14

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20 NEUROPSYCHOLOGY: ITS SOURCES, PRINCIPLES, AND PROSPECTS

Alexander R. Luria

~~A. R. Luria~~

Among that rapidly developing group of sciences of the nervous system which we now call the neurosciences a special place is occupied by neuropsychology. Its roots go back through the centuries, yet at the same time it can be regarded as the youngest, the most recently founded branch of neuroscience.

It differs from the other members of the group of neurological disciplines in that its concern lies not with the deep mechanisms of the molecular or biochemical bases of nervous activity, nor with the morphological structure or evolution of the nervous system, nor with the physiological mechanisms of nervous processes, but rather with the role of individual brain systems in the organization of human psychological activity.

In this respect neuropsychology stands astride the line separating the natural from the social sciences; it is one of the behavioral sciences, and it preserves the closest connection with such other branches of learning ~~such~~ as neurology, psychology, and linguistics. In fact, progress in

neuropsychology is largely dependent on progress in these other sciences; ~~neuropsychology~~ it can develop only on the basis of progress in scientific psychology, and, in turn, it must act as a powerful stimulus to further development in that field.

What are the sources of neuropsychology, the fundamental principles of its work, its theoretical and practical importance for psychology and medicine, and, finally, what are its prospects? RUN IN

The writer has been a direct participant in the creation of neuropsychology. In the pages ~~which~~ that follow, theoretical propositions will therefore naturally be intermingled with personal reminiscences.

The Sources and the Problem

The question of the role played by the different parts of the brain in psychological activity first aroused man's interest in the Middle Ages, and the first major attempt to provide ~~the~~ an answer was made in the ~~18th~~ eighteenth and early ~~19th~~ nineteenth centuries by F. J. Gall, one of the founders of scientific brain anatomy. However, it was inevitable that ~~Even in these earliest stages of the creation of what we now call neuropsychology, it was apparent that~~ the manner of solution of the problems posed by what we now call neuropsychology would ~~which it poses depends on the~~ depend upon

current philosophical and psychological concepts. In the seventeenth and eighteenth centuries the "theory of faculties" held a position ~~The 17th and 18th centuries were a period of undisputed~~ of dominance in psychology (which at that time was still an integral part of philosophy). ~~of the "theory of faculties."~~ All psychological processes (perception and memory, voluntary action and abstract thought) were understood as "faculties" of the human mind, incapable of further subdivision. The Analysis of psychological processes this revolved around attempts to isolate ~~was reduced to the isolation of~~ these "faculties," and it was natural ~~therefore that~~ that an investigator such as Gall, who wished to discover their cerebral mechanisms, would strive to find ~~the~~ brain structures that could be regarded as their organs or centers. ~~of those "faculties."~~ That ~~was~~ is how Gall came to produce his fantastic "brain map" on which all manner of different "faculties" (including "thriftiness" and ~~or~~ "love of children") were ascribed to particular, narrowly localized areas of the brain.

The mythological basis of Gall's map was clearly realized long ago, and his phrenology has been rejected. ~~no one nowadays alludes to the ideas embodied in this theory.~~ However, the principle of the direct localization of complex psychological processes in circumscribed areas of the brain has persisted, virtually unchanged, on the basis of the clinical picture derived from the study of local brain lesions. ~~Its first and, apparently, scientific source was the clinical picture of local brain lesions.~~

In 1861 Broca showed that a lesion of the posterior third of the inferior frontal gyrus causes a disturbance of motor speech but does not impair the ability to understand speech addressed to the patient. To Broca, this was sufficient grounds to localize the "motor images of words" in this area of the brain. When Wernicke in 1873 described the opposite fact—a disturbance of the understanding of speech associated with a lesion of the posterior third of the superior temporal gyrus of the left hemisphere, in which the patient's motor speech remained intact—he felt fully justified in concluding that this area of the cortex is the center of localization of the "sensory images of words" (Wortbegriff).

The view that complex psychological processes can be localized in circumscribed areas of the cerebral cortex just like elementary processes (sensation, motor impulses) proved so attractive that, within a single decade (known in the history of neurology as the "splendid seventies"), scores of brain centers were discovered for such "functions" as reading, writing, calculation, and abstract concepts. The clinical pictures of their lesions, such as "agnosia," "apraxia," "alexia," "agraphia," "acalculia," and so on, also became firmly entrenched in clinical neurology. These views were followed up by investigations based on stimulation

of individual points of the human cerebral cortex and observation of the resulting changes in behavior, which seemed to confirm the existence of cortical centers for complex psychological processes (Hoff and Pötzl, 1930; Foerster, 1936). It was later postulated that more complex disturbances of psychological processes could be interpreted as the result of the disconnection of these "centers." In the first decades of the present century theories about the direct localization of complex psychological functions (essentially indistinguishable from the idea of direct localization of "faculties") reached their climax in the "cerebral pathology" of Kleist (1934) and in the doctrines of Nielsen (1946). Subsequently the concept that the most complex forms of psychological disturbances occuring in patients with local brain lesions result from the "disconnection" of the individual centers (the disconnection syndrome) acquired a firm foothold in modern neurology and was reflected by such writers as Geschwind (1965).

