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PATHOPHYSIOLOGICAL MECHANISMS OF SPEECH ON THE BASIS OF STUDIES ON APHASIA

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I. INTRODUCTORY REMARKS

In a recent book *Integrative activity of the brain* (Konorski 1967, Chapter III and V) the author described the most important gnostic fields in the cerebral cortex of various analysers in man and their interconnections. This has been made on the basis of everyday introspective observation and experimental psychological evidence on the one hand, and on neuropathological data, on the other. Accordingly, in that book the clinical material was scattered among other observations, since it served only as pieces of evidence proving the existence of the given gnostic fields and their interconnections. Therefore, it seemed reasonable to extract this clinical material from the other data in order to present a consistent pathophysiological classification of various forms of disorders of speech. This task is undertaken in the present paper.

According to our ideas of the functional organization of the cerebral cortex, we should discriminate between disorders of speech caused by injuries sustained to particular gnostic fields clustered around projective areas of each analyser, and disorders caused by injuries affecting connections between them. One can argue that, although theoretically acceptable, these two forms of disorders are in practice inseparable. This is, however, not true. It should be realized that gnostic fields of various analysers are localized in various parts of the cerebral cortex and therefore they are interconnected by long pathways or fasciculi; these fasciculi are much more vulnerable than cortical areas because in relation to the latter they form a sort of narrow funnels. As a result,

any lesion involving a small cortical area and penetrating into the white matter is much more likely to produce serious damage to the connections between cortical areas, than to the areas themselves. This is in good agreement with the usual neurosurgical practice in animals showing that when a cortical lesion affects the white matter beneath the cortex, the disorders of functions are much more severe.

This being so, we can discern two forms of syndromes concerning gnostic systems of the brain: one — henceforth denoted as *agnosias* — is that affecting mostly the gnostic fields, the other one — henceforth denoted after Geschwind (1965) as *disconnections* — affects mostly the pathways linking these fields. It may be observed that whereas agnosias always are accompanied by disconnections, the reverse is not necessarily true: since neurons of a particular gnostic area send, as a rule, their axons to *a number* of other gnostic areas, these neurons are not likely to undergo retrograde degeneration, when only one of the fasciculi they give rise to is injured. This does not mean, however, that "pure" injuries of pathways produce lesser disorders of functions than "pure" cortical lesions, because whereas the neurons of a gnostic field are spread over some more or less extended zone, their axons directed to another gnostic field are massed within a narrow tract. To end this speculation let us add that gnostic areas, in contradistinction to projective areas, have a categorial and not topographic arrangement — they are composed of fields which represent particular *categories* of perceptions, each of these fields being to a great extent equipotential; this is because, as assumed elsewhere (Konorski 1967, Chapter II), the gnostic units representing particular stimulus-objects are multiple, being scattered over the whole gnostic field (the principle of redundancy).

In our present survey we shall, first, discuss the effects of lesions affecting particular gnostic fields involved in speech and then turn to the effects of lesions affecting their interconnections, as well as those connections which link the gnostic fields involved in speech, with those representing other categories of perceptions.

II. AGNOSIAS DIRECTLY CONNECTED WITH SPEECH

1. Wordauditory agnosia

Almost the first sound the baby hears after birth is human speech. The words heard are repeated again and again, the baby pays attention to them, and, as the result, in its wordauditory gnostic field (denoted

in our diagram in Fig. 1 as A-W) gnostic units are formed representing particular words. In the time they are formed no connections with units of other gnostic fields are necessary, the child simply recognizes particular words as known sounds. Only gradually are these units overgrown with connections linking them with visual gnostic units representing objects, owing to which the child begins to *understand* words, and with wordkinesthetic units, owing to which words can be repeated.

When the wordauditory gnostic field (localized in the second temporal gyrus of the dominant hemisphere) is injured, the words heard cannot be recognized, whereas other sounds are recognized without difficulty — a proof that the deficit is not caused by the injury of auditory receptors or pathways. The following symptoms are characteristic for this disorder: The discrimination of two similar words is impossible; repeating of words is impaired — the patient often utters a word sounding similarly; the words repeated are distorted (paraphasias) and the patient is unable to notice his errors and to correct himself. When the injury is moderate the patient recognizes the words spoken slowly, but fails to do so when speech is fast. Reading is normal or nearly so, but when writing under dictation, the patient commits analogous errors to those when he repeats the words heard.

All these symptoms are fully intelligible: the impairment of discrimination of phonemes and the lack of the tendency to correct the paraphasic errors are due to the lack of auditory feedback and may be considered primary symptoms. Other symptoms like impairment of repetition or understanding of the words heard, as well as of writing under dictation, are secondary — they are due to the destruction of connections leading from the wordauditory gnostic field to other gnostic fields (see following chapters). Reading is possible because it does not involve the wordauditory gnostic field (see Chapter VI). Good illustrations of clinical cases of wordauditory agnosias are presented in a paper of Stolyarova-Kabelyanskaya (1961).

2. *Wordkinesthetic agnosia (Broca aphasia)*

Normal human speech is based on cooperation of two separate gnostic fields — the wordkinesthetic field localized in the frontal operculum of the dominant hemisphere (field 45, K-W in Fig. 1) and oral somesthetic gnostic field localized in the parietal operculum of this hemisphere (field 40, S-Or in Fig. 1). Although for proper expressive speech both these fields are necessary, the main significance should be

