation. Two of the three patients with moderate difficulty still had the same trouble several weeks later and the third had only very slight difficulty. The tumor case showed moderate difficulty twelve days after operation.

Exploration.

This patient had moderate difficulty before and eleven days after operation.

Summary.

This test is difficult. The results shall be compared as regards differences between testings before and after operations in the various areas rather than absolute scores as done under the area subheads.

Six patients without tumor showed a decrease in ability to obey oral commands at the last testing after operation when compared with the test before surgery. One (T) showed no difficulty before and slight after operation. One temporal case had marked trouble three weeks after surgery though she obeyed all commands before surgery. One (T) had slight difficulty before and moderate difficulty three and one-half weeks after operation. One (F) had very slight difficulty before operation and marked difficulty afterwards. One (T) had slight difficulty before and a marked disturbance after surgery. The other patient (parietal) had marked difficulty seven weeks after operation and moderate difficulty before.

Four patients showed improvement in ability to obey oral commands. Two cases (frontal and temporal) improved from a moderate to a slight or very slight disturbance after operation. Two temporal cases had very slight difficulty originally and no difficulty three weeks after surgery.

All five tumor cases demonstrated decreased ability in the last test after operation as compared with the original test before operation.

Written Commands

Frontal.

None of the five non-tumor patients had any difficulty obeying written commands before operation. One had no disturbance after surgery; another was not tested until three weeks and obeyed all commands then. The other three had disturbances after operation which disappeared in two and was slight in one a month after surgery.

One tumor case had slight difficulty and the other two moderate difficulty before surgery. The former case showed very marked difficulty four weeks later and the other two marked difficulty.

Fronto-temporal.

This patient had slight difficulty before operation but none two weeks after the second procedure.

Parietal.

All three had no disturbance before, some afterwards and the two without tumor returned to the previous level but the tumor case showed a moderate disturbance three weeks later.

Temporal.

One patient had very slight difficulty before surgery. All had a disturbance roughly proportionate to that of spontaneous speech after operation. The patient with the

vascular occlusion showed moderate difficulty on discharge; and three others (including the one with initial difficulty) had a very slight disturbance on discharge. The tumor case had no difficulty before and slight trouble twelve days later.

Exploration.

This patient showed very slight difficulty before and eleven days after operation.

Summary.

Two patients without tumor (T and E) had very slight disturbance before and after operation. One (FT) had slight difficulty before surgery and no difficulty at discharge. One (F) showed slight difficulty and two (T) had very slight difficulty on discharge, though none on admission. The temporal case with vascular occlusion had moderate difficulty seven weeks later.

The three frontal tumor cases had difficulty before operation and all five tumor cases showed a deficit on discharge.

Spelling

Frontal.

Two of the five patients without tumor had slight difficulty, two very slight and one had no difficulty in spelling. The patient with no difficulty before had a very slight disturbance three weeks later. One patient had no difficulty, one very slight, one slight, and one a moderate disturbance at the last testing.

One tumor case showed no difficulty and the other two had slight difficulty before operation. All three had marked difficulty on discharge.

Fronto-temporal.

This patient had no difficulty in spelling on admission or at discharge.

Parietal.

One had very slight difficulty and two had slight difficulty before surgery. The patient with a tumor had moderate difficulty on discharge and the other two still had very slight difficulty.

Temporal.

Four patients spelled correctly; six had very slight difficulty and one moderate difficulty before operation. All returned to the same level of performance at the last test after operation except the patient with the vascular

occlusion who had a marked deficit. The patient with a tumor had very slight difficulty before and after operation.

Exploration.

This patient had slight difficulty before and eleven days after surgery.

Summary.

Three patients of those without tumor failed to demonstrate the same spelling ability on discharge as before operation. Two of these had no difficulty before; the frontal case showed very slight difficulty and the temporal vascular case marked difficulty on discharge. The other patient (frontal) had slight difficulty before and moderate after operation.

All tumor cases except the temporal one showed a definite decrease in spelling ability on discharge as compared with before operation.

Reading Aloud

Frontal.

The German patient was the only one of the group without tumor who had slight difficulty reading before operation. None showed any decrease immediately after operation. Two had quite marked difficulty and one moderate difficulty during the next several weeks; all three returned to their level before

operation. Two had no difficulty with repeated tests after operation. One of these had no difficulty in spontaneous speech and the other was the patient that talked practically not at all but what he said was correct.

The three tumor cases showed slight difficulty before surgery, without increase immediately but with very marked disturbance after several days. Two of these returned to their previous level of ability except that one still had marked difficulty reading letters at discharge. The third patient read simple words and sentences quite well but complicated words and sentences which she had been able to read before operation were read very poorly.

Fronto-temporal.

This patient had no disturbance after the first operation and only slight difficulty after the second, with none on discharge.

Parietal.

These three patients had no difficulty before operation. The one with the vascular anomaly showed slight difficulty immediately after operation, with ingravescence and then improvement to no difficulty on discharge. The other two had very marked difficulty beginning after the first day. The tumor case still showed slight difficulty on discharge but the other patient had no disturbance.

Temporal.

Three patients showed very slight difficulty before operation. One of these was a young girl who had had difficulty learning to read and who still had some trouble. Two patients had difficulty reading immediately after operation. In one patient the disability was slight, became very marked but was not present at discharge. The patient with the vascular occlusion could not read at all immediately after surgery and had marked difficulty fifty-four days later. The disturbance in reading approximately paralleled the difficulty in spontaneous speech in all incidences. The girl with the slight disturbance before operation had moderate difficulty twenty-five days afterwards. The other two patients who had very slight difficulty before had the same amount of trouble on discharge. No other patient had any difficulty at the time of the last examination..

The tumor case had no difficulty before, marked difficulty after several days and a slight disturbance at twelve days.

Exploration.

This patient had no disturbance in reading at any testing.

Summary.

All patients without tumor were able to read as well on discharge as on admission with two exceptions. Both had temporal excisions; one girl had slight difficulty before and moderate difficulty on discharge; the other patient with vascular occlusion had a marked disturbance at eight weeks.

The three frontal lobe tumor cases showed slight difficulty before and after surgery with one being definitely worse in that she could not read anything but simple words and sentences. The other two patients with tumor had no difficulty prior to operation and a slight disturbance on discharge.

Silent Reading

Because of its difficulty only one patient had no difficulty with this test before operation.

Frontal.

Two patients had slight difficulty before and moderate disturbance after operation. Three patients had moderate difficulty before surgery; one of them had moderate difficulty one month later, one had slight difficulty three weeks later and the last one had no difficulty five months later.

Two patients with tumor had moderate difficulty and one had very marked difficulty before operation; all three had very marked difficulty on discharge.

Fronto-temporal.

This patient had slight difficulty with simple French sentences before both operations but was able to read and repeat what she read two weeks after the second operation.

Parietal.

One patient without tumor (the patient with the vascular anomaly was not given this test) had no difficulty before or one and fourteen days after operation. The tumor case had moderate difficulty before and marked difficulty three weeks after operation.

Temporal.

Two patients had very slight difficulty on admission; one had no difficulty on discharge and the other had very marked difficulty. Two had slight difficulty before operation; both showed improvement at the last testing. Six had moderate difficulty before operation; five had moderate trouble and one slight difficulty on discharge. The other three patients were not given this test.

Exploration.

This patient had very slight difficulty initially and slight difficulty eleven days after operation.

Summary.

Nine patients (two F, FT, P, four T, and E) had slight or no difficulty with this test before operation. At discharge both patients with frontal excisions and one with a temporal removal showed decreased ability to read silently and repeat what was read. Nine patients (three F and six T) had moderate difficulty before operation; none of them had more difficulty at discharge.

Of the four tumor cases who performed this test before operation three had moderate difficulty and one very marked difficulty before operation; all had very marked difficulty at the time of discharge.

Spontaneous Writing

Frontal.

Two patients made a few mistakes in writing before operation. All patients including the one without disturbance in spontaneous speech had difficulty in spontaneous writing after operation. One had no difficulty but the other four had very slight difficulty at the last testing.

Two of the three tumor patients had slight difficulty before operation. All three had very marked difficulty on discharge.

Fronto-temporal.

This patient wrote correctly before the first operation, made a few mistakes before the second procedure but no mistake two weeks after the second operation.

Parietal.

One patient had no difficulty before operation or one year afterwards. The patient with the vascular anomaly made a few mistakes seven weeks after operation but she was not tested prior to surgery. The patient with tumor had very slight difficulty before operation and slight difficulty three weeks later.

Temporal.

Four patients made a few mistakes in writing before operation. After operation, all had difficulty which was approximately parallel to the disturbance in spontaneous speech. Two patients who had no difficulty before surgery still made a few mistakes at the time of discharge. The patient with vascular occlusion had marked difficulty on discharge; letters from him indicate definite improvement but he is not back to his preoperative level.

The patient with tumor made a few mistakes prior to operation and had marked difficulty twelve days afterwards.

Exploration.

This patient made a few mistakes before and eleven days following surgery.

Summary.

Seven patients (two F, four T and one E) made mistakes in writing prior to operation. All patients had difficulty in writing after operation. Five patients who wrote correctly before operation (two F and three T) had slight difficulty in writing at the last testing after operation.

Four of the patients with tumor made a few mistakes in writing before operation. One patient (P) had only a slight disturbance in writing at discharge but the other four had very marked difficulty.

Writing to Dictation

Frontal.

None of the five patients without tumor had difficulty writing to dictation before operation. All had difficulty after operation. One had very slight and another moderate difficulty at discharge.

One of the three tumor patients made a few mistakes before surgery. Two had marked difficulty at discharge (the third patient was not tested).

Fronto-temporal.

This patient had slight difficulty after the first operation but none at discharge.

Parietal.

None of the three had any disturbance before operation. All had difficulty afterwards. The patient with tumor had moderate difficulty on discharge; the other two had no difficulty when last tested.

Temporal.

No patient had difficulty writing to dictation prior to operation. One had slight difficulty at discharge and the patient with vascular occlusion had a marked disturbance.

-The patient with tumor had no difficulty before surgery but slight difficulty at discharge.

Exploration.

This patient made a few mistakes writing to dictation before and after operation.

Summary.

One patient (exploration) had slight difficulty writing to dictation before and after operation. Three patients (F, P and T) had slight difficulty, one (F) had moderate difficulty and another (T with vascular occlusion) had marked difficulty on discharge.

One of the tumor cases showed slight difficulty before operation. One had slight, another moderate and two marked difficulty on discharge.

Copying

This test was not given when the patient had no difficulty reading aloud and writing to dictation. No patient had difficulty copying before operation or at the time of discharge, but a number had difficulty in the intervening period.

Oral Calculation

Frontal.

One patient had very slight difficulty and four patients had slight difficulty with these oral calculations before operation. The former and one of the latter had moderate difficulty at discharge. One had slight difficulty and the other two made no mistake.

The three patients with tumor had moderate difficulty before operation. Two had marked difficulty and one was unable to do any of these problems at discharge.

Fronto-temporal.

This patient had slight difficulty before each operation and moderate difficulty two weeks after the second operation.

Parietal.

One patient had no difficulty before operation or discharge. The one with the vascular anomaly had moderate difficulty before and marked trouble seven weeks after operation. The patient with tumor had slight difficulty before and marked difficulty three weeks after operation.

Temporal.

Five patients had no difficulty, two very slight, three slight and one marked difficulty with oral calculations before operation. Of those with no difficulty, one had slight and another moderate difficulty on discharge. One of the two with very slight difficulty had no difficulty on discharge. Two with slight difficulty showed improvement after operation. The one with marked difficulty had moderate difficulty on discharge.

The patient with tumor had moderate difficulty before but was not tested after operation.

Exploration.

This patient had slight difficulty before and after operation.

Summary.

Eleven patients had very slight or slight difficulty with these problems before operation. Three of these patients

(two F and one FT) showed moderate difficulty on discharge. One parietal case showed moderate difficulty before and marked difficulty after operation. Two temporal cases showed no difficulty before but slight and moderate difficulty after operation. One patient (T) had marked difficulty before and moderate after surgery.

One of the tumor cases (P) showed slight difficulty, and the other four had moderate difficulty before operation. Three had marked difficulty and one (F) was unable to do any problem correctly after operation.

Written Calculation

Frontal.

Three had no difficulty before operation; two had no difficulty after surgery but one missed a single problem. Two patients had very slight difficulty before operation and one missed two problems after operation. Two of the tumor cases showed very slight difficulty initially; one was unable to do any problem correctly three weeks after operation (the other was not tested). The other tumor case was unable to do any problem at the time of discharge and had had moderate difficulty before operation.

Fronto-temporal.

This patient had slight difficulty before and after each operation.

Parietal.

The patient with a vascular anomaly was not tested before operation and had movderate difficulty seven weeks after operation. One patient had no difficulty before or three weeks after operation. The tumor case had very slight difficulty before and moderate trouble after operation.

Temporal.

One patient had very slight difficulty before operation but no difficulty at discharge. Three patients had slight difficulty before operation; one had slight, and two moderate difficulty after operation. Seven had no difficulty before or after surgery. The tumor case had marked difficulty initially but was not tested after operation.

Exploration.

This patient missed one problem before but none after operation.

Summary.

Eight patients had very slight or slight difficulty in written calculations before operation. Two of them (T and E) made no errors after operation and two others (T) had moderate difficulty after operation. Eleven had no difficulty before operation but one patient (F) missed a problem after operation. The patient with the vascular anomaly in the parietal region was not tested before operation and had moderate difficulty afterwards.

Three of the patients with tumor had slight difficulty, one moderate and the last marked difficulty before operation. One patient (P) had moderate difficulty, two patients (F) were unable to do any problem and two were not tested after operation.

Motor System

Frontal.

None of the five patients without tumor had a motor deficit before operation, but all had some weakness afterwards. Three patients had weakness immediately but only one had weakness at discharge and this weakness was of the face and not the leg as it had been immediately. One other patient had slight weakness of the right side of the face still present at discharge.

Two patients with tumor had a right hemiparesis most marked in the hand before operation; the third patient had no weakness. One patient had complete right hemiplegia in the operating room, and there was only slight improvement three weeks later. The other had increased weakness immediately ; his strength improved to the state before operation. The third patient had weakness of the right hand on the first day after operation, later it involved the leg and face and there was still some weakness on discharge.

Fronto-temporal.

This patient had no weakness before operation but had an immediate moderate right hemiparesis at operation. Just before the second operation there was only a slight facial weakness which did not change immediately afterwards. However, she again had weakness of the right upper extremity and increased weakness of the face which occurred several days after surgery. Her strength improved but was not quite normal on discharge.

Parietal.

Neither patient had weakness before or immediately after operation. Both developed right hemiparesis, one moderate and the other quite severe. The former had no weakness on discharge but the latter still had some weakness and clumsiness of the right hand seven weeks after operation. The patient with tumor had no weakness before operation but was unable to move her hand and had a slight facial palsy immediately after surgery. Her foot was involved twenty-four hours later. After three weeks she still had some weakness of the hand.

Temporal.

One patient had questionable weakness of the right hand before operation. One patient had an almost complete right hemiplegia immediately (probably due to vascular occlusion), and he still had moderate hemiparesis about two months later.

Seven patients had an onset of weakness of the right half of the body, usually face and hand, several hours to several days after operation. There was no demonstrable weakness of any at the time of discharge. Three patients had no weakness. The patient with tumor had weakness of the right face after operation which was not present after the fifth day.

Exploration.

This patient had no weakness before or immediately after operation but had weakness of the right face and hand beginning on the first day after surgery. There was no weakness at discharge.

Summary.

One patient (T) had questionable weakness of the right hand before operation. Five patients (three F, one FT, and one T) had weakness immediately after operation. At discharge one of these five (F) had slight weakness of the face but not the foot which was alone involved immediately; another (FT) had slight weakness of the face and hand; and another (T) had a moderate weakness. All other patients except three with temporal excisions had weakness beginning several hours to several days after operation. One of these patients (F) had slight facial weakness at discharge.