Very recently these views of the direct localization of complex psychological functions in circumscribed groups of cells received apparent confirmation from the brilliant researches initiated by Hubel and Wiesel (1962, 1963) and continued by many other investigators. These workers established to their satisfaction that isolated cortical neurons respond selectively to very specialized stimuli. They saw

in this fact confirmation of the view that even very complex psychological processes can be "localized" in circumscribed groups of nerve cells and that there is no difference in principle between the localization of elementary functions and that of complex psychological processes. Some workers (for example, Konorski, 1968) saw here fresh grounds for returning to traditional views and for concluding that the secret of the cerebral organization of psychological processes in circumscribed areas of the brain has been discovered and that the brain mechanisms of psychological activity have at last been elucidated.

Clearly neuropsychology has completed a cycle in its development, and a new discipline, supported by a precise and finite system of facts, now exists in the family of the neurosciences.

The Crisis

It would be wrong to suppose that the development of ideas of the direct localization of complex psychological processes in circumscribed areas of the brain or, as they are usually called, the ideas of "narrow localizationism" had marched like a triumphal procession without encountering any resistance and fundamental and undisputed concepts for neuropsychology. History shows that

whenever narrow localizationism has been propounded, opposing facts ~~indicating the opposite~~ have been brought against it, and arguments have been presented that the brain works as a single entity. ~~and that there are in fact no grounds for accepting the concept of narrow localizationism.~~

At the beginning of the last century, Gall's ideas were opposed by Flourens (1824), who showed that there are no firmly fixed centers in the bird's brain and that the specialization of the motor points of the brain can be changed by making the flexor muscles of the wing take over the function and innervation of the extensors. Some fifty years later Broca's views on ~~the~~ "speech centers" were opposed by Hughlings Jackson (1884), who postulated that speech processes (like all complex types of psychological activity) are not localized in circumscribed areas of the brain and that their organization is based on the principle of hierarchical levels and dynamic systems. In the physiology of brain functions the same discussion was repeated between Fritsch and Hitzig (1870) and others who shared their views on the narrow specialization of cortical areas, and Goltz (1881), ~~(1876-1889)~~, who postulated that the brain works as a whole.

In the first decades of this century a similar conflict was repeated in neurology and psychophysiology by leading investigators who were or are our contemporaries. Whereas Kleist (1934) logically defended the narrow localization of complex functions in the cortex, other eminent neurologists such as Monakow (1914) and Goldstein (1927, 1934), with equal conviction, defended the opposite view: only elementary functions can be localized in circumscribed areas of the brain; complex "semic" processes are always the result of the activity of large brain systems (Monakow, 1914); and complex psychological processes are dependent more on the mass of brain substance than on circumscribed areas of cerebral cortex (Goldstein, 1927, 1934).

This ~~The~~ continuing conflict ~~between opposite views~~ shows that the road of development of neuropsychological concepts is by no means easy, that the cerebral organization of higher forms of psychological activity is a far more complex phenomenon than has been ~~was~~ realized, and that further searches must be made, perhaps with significant revision of our basic approaches, in order to break the vicious circle of controversy.

A century of history of what nowadays we might call the theoretical propositions of neuropsychology—the theory

of cerebral organization and of human psychological activity--thus ended in deadlock.

A crisis in the basic views of neuropsychology had arisen, and it would be pointless to pretend that it had not. It was far deeper than a conflict of views between individual scientists. Its bases were theoretical and factual and were concerned with fundamental aspects of our new science.

The theoretical basis of the crisis of concepts in classical neuropsychology centered on ~~comprised~~ two groups of propositions which justifiably aroused the most serious misgivings. First, it could hardly be imagined that complex psychological processes, such as logical perception or voluntary action, not to mention speech, writing, reading, and calculation, could be understood as elementary and even as indivisible "faculties." Such views, which might have been acceptable in the Middle Ages or even at the dawn of the modern ~~this new~~ era, had lost all their justification by the middle of the last century, when these activities began to be understood as complex ~~associations~~ system s of more elementary psychological processes. And now, when higher forms of psychological activity are regarded as a product of development taking place under the combined influences of maturation and of exposure to the formative action of the social environment (Vygotskii, 1956, 1960), they are quite simply untenable. ~~have completely lost their validity.~~

Such complex forms of psychological activity, formed under different conditions and to different degrees, carried out by completely different methods, and having

different structures in different persons, cannot in any sense of the term be regarded as elementary inborn "faculties," and under no circumstances can they be understood as functions of a strictly localized group of nerve cells.