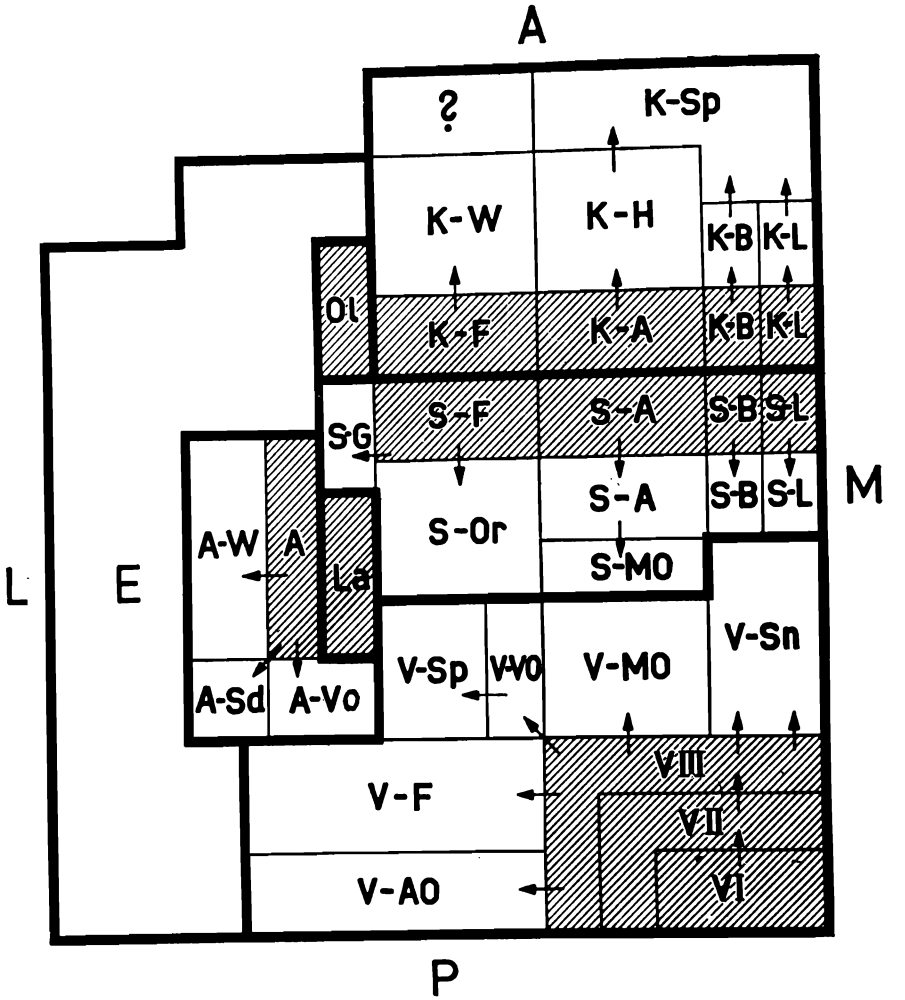
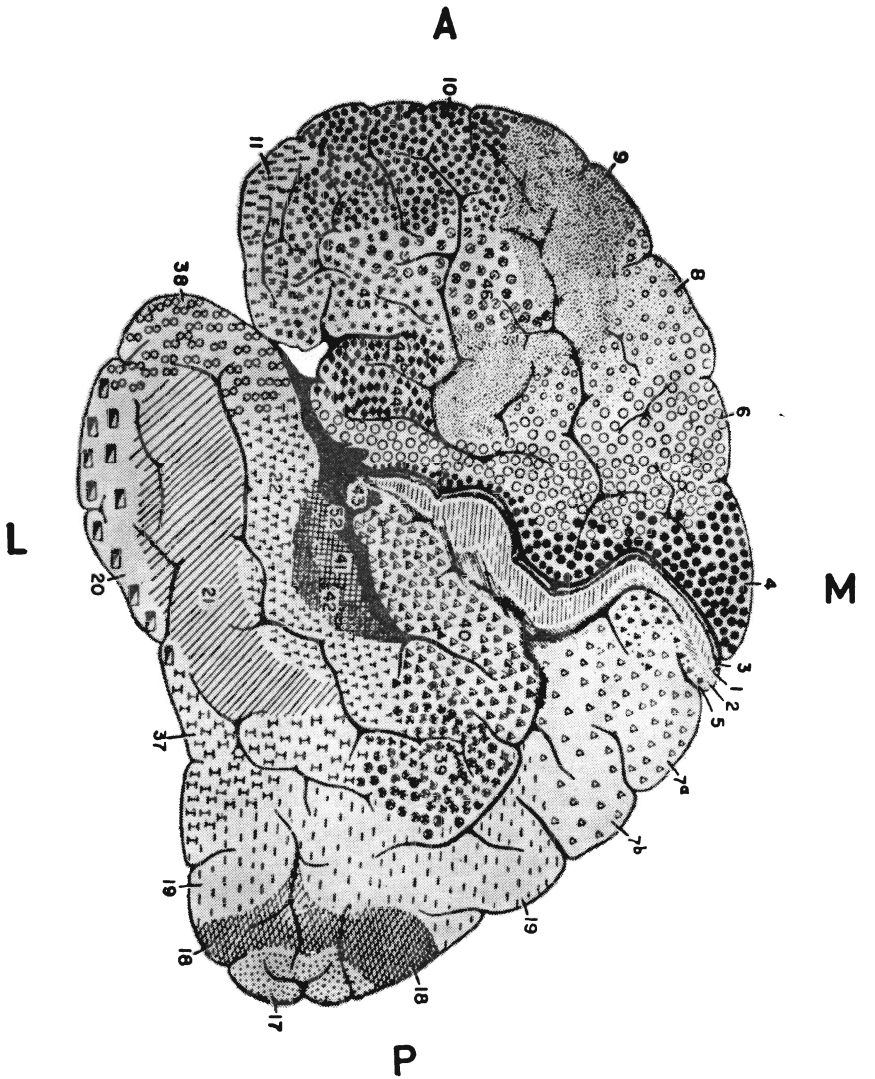