Two patients with frontal tumor had right hemiparesis before operation with immediate increase in weakness at

operation. Weakness was still very marked in one at discharge, but was about the same as before operation in the other. The other patient with frontal lobe tumor had an onset of right hemiparesis the first day after operation, and still had slight weakness on discharge. The patient with a parietal tumor had no weakness before surgery, had complete paralysis of right arm immediately; and she had slight weakness of the hand at discharge. The other patient (T) had a transient weakness of the right face after operation.

Somatic Sensation

Frontal.

No patient without tumor had any sensory disturbance before operation or at discharge.

One patient with tumor had a slight sensory disturbance of the right hand before operation and there was no change afterwards. Examination of another patient was not reliable but there was no gross sensory loss before operation or at discharge. There was no sensory loss before operation or at discharge in the other tumor case.

Fronto-temporal.

There was no sensory disturbance before or after either operation.

Parietal.

There was no sensory disturbance in either patient without tumor before operation. The patient with the vascular anomaly had a disturbance in sensation after operation, but its onset is not recorded. After seven weeks she could not identify objects in the right hand. The other patient had no sensory disturbance on discharge.

The patient with tumor had a sensory deficit in the right hand before operation and over the entire right side at discharge.

Temporal.

No patient had any involvement of sensation before operation. The patient with the vascular occlusion had sensory loss at discharge but the extent was not determined. All other patients except one who was not examined had no sensory disturbance on discharge.

Exploration.

This patient had no sensory loss before operation or at discharge.

Summary.

No patient without tumor had any sensory disturbance before operation. The patient with the parietal vascular anomaly and the one with the vascular occlusion occurring during operation had some sensory disturbance (the exact nature of which was not determined) at discharge. No other

patient had any gross sensory involvement at discharge (one was not examined).

One patient with frontal tumor had slight sensory disturbance in the right hand before operation without change after operation. The patient with parietal tumor had sensory disturbance in the right hand before operation and in hand, face and foot at discharge.

Visual System

Frontal.

No patient with or without tumor had any gross visual field disturbance before operation or at discharge.

Fronto-temporal.

This patient had no defect before either operation but there was complete right upper quadrantic homonymous hemianopsia and a small defect in the lower quadrant at discharge.

Parietal.

The two patients without tumor had no defect before operation or at discharge. The patient with tumor had a questionable right upper quadrantic defect before operation but none on discharge.

Temporal.

One patient had a questionable right upper quadrantic defect before operation and at the time of discharge. No other patient had a visual disturbance before operation. At discharge, one (patient with vascular occlusion) had a right homonymous hemianopsia, two others had right upper quadrantic homonymous hemianopsia, one had a questionable upper quadrantic defect, and six had no disturbance.

The patient with tumor had no visual disturbance before operation or at discharge.

Exploration.

This patient had no visual disturbance before operation or at discharge.

Summary.

One patient without tumor (temporal) had a questionable visual defect in the right upper quadrant before operation and at discharge. Five other patients (one FT and four T) had visual field disturbances at discharge.

One patient with tumor (P) had a questionable field defect on admission but none had a visual disturbance at discharge.

Reflexes

Frontal.

All patients without tumor had normal reflexes on admission and discharge. Two patients with tumor had increased deep tendon reflexes and extensor plantar response before operation. The plantar response became flexor in one patient but remained extensor in the other. The third patient with tumor had normal reflexes on admission and discharge.

Fronto-temporal.

This patient developed an extensor plantar response immediately after the first operation. The next day it was flexor and remained so.

Parietal.

The two patients without tumor had normal reflexes on admission and at discharge. The patient with tumor showed no abnormal reflexes until the day after operation, and she had slightly increased deep tendon reflexes on the right at discharge.

Temporal.

All patients had normal reflexes on admission and only the patient with the vascular occlusion had abnormal reflexes on discharge.

Exploration.

This patient had normal reflexes on admission and discharge.

Summary.

All patients without tumor had normal reflexes before operation and only the patient with vascular occlusion had abnormal reflexes on discharge.

Two patients with frontal tumor had abnormal reflexes before and after operation. The patient with a parietal tumor had slightly increased deep tendon reflexes on discharge.

Seizures

All patients had focal cerebral seizures before operation.

Frontal.

Two patients of those without tumor had no seizures after operation. One of these patients had difficulty with several tests three weeks after operation on leaving the hospital, but no difficulty when examined four months later. The other patient had a marked disturbance in spontaneous writing and slight difficulty writing to dictation ten days after operation but a letter written by him two months after surgery was quite satisfactory. Three patients have had seizures similar to the ones before operation though two of them had had seizures with a different onset on the second day after operation.

Two of three patients with tumor had seizures after operation and they were similar to their habitual ones.

Fronto-temporal.

This patient had the same type of seizure after the first operation but no seizure after the second and she had no appreciable speech deficit on discharge.

Parietal.

Both patients without tumor had seizures after operation which were probably the same type as those before surgery.

The patient with tumor had no seizure before discharge.

Temporal.

Seven patients had aurae or seizures similar to their habitual pattern after operation. Another had seizures, then had a second operation and no seizure after this procedure and no speech deficit on discharge. The patient with the vascular occlusion had seizures of a different type after surgery. Two had no seizuresafter operation.

The patient with tumor had seizures, on the fourth to seventh days after operation, which involved the right side of the face and were not like his habitual attacks.

Exploration.

This patient continued to have the same type of seizures.

Summary.

Fourteen patients without tumor had seizures after operation. The other six had no seizure and no appreciable speech deficit on discharge.

Three of the five patients with tumor had seizures after surgery.

Electroencephalograms

Frontal.

One patient had electroencephalograms that were not considered abnormal before and after operation. He had very slight disturbances in the tests at the time of the E.E.G. after operation and had a recurrence of his habitual seizures several months later. The other four patients had abnormal brain waves before and after operation.

The three patients with tumor had abnormal electroencephalograms before operation and one had abnormal electrical activity after operation (electroencephalograms were not done in the other two).

Fronto-temporal.

This patient had an abnormal E.E.G. before both operations and also after the second procedure.

Parietal.

The two patients without tumor had abnormal electrical activity before and after operation. The E.E.G. of the patient

with tumor was considered within normal limits before surgery; it was not repeated afterwards.

Temporal.

All patients had abnormal electroencephalograms before and after operation (two patients had no E.E.G. after surgery).

Exploration.

This patient had an abnormal E.E.G. before operation; it was not repeated afterwards.

Summary.

One patient (F) had an E.E.G. before and after operation that was considered to be within normal limits. All others had abnormal electroencephalograms before and after operation (when they were performed after surgery).

Cerebrospinal Fluid Pressure

Cerebrospinal fluid pressures were not determined at routine intervals after operation. Correlation of this evidence of increased intracranial pressure with evidence of results of the other tests is poor. Before operation pneumoencephalograms were performed in the sitting position and no patient without tumor had increased pressure. All figures are expressed in millimeters of cerebrospinal fluid.

Frontal.

One patient had a pressure of 165 mm. on the third day after operation at which time he spoke very little, had some difficulty writing but named and read simple things correctly. Another patient had a pressure of 280 mm. on the third day after operation at which time he had definite difficulty with various tests. Another patient had three lumbar punctures with pressures of about 200 mm. on the first and second days after operation; he had no difficulty in the tests performed but writing was not tested.

One patient with tumor had pressures of 170 and 80 mm. on the second and twelfth days respectively. She had difficulty with various tests at both times. Another patient had pressures of 350, 260, 280 and 330 mm. on the first, second, third and fifth days at which times he had definite difficulties in speech. The third patient had difficulties with various tests on the second and fifth days when the cerebrospinal fluid pressure was 180 and 160 mm. respectively.

Fronto-temporal.

This patient had only slight difficulty in speech on the second and fifth days when the pressure was 320 and 100 mm.

Parietal.

One patient had a pressure of 280 mm. on the fourth day when he had marked difficulty with various tests.

Temporal.

One patient had pressures of 185 and 275 mm. on the second and third days while he had marked difficulty with various tests. A patient had slight difficulty with various tests on the ninth day with a pressure of 160 mm. A patient had marked difficulty in various tests on the second, third and sixth days with pressures of 270, 290 and 245 mm. respectively. Another had very marked difficulty in various tests with pressures of 250 and 350 and 215 mm. on the second and fifth days. With pressures of 245, 180 and 180 mm. on the fourth, sixth and eleventh days, another patient had marked difficulty with various tests. The patient with the vascular occlusion had very marked difficulty with various tests with pressures of 250, 270 and 180 mm. on the third, fifth and sixth days respectively. The last patient had no difficulty in the tests given with pressures of 260, 100 and 100 mm. on the first, second and fifth days.

Summary.

Two patients (F and T) had no difficulty with the tests given when the cerebrospinal fluid pressure was elevated

(200 and 260). The latter patient also had no difficulty when the pressure was normal. Twelve patients had difficulty with various tests when the pressure was elevated. Two of these (FT and F tumor) also had difficulty with normal pressure. One patient (temporal) had slight difficulty with a slightly increased pressure (160 mm.).

Figure 15

23 Patients with Aphasia*

1. The line below "Age" represents time. P. represents preoperative; I. immediately afterwards; and the numbers indicate days after operation.

2. The top of each graph represents no deficit, and the bottom of each graph is 100% deficit in each category.

3. Spontaneous Speech - under E.Ra., For.Acc. represents foreign accent.

4. Repetition - o--o represents repetition of names of six objects.

5. Reading Aloud - W represents words; L, letters; and S, simple words and sentences.

6. Motor and Somatic Sensory Systems - R represents right; H, hand; A, arm; L, Leg; F, foot; Sl, slight deficit; M or Mod, moderate deficit; S, the same amount.

7. Visual System - R represents right; HH, homonymous hemianopsia; UQ, upper quadrantic; P, Perimetry; DEF, defect.

8. Reflexes - Inc. represents increased deep tendon reflexes; B, Babinski's sign; S, the same.

9. Seizures - the letters represent various initial phenomena and the numbers, days after operation.

10. EEG - Sl represents slow waves; sh, sharp waves; sp, spikes; D, delta waves; numbers are number per second; L, left; F, etc., Frontal, etc.

* Excluding the one with fronto-temporal excision and the one with exploration only.