On the other hand, the crisis of basic views in neurology inevitably implicated fundamental views of the brain--the highest apparatus of psychological activity. With the modern development of the neurosciences it is impossible to imagine the brain as a homogeneous mass, for whose activity the mere volume of brain tissue is of decisive importance, or as a group of isolated micro-organs, each of which possesses the highest degree of specialization and can function independently of ~~the~~ neighboring cell formations.

Moreover, the specificity of the work of single neurons (admittedly, often responding selectively to very specialized stimuli) has been shown to depend not so much on their isolated qualities as on the work of the "functional ensembles" discussed at various times by such eminent workers as Monakow in Switzerland, Ukhtomskii and Anokhin in the Soviet Union, and Hebb in Canada. They described them variously as "functional constellations," "cell ~~ensembles~~ assemblies," ~~or~~ and "functional systems." But whatever

term they used, these investigators always implied that the specific character of the activity of a group of nerve cells is determined chiefly by the architectual entity into which they fit.

These considerations raised fundamental doubts about whether the cerebral mechanisms of complex psychological activity can be approached either in terms of narrow localizationism, or in terms of viewing the work of the whole brain as an undifferentiated entity. What was acceptable as an hypothesis a century ago is no longer acceptable today, and the profound theoretical crisis of concepts in classical neurology is perfectly evident.

However, this crisis has another, factual aspect. The view that complex psychological functions are "localized" in circumscribed areas of the brain originated from clinical observations that lesion of localized area of the cortex leads to the loss of isolated psychological processes such as motor speech, the understanding of speech, spatial representation, reading, writing, calculation, and so on. These observations provided the basis for the views that the cerebral cortex contains highly specialized centers for complex psychological processes and that complex forms of psychological activity are "localized" in circumscribed areas of the cortex in precisely the same way as the most elementary functions

such as cutaneous sensation, visual and auditory perception, and so on. However, this original viewpoint, on which all the ideas of classical "localizationism" were sustained, has proved to be misleading, if not completely incorrect.

In any deductive activity, and particularly in science, the law we can call the "law of disregard of negative information" holds good: facts which fit into a preconceived hypothesis attract attention, are singled out, and are remembered; facts which are contrary to it are disregarded, treated as "exceptions," and forgotten.

This explains all those "facts" which gained a secure foothold in the textbooks of neurology and were repeated in them for almost 100 years. Lesions of the lower part of the premotor area (Broca's area) are known to cause disturbances of motor speech; however, the fact that lesions of the lower part of the postcentral region also can cause similar speech disturbances (although with different mechanisms) has only rarely attracted attention and has usually been dismissed or interpreted as unexplained "exception." Lesions of the anterior zones of the occipital region are known to cause a disturbance of complex visual perception and "optical agnosia." The fact that a disturbance of perceptual activity can be found in patients with other lesions (for example, lesions of the frontal cortex) was not

in accord with the customary views and so almost failed to attract its due attention. Finally, disturbances of writing, which, in the classical view, should be found in lesions of "Exner's center" (the middle zones of the premotor cortex of the left hemisphere), ~~could~~ can in fact arise as a result of lesions in many different zones of the cortex of the dominant hemisphere (although, admittedly, their psychological structure ~~was~~ is totally different). These facts, which I have repeatedly pointed out (Luria, ~~1966~~, 1962a, 1963a, 1970~~b, c, 1973b~~d, 1971a), have usually been ignored or disregarded.

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A situation of profound factual crisis ~~of classical ideas thus was~~ was thus created. The facts on which the classical theory of the direct localization of complex psychological processes in circumscribed areas of the brain ~~was~~ had been constructed proved to be insufficiently precise, and the theory itself appear~~ed~~ed to be invalid. A radical revision of the classical views became necessary. This task of revision has been undertaken by neuropsychology in the last ~~40~~ forty years, and in the process this field of knowledge has become one that meets the strictest demands presented to a properly based scientific discipline.

Let us now consider this revision in its most general features.

#1 HEAD Follows!

#1

The Way Out of the Crisis: A Revision of the Concept of "Localization of Functions"

A solution to the problem of the cerebral mechanisms of psychological activity was possible only after a radical revision of all the basic principles on which the classical neurologists had based their assumptions and which had led to the the equally false notions of "narrow localizationism" and "antilocalizationism."