Fig. 1. Conceptual map of the human cerebral cortex of left hemisphere (left) and the cytoarchitectonic map of that hemisphere according to Brodmann (right). Symbols: A, P, L, M, outside the figure denote the anterior, posterior, lateral (and latero-basal) and medial sides of the cortex. Projective transit fields are hatched; gnostic (exit) fields are plain. The boundaries of particular analyzers are drawn by thick lines; the boundaries of particular fields by thin lines. Arrows denote connections between transit and gnostic fields. The projective and gnostic fields of the conceptual chart are tentatively related to the cytoarchitectonic fields of the Brodmann chart. *Visual analyzer* (V): VI, VII, VIII, transit visual fields (areas 17, 18, 19 respectively); V-Sn, signvisual field (area 7b); V-MO, visual field for small manipulable objects (7b); V-VO, visual field for large purely visual objects (39); V-Sp, visual field for spatial relations (39, right hemisphere); V-F, visual field for faces (37); V-AO, visual field for animated objects (37). *Auditory analyzer* (A): A, projective auditory field (41, 42); A-W, audioverbal field (22); A-Sd, auditory field for various sounds (22, right hemisphere); A-Vo, auditory field for human voices (21). *Somesthetic analyzer* (S): S-F, S-A, S-B, S-L, projective somesthetic



fields for face, arm, body and leg, respectively (3, 1, 2); S-Or, oralsomesthetic field (40); S-A, S-B, S-L, gnostic somesthetic fields for arm, body and leg, respectively (5, 7a); S-MO, somesthetic field for small manipulable objects (7a); S-G, gustatory field (43). *Kinesthetic analyzer* (K): K-F, K-A, K-B, K-L, projective kinesthetic fields for face, arm, body and leg, respectively (4); K-W, wordkinesthetic field (44, 45); K-H, handkinesthetic field (6); K-B, K-L, gnostic kinesthetic fields for body and leg, respectively (6); K-Sp, kinesthetic field for spatial relations (9, right hemisphere); La, vestibular analyzer (not known); Ol, olfactory analyzer (not seen on Brodmann's map); E, emotional analyzer (not seen on Brodmann's map). Note that for the sake of simplicity *all* the gnostic fields have been put in the left hemisphere, although in reality some of them are situated in the right hemisphere. Note also that our conceptual brain map is unfolded so as to show the latero-basal aspect of the cortex (not seen in Brodmann's map). The medial part of the emotive brain is not shown.

ascribed to the wordkinesthetic field, because speech belongs to those types of skilled movements in which the muscular proprioception plays a much more important role than articular proprioception (cf. Konorski 1967, Chapters III and V). In fact, many phonomes are pronounced only by moving the tongue and the lips without changing the position of the mouth. Therefore, when a baby begins to babble and then speak, the kinesthetic units for speech are established, their presence being indispensable, although not quite sufficient for correct speech.

The great majority of word-kinesthetic units, similarly to the word-auditory units, represent *words* or short phrases, because these are the single stimulus-patterns (kinesthetic or auditory) whose innumerable combinations take part both in expressive and heard speech. In children, *before* they learn to read and write, as well as in illiterate persons and in nations having picture writing, decomposition of words into letters does not exist, and therefore letters are not represented in their wordkinesthetic gnostic field. The corresponding units are formed only later, when the subject learns to read.

The injury of the wordkinesthetic gnostic field leads to a classic syndrome generally denoted as "motor aphasia" or "Broca aphasia". Its correct name should be "wordkinesthetic agnosia". The main characteristic of this syndrome is the disability to pronounce words, equally in spontaneous speech as in repetition and reading, whereas understanding of speech is fully preserved. This feature indicates that the final common link of speech is impaired.

If the motor aphasia is not total, the patient is able to pronounce particular words and phrases; if Broca aphasia is not accompanied by anarthria, the pronunciation of words the patient is able to utter is correct, because of partial survival of units representing these words. Most often a patient makes use of this modest vocabulary as a unique form of verbal expression, realizing that the words he utters are completely inadequate. The intonation of speech is preserved, since it depends on a different gnostic field, perhaps localized in the minor hemipshere. Singing without words is also preserved.

The selectivity of the words preserved in the Broca aphasia follows the redundancy principle according to which words earlier acquired, more often used and/or emotionally tinted are more likely to survive than words which are rarely used or lately acquired (for instance words of a foreign language), because they are represented by more numerous gnostic units. On the other hand, the difficulty of pronunciation of a word is not essential for whether it is preserved or not. Thus, a patient may be able to pronounce a "difficult" word and fail to pronounce an easy phoneme.

The gradual recession of the Broca aphasia with the lapse of time is due to the fact that immediately after the trauma many units are temporarily inactivated and then gradually recover. In the state of partial aphasia the speech is possible and makes sense, although it is very poor. For reasons which will be explained later it consists mainly of nouns.

The wordkinesthetic units control not only externalized speech, either loud or whispered, but also internal speech, or verbal thinking; this thinking is impaired or abolished exactly to the same extend as external speech, because the wordkinesthetic units are concerned with programming of speech rather than with its execution. Of course, we cannot learn directly from the patient that he is unable to think in words, because he cannot tell us about it; we can, however, recur to the indirect method to prove this: it may be shown that a patient suffering from the Broca aphasia is unable to write the words he cannot pronounce, since writing is mediated by internal speech (see Chapter VI); thus the deficiency of writing (when copying is preserved) is the evidence of the deficiency of internal speech.

3. Oralsomesthetic agnosia

The oralsomesthetic gnostic field (S-Or) localized caudally to the projective somatosensory area for face and mouth has quite different functional properties. Since the units of this field represent positions of the oral cavity assumed during the pronunciation of certain phonems, the injuries sustained in that field produce disorders in assuming these positions. Hence typical errors encountered in this form of agnosia, described by Maruszewski and Mierzejewska (1964), are present both in spontaneous speech and in repeating the words heard. Since, as we said before, in writing a subject must verbalize the words he is to write, a patient with oralsomesthetic agnosia commits the same errors as in speaking. Reading is generally better preserved than speaking; this may be explained by the assumption that this function occurs through the connections of signvisual units (V-Sn) with wordkinesthetic units without the intervention of oralsomesthetic units. Well established automatized verbal sequences are also preserved, which shows that in this function, too, the wordkinesthetic units are activated independently of the oralsomesthetic units.