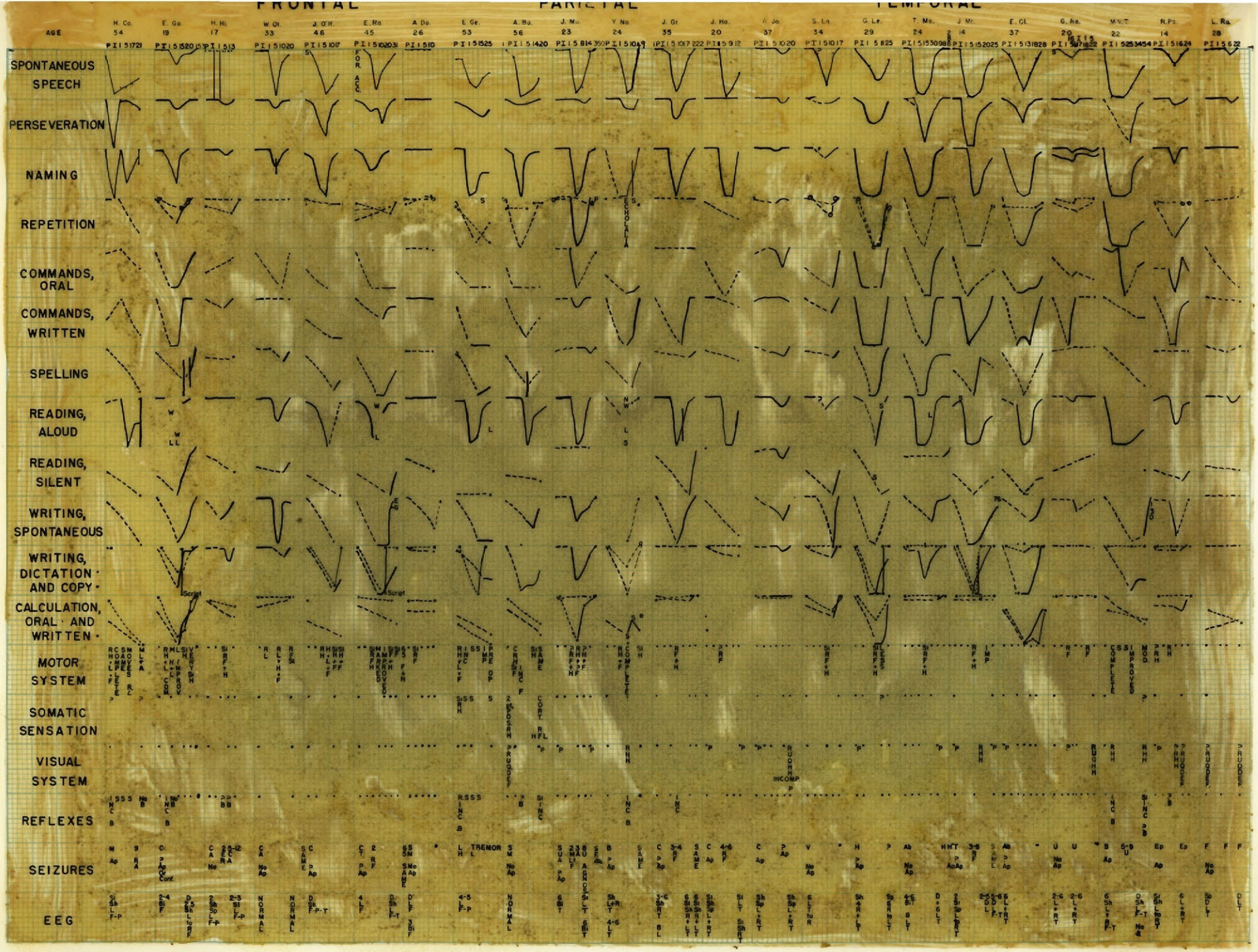

Figure 15

b. Nineteen Patients Without Aphasia

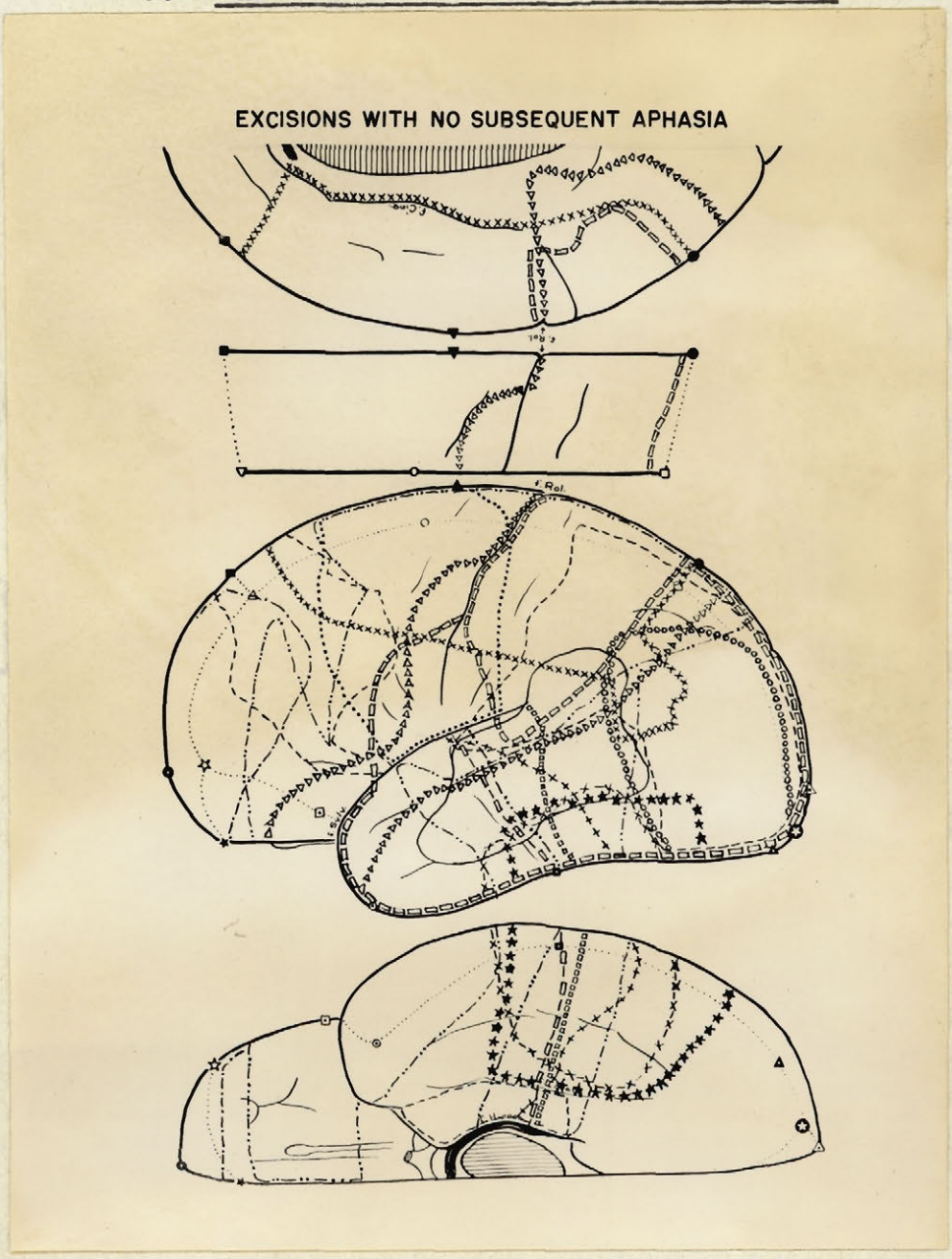

Figure 16

This entire group of 19 patients upon whom 21 operations were performed will be considered as a whole. One of these patients had had two previous operations after each of which she had speech disturbances (the author did not see the patient then). She recovered speech functions but later deteriorated and had definite speech disturbance before the third operation (TO). As there was no appreciable change following this procedure she is included in this group. Two other patients had two operations each and were examined before and after all the procedures by the author.

Spontaneous Speech

Eight patients had some difficulty in spontaneous speech prior to operation. Three of these (FP, FPT and T*, and FPT) had stuttering or stammering but without incorrect use of words. Two patients were slow in speaking; one (FPTO) markedly so and the other (T) only very slightly. Two patients (TO and E) made definite grammatical errors in speaking. One little girl (P and FPTO) used neologisms; she had definitely improved before the second operation.

Only one (TO) of these patients showed any increased disturbance after operation. This increase followed a seizure and was similar to the increase noted after seizures

* This patient had two operations.

occurring before this third operation. Only one patient (P) showed definite improvement and she mispronounced words 582 days after her initial operation but did not use neologisms. There was no appreciable change during the three weeks after her second operation (FPTO).

The other nine patients showed no disturbance before operation and only one (T) may have had slight difficulty during the first few days afterwards.

Perseveration

No patient showed evidence of perseveration before or after operation.

Naming

Five patients failed to name from one to five objects before operation, but there was no change in their ability following surgery. The little girl used neologisms for about forty per cent of the objects before and after the first operation. Eleven months later she failed to name only four objects and there was no change following the second procedure. One patient (T) had questionable difficulty a couple of days after operation. "Questionable" is used because she named a couple of objects, misnamed several objects, but corrected herself, then could or would not name others. When she became more cooperative she had no difficulty naming. No other patient had difficulty naming before or after surgery.

Repetition

All patients except the little girl who used neologisms had no difficulty repeating simple words before or after operation. The little girls had moderate difficulty before the first operation but had no trouble before or after the second operation. Four patients (FPT, PT, PTO, and T) had slight difficulty repeating the test phrases before operation; one of them (PT) showed no difficulty after operation and the other three showed no change. Two patients (both FPTO) showed moderate difficulty before operation; the little girl showed no change (it had been impossible for her to repeat these phrases before and after the first operation), and the boy improved slightly. No other patient had any difficulty before or after operation.

Oral Commands

Eight patients had slight difficulty executing the oral commands. One (F) had no difficulty at the time of discharge, another (PT) had marked difficulty and a third (T) had moderate difficulty at discharge. The other five (F, FPT and three T) showed no change. Two patients (FP and FPT) had moderate difficulty before operation and one had marked difficulty at discharge. One (FPTO) had marked difficulty before and moderate after operation. Five patients (PTO, three T and O) had no difficulty before surgery, but one (T) had

moderate difficulty fifteen days afterwards. Three patients (P and FPTO, TO and E) were not given this test.

Written Commands

Three patients (F, FPT and PT) had slight difficulty executing written commands before operation; two showed no change but one (F) had no difficulty after operation. Four patients (FP, FPT, FPTO, and TO) before and after operation had moderate difficulty. One (T) had no trouble executing these commands before operation but had slight difficulty ten days afterwards. The little girl (FPTO) could not do any of them. One (E) was not tested. The remaining nine patients had no difficulty at any time.

Spelling

Ten patients had slight difficulty in spelling before operation. Two (T) had no difficulty, one (E) had marked difficulty and the remainder showed no change after operation. Three patients (two FPTO and TO) had moderate difficulty spelling very simple words before and after operation. One patient (T) spelled all words correctly before surgery but had slight difficulty afterwards. The others had no difficulty before or after operation.

Reading Aloud

Four patients (FPT and T, PT, FPTO, and E) had slight difficulty before and after operation. The little girl (P and FPTO) had not learned to read before the first operation, read a little before the second procedure and showed no change after this latter procedure. One patient (TO) read simple words without difficulty, except on one occasion on the second day after what might have been a seizure when she had slight difficulty. She read with moderate difficulty simple sentences and could not read anything complicated before or after operation. No other patient had any difficulty before or after operation.

Silent Reading

Five patients (FPT, three T, and O) had slight difficulty with this test before operation and at discharge. Four patients (F, two FPT, and PT) had moderate difficulty before and after operation. One (F) had moderate difficulty before and slight difficulty after operation. One patient (T) had marked difficulty before and only moderate after operation. Four (FPTO, P and FPTO, T, and TO) had very marked difficulty before and after surgery. Four were not given this test.

Spontaneous Writing

Six patients (two FPT, FPTO, PT, and two T) made several mistakes in writing before operation; five showed no change, but one (FPT) made no mistakes after operation. One patient (E) had moderate difficulty writing before and after surgery. One (TO) had marked difficulty before and after operation. The little girl (P and FPTO) wrote only a few letters before the parietal lobectomy; learned to write most of the alphabet and some words and short sentences before the second procedure and showed no change afterwards. All other patients had no difficulty before or after operation.

Writing to Dictation

One patient (T) had slight difficulty writing to dictation before and after operation. One (TO) had moderate difficulty writing simple words to dictation before and after surgery. One (FPTO) was able to write simple words before and after surgery. The little girl had moderate difficulty writing to dictation simple words but seemed to improve after the second operation. All others had no difficulty.

Copying

The little girl still had slight difficulty copying after the second operation. All others copied without difficulty.

Oral Calculations

Seven patients (F, FPT, PT, and four T) had slight difficulty with these calculations before operation; four had the same difficulty and three (FPT, two T) made no mistakes after operation. Three (FPT and T, FPT, and E) had moderate difficulty before and after surgery except for the first patient who made no mistakes after the second operation. Two (FPTO and TO) had marked difficulty before and after surgery. The little girl had learned to do some adding and subtracting before the second procedure and showed no change afterwards. Five patients (F, PTO, two T, and O) had no difficulty before or after surgery except for one (PTO) who missed one problem afterwards. One (FP) was not tested.

Written Calculation

Six patients (F, two FPT, PT, T, and O) had slight difficulty on admission; four had the same trouble but two (FPT and O) made no mistakes at the time of discharge. Two (FP and E) had moderate difficulty before operation; one (E) had the same amount of difficulty, and the other

showed improvement after operation. Two (T, and FPTO) had marked difficulty before operation though the former after her previous operation had only had slight difficulty; this patient again had only slight difficulty after the second procedure but the other continued to have marked difficulty. One patient (TO) had moderate difficulty with simple problems before and after operation. The little girl had learned to do a little arithmetic between operations and showed no change after the second procedure. Eight (F, FPT, PTO, and five T) had no difficulty before but three (FPT, PTO, and T) had slight difficulty afterwards.

Motor System

Six patients (FP, three FPT, FPTO, and PTO) had a moderately severe spastic right hemiparesis prior to operation. The three patients with excisions involving the frontal, parietal and temporal lobes showed an increase in weakness immediately after operation with subsequent improvement. One of these had about the same use of the extremities as before operation fourteen months later; the other three did not regain their previous ability. The little girl had slight weakness before the first operation. There was transient increase in weakness. Later there was marked right hemiparesis self-inflicted (bone flap had been removed). Motor control improved; then there was increased weakness immediately after the second operation; control

again began to improve. One patient (PT) had moderate weakness of the right extremities without spasticity before operation and no change afterwards. The other patients had no weakness before surgery. Three of the patients with temporal excisions may have had slight weakness of the right hand and face in the immediate period after operation, but it was not definite. No other patient had any disturbance in motor function after operation.

Somatic Sensation

All patients who had weakness of the right side of the body had defects usually described as cortical sensory loss in the same parts, before operation. There was no essential change in these sensory disturbances at the time of discharge. One patient (T) had transient numbness of the right hand in the immediate period after operation. All other patients had no sensory defects on admission or at discharge except for the little girl. Examination of the little girl was practically impossible. She probably had no defect before operation but did after the first procedure and it probably did not change after the second operation.

Visual System

Four patients (FPT and T, FPT, FPTO, and PTO) had a right homonymous hemianopsia before and after operation. One patient (TO) may have had a visual defect in the left visual field before operation but neither this examination nor the examination after operation is considered reliable. No other patient had any visual field defect before operation. Seven patients (FPT, five T, and O) had incomplete right homonymous hemianopsia after operation. One (T) had no defect at discharge but it persisted in the others. Seven patients had no disturbance after operation.

Reflexes

Six patients (FP, FPT and T, two FPT, FPTO, and P and FPTO) had increased deep tendon reflexes with an extensor plantar response on the right, before and after operation. Two patients (PTO, and O) had increased deep tendon reflexes without abnormal plantar responses before operation; reflexes were normal in one (O) after operation. One patient (TO) had decreased right abdominal reflexes and extensor plantar response before and after operation. Another patient (E) had an equivocal right plantar response before surgery but it was normal afterwards. No other patient had abnormal reflexes before or after operation.

Seizures

All patients had seizures before operation; two had a tumor (T and O). Nine patients (FP, FPT, FPTO, P, three T, TO, and E) had seizures after operation. Two had a different aura (FPT, and P); both had a second operation with no seizures occurring during the time observed. One (FPTO) may or may not have had a different seizure pattern after operation. The others complained of the same aura as before operation.

Electroencephalograms

All patients had abnormal electroencephalograms before operation with either sharp waves or spikes. Three (F, FPT, T) had only delta waves after operation. After the second operation in one patient (FPT and T) there was electrical abnormality only in the opposite hemisphere; similar activity had been noted before operation. Two patients (TO and E) had no examination after operation. The other patients continued to have abnormal electroencephalograms with sharp waves or spikes.

Cerebrospinal Fluid Pressure

One patient (F) had pressures of 210 and 200 mm. of cerebrospinal fluid on the third and fourth days after operation when he had no signs of difficulty in speech. Another (FP) had a pressure of 190 mm. on the eighth day after operation while he had no difficulty in speech.

Another patient (FPT and T) had pressures of 325 and 125 mm. on the third and fifth days after the first operation and pressures of 350 and 160 mm. on the fourth and seventh days after the second procedure, during which time she had no increased difficulty with the various tests. Another patient (FPT) had no difficulty with language with pressures of 235, 150, and 230 mm. on the second, fourth and seventh days after operation. When the cerebrospinal fluid pressures were 165, 150, 150 and 90 mm. on the sixth, seventh, ninth and twelfth days after operation, he (FPTO) had no increased difficulty in the various tests. The little girl (P and FPTO) had pressures of 300 and 180 mm. on the fourth and twenty-second days after the first operation and pressures of 220, 435, and 145 on the first, fourth, and eiththh days after the second procedure. She had no decrease in language function at these times. Another patient had no difficulty with various tests on the third, fourth, eighth, ninth and tenth days after operation with pressures of 230, 200, 110, 105 and 200 mm. Another patient (T) had no difficulty with various tests on the seventh day after surgery with a pressure of 230 mm. Another (T) had pressures of 225 and 95 on the first and second days after operation with no difficulty in speech and another (T) had pressures of 250 and 120 mm. on the first and eleventh days after surgery without difficulty in speech. A patient (0) had no difficulty with various tests on the second, third and fourth days after operation with pressures

of 280, 290 and 130 mm.; she was the only patient in this group to have increased intracranial pressure, by ventricular puncture, before operation. And finally, with pressures of 200 and 210 mm. on the second and third days after operation, a patient (E) had no change in speech.

3. Operations Involving the Right Hemisphere

a. A Patient with Aphasia

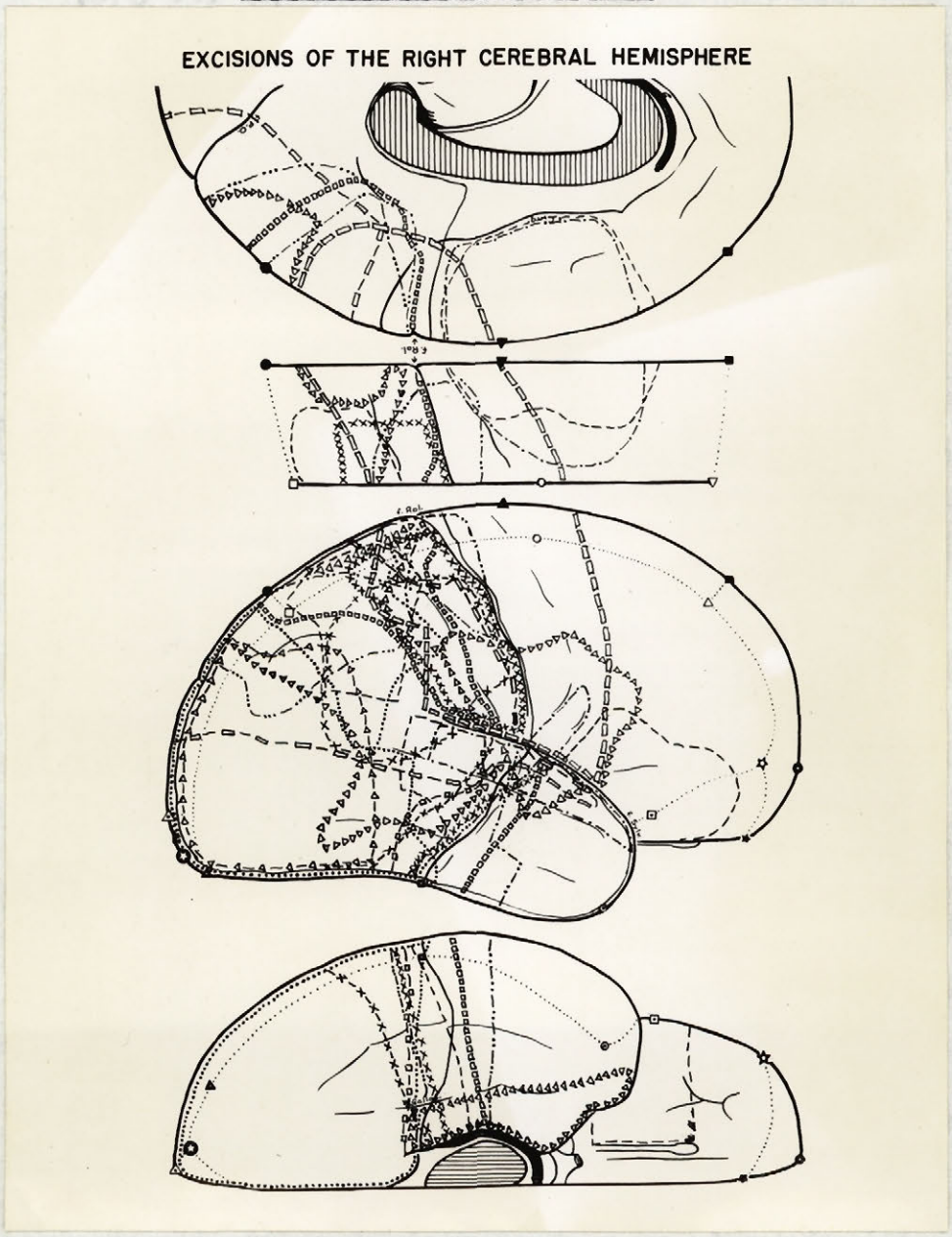

Figure 17

Spontaneous speech was fairly rapid, poorly enunciated and slurred in a careless manner prior to operation. Speech did not seem to be changed the night after operation. The next day speech was slow and more slurred. This difficulty progressively increased until he did not speak at all on the fifth day at which time he was having seizures every five to ten minutes lasting one to two minutes. Speech began to improve on the eighth day and by discharge it was about the same as on admission except slower.