This work of revision, without which the further development of scientific neuropsychology was impossible, required a radical reexamination of the two underlying concepts of the theory of the "localization of brain functions": the concept of "function" and the concept of "localization."

The term "function" can be understood in two completely different ways. ~~On the one hand, the word "function" can mean~~ It can refer to the function of a particular tissue. In this sense the function of the pancreas is to secrete insulin, the function of muscle tissue is to contract, and the function of the retina is to decompose visual purple. ~~In this sense of the word a function is specific~~ Such functions are specific, and even indivisible, and ~~is~~ are strictly "localized" in the particular tissue.

However, the term ~~"function"~~ has another meaning, as has been made clear in particular by the work of the Soviet physiologist P.K. Anokhin (1935, 1949, 1955, 1968): a "function" can be understood as a complex adaptive activity aimed at the performance of some vitally important task, or, in other words, as a complex functional system, ~~which~~ that pursues its constant (invariant) aim by complex and variative methods.

Perhaps the best and the simplest examples are the "functions" of respiration and locomotion. The function of respiration is to supply air to the alveoli of the lungs. However, the fulfillment of this task requires expansion of the chest, and this act in turn requires the participation of a system of muscles, particularly the muscles of the diaphragm. However, if the muscles of the diaphragm are paralyzed, the person does not die from asphyxia: the intercostal muscles are brought into action, and to a large extent they take over the function of the muscles of the diaphragm. If for some reason the intercostal muscles are also out of action, the person can swallow air and utilize the apparatus of the pharynx and larynx, not previously concerned with the act of respiration.

The situation is the same with respect to the "function" of locomotion. As several workers have shown, it is impossible to regard locomotion as a fixed chain

of motor innervations. It was Lashley (1937) who showed originally that if the cerebellum is extirpated or both halves of the spinal tract are divided at different levels in a rat trained to walk through a maze, the animal cannot perform any of its previous movements; yet it will reach its goal by falling head over heels or by moving in totally different and unusual ways.

~~Neither~~ respiration ~~nor~~ and locomotion ~~can~~ must thus be regarded not as functions of a fixed tissue, but as complex "functional systems" in which the constant (invariant) task leads to a constant (invariant) effect through the use of interchangeable (variative) methods, as ~~the following scheme~~ Figure 20.1 illustrates.

Figure

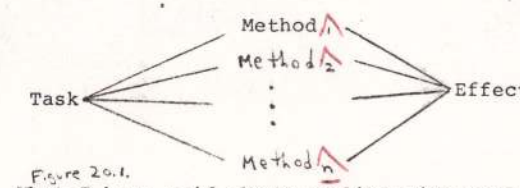

Figure 20.1.

What I have said above applies with even greater force to higher psychological processes, which are not "functions" in the first meaning of ~~this~~ the word, but, rather, ~~are~~ complex and variable functional systems. ~~It was~~ The famous Soviet psychologist L. S. Vygotskii (1934, 1956, 1960) ~~who~~ made the decisive contribution

to the development of scientific psychology when he stated that psychological processes are not elementary and inborn "faculties," but are, rather, ~~are~~ formed during life in the process of reflection of the world of reality, that they have a complex structure, utilizing different methods for achieving their goal, which ~~and~~ ~~they~~ change from one stage of development to the next. He considered that the most important feature characterizing higher psychological functions is their mediated character, the fact that they rest on the use of external aids (tools for movements and actions, language for perception, memory, and thought), and that the structure of these complex psychological processes changes radically in ontogeny. He pointed out, for example, that, whereas a small child thinks by recalling, an ~~the~~ adult may ~~even~~ recall by thinking, and that even the structure of these processes varies during development. I have shown by special investigations that during the development of memory not only its structure changes, but also its relationship to its genotypic prerequisites, and thus that even such a comparatively simple process as memory cannot ~~thus~~ be regarded as elementary and unchanging (Luria, 1936, 1962b).

Further investigations by Leontiev (1959) and Gal'perin (1969) have shown ~~showed~~ the decisive role of the active manipulation of objects in the development of complex human psychological processes, and the complexity of both the pathways of formation and the structures of these processes. ~~and of their structure~~ We thus reach the indisputable conclusion that complex forms of psychological processes cannot in any way be regarded as functions incapable of further subdivision (resembling the "faculties" of the older writers), but that they are ~~complex~~ functional systems, using different methods and having a complex structure.

This revision of the concept of "function" leads inevitably to a radical revision of the concept of "localization." When speaking about the "center of respiration," Pavlov stated that the old, classical concepts of the narrowly localized "respiratory center" had recently been radically modified. Whereas "~~...~~ from the very beginning we thought that it was something the size of a pinhead in the medulla; now, however, it has proved extremely elusive, climbing up into the brain and sinking down into the spinal cord, so that now nobody knows its precise bondaries" (Pavlov, 1949): Vol. 3, p. 127).