The main difference between the expressive speech in patients suffering from wordauditory and oralsomesthetic agnosia is that whereas in the former the subjects do not notice their errors in pronunciation, because of the lack of auditory feedback, in the latter they try to correct themselves repeating the same word many times in succession; for instance, when a patient is required to say "talerzyk" (plate), he says:

"ta... tasz... tateczek... tarek... taleczek... tarelik". Because of this difficulty to find the proper sound of the word, some patients are so frustrated that they refuse to speak altogether. Understanding of the words heard is, of course, very well preserved.

4. Signvisual agnosia

Among gnostic fields of the visual analyser, the signvisual field (V-Sn in Fig. 1) representing letters of the alphabet and numbers is directly related to speech. The injury sustained in this field gives rise to *alexic agnosia*, or primary alexia; a subject suffering from it is unable to discriminate letters and numbers, while being able to discriminate without difficulty other visual patterns, such as manipulable objects, human faces, animals, etc. The primary alexia should be distinguished from secondary alexia, in which the subject is able to discriminate signs he knows, but cannot name them because of the injury of corresponding connections (cf. Chapter VI). In order to know which form of alexia we are confronted with, we ask the patient to copy a text seen. This function is severely impaired in primary alexia but is preserved in secondary alexia.

Very instructive are those cases of alexic agnosia in which the signvisual field is only partially destroyed (Alajouanine et al. 1960). The patient is then capable of recognizing the majority of letters, but he has difficulties in recognizing letters rarely used and in discriminating similar letters. Moreover, although recognition of single letters is fairly good, he is strongly incapacitated in reading words and phrases, because he must recur to spelling each letter separately, in order to integrate them into a whole word. This type of deficit may be explained by assuming that short words are represented in the signvisual gnostic field by single units which, however, according to the principle of redundancy, are much less numerous than those representing letters and therefore are more vulnerable.

The thesis that not only letters but also common words are represented by single units is documented by the following interesting fact (Konorski 1967, Chapter III): a patient suffering from a severe spatiovisual agnosia was able to read fluently known words, but failed completely to do so when the word was unknown (for instance a neologism) even though the rules for Polish pronunciation are strictly regular; he was also unable to spell the known words because this operation required decomposition of words in space order.

While in alexic agnosia reading is impaired, writing remains quite normal because it is based exclusively on graphic praxia, depending on

the integrity of the handkinesthetic gnostic field. When, however, the alexic patient is asked to read the words he just wrote, he is unable to do so, thus clearly showing that reading and writing depend on quite different gnostic fields.

III. SENSORY APHASIA
(IMPAIRMENT OF COMPREHENSION OF WORDS HEARD)

After considering the effects of lesions in particular gnostic fields engaged in speech, we now turn to the discussion of the effects of injuries sustained to particular cortico-cortical connections. We shall begin by discussing transections of those connections whose integrity is responsible for understanding of speech heard. These connections run from the wordauditory gnostic field to the gnostic fields representing stimulus-patterns of various analysers. These are schematically represented in Fig. 2.

In humans the main source of information about the external world comes by vision. Accordingly, understanding of words representing the

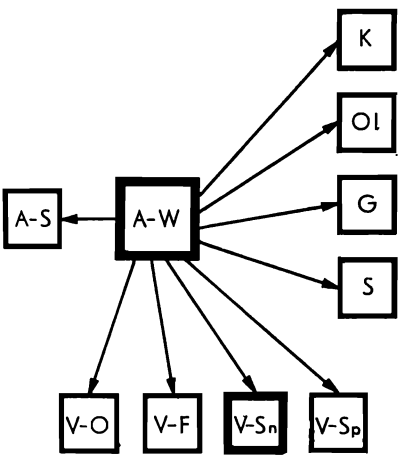


Fig. 2. Diagram of cortical connections involved in comprehension of speech. A-W, wordauditory field; V-O, V-F, V-Sn, V-Sp, visual gnostic fields representing visual objects, human faces, letters and words, and spatial relations respectively, S, somatic gnostic area; G, gustatory gnostic area; Ol, olfactory gnostic area; K, kinesthetic gnostic area, representing various movements of the body; A-S, auditory gnostic area representing sounds of the environment. It is assumed that each gnostic area receives connections from wordauditory field directly and not via the visual gnostic area. In this and in other diagrams squares with thick lines denote gnostic fields directly involved in speech. Arrows denote the direction of connections.

names of objects and events perceived by vision is based on the connections running from the wordauditory gnostic field to various gnostic fields of the visual analyser, namely connections running to object-visual fields (V-MO, V-VO, V-AO) responsible for understanding the names of inanimate and animate objects, connections running to facevisual fields (V-F) responsible for correlations between the names of our acquaintances and their faces, connections running to spacevisual fields (V-Sp), responsible for understanding such names as "near-far", "below-above", "in front-behind" etc., and finally connections running to the signvisual field (V-Sn), responsible for correlations between the sounds of the phonems and words and their graphic signs. The integrity of these connections is examined by the method of auditory-gestural responses in which a subject is asked to point to objects or pictures named by the examiner.

The interruption or injury of pathways leading from the word-auditory field to the above mentioned gnostic visual fields, that is the pathways running under the infero-posterior part of the temporal lobe, is called by us *auditory-visual aphasia*. Theoretically, we may assume that these pathways are not necessarily damaged to the same extent, and in consequence understanding of names of various categories of objects may be impaired in various degrees. Unfortunately, to my knowledge, the function of understanding was not examined in relation to the categories of tested objects.

The connections between wordauditory and visual gnostic units are not the only connections responsible for comprehension of the words heard. There are sounds, tastes, and smells which also have their names, such as "barking", "bitter", or "smell of scent", respectively. We do not know whether understanding of these names is based on direct connections between wordauditory units and units representing perceptions of these modalities, or whether understanding these names is mediated by visual images. The fact that blind people are able to understand names of objects recognized by sounds, tastes and smells speaks in favor of the first assumption.