This patient showed no evidence of perseveration before or after operation.

He had no difficulty naming before operation or during the first day afterwards. For the next two days he would name one object and then would not cooperate any more. He then named no object until the eighth day when he named several without difficulty. On the fifteenth day he named all objects.

This patient had slight difficulty repeating test phrases both before operation and fifteen days after it when tested again.

He had no difficulty with simple oral or written commands before operation or fifteen days afterwards. He had slight difficulty in spelling before operation and moderate difficulty fifteen days afterwards.

The patient had no difficulty reading aloud before or during the first day after operation. During the next two days he would read words on two cards and then stop, just as in naming. On the fifth day he read nothing but on the eighth he again read a few sentences correctly. On the fifteenth day there was questionable difficulty reading in that he made such mistakes as saying "in the above form" for "above the form". He had slight difficulty reading silently before operation and slight to moderate difficulty fifteen days afterwards.

He had no difficulty in spontaneous writing before surgery though he wrote little, but had moderate difficulty two weeks afterwards. Writing to dictation and copying were correct before operation; he had slight difficulty with these tests fifteen days afterwards.

He had slight difficulty with oral calculation before and fifteen days after operation; slight difficulty with written calculations on admission and moderate difficulty with them on discharge.

He had slight weakness of the left face before surgery weakness of the left hand developed on the third day after operation. There was still slight weakness of the face and hand on discharge. He had no sensory disturbance before or immediately after operation. Sensory disturbance in the left face and hand developed but disappeared before discharge.

He had no visual field defect before or immediately after operation. There was a questionable defect in the left visual field on the eighth day.

Reflexes were normal before surgery and the first day afterwards. On the fourth day, deep tendon reflexes were bilaterally increased more on the left. There was an extensor plantar response on the left and an equivocal one on the right with bilateral ankle clonus. Deep tendon reflexes were increased on the left at discharge.

Before operation he had seizures beginning with visual blurring and followed by nausea and automatism. From the third to eighth days after operation he had repeated seizures involving the left face and hand and occasionally foot.

The E.E.G. was abnormal before operation but showed no definite abnormality sixteen days afterwards.

He had pressures of 200, 210 and 180 mm. of cerebrospinal fluid on the second, third and fifth days after operation.

This patient was examined one year after operation. He had had one series of seizures four months after surgery but none since. His spontaneous speech seemed to be slightly improved as compared with before operation. Testing revealed no change from before operation, except that he had no difficulty with oral calculations.

b. Twenty-Six Patients Without Aphasia

This group consists of 26 patients. Six had two operations but only one of them (FPT and PT) was examined by the author after both procedures. Two patients, both with frontal lobe excisions, were not examined prior to surgery.

Spontaneous Speech

Six patients (F, FP, FPT and PT, P, and two PTO) had hesitation, stuttering or slurring of speech. Two (F and FP) may have shown a slight improvement after operation. One patient (T) had attacks of slurring or complete inability to speak before and after operation. Another patient (T) had slurring of speech just before and for several days after evacuation of an extradural hematoma two days after the original operation. No other patient had any disturbance in spontaneous speech.

Perseveration

No patient showed any evidence of perseveration before operation. One patient (P) showed slight perseveration in naming, which was corrected, on the first day after operation only. Another patient (P) showed slight perseveration in writing in that letters and syllables were repeated on the fifth and eighth days after operation.

Naming

One patient (PTO) was unable to name several objects before or after surgery. Another (T) could not name several objects in English though he knew them in French. All other patients named correctly before and after operation.

Repetition

Eight patients (F, two P, PT, two PTO, T, E) had slight difficulty in repeating the test phrases. Five (F, P, PTO, T, E) however, had no difficulty at the time of discharge. Three patients (PTO and two T) had slight difficulty in repeating these phrases in the first week after operation; and one (PTO) still had very slight difficulty on the seventeenth day afterwards. No other patient had any difficulty.

Oral Commands

Eleven patients (F, FP, FPT and PT, two P, PT, PTO, three T, and E) had slight difficulty with oral commands before operation. Nine patients (F, FPT and PT, two P, PTO, three T, and E) showed no change, one (PT) had moderate difficulty, and one (FP) had marked difficulty at the time of discharge. One (P) of the group with slight difficulty had moderate difficulty when tested about a week after operation but at

discharge only had slight difficulty. One patient (PTO) had marked difficulty before operation, moderate difficulty on the fifth day after operation and only slight difficulty seventeen days later. Ten patients (FP, two P, PTO, and six T) had no difficulty before operation; two (two T) had no difficulty, seven (FP, two P, PTO, three T) had slight difficulty, and one (T) had moderate difficulty on discharge. One (PTO) who had slight difficulty on discharge had had moderate difficulty eleven days after operation. Two patients (P, and PTO) were not given this test. The two who had no testing before operation (two F) had slight difficulty with these oral commands at the time of discharge.

Written Commands

Seven patients (PT, P, two PTO, two T, and E) had slight difficulty following written commands before operation. Four (two PTO, T, and E) had no difficulty, and three (PT, P, and T) had slight difficulty on discharge. Four patients (FP, two P, and PT) had slight difficulty on discharge though they had had none before operation. Two others (PTO and T) had slight difficulty about a week after operation but none initially or on discharge. The patient who had two operations was not given this test before the first one. One of the patients who was not tested at all before surgery had slight difficulty at discharge. All other patients had no difficulty.

Spelling

Slight difficulty was noted in spelling in 13 patients (F, two FP, FPT and PT, three P, PT, two PTO, two T and E) before and after operation. Two patients (PTO and T) had moderate difficulty spelling before and after surgery. One patient (T) had slight difficulty about a week after operation but none before or at discharge. The two patients not examined prior to surgery had slight difficulty at the time of discharge. No other patient had any difficulty spelling before or after operation.

Reading Aloud.

No patient had difficulty reading letters, numbers, words or simple sentences. Ten patients (FPT and PT, three P, three PTO, two T, and E) had difficulty reading some of the difficult words, particularly "applicable", "individuals", "phrases" and "sequence", before operation. One patient (T) had slight difficulty reading aloud immediately after operation, at the same time she had a right hemiparesis and slurring of speech; some of the words she attempted to read were entirely unintelligible; the day after operation she read correctly. Three patients (two P and PTO) had difficulty reading during the first week after surgery as a result of omitting the letters or words on the left. This visual disturbance disappeared prior to discharge

though they had to concentrate upon seeing the initial words on the left and their reading was slowed. The patients who were unable to read some of the words before operation had no increased difficulty at discharge, and some had learned those particular words.

Silent Reading

Three patients (P and two T) had no difficulty with this test before or after operation. Ten patients (two FP, PT, P, PTO, and five T) had slight difficulty before operation and only three (three T) showed a change at discharge. Two of them repeated the sentences correctly and one had moderate difficulty. Five (F, two P, and two PTO) had moderate difficulty before operation; two (F and P) had only slight difficulty at discharge and the other three showed no appreciable change. Three (two T and E) had marked difficulty with this test before surgery; both temporal cases showed slight improvement after operation. One patient (PTO) had very marked difficulty before operation but only moderate difficulty at discharge. Four (two F, P, and PTO) were not given the test before operation; one (F) had slight difficulty and two (F and PT) had moderate difficulty at discharge (the other patient was not given this test).

Spontaneous Writing

None patients (PT, two P, four PTO, T and E) had slight difficulty in spontaneous writing before operation and at discharge. One of these also showed perseveration in writing letters during the first eight days after operation but not later. No other patient had difficulty in spontaneous writing.

Writing to Dictation

Two patients (P and PTO) had slight difficulty writing to dictation before and after operation. One patient (T) had moderate difficulty writing to dictation before and after surgery. No other person had any difficulty.

Copying

No patient had any difficulty copying.

Oral Calculation

Five patients (PT and four T) made no mistakes in oral calculation before operation and only one (PT) made a single mistake afterwards. Fifteen patients (F, FP, FPT and PT, five P, two PTO, four T, and E) had slight difficulty with oral calculation before operation. Three of these patients had moderate difficulty about a week after operation but only slight difficulty at discharge. One (PTO) had moderate difficulty at discharge and three (P, PTO, and T) had no

difficulty at discharge. The remaining eight had slight difficulty after operation. Two patients (two PTO) had moderate difficulty before operation and only slight difficulty at discharge. One patient (T) had marked difficulty before operation and only moderate difficulty afterwards. Of the two frontal lobe cases not tested before operation, one made no mistakes and the other only one mistake after operation.

Written Calculations

Ten patients made no mistakes in the written calculations before operation and seven (P, PTO, and five T) made none afterwards, but three (FP, P, and PTO) had slight difficulty. Eight had slight difficulty before operation; one (P) had no difficulty afterwards, one (PTO) had moderate difficulty, and six (F, P, PT, and three T) still had slight difficulty. Four patients (FP, PT, P, and E) had moderate difficulty before and after operation except for one (P) who only had slight difficulty afterwards. Two patients (PTO and T) had marked difficulty before surgery; one (PTO) did slightly better after operation. Three patients (two F, and FPT and PT) were not tested before operation; the former two made no mistakes after operation and the latter had moderate difficulty after the first and second procedures.

Motor System

Four patients (two F, and two P) had slight weakness of the left hand and upper extremity before operation. One (F) showed immediate paralysis of the left lower extremity; a few days later there was increased weakness of the left hand. At discharge this patient had about the same weakness in the hand as before operation and moderate weakness of the foot. One (P) had a marked hemiparesis the first day after operation and still had slight weakness at discharge. The other two patients showed no change after operation.

One patient (T) had slight weakness of the left face before operation, moderate to marked left hemiparesis immediately which disappeared by the fifth day, leaving the slight facial weakness.

One patient (P) had slight weakness of the left face and hand. The weakness increased on the second day after operation, then improved so that there was no detectable weakness about two months later.

Two patients (FP and PTO) had slight weakness of the left upper and lower extremities before operation. One (FP) had almost complete hemiplegia immediately. This improved so that he could walk and had slight use of his hand at discharge. Seven months later he had slight weakness of left extremities. The other patient had no change after operation.

One patient (FP) had a moderate left hemiparesis before surgery; he then had complete paralysis of the arm immediately after operation. At discharge he had moderate hemiparesis which was most marked in the hand.

One patient (FPT and PT) had slight weakness of the right extremities before operation with no change after either operation. Several days after the first operation he had weakness of the left face, which disappeared. On the first day after the second procedure he developed slight weakness of the left face and hand, and there was still slight weakness at discharge.

All other patients had no weakness before operation. Immediately or shortly after operation two patients (P and PTO) developed a slight weakness of the left face and hand and later moderate hemiparesis. The former had no weakness on discharge but the latter still had slight weakness.

Seven patients (P, PT, two PTO and three T) developed weakness on the left, one or more days after operation. Two (PTO and T) had no weakness on discharge but there was still slight weakness in the other five.

Somatic Sensation

Five patients (F, two FP, P, and PTO) had some loss of sense of posture, passive movement, recognition of two-points, or figure writing, etc. (i.e. loss of cortical sensation) before operation and at discharge. One (P) had

no definite sensory loss when seen two months after operation.

All other patients had no sensory disturbance before operation. One (P) had a sensory deficit in the left hand immediately after operation and at discharge. Other patients might have had some sensory disturbances immediately after surgery because sensory examination was not performed routinely at that time.

Seven other patients (three P, two PT, and two PTO) had sensory disturbances after operation which were still present at discharge. The remaining patients had no sensory disturbance at discharge.

Visual System

Two patients (two PTO) had an incomplete left homonymous hemianopsia; one showed no change after operation, and the other showed a complete hemianopsia (she may have seen less than one degree to the left, but more probably there was fluctuation in fixation). One patient (P) had an upper horizontal defect in the left eye before and after operation, without change. Another patient (PTO) had a questionable upper horizontal hemianopsia before operation; after operation he had an incomplete left homonymous hemianopsia.

No other patient had a visual field defect before operation. Three patients (FP and two P) showed a complete left homonymous hemianopsia to gross testing immediately after operation. At discharge one (FP) showed no defect and the other two had an incomplete hemianopsia. A fourth patient had a questionable left upper quadrantic defect immediately after surgery. This defect increased and she had an incomplete homonymous hemianopsia at discharge.

Seven patients (PT, P, PTO and four T) developed an incomplete left homonymous hemianopsia after operation and in all but one (T) it was still present at discharge. One patient (T) had subjective difficulty seeing in the left upper quadrant but this could not be demonstrated by perimetry or tangent screen.

No other patient had any visual disturbance after operation.

Reflexes

Four patients (two FP and two PTO) had increased deep tendon reflexes on the left before operation; only one (PTO) had an extensor plantar response. After operation, two (FP and PTO) had an extensor plantar response which was still present in one (FP) at discharge; the third patient developed an equivocal response to plantar stimulation. One

patient (F) had an equivocal plantar response before operation but it became flexor afterwards. One patient (P) had absent abdominal and left cremasteric superficial reflexes before and after operation.

All other patients had normal reflexes before operation. One patient (T) had Babinski's sign associated with hemiparesis on the left immediately after surgery, but it was absent the next day and thereafter. Four patients (P, PTO, and two T) had abnormal reflexes after operation but they persisted until discharge in only one (P) who had an extensor plantar response, absent abdominal reflexes and ankle clonus on the left.

Seizures

All patients had seizures before operation. Ten patients (two F, two FP, FPT and PT, two P, PT, PTO and T) had the same type of seizures after operation. Seven patients (P and six T) had seizures with a different initial phenomenon after operation. Two (P and PTO) had tactile and visual phenomena respectively which may or may not have been aurae. Seven (F, P, two PTO, two T and E) had no seizures after operation.

Electroencephalograms

All patients except two (PTO and E) had abnormal brain waves before and after operation with four (P, PTO, and two T) having only delta waves after operation. One (PTO) had delta waves over the right parieto-temporo-occipital region before operation and a flat record over the parietal region afterwards. The other patient (E) had a depression of the alpha rhythm over the right side before operation and a normal record after surgery.