Exactly the same comment can be made about the "center for locomotion" and, with even greater justification, about the "centers" of complex psychological processes. If the higher psychological processes are complex functional systems, any attempt to "localize" them in circumscribed groups of cells is meaningless. Instead of trying to localize psychological functions in narrowly circumscribed areas of the cortex or subcortex, we must change our task and instead consider the arrangement of complex functional systems in the cortex and lower formations, the role of each part of the brain ~~system~~ in the activity of complex functional systems, and the contribution ~~it~~ each makes to their performance. This has become the basic problem in neuropsychology, the branch of science whose purpose it is to analyze the cerebral organization of complex forms of human psychological activity.

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The Way Out of the Crisis: Revision of the Concept of "Symptom"

Revision of the concept of "localization of functions" has made it necessary for us to revise a third concept that plays a key role in the history of neuropsychology—the concept of "symptom." As I said above, much of ~~the~~ our

neuropsychological evidence ~~has been~~ was obtained by observations made on patients with local brain lesions. If a local brain lesion led to a clearly defined loss of function or, in other words, if it caused a definite symptom, observers concluded that ~~the~~ that particular area of the brain ~~is~~ was the "center" in which the corresponding function ~~is~~ was "localized." The idea that the concepts of function and symptom coincide, even though they are opposite in sign~~, and that the symptom of loss of a function arising as the result of a local brain lesion points directly to the localization of that function in the corresponding area of the brain~~, gave basic support to the ~~views~~ idea of the direct localization of functions ~~so typical of classical neurology~~.

However, despite the apparent simplicity and attractiveness of this idea, it began long ago to arouse fundamental misgivings, and the idea that the concept of "symptom" is by no means equivalent to the concept of "function" gradually began to penetrate deeper and deeper into classical neurology.

The neurologist who did more than anyone else to shed light on the complexity of the true state of affairs was Kurt Goldstein, one of the most brilliant intellects of our time. It was in ~~1923~~ 1925 that he published his well-known paper, "The Symptom, its Origin and Significance," which

can with complete justification be regarded as an original work of modern scientific neuropsychology.

The basic idea expressed by Goldstein is simple. If a local brain lesion causes a certain disturbance of complex forms of psychological activity such as perception, or thought, speech, writing, or reading or, in other words, if it leads to the appearance of the "symptom" of agnosia, or aphasia, alexia, or agraphia this by no means implies that this complex function is localized in that particular part of the brain.

A careful neurological (we should now call it neuropsychological) analysis shows that the symptom is complex in character. It may be based upon a primary, basic disturbance (Grundstörung) which by itself does not account for the whole range of the symptom, but which merely removes the fundamental condition required for the particular "function" to be performed. The actual symptom arising as the result of the local brain lesion, in Goldstein's opinion, is only the secondary result of the basic disturbance, and it can in no way be regarded as the direct consequence of a focal disturbance or as the result of the fact that the particular "function" is directly "localized" in the corresponding area of the brain.

In order to understand the true mechanisms that lead to the actual disturbance of psychological processes, a careful analysis must be made of the structure of the resulting symptom, the primary disturbance at its base must be distinguished, and the ways in which the secondary disturbances that constitute the directly observed pattern of the disorder arise must be shown. Inability to draw an object in a conventional picture, for instance, may be the result of the fact that the patient cannot discontinue a concrete activity and change to the act of conventional representation; inability to repeat a sound or word is by no means necessarily the result of an audio-verbal disturbances, but may arise because the patient has lost the particular "abstract set" that he needs in order to change from the cognitive activity of spoken communication to the artificial act of repeating groups of sounds (Goldstein, 1948).

An externally manifested "symptom" is completely different from the primary defects that lie behind it. Careful analysis of the "psychological qualification of the symptom" thus is required to progress from the externally observed picture of disturbances of behavior to the mechanism lying at their basis. This was shown by Goldstein and his colleague Gelb in a series of meticulous

investigations described under the general heading of "Psychological Analysis of Cases of Brain Pathology" (Gelb and Goldstein, 1920). This careful analysis of the internal logic of the changes in psychological activity arising as the result of local brain lesions can be regarded as the main contribution of these eminent authors and as the true foundation of scientific neuropsychology.

No matter that the basic principles from which Goldstein set out were incorrect, and that there are few nowadays who would agree with his view that every brain lesion (almost regardless of its localization) causes, as its "basic disturbance," the disintegration of the "abstract set" or of "categorical behavior." The facts gathered by subsequent generations of investigators confirmed neither this view nor the hypothesis that the extent of the brain damage plays a more important role in the genesis of disturbance of higher psychological functions than the localization of the focus. The facts established by neuropsychology have proved to be incomparably richer and more varied than these examples of the "finest abstractions."