Special attention should be paid to the comprehension of names of somesthetic perceptions concerning the "feeling" of particular parts of the body and textures. Their comprehension may be easily tested in a routine examination by asking a patient with closed eyes to point to various parts of his body named by the examiner, or to various textures (such as rough vs. smooth, or hard vs. soft).

Examination often shows that comprehension of names of parts of the body (or perhaps textures) and comprehension of visual objects may be impaired in various degrees. Accordingly, we can distinguish a special

form of sensory aphasia which may be called *auditory-somesthetic aphasia*. It may be assumed that there also exists auditory-kinesthetic aphasia, in which a patient fails to understand the names of particular motor actions.

Let us now consider other symptoms characteristic of sensory aphasia, and examine for this purpose its best known form, namely auditory-visual aphasia.

Repetition of words heard is fully preserved. We often observe that a patient when hearing a name of an object repeats it several times to "recall" what this name can denote. If a patient manifests, not only impairment of comprehension, but also of repetition of the word heard, then we should diagnose that he suffers from wordauditory agnosia (if impairment of hearing is excluded), because it is improbable that the wordauditory gnostic field is preserved and the connections running from it rostrally and caudally (to the wordkinesthetic field and to visual gnostic area) are injured. The test of discrimination of similar phonemes should prove this diagnosis, because it is impaired in the wordauditory agnosia, but not in auditory-visual aphasia.

Patients suffering from sensory aphasia are able to read well, since the function of reading aloud or in whisper is based on direct pathways linking the gnostic signvisual field with the wordkinesthetic field. But these patients fail to point properly to letters or short series of letters, when we pronounce them. Writing both under dictation and by copying is also normal.

Narrative speech is fluent and without paraphasias. We notice, however, the predominance of adjectives and verbs over nouns. If we examine the function of naming by showing to a patient objects or pictures and asking him to name them, he appears to be amazingly incapable of performing this test, in clear disproportion to the ease of his narrative speech. This discrepancy may be explained in the following way. As will be stated later, naming of visual objects occurs in most persons through the mediation of the wordauditory gnostic field. Since in sensory aphasia the connections running from the word-auditory field to the visual gnostic fields are injured, we have every reason to believe that the connections leading in the opposite direction are also injured, since they probably run in the same fascicle. Accordingly, naming of visual objects is impaired. However, since the fluency of speech mainly depends on interconnections between the wordauditory field and the wordkinesthetic field (see below) and these connections are intact, it follows that speech as such is preserved.

IV. AUDITORY-VERBAL APHASIA (IMPAIRMENT OF REPETITION OF WORDS HEARD)

In the course of development of speech we observe in children a strong tendency to echolalia, consisting in repeating the words heard, irrespectively of whether a child does or does not understand them. This tendency, very prominent in the early phase of development of speech, gradually becomes inhibited, but the ability to repeat words or phrases is fully preserved and is displayed when a person tries to keep them in memory.

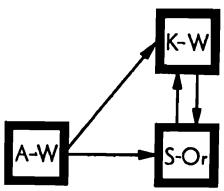


Fig. 3. Diagram of cortical connections involved in repetition of words. A-W, wordauditory field; K-W, wordkinesthetic field; S-Or, oral somesthetic field. It is assumed that wordauditory field is directly connected not only with wordkinesthetic field but also with oralsomesthetic field, although the evidence of the latter connections is lacking. Note bilateral connections between wordkinesthetic and oralsomesthetic fields.

The ability of humans to reproduce verbal sounds, that is to display auditory-verbal responses, shows that the human brain is equipped with a pathway linking the two fields involved (Fig. 3). We have assumed (Konorski 1961) that the arcuate fascicle running from the posterior part of the temporal lobe to the frontal operculum plays this role. In fact, lesions localized in the border of the temporal lobe and the parietal lobe just behind the sylvian fissure produce, sometimes selectively, disorders of repetition of words heard (Koźniewska 1961). Such disorders have been denoted as "conductive" or "central" aphasia. Since these names are inappropriate (all aphasias are both "central" and "conductive") we have proposed the term "*auditory-verbal aphasia*".

The syndrome characteristic for auditory-verbal aphasia has been frequently described (cf. Stengel and Patch 1955, Koźniewska 1961). Here we present its main features.

Depending on the degree of the impairment of the auditory-verbal responses the patient is either completely incapable of repeating the words heard, or the repeated words are distorted. Since his wordauditory gnosis is preserved, he is aware of his mistakes and tries to correct them. Very often the patient recurs to such a trick that, hearing the name of

an object and understanding it, he looks at the object (or visualizes it) and then pronounces its name correctly. This trick is particularly useful when a patient is asked to repeat a short phrase. Whereas most people repeat the phrase echolallically, without even entering into its meaning, the patient pronounces its topic changing the words or their order. Therefore, the deficit of repetition is most obvious when we request the patient to repeat nonsensical words — he is then completely incapable of doing so.

Another interesting test is this. Suppose that a patient uttered correctly a given sentence by himself. After a while we utter the same sentence and require the patient to repeat it. It appears that he is completely unable to do this, because now he has to utter the sentence on the basis of the auditory-verbal connections.

Comprehension of words heard is completely preserved in these patients. We note, however, that their memory span is much lowered. When the patient is confronted with a number of objects and the examiner names two or three asking him to point to them, he usually points only to one and says: "the other ones I forgot". The same is true when we ask him to perform two tasks in succession. He performs only one order and says that he has forgotten the other one. The reason for this defect is that when we have to perform two orders requested in advance, we repeat them in our internal speech and preserve them in our wordkinesthetic short-term memory, being able to perform them seriatim. Since the patient is unable to repeat the order, he obviously cannot remember it. We saw a patient who being aware of his defect managed to look quickly at the object whose name he had just heard and in this way he was able to point to several objects named in advance; instead of utilizing his wordkinesthetic short-term memory he preserved the objects named in his visual memory.