Cerebrospinal Fluid Pressure

No patient had an elevated cerebrospinal fluid pressure before operation. One patient (F) had pressures of 230 and 200 mm. of cerebrospinal fluid on the third and sixth days after operation. One (FP) had a pressure of 200 mm. on the second day after surgery. Another (FP) had pressures of 280 and 185 mm. on the first and second days after operation. Pressures of 250 and 410 mm. were recorded in another patient (FPT) three and four days after operation, at which time he had no difficulty in speech. One (P) had a pressure of 90 mm. on the second day after operation. Another (P) had pressures of 360 and 200 mm. on the second and fourth days after surgery. Pressures of 250, 280, 250 and 250 mm. were recorded on the second, third, fourth and fifth days after operation in another case (P). One (PT) had a pressure of 150 mm. on the eighth day after operation. One (PTO) had

a pressure of 210 mm. on the second day. Another (PTO) had pressures of 185 and 250 mm. on the sixth and fourteenth days after operation. Still another (PTO) had pressures of 210, 130, and 195 mm. on the eighth, tenth and sixteenth days afterwards. One (T) had pressures of 380, 240 and 110 on the fourth, fifth and eleventh days after operation. On both the third and fourth days after operation another (T) had a cerebrospinal fluid pressure of 200 mm. Two others (T) had pressures of 190 and 230 mm. on the second day after operation. One other (T) had a pressure of 275 mm. on the first day after operation and 400 mm. on the second day just before removal of an extradural hematoma. The next day the pressure was 275 mm. of cerebrospinal fluid.

4. Statistical Analysis

The subsequent statements apply to those patients who had aphasia after excision of parts of the left frontal, parietal or temporal lobes. A person is classified as having difficulty at some time after operation with a particular test (e.g. obeying oral commands) only if he had more difficulty than before operation. There is no significant difference* in the number of patients having difficulty in spontaneous speech, perseveration, naming or reading aloud

* $\left(S_{\bullet} = \frac{P_1 - P_2}{\frac{p \times q}{N_1} - \frac{p \times q}{N_2}} \right)$

immediately or the day after operation (see Table 15). Nor is there any significant difference in the number having difficulty with any test five days, two weeks or at the time of the last test after operation (see Table 16).

The numbers 0, 1, 2, 3, 4 and 5 may be used to designate no, questionable, slight, moderate, marked and very marked difficulty in the various tests. The tests before operation and at the various times afterwards may be compared numerically. In this way, the group classed as aphasic may be shown to have a statistically significant difference in the scoring on tests before and after operation -

$$T = \frac{\bar{D}}{\sqrt{\frac{\Sigma x^2 - \frac{(\Sigma x)^2}{N}}{N(N-1)}}}$$

as is shown five days after operation, for example, in Table 17.

TABLE 15

TIME AFTER OPERATION

	Immediately			One Day		
	Frontal	Parietal	Temporal	Frontal	Parietal	Temporal
Spontaneous Speech	1:5	0:2	3:12	2:5	1:2	9:12
Perseveration	1:5	0:2	2:12	1:5	0:2	5:12
Naming	1:5	0:1	5:12	2:5	1:2	6:12
Reading Aloud	1:5	0:1	2:10	2:5	0:1	5:12

TABLE 16

TIME AFTER OPERATION

	Five Days			Two Weeks			Time of Last Test		
	F.	P.	T.	F.	P.	T.	F.	P.	T.
Spontaneous Speech	3:5	2:2	10:12	3:5	2:2	9:12	2:5	0:2	3:12
Perseveration	4:5	1:2	10:12	2:5	1:2	7:12	0:5	0:2	3:12
Naming	4:5	2:2	10:12	0:5	1:2	6:12	0:5	0:2	4:12
Repetition	1:1	2:2	7:7	1:5	1:2	6:12	0:5	1:2	5:12
Oral Commands	1:2	1:2	5:6	2:5	2:2	7:12	1:5	1:2	4:12
Written Commands	2:3	2:2	6:7	1:5	1:2	6:12	1:5	0:2	1:12
Spelling	-	-	-	3:5	1:2	4:12	1:5	0:2	1:12
Reading, Aloud	3:5	2:2	10:12	1:5	1:2	6:12	0:5	0:2	2:12
Reading, Silent	-	-	-	3:5	0:1	3:9	2:5	0:1	1:12
Writing, Spontaneous	4:4	2:2	5:6	3:5	2:2	8:12	0:5	0:2	0:12
Writing, to Dictation	3:3	2:2	5:8	2:5	2:2	6:12	1:5	0:2	2:12
Calculation, Oral	1:1	2:2	2:3	2:5	1:1	3:10	2:5	1:2	2:12
Calculation, Written	-	-	-	2:4	1:1	2:10	0:5	0:1	2:12

TABLE 17

NUMERICAL DIFFERENCE BETWEEN TESTING BEFORE AND FIVE DAYS AFTER OPERATION.

	Sp.Sp.	Pers.	Nam.	Rep.	Com. Or.	Com. Wr.	Spell.	Read Al.	Writing Sp.	Writing Dict.
Frontal	-2	-2	-4	-3	-4	-5	—	-4	-5	-4
	0	-1	-1	0	—	-1	—	0	-2	-2
	-5	-2	-3	—	—	—	—	-3	-5	—
	-4	-2	-3	—	-4	—	-4	-4	-4	-5
	0	0	0	—	0	0	—	0	—	—
F.-T.	-1	-1	0	—	0	—	0	-1	—	—
	-2	-2	0	—	0	—	—	0	0	0
Parietal	-5	0	-5	-5	-4	-1	+1	-5	-3	-3
	-5	-2	-5	—	-2	-5	—	-3	—	—
Temporal	-5	-3	-5	—	—	—	—	-5	-5	—
	0	0	-5	-1	0	+1	-1	-1	-2	0
	-4	-1	-5	-1	—	—	—	—	—	—
	-4	-3	-1	-5	—	-5	-5	-5	-5	-5
	-5	-5	-2	—	-5	-5	-5	-5	—	-3
	-5	-5	-5	-5	-3	-4	-5	-5	-5	-5
	-4	-3	-5	-5	-2	-4	-5	-5	—	-5
	-2	-1	-5	-1	-2	-3	—	-1	0	—
	0	0	0	0	-3	0	—	0	0	0
	-5	-5	-5	-5	-5	—	—	-5	—	—
	-2	-1	-1	-4	-3	-5	—	-3	-4	-1
	0	0	0	—	—	—	-1	0	0	—
Exploration	0	—	-1	—	—	0	—	-1	—	—

The following three tables give the results of the last test after operation in all cases. In those patients with aphasia after operation on the left hemisphere, writing to dictation is the only test showing a significant difference (if the patient with the temporal excision complicated by hemiplegia is excluded, then there is no significant difference). In those patients classified as without aphasia following operation on the left hemisphere, no test shows a significant difference. After operation on the right hemisphere, patients had difficulty in obeying oral commands (significant at 0.05 level); but they made better scores in the test of silent reading (significant at 0.02 level).

PATIENTS WITH APHASIA BUT WITHOUT TUMOR BEFORE OPERATION AND LAST TEST AFTERWARDS

	Sp.Sp.	Pers.	Nam.	Rep.	Com. Or.	Com. Wr.	Spell.	Reading Al.	Reading Sil.	Writing Sp.	Writing Dict.	Calculation Or.	Calculation Wr.
	0	0	0	0	0	0	+1	0	+3	0	0	+2	0
	0	0	0	+1	+1	0	0	0	-1	0	0	-2	0
Frontal	-1	0	0	0	0	0	-1	0	0	-1	0	+2	0
	-1	0	0	0	-3	-2	-1	0	0	0	-2	-1	-1
	0	0	0	0	-1	0	0	0	-1	-1	-1	0	0
F.-T.	0	-1	0	0	0	+2	0	0	0	0	0	0	0
	0	+1	0	0	0	0	0	0	+2	0	0	-1	+1
Parietal	0	0	0	0	-1	0	0	0	0	0	0	0	0
	0	0	0	-1	-1	0	0	0	—	-1	0	-1	—
	0	0	0	0	0	0	0	0	+1	0	0	0	+1
	0	0	0	0	+1	0	0	0	+1	-1	0	0	0
	0	0	0	0	+2	0	0	0	0	0	0	+2	0
	-2	-1	-1	-1	+1	0	0	0	-3	-1	-2	-1	0
	0	0	0	0	0	0	0	0	+1	0	0	+1	0
Temporal	-2	-1	-2	-2	-1	0	-0	-1	0	-1	0	0	0
	0	0	-1	-1	0	0	0	0	-1	0	0	0	0
	0	0	0	0	-1	0	+1	0	+1	0	0	0	0
	0	0	0	0	-1	0	0	0	0	0	0	0	0
	-2	-1	-1	-2	-2	-3	-4	-4	—	-1	-4	-3	-1
	0	0	0	-2	0	-1	0	0	0	0	0	+1	0
	0	0	0	+1	-4	-1	0	0	0	0	0	+1	-1
Exploration	-1	0	0	0	0	0	0	0	-1	-1	-1	0	+1

LEFT HEMISPHERE

	Sp.Sp.	Pers.	Nam.	Rep.	Com. Or.	Com. Wr.	Spell.	Reading Al.	Reading Sil.	Writing Sp.	Writing Dict.	Calculation Or.	Calculation Wr.
Frontal	0	0	0	0	0	0	+1	0	—	0	0	0	0
	0	0	0	0	+1	+2	0	0	+1	0	0	0	0
F.-P.	0	0	0	0	—	0	0	0	—	0	0	—	+1
	0	0	0	0	—	—	0	0	-1	+1	0	0	0
F.-P.-T.	0	0	0	0	0	+1	0	0	0	0	—	+1	-2
	0	0	0	0	-1	0	0	0	0	0	0	0	-1
	0	0	0	+2	+1	0	0	0	0	0	0	-1	0
F.-P.-T.-O.	0	0	0	0	—	—	0	0	—	+1	+1	0	-2
Parietal	0	0	0	0	—	—	—	0	—	0	—	—	—
P.-T.	0	0	0	0	-2	0	0	0	0	0	0	0	0
P.-T.-O.	0	0	0	0	0	—	0	0	—	0	0	-1	-1
	0	0	0	0	-1	0	0	0	0	0	0	+3	+3
	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	+1	0
Temporal	0	0	0	0	0	-2	+1	0	0	0	0	-1	0
	0	0	0	0	-3	0	-1	0	0	0	0	0	-1
	0	0	0	0	-1	0	0	0	0	0	0	+1	0
	0	0	0	0	0	0	+1	0	+1	0	0	0	0
T.-O,	0	0	0	0	—	0	0	0	0	0	0	0	0
O.	0	0	0	0	0	0	0	0	0	0	0	0	+1
Exploration	0	0	0	0	—	—	-2	0	—	0	0	0	0

RIGHT HEMISPHERE

	Sp.Sp.	Pers.	Nam.	Rep.	Com. Or.	Com. Wr.	Spell.	Reading Al.	Reading Sil.	Writing Sp.	Writing Dict.	Calculation Or.	Calculation Wr.
Frontal	0	0	0	0	0	0	0	0	+2	0	0	0	-1
F.-P.	0	0	0	0	-1	0	0	0	+1	0	0	-1	0
	0	0	0	0	-3	-2	0	0	0	0	-1	-1	-2
F.-P.-T.	0	0	0	0	—	—	0	0	—	—	0	0	—
F.-T.	0	0	0	0	0	0	0	0	0	0	0	+1	0
Parietal	0	0	0	0	+1	+2	0	0	0	0	0	0	+1
	0	0	0	0	0	-2	0	0	0	0	0	0	-1
	0	0	0	+1	-1	0	0	0	0	0	0	0	0
	0	0	0	0	—	0	0	0	—	0	0	—	0
	0	0	0	0	-2	-1	0	0	+1	0	0	0	+1
P.-T.	0	0	0	0	0	0	0	0	0	0	0	-1	0
	0	0	0	0	-1	-1	0	0	—	0	0	-1	0
P.-T.-O.	0	0	0	0	0	0	0	0	+2	0	0	+1	+1
	0	0	0	+1	+2	+1	0	+1	0	0	0	+1	-1
	0	0	0	0	0	0	0	0	0	0	0	+1	0
	0	0	0	-1	-1	+1	0	+1	0	0	0	-1	-2
Temporal	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	+1	0
	0	0	0	0	-1	0	0	0	0	0	0	-1	0
	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	-1	0	0	0	-1	0	0	0	0
	0	0	0	0	-1	+1	0	0	+1	0	0	0	0
	0	0	0	+2	-0	+1	0	0	+1	0	0	+1	0
	0	0	0	0	-2	0	0	0	+1	0	0	—	0
	0	0	0	-1	0	0	0	0	+1	0	0	0	0
Exploration	0	0	0	-1	0	+2	0	0	0	0	0	0	0

V. DISCUSSION

The positive effect on speech produced by stimulation of the human cerebral cortex is vocalization, which was first noticed by Penfield in 1938. Vocalization is obtained from that part of the precentral and postcentral gyri which yields movements of the lips, jaw and tongue on stimulation, and also from the supplementary motor area. Vocalization occurs during stimulation of these areas, but no others, in either hemisphere. Brickner (1940), Penfield and Welch (1951) and Erickson and Woolsey (1951) have reported vocalization from the supplementary motor area.

The negative effect on speech caused by electrical arrest is inability to vocalize or to use words properly. The electric current causes a complete arrest of speech when applied to those same areas where vocalization is produced. In obtaining arrest of speech from the supplementary motor area, Erickson and Woolsey (1951) have confirmed the results of Penfield and Welch (1951). Because movements of some of the muscles necessary for speech may be obtained from stimulation of these same areas, it is believed that these results are due to an interference of the motor mechanism of speech. Hesitation, slurring, distortion and repetition of words also occurs from these same areas, and for the same reason. Brickner (1940) was the first to report repetition of a number from the supplementary motor area.

The preceding negative effects, as well as inability to name with retained ability to speak, confusion of numbers while counting, and misnaming with or without perseveration, have occurred during electrical interference of the left Broca's, supplementary motor, inferior parietal and posterior temporal regions. This is an arbitrary classification of the results noted during stimulation while the patient names a series of pictures of objects. Obviously he must have some type of "set" to be able to name. One might expect that were it just the "set" which influences the naming, stimulation of either frontal regions, or other areas might alter the act. However, it is only during electrical arrest of certain areas of the left hemisphere that these results have occurred. It is believed, therefore, that this is an interference with language. Of the two patients who had interference with speech from the right hemisphere, the left-handed man had difficulty in naming on the fifth day after operation and the right-handed woman had loss of speech associated with her seizures, and also had two brief periods of loss of speech without overt seizure following operation. Regardless of the handedness of the patient the electric current causes alterations in speech when applied to the previously designated areas of the left hemisphere, and not of the right (except in the motor regions), in practically all patients.

Other parts of the left hemisphere, the frontal and occipital poles, etc., have been stimulated without affecting speech. However, the number of stimulations is not sufficient to be statistically significant.

In the areas from which effects have been obtained, there is an area-localization and not a point-localization. For example, electrical arrest in the temporal region five centimeters, seven centimeters and nine centimeters from the tip may interfere with speech; whereas at other points between them no interference is produced. Also, stimulation of the first, second and third gyri anterior to the left precentral face area may produce effects upon speech, though stimulation of the same gyri at other points does not. Electrical interference in a given area is only effective about fifty percent of the time. Similarly, stimulation of one point in the motor region may produce a particular movement at one time and no movement on the next occasion, or else a slightly different one. As we have attempted to show in our data and will discuss subsequently, the left hemisphere still subserves speech functions after one part of the speech area has been injured or diseased. We believe that the anatomical substratum for speech is in those areas which remain where electrical interference produces speech interference. For example, if the left Broca's region is destroyed, speech is still subserved by the left hemisphere.