Neuropsychology must be indebted to Gelb and Goldstein for having introduced the idea of the existence

of "basic" or "primary" disturbances and associated secondary disorders and for having shown that instead of a superficial description of symptoms it is essential to give a careful "psychological qualification of the symptom" and to distinguish the "basic disturbance" this way (and not the superficial statistical assessment of symptoms) is the only possible highway of neuropsychological investigation.

Qualification of the symptom and identification of the basic disturbance are the first stage in every neuropsychological investigation. The second, no less important stage is the comparison of all the symptoms presented by the patient and their synthesis into a single picture or, in other words, establishment of the syndrome arising because of the local brain lesion. This is the final stage and a special examination of the logic behind it is called for.

American workers, including Hans-Lukas Teuber (1959), have formulated a "principle of double dissociation," which has been accepted in neuropsychology as a basic principle of its techniques. Its essence

can be stated as follows: "If a local brain lesion leads primarily to the loss of a particular factor directly connected with the work of that part of the brain, all types of psychological activity that incorporate this basic factor will be disturbed, whereas all types of psychological processes that do not incorporate this factor will remain intact." An example is the comparative analysis of the pattern of disturbance of psychological processes in lesions of the temporal and parieto-occipital region of the left hemisphere. The first of these lesions directly disturbs complex phonemic hearing; processes that include this factor (for example, the understanding of speech, the recalling of words, writing) must therefore inevitably disintegrate, whereas processes that do not incorporate this factor (for example, orientation on a map, written calculation) remain intact. The opposite situation is found in lesions of the parieto-occipital region of the left hemisphere. The primary result of such lesions is a disturbance of visuo-spatial synthesis; types of psychological activity that do not incorporate this factor (for example, the understanding of speech, writing) therefore remain intact, while those for which the preservation of spatial synthesis is an essential condition (orientation on a map, calculation) disintegrate.

The ~~comparative~~ analysis of whole syndromes, the description of their structure, and their comparison thus constitute the final stage of neuropsychological investigation; they are its most important component for the study of the role played by individual brain systems in the construction of psychological activity.

Modern Approaches

Fifty years have passed since the publication of Goldstein's first paper, which was one of the original sources of neuropsychology. These have been years of intensive development of the whole range of neurosciences: neuro~~psychology~~, neurophysiology, neurochemistry, neuropathology. We have acquired much new and valuable information, leading to a new system of ideas in the light of which many of the factual statements by neurologists such as Goldstein can no longer stand up to criticism, although, as I have stated, their original theoretical propositions still have great importance.

Important new facts have been obtained in the last few decades in neuroanatomy and neurophysiology. The work of many eminent investigators, among them ~~foremost among whom were~~ such authorities as Moruzzi and Magoun (1949), Jasper (1954), and Lindsley (1960), has shown that neither

the waking state of the cerebral cortex nor its precise, selective activity can exist without the participation of the nonspecific activating system of the brainstem and basal ganglia, and that any interruption of the structural continuity of the ascending and descending activating formations must lower the working tone of the cortex or interfere with the control of its waking state.

A no less important field of research was initiated by the classical studies of Olds (1955) on the one hand, and those of Penfield and Milner (1958) and Scoville and Miller (1957) on the other. These studies ~~They~~ showed that structures of the thalamo-hypothalamic region, hippocampus, and caudate nucleus, as well as structures of the limbic system participate in the activity of the more complex zones of the neocortex. They also revealed ~~found~~ that these structures, which are nonspecific in character, play the decisive role in the comparison of actions, the retention of traces, and the production of responses to novelty, all of which are essential conditions for the performance of any type of complex psychological activity.

These investigations later underwent substantial development as a result of progress in new techniques, culminating in morphological studies of single neurons (Hubel and Wiesel, 1962, 1963). These later studies showed that, besides nonspecific neurons, which form ~~occupy~~ a large part of the neuron population of deep structures and of the limbic region, there are other neurons with a

surprisingly high level of specialization in some parts of the cortex, neurons that ~~which~~ respond only to features exhibiting the finest selectivity and that ~~which~~ are evidently the elementary systems for the reception of information from the outside world.

Finally, work begun on the initiative of Grey Walter (1953, ~~1964~~, 1966, 1973) (Walter et al, 1964), allowing the formation and spread of slow electrical phenomena to be investigated through the use of implanted electrodes, demonstrated the role of the frontal cortex in the regulation of complex forms of activity. Another important contribution was made by Livanov (1972; Livanov, Gavrilova, and Aslanov, 1964, 1966, 1973) ~~and his colleagues (1966, 1967, 1972)~~ who studied the spatial spread of excitation over the cortex and discovered new criteria for the objective evaluation of its organized work. These advances, even at this early stage, could not fail to have made great changes in the information available to modern neurology.