As far as spontaneous speech is concerned, it is impaired in various degrees. In some cases it is almost normal — the patient is able to express his thoughts, although he lacks some of the words and makes agrammatic and/or paraphatic errors. In other cases we observe a jargon speech to such a degree that verbal contact with the patient is impossible. Naming objects and pictures seen is also impaired in various degrees. It is important to note that when a patient is unable to utter a given name he cannot be helped to do so by hearing the beginning of the word, since he cannot repeat what he has heard. In contradistinction to this, he easily names letters seen, and reading does not present any difficulty to him. This is because, as was said before, reading is based on direct pathways leading from the signvisual field to the wordkinesthetic field.

Automatized verbal sequences, such as counting from one to ten, saying prayers, enumerating the days of the week or the months in the year are impaired in various degrees. The strongly consolidated sequence, such as counting from one to ten, is preserved completely, whereas other ones are impaired or abolished. This certainly depends on the mechanism of memorizing a given sequence. If it is memorized by connections being formed *within* the wordkinesthetic gnostic field, then the automatized sequence is preserved. If, however, the sequence is based on the wordkinesthetic-wordauditory interplay, in which hearing one word pronounced leads to uttering the next word of the sequence, then, of course, the injury of the connections between the two fields involved is detrimental for recitation of such a sequence.

As far as writing under dictation is concerned, it is impaired to exactly the same extent as repetition; this is because, as will be shown in Chapter VI, writing requires verbalization of words to be written.

V. AMNESTIC APHASIA (IMPAIRMENT OF NAMING OBJECTS)

The third basic component of speech, besides comprehension and repetition, is naming. We should realize that this function is the basis of our expressive and internal speech, in fact all our normal speech (except automatized verbal sequences) is "permeated" with names of objects and events. Names are of course embedded in automatized phrases and idioms and in short automatized verbal sequences which form a framework of normal speech making it fluent and correct. This side of speech, however, depends mainly on the wordkinesthetic field and/or its interplay with the wordauditory field. In fact, subjects suffering from wordkinesthetic agnosia (Broca aphasia) have precisely this aspect of speech mainly impaired. On the contrary, people with severe lesions in the "posterior speech area" may have speech formally completely preserved, but it makes no sense whatsoever, because it is deprived of the function of naming. The same concerns verbigerations ("wordsalad") of some schizophrenic patients. Depending on the context, the names denoting events and objects perceived by different afferent systems are predominantly used. For instance, when describing the events we have directly witnessed, we make use mainly of visual images, fixed in our visual-gnostic fields — consequently our speech is based on the visual-wordkinesthetic connections. When describing our own behaviour ("I did this or that", "I went", "I said" etc.) we make use mainly of the images of our motor acts and postures — consequently our speech is based on connections linking the kinesthetic gnostic fields

representing our actions with the wordkinesthetic fields. Finally, when we speak on abstract subjects we use concepts which perhaps derive from both these analyzers.

If we examine the ability of naming by showing a patient objects, pictures, etc., we introduce an artificial condition, since we detach names from a narrative context in which they are normally enveloped. Nevertheless, such examination is valuable, because in this way we are able to analyse separately particular kinds of connections involved in naming and determine the degree of their impairment.

First we should refer to connections directed to the wordkinesthetic field from the gnostic fields of the visual analyser. These connections constitute a substrate for naming of the visual objects (alive and inanimate) of our surroundings, of the visual features of these objects (colors and forms), of spatial relations, and letters of the alphabet. The tests by which the integrity of these connections is examined we call visual-verbal responses, and the impairment of these connections, whatever their course, is termed *visual-verbal aphasia.*

There are, however, objects or events which are detected by receptors of other modalities, namely by acoustic receptors, olfactory receptors, gustatory receptors, somesthetic receptors and kinesthetic receptors. Accordingly, we should deal with various forms of amnestic aphasias depending on which pathways are affected. This problem was, however, not studied in detail.

In this connection we would like to draw attention to an important, although so far neglected category of naming concerning that of *motor actions*. Here belong almost all verbs and verbal nouns. A good illustration of the existence of connections linking the kinesthetic gnostic fields representing motor acts and the wordkinesthetic gnostic field, is a common fact that when we name a given motor act, we perform it, at least in a rudimentary form.

In patients suffering from amnestic aphasia due to the injury sustained to the "posterior speech area" naming of motor actions is much better preserved than naming of objects (Konorski 1967, Chapter V). These patients instead of saying — pen, will say "this is for writing", instead of — fork, "this is for eating", instead of shovel, "this is for digging" etc. Perhaps this phenomenon is even better manifested in Polish than in English, because in Polish nouns denoting objects are as a rule quite different from the verbs denoting their usage (cf. "grzebień" and "czesanie" in Polish, but "comb" n. and "comb" v.t. in English).

In special tests performed on amnestic patients we could ascertain that a subject who could not name even a single visual object, very easily named his own and also the examiner's actions saying "now you

sit down", "now you get up", "now you run", "now you raise one hand". These findings are in good agreement with the fact that speech of patients suffering from amnestic aphasia due to injuries of the "posterior speech area" is composed of verbs but is very poor in nouns. On the contrary, patients suffering from injuries in the "anterior speech area" have a "telegraphic" style using only separate nouns. This last deficit may be explained either by assuming that a patient suffering from the Broca aphasia has lost the gnosis of "structure of sentence" which probably depends on the wordkinesthetic field, or else that the injury affects connections responsible for naming motor actions, connections which may be very easily entangled in lesions of the frontal area.