Few of our patients scored perfectly on all tests. As we were primarily interested in the comparison between before and after operation, we attempted to make the test as difficult as practical. All normal people could not do some of these tests as they are more difficult than those of Head (1926), which Weisenberg and McBride (1935) criticized. Nonetheless, we are unable to find a difficulty in any particular test prior to operation - as these patients all had lesions - to be associated with that particular area of removal, and not another. Some of our patients had birth injuries; and they may well have had lowering in both verbal and performance scores as Hebb (1942) has shown (but we did not carry out this type of psychological testing).

Those patients who are classified as having aphasia varied considerably as to degree. They varied also as to the length of time the aphasia was present. Some patients were so aphasic that the only words, not propositions, present were the incorrect use of "yes" and "no". No patient had such a marked difficulty in understanding speech that he understood nothing. There were patients who were able to read numbers very well but unable to read most letters or words. Others could write what they could not say. In other words, a great many of the various disorders of language have been noted.

After analysis of the seventy-one personally observed cases, we are not able to state that an excision of a particular area is followed by a specific type of aphasia. This may be due to the fact that limited cortical removal is not followed by a special type of aphasia; or the explanation may be that there are not enough cases in the various groups; or removal of the areas of the dominant hemisphere not included in our study might be followed by a specific type of aphasia. The areas of the dominant left hemisphere not included in the removals of the cases personally observed are the frontal pole, Broca's area, the Rolandic face area, the posterior temporal region, the temporo-parieto-occipital "no man's land" and the occipital lobe. The entire supplementary motor area of the left hemisphere had been removed without permanent aphasia. Patients with this removal had, among other things, during the course of their transient difficulties a "disorder of rapid and complex movements" as described by Ethelberg (1951) for both speech and motor movements and by Penfield and Welch (1951) for motor movements.

Had we been able to examine all five hundred and seventy-five cases perhaps we would have been able to correlate a specific defect with a specific removal; however,

this is very doubtful. If the excisions of the left hemisphere performed in different patients who had transient aphasia after operation are combined, it may be concluded that the entire left hemisphere may be removed with transient but without permanent aphasia. The Rolandic face area and the gyrus anterior (Nielsen's Broca's area) may be removed without permanent speech disturbance. The frontal lobe may be removed back to one gyrus anterior to the precentral face area without permanent aphasia. There is one patient (D.H.) who had an incision into the cortex of the first two gyri anterior to the precentral and some subcortical removal with transient aphasia. His seizures continued; and he returned ten years later for removal of the precentral gyrus and the three gyri anterior to it, as well as the anterior half of the first temporal convolution. Following the second operation he had no speech disturbance and no signs of neuroparalytic edema. He died accidentally three years later. At autopsy there is no evidence of tumor and perhaps what had been called an astrocytoma at the time of both operations was a congenital abnormality. A localizationist probably would say that the right Broca's area had assumed the function of the left; but this assumption is by no means proved, as he had no evidence of disturbance of function of the left hemisphere after the second operation.

Most of the cases involving removal of the posterior temporo-parietal region are similar to the one reported by Wechsler (1937); this patient had marked aphasia with original injury, subsequent improvement and no definite alteration in speech following the surgical procedure. There is the case of a woman (E.L.) who at the age of thirty-three had evidence of a vascular occlusion, associated with marked aphasia. She recovered from her speech disturbance and began to have seizures. At operation there was a large cyst of the supra-marginal, angular and first temporal convolutions. The cyst was punctured and no cortical removal performed. Following operation she had transient aphasia. There are four patients with permanent speech disturbances with lesions of the left parieto-temporal region. None of these showed a definite change following surgery; and, as previously noted, they are classified as negative. All of them have continued to have seizures. There is a similar case who did not have any seizures after operation and nine months later showed marked improvement to the extent that there was no detectable speech disturbance.

The reason for the immediate aphasia in eight of the thirteen cases who had operations in the left hemisphere for lesions other than tumor are believed to be seizures, fatigue and vascular occlusion. Because the same areas that were

removed in the other five have been removed in other patients without producing immediate aphasia, it is concluded that the immediate aphasia was not due to the area removed. Most patients had transient aphasia lasting no more than several weeks. Because areas similar to those removed in the eighteen patients who had a permanent disturbance in speech have been removed in other patients without producing a permanent defect and because all patients who have a permanent disturbance in speech also have continued to have seizures, it is concluded that the brain removed is not in itself responsible for the permanent aphasia. As Prados, Strowger and Feindel (1945) and Odom, Dratz and Kristoff (1949) have shown pathological changes in cortex of animals exposed to air and ultraviolet radiation, it seems likely that similar changes occurred in our patients; and these changes may explain, in part, some of the continuing aphasias and seizures.

Any limited cortical area of the left cerebral hemisphere (so far as our excisions demonstrate) may be excised without producing permanent aphasia - providing the remaining brain functions normally - and also without producing immediate aphasia. The entire supplementary motor area, the second frontal convolution, the precentral face area and gyrus anterior, the anterior seven centimeters of the temporal lobe, the angular and supramarginal gyri, the superior part of the parietal lobe and entire occipital lobe - each may be removed.

If our one case of possible tumor and Mettler's (1949) claims be substantiated, then the entire left third frontal convolution may be removed. If the patient has an extensive lesion of the left cerebral hemisphere prior to the age of two years, then the entire hemisphere may be excised without permanent aphasia. Exactly how much of the left cerebral hemisphere may be excised in the adult without producing a permanent disturbance in speech is unknown. Zollinger's (1935) case of hemispherectomy for tumor in an adult demonstrates that some speech may return. However, this patient did not live long enough to determine how much of his language would be useful. Nielsen (1947) states that the right hemisphere functioned for speech in Zollinger's case. It seems possible that subcortical structures might have subserved such a function. If bilateral removal of Broca's area, as Mettler (1949) claims, does not produce permanent aphasia, then some other area than the opposite Broca's must subserve speech. Since these data were collected, there has been a case of bilateral removal of the anterior end of the temporal lobe without disturbance of appreciation of music. This case conclusively proves that there is no center for music comprehension here as Henschen (1920-22) and Nielsen (1947) contended; and the relationship of music to speech remains unsolved as Ustdedt (1937) pointed out.

The fact that the patient has aphasia after initial injury and then again has aphasia after operation for excision of the scar indicates that the left hemisphere still functions for speech. It is true that aphasia occurred after operations on patients who had had injuries slightly less frequently than on those who had not had any type of injury. However, if those patients with residual aphasia are excluded the difference is not significant at the one per cent level. Of those patients who had injuries and did not have aphasia after operation, only one showed evidence of neuroparalytic edema.* It may be that aphasia occurs only after a considerable area is knocked out of function. It is certainly possible that after extensive injury to the left cerebral hemisphere speech occurs during physiological activity of another part of the brain - the right hemisphere or elsewhere.

The author agrees that <u>lesions</u> in particular localities may result in specific clinical syndromes. Lesions in the region of the precentral face area and of Broca's area may result in aphasic disorders which are predominantly expressive in type. This does not mean that a center for eupraxia and

* Weakness and somatic or visual sensory disturbance are permitted only after excision of precentral, postcentral or calcarine cortical areas respectively; otherwise, if one occurs, there is edema. If weakness of the face occurs three days after excision of the precentral leg area, there is neuroparalytic edema.

another center for movements of the lips, etc., have been destroyed. There is no one specific site where what Nielsen (1947) calls the motor engrams of speech are stored. A large part of the cortex and sub-cortex appears to be active during the psychical production of a proposition. The transmission of impulses from the precentral gyrus to all of the complex musculature necessary for speech is certainly occurring; and there is activity in Broca's area or another speech area. There is, however, no localized area for articulate language in Broca's convolution. Broca's convolution is only part of the whole.

Generally, we believe that lesions in the posterior parieto-occipital region may produce aphasic disorders with the most pronounced difficulty in the visual sphere. However, there is no localized center in the angular gyrus for the recognition of letters, numbers or words. One of the chief things that has retarded progress is the acceptance of such a concept as that perception is divided into first, conscious perception of sensory impressions, and second, linkage of content of perception with other images. We have only an imperfect idea of the exact mechanism of perception. Senden (1932) demonstrated the prolonged period of time required for the appreciation of visual cues in older children who have had congenital cataracts removed. Theory is indispensable; but terms such as those of agnosia, particularly

when subdivided into visual verbal, visual literal, etc., do nothing but confuse us. There is not a single case of visual verbal agnosia in the literature without other defects, and also with the ability to recognize some word at some time if the examination is detailed enough. We must record what the patient sees and does under this and that circumstance and not use such terms as visual verbal agnosia and auditory agnosia unless these things actually exist which, as far as this writer is concerned, has never been proved.

We shall not describe various syndromes which certainly do occur clinically - as Gerstmann's syndrome, and so forth. We do believe, however, that the supplementary motor area has something to do with speech. Other than our own results from stimulations and excisions there are those of Critchley (1930), Cushing and Eisenhardt (1938), Ethelberg (1951) and Erickson and Woolsey (1951). Perhaps this area is only used supplementarily after the damage of another area.

Jackson's (1931) dictum that a lesion produces negative effects and the action of the remaining brain produces the positive ones needs to be modified slightly. Part of the remaining brain may be abnormal and this discharging abnormal brain may give rise to certain effects. The author believes that aphasia may be caused not by the lesion but by the discharging abnormally functioning brain. Hebb (1939) stated that some of the signs of frontal lobe damage may be due not

to the loss of the tissue itself but to the disfunctioning of the remaining tissue. Penfield and Welch (1950) have shown that this may be true also in the paradoxical improvement in hemiplegia following the removal of motor cortex. Penfield and Humphrey (1940) stated that chronic progressive degeneration may continue in an area of local cortical atrophy over a period of years. From a slightly different point of view but still related, Bonnefort (1865) stated that signs which might be expected to be present in a lesion of a given area might not be there if that lesion is a very slow growing tumor.

It seems quite definite from the review of the literature and from our cases that the left cerebral hemisphere is dominant in practically all individuals regardless of handedness, except those who have gross lesions of the left hemisphere within the first few years of life. Lesions of the right hemisphere rarely if ever produce a permanent aphasia. The author has searched unsuccessfully for a case with a gross lesion of the left hemisphere early in life, and subsequent injury to the right hemisphere. The type of disturbance, which occurs with disease of the right hemisphere seems different from that of the left. Head's (1926) single case of involvement of the right hemisphere had semantic aphasia (see page 16); this type is quite different from the others and might be considered as a disturbance of some psychological processes and not as an aphasia at all. Schiller's (1947) two patients had as their only residual defect difficulty in learning to

write with the right hand, which was much more marked than the patients learning to write with their left hand. Bucy (1951) remarks that transient aphasia may follow operations in the posterior fossa. The author has seen a similar case. It is tempting to believe that the right hemisphere has no more to do with speech than the cerebellum. Does it function following destruction or removal of the entire left hemisphere? Perhaps, but this is an exception.

The fact that after excisions involving the right cerebral hemisphere, patients had increased difficulty obeying complicated oral commands may indicate some decrease in attention. That these same patients did better on the test of silent reading may indicate a practice effect.

There is one other observation requiring comment. Stimulation of the non-dominant right temporal lobe may yield well formed visual and auditory hallucinations. How does the patient tell someone of these hallucinations as they unfold themselves? Speech, a psychical act, may occur during activation of the upper brain stem and the left hemisphere produced by the discharge in the right temporal lobe. Speech occurs during activity of one or more of the cortical areas outlined in Figure 18, and of the upper brain stem. Various parts of the cortex and adjacent white matter of the left hemisphere may be removed and yet the left hemisphere still functions during speech; with these removals trans-

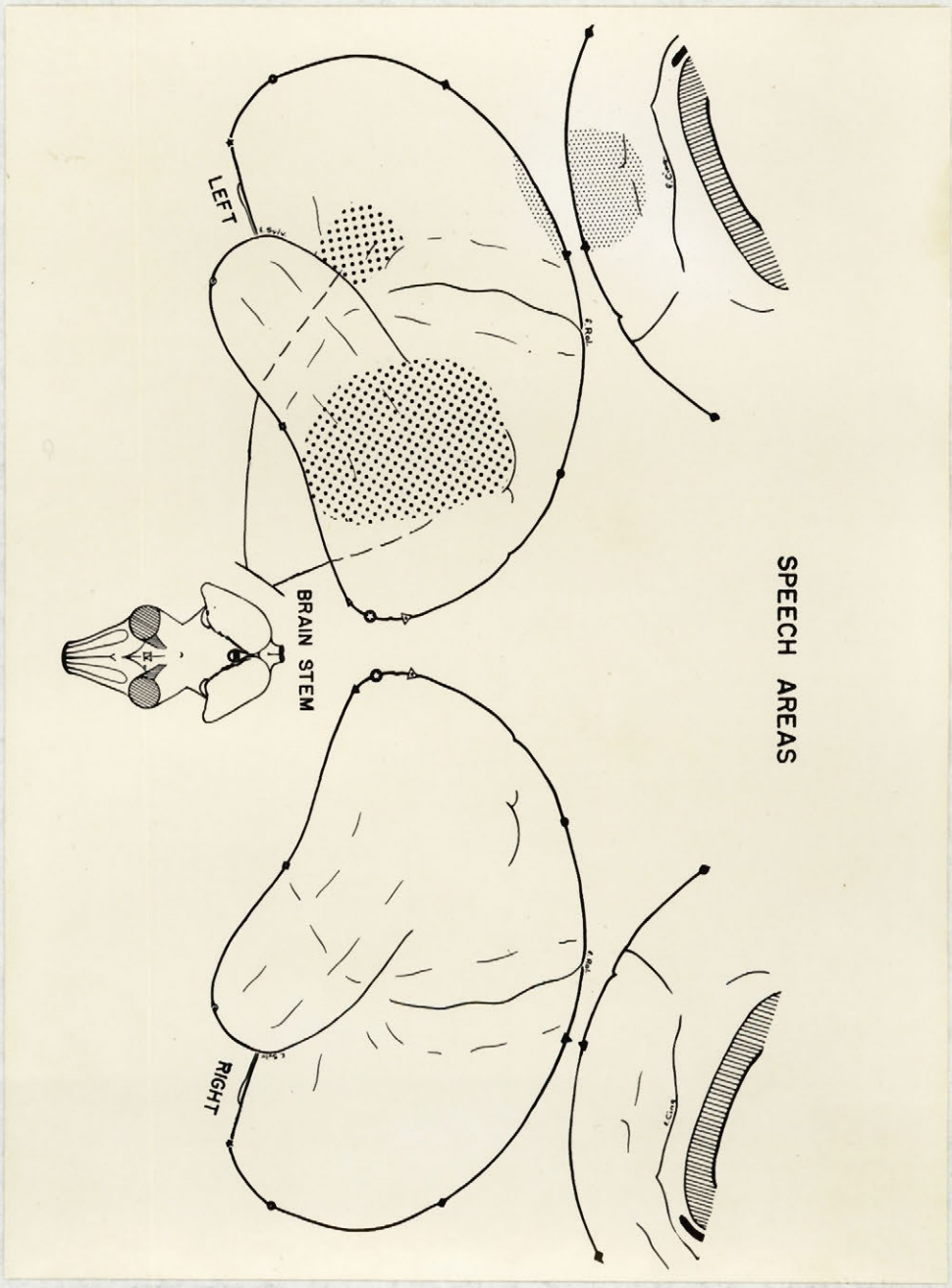

Figure 18

cortical connections may be severed. Therefore, it would seem that the activity which accompanies speech must include that of some subcortical gray matter as well as that of the cortex.