There have also been developments in our knowledge of the morphophysiology of cortical structures. Two generations ago we had only theoretical views on the hierarchic organization of cortical structures, the foundations of which were laid by Campbell (1905), Brodmann (1909), and the Vogts (1919 ~~-1920~~, 1927). It is now possible to add the wealth of information obtained

by morphologists, such as Filimonov (1940) and Polyakov (1956, 1962, 1966) in the Soviet Union and Nauta (1958, 1964, 1971) in the West, who have described not only the details of the neuronal structure of the cortex at different genetic levels, but also the connections that actually exist between the various parts of the cerebral hemispheres and that are fundamental to the activity of the living brain.

A field of particularly intensive and important research has been ~~was~~ that connected with hemisection of the brain, which developed rapidly following the work of Sperry (1966, 1967, 1968) and Gazzaniga (1972). This research has provided completely new information on the work of the isolated hemispheres and has compelled us to revise many views that seemed hitherto to be ~~apparently~~ soundly based.

A rapid flow of new information also has begun to arrive in recent decades from investigations conducted at the molecular level, and it now forms the material for an important subdivision of the neurosciences.

#1

Medical Advances in the Development of Neuropsychology

In the preceding section ~~paragraph~~ I have mentioned the theoretical issues of modern neuropsychology. However, the practical sources of its development are perhaps no

less important.

Recent years have ~~also~~ seen great developments in neurology and neurosurgery. With the introduction of new methods of contrast investigation, such as angiography, with the improvement of techniques for studying the cerebral blood flow, and with the use of methods involving radioactive isotopes, the scope of investigation of the living brain has become significantly widened. We can now localize a pathological focus very precisely; whereas only two generations ago it was a matter of pure guesswork, we can now rely on objective verification. The considerable extension of the frontiers of operative surgery, methods of stereotaxic neurosurgery, and methods of influencing the dynamics of the cerebrospinal fluid, have provided even greater opportunities for the objective verification and study of local brain pathology. It is therefore not surprising that progress in this field of medicine has provided extraordinarily favorable conditions for the development of neuropsychology at its new level. That is why in the last few decades rapidly developing centers of neuropsychology have been created in many ~~the major~~ countries. It is hard to exaggerate the contribution made to this field of knowledge by workers such as Pribram, Teuber, Benton, and others in the United States, Milner in Canada, Zangwill, Critchley, and

Weiskrantz in England, Hecaen in France, De Renzi in Italy, and many others.

It is difficult and, indeed, it would be superfluous for me to summarize the facts my colleagues and I have obtained on these fundamental problems in neuropsychology, which I began to investigate originally forty years ago in conjunction with L. S. Vygotskii. These facts have been published collectively in such books as Traumatic Aphasia (1947, English edition, 1970), Higher Cortical Functions in Man (1962, ~~1969~~, English edition, 1966), The Human Brain and Psychological Processes (Volume 1, 1963, English translation, 1967; Volume 2, 1970), and Fundamentals of Neuropsychology (English edition: The Working Brain, 1973), and also in the survey "Neuropsychological Research in the USSR" published in the Proceedings of the National Academy of Sciences of the USA in 1973. ~~There is thus no need to describe these facts again, and if~~ In the remainder of this article I will ~~it is possible to~~ concentrate only on the fundamental principles underlying these investigations.

All the facts I have obtained have led me to conclude that the higher forms of human psychological activity and all human behavioral acts take place with the participation of all parts and levels of the brain, each of which makes its own specific contribution to the work of the functional system as a whole.

With a little approximation we can say that the apparatus of the brain comprises three principal functional units, each of which participates in the organization of psychological activity in its own particular way.

The first unit, which can be thought of as ~~conventionally be called~~ the unit providing the tone or "energy" of the brain, is connected with the structures of the brainstem, the thalamo-hypothalamic region, and part of the old limbic system. It is this unit which, through the intermediary activity of the ascending reticular formation, exerts activating influences on the cortex and maintains its tone, and in turn is controlled by descending influences from the cerebral cortex. Careful observations on patients with lesions (usually tumors) of the deep structures of the brain, which I shall discuss again below, have shown how the cortical tone is sharply reduced when the corresponding impulses cease to reach the cortex, how the state of vigilance fluctuates in them, how their level of consciousness varies, and how quickly they

become exhausted by any activity. Although they remain nonspecific in character, these influences participate in the course of all psychological activity and maintain the necessary level and background for primary psychological activity.