We now proceed to a discussion of an important but controversial problem concerning the course of the pathways responsible for naming

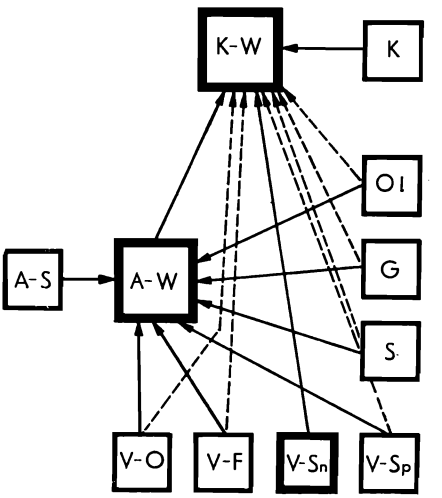


Fig. 4. Diagram of connections involved in naming. K-W, wordkinesthetic field; A-W, wordauditory field; V-O, V-F, V-Sn, V-Sp, visual gnostic fields as indicated in Fig. 2; S, G, Ol, K, A-S, somesthetic, gustatory, olfactory, kinesthetic and sound-auditory gnostic areas respectively. It is assumed that all main connections between particular gnostic areas and wordkinesthetic field run via wordauditory field, except connections form signvisual field and from kinesthetic field for movements of the body, which run directly. Sustaining connections from the above gnostic areas (denoted as interrupted lines) are assumed to run directly to the wordkinesthetic field.

the objects and events of the external world, as well as postures and motor acts: whether these pathways run directly from the gnostic fields concerned to the wordkinesthetic field, or whether they pass through the wordauditory gnostic field (Fig. 4). Speaking psychologically we may ask whether naming a given object is mediated by evocation of an

auditory image of the word denoting it, or whether this intermediary link is not necessary.

The possibility of the existence of direct connections is evidenced by the fact that persons who are born deaf are able to learn to speak. There is the question, however, whether these direct potential connections are actually utilized in speech of normal persons.

As was indicated in the preceding chapter, lesions sustained in the temporal lobes, involving either the wordauditory gnostic field itself, or pathways leading to either the visual gnostic area or to the wordkinesthetic gnostic field frequently produce a very pronounced amnestic aphasia. There are cases when a patient with a lesion in the temporal lobe fails completely to name objects, although his narrative speech, composed mainly of verbs may be still possible. This would indicate that the pathway leading from the visual gnostic area through the wordauditory gnostic field to the wordkinesthetic gnostic field is certainly involved in expressive speech. On the other hand, lesions sustained in the parieto-occipital region produce also typical amnestic disorders. The main difference between the effects of temporal lesions and parieto--occipital lesions is that the parieto-occipital lesions produce a "pure" amnestic syndrome, in which both comprehension and repetition is completely preserved, and prompting is most useful in naming objects.

It should be added that naming letters of the alphabet and digits seems to depend exclusively on direct visual-kinesthetic pathway. This is documented by the fact that lesions in the temporal lobe producing severe amnestic aphasia leave completely intact both naming of letters and reading. On the contrary, after occipito-parietal lesions producing less severe amnestic syndrome, naming of letters and reading are strongly impaired (see Chapter VI). This is the so called alexic aphasia.

All these data seem to suggest that human expressive speech may be based *both* on direct and indirect connections between the gnostic units representing objects and corresponding units in the wordkinesthetic field representing their names. The preponderance of these or those connections may depend on a number of factors which are so far not clear. We assume that in various persons, depending on the ways of development of their language, either direct or indirect connections may take an upper hand, and this may be the cause of why amnestic symptoms after lesions in the temporal lobe vary in intensity to a great extent. Besides this, the preponderance of these or those connections may depend on the objects to be named. Thus, the units representing visual objects seem to be connected with wordkinesthetic units representing their names mainly through wordauditory units, because lesions in the temporal lobes are usually detrimental for their naming.

On the other hand, units representing letters of the alphabet and numbers are linked with the wordkinesthetic units rather by direct connections. It would be extremely interesting to know, whether connections linking the kinesthetic units representing motor acts with the corresponding wordkinesthetic units, run directly as short-distance U-fibers within the frontal lobe, or whether they make a long détour through the arcuate fascicle (in both directions) to have a relay station in the wordauditory field. As indicated earlier we have some hints suggesting that rather the direct connections are here in operation.

VI. DISORDERS OF READING AND WRITING

1. Reading

Reading and writing arose very late in the evolution of the human species, probably in that period when speech had been already well developed. The graphic signs were originally pictorial, and only later did they begin to represent phonemes, from which they are composed.

For the function of reading the necessary condition is the development of the visual sign gnosis, that is learning to recognize signs representing letters and words (cf. Chapter II, section 4). As was said above, the damage to the signvisual gnostic field (V-Sn) produces sign agnosia (or primary alexia) manifested by the patient being unable to copy the signs seen, in spite of the fact that his writing is preserved.

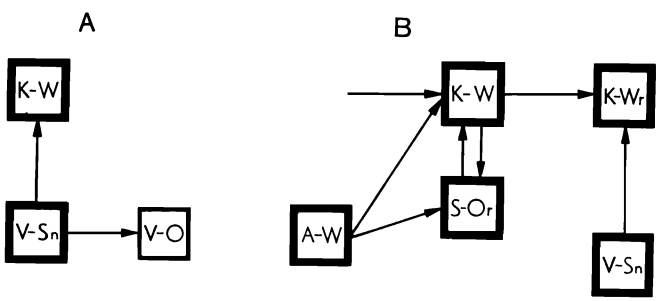


Fig. 5. Diagrams of connections involved in reading (a) and writing (b). V-Sn, signvisual field representing letters and words; K-Wr, signkinesthetic field representing letters and words; K-W, wordkinesthetic field; A-W, wordauditory field; V-O, objectvisual field. Note that there are direct connections linking signvisual field with visual gnostic fields for objects, bypassing wordkinesthetic field; note also that writing (except copying) is always mediated by wordkinesthetic field.

The integrity of the signvisual field is, however, not sufficient for reading (aloud or in whisper) the letter sequences seen. For this he must have the wordkinesthetic field and the pathways linking the two fields

intact (Fig. 5a). Accordingly, the wordkinesthetic agnosia (Broca aphasia) makes the verbalized reading impossible.

As noted before, the pathways from the signvisual field to the wordkinesthetic field are not mediated by the wordauditory field, since patients suffering from amnestic aphasia due to lesions in the left temporal lobe are able to read rather fluently. On the contrary, patients suffering from a "pure" amnestic aphasia display a clear alexic syndrome (secondary alexia) — they are able to copy the letters seen, but they fail completely to "name" them because of the damage of corresponding connections. We saw a patient who seeing a letter copied it (even in the air), and only then did he succeed to pronounce it. Clearly, he utilized the intact connections between the signvisual field and signkinesthetic field (running probably through the minor hemisphere, cf. Geschwind 1965) and the connections leading from the latter field to the wordkinesthetic field.