VI. SUMMARY AND CONCLUSIONS

1. Electrical interference has produced alterations in speech similar to some of the disordered speech of aphasic patients. The areas involved are Broca's, inferior parietal, posterior temporal and supplementary motor of the left hemisphere. It is concluded that Rolandic regions of both hemispheres and right supplementary motor area function only for the motor control of speech organs.

2. Parts of the posterior half of the left third frontal convolution, inferior parietal and posterior temporal regions, as well as the entire supplementary motor area have been excised with only transient aphasia. Analysis of seventy-one personally observed cases shows no speech defect to be consistently more or less present after excision of one area, as compared with another (these cases do not include excision of the left Broca's, lower Rolandic, posterior temporal, or temporo-parieto-occipital regions).

3. It is believed that there is a subcortical area for integration of speech; and that normal speech occurs during activity of Broca's, parietal and temporal regions with this subcortical area. This provides a physiological mechanism for the psychical act of speaking. There is considerable reserve of brain tissue in these three regions and a second additional area in the left supplementary motor region.

4. Excision of the usually delineated cortical areas of speech in the left hemisphere of patients having initial injury at birth or within the first two years of life usually has not resulted in aphasic defects, because of displacement of function due to the lesion. Electrical interference with speech and excision followed by transient aphasia have shown the left hemisphere to be dominant in practically all other patients, regardless of handedness. Disturbances in language as a result of disease of the right hemisphere differ from those of the left hemisphere and are probably never permanent. Physiological activity of the right hemisphere probably accompanies the psychical state - speech - after destruction of the entire left hemisphere. The left hemisphere is used in retraining. When this hemisphere is completely destroyed, the patient may remain permanently aphasic or may relearn by use of subcortical structures, or by use of the right hemisphere.

5. The discrepancy between these results and those found following injury, vascular disease and tumor may appear irreconcilable. However, it is believed that the well-known clinical syndromes of various aphasic difficulties occurring as a result of lesions in particular localities may be due not to the lesions themselves but to the discharging abnormal brain within or surrounding the involved cerebral tissue.

This concept necessitates a slight modification of Jackson's principle of positive and negative effects occurring as a result of cerebral lesions.

VII. APPENDIX

As it would require too much space to present all of these cases in full, only a very few illustrative ones will be given briefly.

CASE 1 W.O. is a 33 year old right-handed man who was struck in the left posterior frontal region by a tool box at the age of 28. He had a small laceration but was not unconscious. Three months later he began to have recurrent seizures. The seizures were characterized by a peculiar sensation in the head with head and eyes turning to the right, and then inability to speak or to understand what was said to him. At times he would turn around several times to the right. He would then lose consciousness and have a generalized convulsion.

On examination there are no abnormal neurological signs and repeated electroencephalograms, even with the use of metrazol, shows no abnormality. On testing, the only abnormalities are an occasional mistake when three commands are given (i.e., put your left third finger on your right eyebrow and your right second finger on your left ear and then put your right fourth finger on your right ear); marked difficulty in repeating the three sentences he reads (he says: "Do not help the patient out. Record verbatim, but I do not know what that means. All

hesitations will be like a mark against the patient".); and two mistakes in oral calculation (29 plus 36 equal 55 and 16 times 16 equal "132, no 156"). At operation there is no objective abnormality. The central fissure is outlined in the usual manner. Stimulation at point 17 produces something like an attack. He says, "When I have an attack my head turns around like that and I cannot talk". Stimulation at 18 causes him to stop speaking. At 20, he makes a number of different sounds but is unable to name. At 18 again, he says "that is a . . .", but is unable to name. At 22, he is unable to speak. At 25, he says, "This is a comb" (correct), and then says, "this is a . . .". When asked the use of the object shown, just as the electrode was being withdrawn, he says "to cut", and then names the knife. At 31, the patient says "This is a trowel", but then said "This is a hammer", which is correct. Afterwards he repeats "This is a . . .", several times. After removal of the electrode he names "a flag" correctly. Points 17, 18, 20 and 31 are in the supplementary motor region, and 20 and 22 in Broca's area. These are illustrative examples. The outline of the excision is indicated by the dashes in the supplementary motor area in Figure 14.

Following the excision there is some weakness of movements of the right foot. He has no difficulty in speech, naming or reading. Twenty-four hours later there is the same amount of weakness in the foot as previously.

There is no difficulty in spontaneous speech, naming, reading, or writing. Two days later, although he complains of some slowness in thinking and in speaking, there is no obvious defect in spontaneous speech, naming, reading or writing. The next day, however, there is very marked disturbance in spontaneous speech. He says nothing voluntarily. There is marked difficulty in articulation. In naming he usually mispronounces those pictures that he is able to name; for example he calls 'bird', "birt", and 'comb', "homb". He shows evidence of perseveration. Finally, however, he is able to name eight out of the ten objects. He has some difficulty in naming letters, for example 'g' is called "c". He reads the word 'pen' as "two" and "dwo" and "too". When asked if it were "pencil", he says "yeh", if it were "pen", "yeh", if it were "pencil", "yeh". He is unable to read a sentence. At this time he is quite fatigued.

On the fifth day after operation the condition is about the same. There is evidence of weakness of the entire right side, which is more marked in the foot. Writing with the right hand is unrecognizable. With the left hand he is able to write some words but not others and some letters but not others.

Ten days after operation he shows definite improvement. Spontaneous speech shows evidence of mispronounciation but not of substitution. He names practically all objects.

There is slight difficulty in reading. He writes "he filped open his big ring notbook and began to read", misspelling flipped and notebook.

On the twentieth day after operation complete testing shows him to have very slight disturbance in pronunciation and inflection. He is unable to name a swastika but says that it is German. He makes no mistakes in oral calculations. In all other tests he does the same as he did before operation.

CASE II A.D. is a 26 year old right-handed man who was in an automobile accident at the age of 19. He spoke immediately after the accident. He had a compound depressed **fracture** of the left frontal region with laceration of the frontal lobe. Débridement and primary closure were carried out. He was unconscious from the fifth to the fourteenth day after operation and then had difficulty in speech for at least three weeks thereafter. His habitual seizures began four months after the accident.

On examination there are no abnormal neurological signs. On testing he has slight difficulty with silent reading, makes three mistakes in oral calculation and one in written calculation. At operation, stimulation of the second gyrus anterior to the precentral just above the fissure of Sylvius causes the patient to hesitate for some time and then say "This is a cold". After withdrawal he names 'comb' correctly.

The excision includes a dense scar with surrounding cortex in the intermediate precentral region above the fissure of Sylvius, as outlined by the solid line in Figure 14. Following a seizure produced by stimulation he developed slight weakness of the right face, but this is not increased after the excision. After the excision there is no difficulty in spontaneous speech, naming, reading or obeying a single written command.

The day after operation there is no facial weakness. He has no difficulty in spontaneous speech, naming, or reading on the first, second, sixth or ninth days after operation. Complete testing is repeated on the ninth day after operation. At this time he has a little more difficulty with the silent reading, and all other tests are done as well as before surgery except for writing. He writes "Well I thought thing I am going to the (which is struck out) tell is about my operation and it is not about all I can tell is about the preparation the had was always the v (struck out) time was when they had me to get ready that is they shaved off all my hair was and a few odd parts of pencil they pr (struck through) quive me in the fanny.

"My why (both struck through) when they quite me upstair they had me in a quite a few places until they had me comfortably and they (struck through) then they were in to the operation room and they asked me all sorts of questions to quite me memory quite quickly and keep it fresh." When

given - "Around the rugged rock the ragged rascal ran", to write to dictation, he writes - "Around the rugged rock the rackket rascal ran". No such mistakes were made prior to operation. Three months later he writes an excellent letter without mistakes.

CASE III J.M. is a 23 year old right-handed man who had seizures for six years without preceding injury or disease. His attacks began with numbness of both sides of the tongue and then he became confused and unable to understand what he heard or saw and could not speak, though he states that he was aware of something going on around him. Following this he was unaware of his surroundings and became automatic, looking at first his right thumb and then his left thumb, or vice versa.

Neurological examination shows no abnormalities. Patient has no difficulty with any of the tests. The electroencephalogram is normal until the onset of a seizure when there are bilateral 6 per second slow and sharp waves in the temporal regions.

The surface of the brain appears normal at operation. Stimulation of the gyrus posterior to the postcentral face area causes the patient to suddenly look at his left hand, open and close it several times, and then to swallow and lick his lips. Following this he is able to talk but then has a spontaneous seizure beginning by looking at the right

hand; and a short time later he has a second spontaneous seizure. Numerous stimulations are carried out while the patient is naming, but most of these are associated with electrographic after-discharge. The gyrus from which the seizure was produced is removed as outlined by the dots in Figure 14.

The day after operation the patient is unusually cooperative and has no difficulty in spontaneous speech, naming, reading, silent reading, repetition, obeying oral or written commands, or in writing. On the third day there is slight weakness of the right grip as compared with the left. Although he states that he is slow, he has no difficulty in spontaneous speech, naming, reading, obeying written command, silent reading or oral calculations, but has slight difficulty with the more complicated oral commands. The next day, however, he has moderate difficulty in spontaneous speech and naming, reading and writing spontaneously. He has marked difficulty in obeying oral commands and in writing to dictation. When asked to write "The light is poor in this room", he writes - "The light in the nooms which". He tries again: "The light in the rooms with house". When asked to write - "Those flowers are beautiful", he writes - "The these flowers the rose kind".

By the next day the patient has practically no spontaneous speech. He is able to write some things that he is not able to say. He by no means understands everything that is said to him. However, he does not believe this. I, therefore, dictated to his nurse as well as to him and he is able to see the difference. For "the radio is on", he writes, "a radio even"; for "The flowers are pretty", he writes, "A light flowers pretty"; for "the weather is hot", he writes, "a very warm weather"; for "You do not understand everything", he writes, "he of understand?". The same type of difficulty is noted in giving him arithmetic to do. He not only mixes up the numbers dictated but also the arithmetical operation, although he makes only two mistakes out of twenty-seven in the actual problems that he finally writes down. He is only able to name about one tenth of the objects shown, although he can write the names of most of them. He is unable to read aloud, but he has only slight difficulty in obeying written commands.

On the eighth day after operation this patient has two minor seizures of numbness in his lip and tongue. Shortly thereafter he had a period of an hour or more in which he is unable to speak at all, or to recognize objects, though he is able to recognize people. Unfortunately I did not see him during them. During the period of time in which he is having so much difficulty in speech there is no

detectable disturbance in sensation or in the visual fields, as judged by simultaneous movements in both visual fields. There is slight weakness of the left hand but no abnormal reflexes.

He shows a rapid improvement and two weeks after operation the only difficulty found on testing is slight difficulty in oral commands and spontaneous writing. Since discharge from hospital this patient has continued to have an occasional seizure.

CASE IV E.O. is a 37 year old man who has had seizures intermittently since the age of one year. There was no known difficulty at birth. He had seizures from the age of 1 to 7 years, again at the age of 18, and then from the age of 27 to 37. His seizures began with an epigastric sensation, then confusion in speech and loss of consciousness with a generalized seizure followed by automatic behavior.

Neurological examination shows no abnormalities. Testing shows moderate difficulty in obeying the oral commands, slight difficulty in spelling and oral and written calculations and an occasional error in reading aloud and in spontaneous writing, as well as moderate difficulty in the silent reading. At operation there is no abnormality on the surface of the brain but there is slight abnormality of the gray matter adjacent to the island of Reil and in the hippocampal gyrus. The precentral gyrus is outlined in the usual manner. Stimulation at point 17 (Broca's

area) causes the patient to stop naming. At point 20 (posterior part of first temporal convolution) he says "there is a camel", and names a 'comb' correctly after withdrawal. This is repeated later; he says, "that is a tree", and then says "that is . . .". After removal of the electrodes he names a drum correctly. Stimulation is repeated on two other occasions but there is no interruption in naming. The anterior four centimeters of the temporal lobe are removed.

Shortly after returning to the ward this patient is disorientated as to place, thinking that he was at home; but he is orientated as to time. There is no difficulty in spontaneous speech. He names three pictures correctly and then calls a glove a flashlight; glasses, a tre; pencil, an envelope and letter. He reads several numbers and letters correctly and several sentences. There is questionable weakness of the right grip. On the day after operation the patient is not very cooperative. He has moderate difficulty in spontaneous speech, slight difficulty in reading and marked disturbance in obeying oral commands and naming.

On the fifth day after operation the patient has marked difficulty in spontaneous speech, much of what he says is unintelligible. Occasionally he produces a complete sentence such as "I'm bird of damn few words". He is unable

to name any object correctly, to repeat, to read, to write spontaneously or to dictation, but he is able to copy with only a few mistakes and able to obey some oral commands. At this time he shows no weakness, visual field disturbance or reflex changes.

On the tenth day after operation the patient still has marked difficulty in spontaneous speech, is unable to name or read aloud, though he is able to point to objects correctly after reading the name on a card. In writing the name of the object shown to him, he writes 'key' correctly; 'pencil' spelled "penson"; 'match', "minon"; 'scissors', "sen"; 'comb', "min"; and 'spoon' he does not attempt. He writes no word correctly to dictation but copies correctly. He has marked difficulty in executing oral commands. At this time he shows no abnormal neurological signs.

On the eighteenth day after operation he has only slight difficulty in spontaneous speech, naming, repeating and reading aloud. He has marked difficulty in executing written commands, spelling, spontaneous writing, writing to dictation and oral calculations. He has marked difficulty executing oral commands and silent reading and he is unable to do but the most simple written calculation.

Four weeks after operation, testing shows no difference from before operation except very slight difficulty in naming and a little more difficulty in the test of silent reading.

CASE V J.M. is a 14 year old right-handed girl who had measles at the age of 9 years and a generalized convulsion. Three months later she began to have habitual seizures. The attacks consisted in a sensation in the mid-sternal region, followed by salivation, urinary urgency and automatism. Following the attacks she had difficulty in speech and might use unintelligible words.

Neurological examination shows no abnormality. X-rays of the skull show slight smallness of the left side of the skull with elevation of the left petrous pyramid. The pneumoencephalogram shows slight ventricular dilatation without focal deformity. The electroencephalogram shows two per second slow waves and spikes from the left temporal region transmitted to the right. Testing shows that she has slight difficulty in obeying oral commands, reading aloud, spontaneous writing and oral calculations. She has moderate difficulty in spelling and in silent reading. Her parents state that she had more difficulty than normal in learning to read and spell.

At operation there is abnormality of the anterior end of the first temporal convolution and in the gray matter adjacent to the insula and in the uncus and hippocampus. No stimulations are carried out while the patient is naming.

The anterior five centimeters of the temporal lobe are amputated. At the end of the operation and during the first twenty-four hours thereafter she has no difficulty in spontaneous speech, naming, reading or obeying written commands. There is no weakness or abnormal reflexes and the visual fields are full to gross testing.

Thirty-nine hours after operation she is speechless and can only make a single sound "owl". How much she understands is difficult to say. She takes objects handed to her but does not show their use. She does not obey any written command and is unable to point to any object after reading its name. There is slight weakness of the right side of the face and the right hand. From the third to the eighth day after operation she has a number of minor seizures consisting of movements of the right face, smacking of the lips, turning of the head to the right, and sometimes movement of the right hand. Cerebrospinal fluid pressure by lumbar puncture on the fourth day is 245 mm. of C.S.F. and on the sixth and eleventh days, 180 mm. of C.S.F.

On the fourth day after operation she says nothing that is intelligible. She is unable to name any objects. She points to some objects when the name is said to her and she points to all objects after she reads the word on a card. She is unable to write with her right hand because of weakness; she writes her name with her left hand, but is not able to write the alphabet. She is able to obey some

simple oral commands. When shown pictures of an apple, fish, house, hat and cow and asked to indicate those good to eat, she picks out the apple and the fish.

Two weeks after operation she shows some improvement. She is able to say a few words and an occasional sentence, but uses many incorrect words. She is able to name only three objects of the entire group but she usually indicates the correct one when the name is repeated to her. She is able to repeat some words and sounds, but not others. She is able to read some words and letters aloud and most numbers. She executes half of the written commands correctly. She writes the names of the objects repeated or shown to her. She is unable to write a sentence to dictation or spontaneously.

Three weeks after operation she shows definite improvement. She has moderate difficulty in spontaneous speech and in naming objects shown to her. She is unable to name any object placed in either hand or to identify sounds by name. There is marked difficulty in executing oral commands and moderate difficulty in written commands, and reading aloud. She has only slight difficulty with oral and written calculations.

Twenty-five days after operation she has no abnormal neurological signs. In comparison with the test before operation she shows slight difficulty in spontaneous speech, naming, repeating, executing oral commands, reading aloud

and writing spontaneously. All other tests are the same as before operation. Two and a half months after surgery a letter shows a number of defects in spelling. She has continued to have occasional seizures.

CASE VI T.M. is a 24 year old right-handed man who is able to do a number of things with his left hand. Several members of his family were left-handed. His younger brother was left-handed and had definite difficulty in learning to read. He was then changed to right-handed and learned to read and write very well at a special school.

This man had left mastoiditis and an epidural abscess as a child. He graduated from the U.S. Military Academy at West Point. His seizures began at the age of 22 and he had to retire from the army because of them. His seizures began with an abdominal aura followed by definite difficulty in speech. Examination on admission shows no abnormal neurological findings. Testing shows slight difficulty in the silent reading and in spelling.

At operation there are cerebral adhesions and abnormal brain on the under surface of the temporal lobe overlying the petrous pyramid. During stimulation in the temporal region he had some difficulty in naming. About seven centimeters of the third temporal convolution beginning 2.5 centimeters posterior to the tip are excised as indicated by the solid line in this region in Figure 14. After the excision he has no difficulty in spontaneous speech or in

reading words and short sentences but he does have moderate difficulty in naming. For example, a drum is "something you beat on and noise comes out"; an apple is "something you eat", and a butterfly is "something that flies". Several hours later he makes some mistakes in spontaneous speech and has moderate difficulty in naming and reading aloud. He makes one mistake in writing several words to dictation and is unable to execute one of the written commands. There are no abnormal neurological signs. The next day he is practically speechless, though emotional speech, particularly swearing, is present. He is unable to name or read, or to obey oral or written commands.

On the fifth day after operation the condition is about the same with total inability to name, read, obey oral commands or select pictures of objects that are good to eat. At this time he shows slight weakness of the right face and hand but no other abnormal signs.

About two weeks after operation he has improved. He has marked difficulty in spontaneous speech. He is able to spell and write some things that he cannot say and vice versa. He has marked difficulty in naming and reading, though he is able to read letters and numbers better than words and sentences. He has marked difficulty obeying written commands. He seems to write a little better than he is able to name or to read. He draws a very good plan of the battle of Iwo Jima. At this time he has no abnormal neurological

signs.

One month after operation he has slight difficulty in spontaneous speech, naming, obeying oral commands, reading aloud and silently and writing spontaneously and to dictation.

Three months after operation testing shows no difference from that prior to surgery. Six months later he has one seizure beginning with inability to speak and name correctly.

CASE VII W.M. is an 18 year old left-handed boy who had a difficult birth and difficulty in feeding during the first few weeks of life. At the age of about four months weakness of the right arm and leg were noted. His seizures began with a sudden sensation and jerking of the right arm, and turning of the head to the right, at times; and at other times, they began with an inability to respond and turning of the head to the right. At the age of 12 an operation was carried out elsewhere with excision of the mid-part of the precentral and postcentral gyri on the left side.

On examination there is a right spastic hemiparesis, more marked in the upper extremity than in the face or leg. All types of sensation are decreased over the entire right side. The reflexes are abnormal in the right upper and lower extremities. There is no visual field defect. Spon-

taneous speech shows poor enunciation and pronunciation with slowness and stuttering. Testing shows moderate difficulty in oral and written commands, spelling and written calculations (silent reading and oral calculations were not given).

At operation there is a scar in the mid-central region extending down to involve the cortex of the lower precentral gyrus and anterior to it. The cortex is most abnormal just above the fissure of Sylvius. Stimulation of the two gyri anterior to the precentral face area does not interfere with speech. A large excision of the postcentral face area, precentral face and hand areas and of practically all the intermediate precentral region is carried out as shown by the dotted line in this region in Figure 16.

Repeated testing during the first week after operation shows no change in spontaneous speech. Complete testing thirteen days after operation shows no change from that before surgery except for improvement in ability to do written calculations.

CASE VIII E.L. is a six year old left-handed girl at the time of her first operation in 1949. At the age of 14 months she had learned to walk and to say a few words and her parents thought that she was right-handed. At the age of 14 months she had a rash and an elevated temperature and seizures

beginning on the left side of the body. Later she had seizures beginning on the right side of the body which were followed by hemiparesis on that side. At 18 months she learned to walk again and started to speak at 19 months. Her habitual seizures began shortly thereafter.

On examination there is slight weakness of the right side of the body including the face. The deep tendon reflexes are increased and there is a Babinski sign on the right. There does not seem to be any sensory or visual field disturbance. This child has her own vocabulary. She is not understood by anyone except her mother. She is quite active and willing to cooperate and after spending a number of hours with her it is possible to decipher her speech. Without going into detail the following examples may be given of the way she named pictures on three different occasions:

bird - picet peapea peapea
comb - combe comb comb
horse - hawe horhie hore
tree - quiquital kikitel deree
drum - baube dum dum
apple - aubelle abpel abpel
butterfly - bubeblie bee bee
table - babel tatal tatel
clock - galcke gadougga tont
scissors - ditder sercier sirser
glove - han gloe han hand

She is able to read some of the letters and numbers and she is able to write some of the alphabet, although some letters are made as in mirror writing and others are markedly distorted.

At operation there is widespread atrophy of the entire posterior half of the left hemisphere. Most of the left parietal lobe is removed. Following operation there is increased weakness and sensory disturbances on the right side of the body but there is no definite change in speech.

She has a wound infection after operation which is believed to be due to removal of the dressing and contamination of the wound the day of operation. The bone flap is removed.

She is readmitted about seventeen months later to investigate marked increase in weakness of the right side of the body. It seems as though she delighted in striking herself over the area of decompression and this injury produced, on several occasions, minor increase in her disability and finally a marked increase in weakness of the right side. Her speech at this time shows definite improvement. Although many words are mispronounced, the use of neologisms is no longer noted. She is able to read letters correctly practically all of the time. She makes only about six mistakes and she is able to write the alphabet with only

six letters made incorrectly. She writes some words correctly.

Three months later she comes in again and shows definite improvement in the weakness in the right side of the body and also in her speech. Pronunciation is definitely improved as well as her reading and writing. At this time the precentral gyrus and the gyrus anterior to it in its inferior part, as well as the entire parietal, temporal and occipital lobes are removed. There is no change in speech after this procedure.

CASE IX E.N. is a 16 year old right-handed boy who had a difficult forceps delivery with a scalp laceration. He had to be placed in the incubator for several days. It was noticed that the left side of his mouth drooped as a baby. His seizures began at the age of 11, with a hot feeling in his left leg and drawing up of his leg, and a hot feeling in the left side of his abdomen.

Neurological examinations show slight weakness of the left upper extremities with some loss of discriminative sensation. The patient has some difficulty in articulation with stammering, which he has noted since his seizures began at the age of 11 years. There is slight difficulty in the execution of oral commands and in oral and written calculation and moderate difficulty in the silent reading.

At operation there are a few adhesions with some atrophy which is most marked in the postcentral gyrus and the medial surface of the hemisphere. Electrical arrest causes slowing of counting, with complete arrest of speech on one occasion, in the supplementary motor area. The excision is outlined by dashes in the supplementary motor area in Figure 17. After the excision there is complete inability to move the left foot and no response to plantar stimulation. There is still some hesitancy in speech, but he names and reads without difficulty. Repeated testing during the first two weeks after operation shows no change in spontaneous speech, naming or reading.

Complete testing twenty days after operation shows that he has improved in silent reading but otherwise there is no change. On the fifth day after operation it is noted that there is weakness of the left upper extremity as well as the lower; which is still present though decreased at time of discharge. Three weeks after operation it is noted that the deep reflexes are increased over the left side, the plantar response is equivocal and there is no sensory or visual disturbance.

CASE X S.T. is a 24 year old man who as a small child used his left hand but was taught to write with his right at the age of six. He then began to use his right hand more for

other things. Following a series of seizures with weakness of the left hand at the age of 18, he stopped using his left hand for everything except cutting. He was vaccinated at the age of 5, and twelve days later fell, but was not unconscious. Twenty-four hours later he had a series of seizures. At the age of 7 the right hemisphere was explored in another hospital and no removal made. However, he was free of seizures for one year following the operation and again for a two year period after chickenpox at the age of 12. His seizures began with a sensation in the left arm, followed by paralysis of the left arm, palpatation of his heart and raising of the left arm above his head with turning to the left.

Examination shows weakness, ataxia and adiadokokinesis of the left arm. Tremor and choreoform movements of the left wrist, hand and fingers are noted. The left hand is smaller than the right. All abdominal reflexes are absent as is the left cremasteric reflex.

Spontaneous speech is a little slow and stuttering is very pronounced, and he has increased slowness and stuttering after a seizure. There is moderate difficulty in silent reading and in written calculations and slight difficulty in oral calculations.

At operation the two gyri posterior to the middle part of the postcentral gyrus are slightly wider than normal, tough and abnormal. Stimulation of parietal and Broca's region causes no difficulty in naming. The middle parietal region is excised as shown by the dash outline in Figure 17.

Repeated testing during the first week after operation shows no difficulty in naming or reading. Spontaneous speech is approximately the same. There is increased weakness of the left arm. Complete testing two weeks after operation shows slight difficulty in executing oral commands but improvement in silent reading and written calculations. Strength and coordination in the left arm are better than before operation and there is no tremor. There is decreased sensation to touch and pin prick and two point discrimination over the third, fourth and fifth digits, and the palm of the left hand. There is no difficulty in identifying objects with the left hand.

CASE XI D.Y. is a 16 year old left-handed girl whose mother and maternal great aunt are also left-handed. She had a difficult birth but nursed well following delivery. Her seizures began at the age of 9 and were characterized by a sensation in the throat with nausea, vertigo, and a sensation in the head, and then swallowing, smacking and

automatic movements. During the period of automatism she makes irrelevant remarks; and after the automatic stage she is confused for a short period.

Neurological examination shows no abnormalities. There is slight difficulty in silent reading and oral and written calculation.

At operation there is an excrescence of bone over the floor of the middle fossa and the brain above this is yellow, tough and abnormal, particularly in the hippocampal gyrus. Stimulation of Broca's parietal and temporal region causes no interruption in naming. The tip of the temporal lobe is amputated six centimeters along the first temporal convolution and seven and a half centimeters along the third temporal convolution, as indicated by the dash cross outline in Figure 17. Immediately after the excision and during the first day after operation she has no difficulty in spontaneous speech, naming or reading and there is no weakness.

On the second day after operation she develops a marked left hemiparesis. There is no movement of the hand and only slight movement at the elbow and slight movement of the toes and more of the knee and hip. At this time she is drowsy, and her speech is slightly slurred but otherwise not abnormal. She is able to name without difficulty. By lumbar puncture the cerebrospinal fluid pressure is 275 mm.

of C.S.F. on the first day after operation and 400 mm. of C.S.F. the second day. An extradural hemorrhage is evacuated on the second day after operation. During the next two days she is drowsy and not very cooperative. There is some slurring of speech but it is otherwise not abnormal. She is able to name, repeat, read and obey oral commands.

A week after operation she has no difficulty in spontaneous speech, naming or reading. There is only slight weakness of the left hand and inability to carry out fine movements. The abdominal reflexes are absent and Babinski sign is present on the left. Complete testing three weeks after operation shows that she has not changed since before operation except for no difficulty in the silent reading and moderate difficulty in obeying oral commands. There are no abnormal neurological findings except for a left homonymous hemianopsia which was first noted on the second day after operation.

CASE XII J.T. is a 17 year old boy at the time of his first admission. He has always used both hands since a child. He writes with his right hand and uses a knife, spoon, tennis racket, and axe and throws a hard ball with it. He lifts heavy objects, throws a shot and discus and a soft ball and uses a fork with his left hand. One cousin is left-handed but no other members of his family are known

to be left-handed. He had a difficult birth; paralysis of his left arm and left side of the face were noted two days after birth. Seizures began at the age of ten years. His attacks began with a sensation in his chest, pounding of his heart and a sound in his throat with salivation.

Examination shows slight weakness of the right hand and leg. Electroencephalogram shows 4 to 6 per second sharp waves in the right temporal region transmitted to the left. Pneumoencephalogram shows moderate generalized ventricular enlargement, more marked in portion three on the left. Plain x-rays of the skull show smallness of the left hemicranium. There is slight hesitancy in speaking, slight difficulty in oral calculations and moderate difficulty in silent reading.

At operation there are scattered adhesions and atrophy, most marked in the posterior part of the right third frontal convolution. The central face area and posterior part of the third frontal convolution and part of the first temporal gyrus are removed.

During the first week after operation he shows no change in spontaneous speech, naming, repeating, reading or writing. Testing on the eighth day shows no change to that before operation. There is weakness of the left face.

His seizures continue and he is readmitted sixteen months later. Testing at this time shows slight difficulty in oral and written commands, spelling, silent reading, and oral calculation and moderate difficulty in written calculations. At the second operation most of the parietal lobe and the posterior part of the temporal are removed as shown by the triangles in Figure 17. Immediately after operation there is no change in spontaneous speech, naming or reading. The next day spontaneous speech, naming and reading and writing are the same but he has moderate difficulty obeying written commands. There is some weakness of the left face and hand. Six days after operation there is no difficulty in naming, reading or writing and he has only slight difficulty with written commands.

Twenty-six days after operation complete testing shows no change to that before the second procedure. There is still slight weakness of the left hand and left side of the face and decreased sensation to touch and joint movement, as well as lack of recognition of stimuli in the left visual field when stimuli in the right visual field are given simultaneously.

CASE XIII R.W. is a 12 year old right-handed boy who has had seizures for four years. His birth was difficult and there were forceps marks. The pattern of his attacks is colored triangles, then a visual hallucination of a robber

coming after him with a gun, followed by automatism and confused speech. He has no difficulty in speech after the seizure. Examination shows no abnormal neurological signs. There is slight difficulty executing written commands, spelling, reading aloud, spontaneous writing, oral and written calculations and moderate difficulty in silent reading.

At operation the under surface of the right occipital lobe is yellow and abnormal. Visual hallucinations are produced by stimulation in the occipital region and auditory hallucinations in the temporal region. The entire occipital lobe and posterior part of the temporo-parietal region are removed as indicated by the dash triangle in Figure 17.

Immediately after operation and during the first day there is no difficulty in spontaneous speech, naming or reading. Examination the day after operation shows a complete left homonymous hemianopsia, slight weakness of the left hand and face and some alterations in sensation in the left hand. The day after operation there is no difficulty in spontaneous speech, naming, repeating or writing to dictation, but there is slight difficulty in executing written commands and when he reads he completely ignores the first one to three words on the left. Complete testing seventeen days after surgery shows the following changes as compared with before operation: he has no difficulty with

written commands, slight difficulty with oral commands and moderate difficulty with both oral and written calculations. There is also a definite disturbance in his ability to copy designs with matches, which he could do before operation. He also has difficulty in drawing a floor plan. The electroencephalogram shows two per second sharp and delta waves in the right temporal region.

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