The fact that the pathways linking the signvisual field with the wordkinesthetic field do not pass through the wordauditory field produces the following paradoxical phenomenon. Suppose that in front of a patient suffering from sensory aphasia we expose letters of the alphabet and we ask him to name them. He does it with no difficulty. Then we pronounce the name of each letter and ask the patient to point to it. It turns out that he fails completely to do so; he either points haphasardly to incorrect letters, or refuses to do it at all. This discrepancy of the two apparently kindred responses is explained by the fact that the auditory-visual pathways are in this patient impaired, whereas the visual-kinesthetic pathways are preserved.

To end this analysis of reading we should note another curious fact observed in patients suffering from Broca aphasia. As was said before, these patients are completely unable to read either aloud or in thought because of destruction of the wordkinesthetic field. However, they are able to read in that sense that they peruse a text and understand it to a greater or lesser extent. If we make a test in which we expose to a patient a set of names and a set of corresponding objects, he is able with minor errors to match the objects to the correct names. This shows that, at least in some people, reading is based on direct connections linking the signvisual units representing words with objectvisual units representing the corresponding objects.

2. Writing

Writing occurs in the following situations (Fig. 5b): (1) when a subject copies a text seen; (2) when he writes under dictation; (3) when he writes "spontaneously" expressing his thoughts; (4) when he signs his

name, or other well fixed sequences of letters. Of course, the final common link for all these responses is the signkinesthetic field localized in the premotor cortex in the so called Exner center. If this field is destroyed, *all* acts of writing are abolished, because the patient has lost kinesthetic patterns involved in this function. If the signkinesthetic field is preserved, then the very act of writing is normal.

There are many clinical observations to show that abolition of the verbalized speech due to damage sustained to the wordkinesthetic field makes "spontaneous" writing, or writing under dictation, impossible. Hence we can deduce that normal writing occurs through verbalization, that is, that in order to write a word we must first verbalize it, either aloud or in our internal speech. If the patient's condition improves, so that he is able to utter some words, he succeeds in writing them either under dictation or "spontaneously". Patients with Broca aphasia are, however, able to copy the texts seen, because there is a direct pathway from the signvisual gnostic field to the signkinesthetic gnostic field, which is not mediated by the wordkinesthetic field.

What is the ability of writing in amnestic aphasia? The answer is that this depends completely on the ability of verbalization of the words heard (in dictation) or thought (in spontaneous writing). Accordingly, if a patient is able to repeat words, as is the case in sensory aphasia, he can also write them under dictation. But if he cannot repeat words because he suffers from wordauditory agnosia, or auditory-verbal aphasia, then he cannot write them correctly. He also cannot write correctly when he suffers from oralsomesthetic agnosia, writing reflecting exactly his poor pronunciation.

Finally, it is worthwhile to note that even when a patient is unable to copy, or write under dictation, he may still be able to sign his name. This shows that this graphic sequence is so well fixed that it does not depend on the connections which are indispensable for writing other words.

These considerations show how important is the analysis of disorders of reading and writing due to cerebral lesions for understanding the normal mechanisms of these functions. There is no doubt that no tests performed on normal persons would be sufficient for disclosing these mechanisms to such an extent, as was possible by examining aphatic patients.

SUMMARY

Speech disorders after lesions of the cerebral cortex may depend either on lesions in gnostic fields involved in various aspects of speech, or on severance of connections between these fields, or else on severance

of connections linking the gnostic fields involved in speech with those representing exteroceptive or proprioceptive perceptions.

The gnostic fields directly involved in speech are the following:

1. The wordkinesthetic gnostic field representing kinesthetic patterns of words and short phrases. Its lesion produces the disorder of the external or internal speech.

2. The oralsomesthetic gnostic field representing somesthetic articular and tactile stimulus-patterns for positions of the mouth. Its lesions produce disorders in pronunciation of particular phonems.

3. The wordauditory gnostic field representing auditory patterns of words and sort phrases. Its lesions produce disorders of recognition of phonems and words.

4. The signvisual gnostic field representing the visual symbols of letters, short words and numbers. Its lesions produce disorders in recognition of graphic signs.

5. The signkinesthetic gnostic field representing the kinesthetic patterns involved in writing. Its lesions produce disorders of writing.

The most important connections involved in speech are the following:

1. The connections running from wordauditory gnostic field to gnostic fields representing stimulus-patterns perceived by various analysers (visual, kinesthetic, somesthetic, gustatory, olfactory, auditory). Their severance produces disorders of understanding of the names heard of respective modalities of stimulus-patterns.

2. The connections running from the wordauditory gnostic field to the wordkinesthetic gnostic field. Their severance produces disorders of repetition of the words heard.

3. Connections running from the gnostic fields representing stimulus-patterns of various analysers (visual, somesthetic, kinesthetic, gustatory, olfactory, auditory) to the wordkinesthetic gnostic field. These connections run either indirectly, through the wordauditory gnostic field, or directly, bypassing this field. Connections between the signvisual field and the wordkinesthetic field, and probably between the kinesthetic field for movements and wordkinesthetic field run directly. The other ones run mainly via the wordauditory field.

4. Connections running from the signvisual gnostic field to wordkinesthetic gnostic field. Their severance produces disorders of verbalized reading, both external and internal.

5. Connections running from the signvisual gnostic field to the signkinesthetic gnostic field. Severance of these connections leads to the disorders of copying the signs seen.

6. Connections running from the wordkinesthetic gnostic field to the signkinesthetic gnostic field. Spontaneous writing and writing under

dictation is accomplished through the wordkinesthetic field, therefore its destruction, or severance of the connections running to it, produces the disorders of writing which occur parallelly to those of naming.

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