The second unit can be described as the unit for the reception, analysis, and storage of information reaching the body from the outside world. It comprises the posterolateral zones of the cerebral hemispheres and ~~it~~ is subdivided into parts possessing high modal specificity: (occipital—(visual), temporal—(auditory), and postcentral—(general sensory). The cortex of each of these zones has a hierarchic structure, with primary (projection), secondary (projection-association), and tertiary (integrative) areas (the last are sometimes called "zones of overlapping"), and their structural plan is one of "diminishing specificity" or "increasing integrative action." A lesion of the secondary zones of any ~~each~~ of these cortical areas leads to the corresponding modality-specific disorders which, in turn, lead to manifestations of one of the forms of disturbance of analytico-synthetic activity known in classical neurology as optical, acoustic, or tactile agnosia, ~~respectively~~. A lesion of the tertiary zones of the cortex of this

second unit (the parieto-temporo-occipital region or zones of overlapping) inevitably leads to disintegration of the combined activity of these areas and gives rise to primary disorders of simultaneous and spatial organization of incoming information.[1]

The third functional unit of the brain, which so far has been studied less than the other two, can be described as the unit for programing, regulating, and verifying complex forms of activity. It comprises the anterior zones of the hemispheres and, in particular, the frontal lobes of the brain. Many investigations (Luria, 1966a,b, 1969a, 1973a; Luria and Homskaya, 1966; Pribram and Luria, 1973) have shown that lesions of the zones of the brain composing this unit ~~did not~~ neither give rise to modality-specific disturbances ~~nor did~~ nor ~~they~~ cause disintegration of any special operations. Such lesions ~~did~~ do lead invariably to disturbance of the regulation of the state of activity (Homskaya, 1973). They also caused disintegration of the complex organizations of goal-directed activity and loss of that process of comparison of the effect of an action with the original

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FOOT-NOTE

1. Besides the sources mentioned above I have also made a detailed analysis of this syndrome in a patient described in ~~the book first published in 1971, later published in English translation as~~ The Man with the Shattered World (1971a). ~~The Man with a Shattered World~~

intention, which Anokhin (1955, ~~1963,~~ 1968) has described by the term "acceptor of the results of action" and which is a fundamental mechanism for the control of an individual's behavior and the awareness of his defects.

Careful analysis has shown that all three functional units of the brain participate in all types of activity, but each unit, as I have already said, makes its own particular contribution to the organization of psychological processes. It is therefore natural to find that a lesion of ~~each~~ of these units leads to disorders of higher cortical functions that are totally different in character from one another. It is this feature that has made it possible to describe the complex cerebral organization of human behavior and that has provided an approach to the study of the psychophysiological composition of the more complex forms of human conscious activity. ~~(Luria, 1969b).~~

It was along these lines that such complex psychological processes as perception and manipulative action, speech, writing, reading, calculation, and problem solving ~~were~~ have been analyzed (Luria, 1962a, 1963a, 1966a,b, 1970b, 1973a; Luria and Homskaya, 1966; Luria and Tsvetkova, 1966, 1967). These analyses ~~showed~~ have shown how complex is the cerebral organization of these forms of human conscious activity and how many different components are involved in it. They ~~showed~~ demonstrate how far

our ideas have progressed both from the "faculties" and ~~the~~ narrow localizationism of classical neurology and from the notion that such activity is based on the "abstract set" and on "categorical behavior," functions of the "whole brain" whose mechanisms we are not yet able to unravel.

~~The~~ These investigations ~~I have just mentioned~~ led to the discovery of the functional processes that are the working units of the secondary zones of the cerebral cortex and yielded descriptions of the disturbances of phonemic hearing ~~which~~ that arise in patients with lesions of the left temporal region; the disintegration of simultaneous visuo-spatial syntheses ~~as a~~ that result ~~of~~ from lesions of the parieto-occipital zones of the cortex; and the disturbance of the synthesis of movements into "kinetic melodies," that is observed ~~in~~ following lesions of the premotor area.

They also yielded descriptions of the complex disorders arising as the result of lesions of the tertiary zones of the cortex. Special attention has been paid to analyzing disturbances of the ability to convert consecutively incoming information into simultaneously observable syntheses, such as are found in patients with lesions of the parieto-temporo-occipital zones of the left hemisphere and ~~which~~ are manifested

equally during orientation in space and in such complex symbolic operations ~~such~~ as calculation and the understanding of complex, "reversible" grammatical constructions. Finally, I have been occupied for many years with the detailed analysis of the function of the frontal lobes, lesions of which lead to the disintegration of programmed action and of the sustained verification of its results. All these investigations are described in the long series of publications cited above, and I shall not discuss them in more detail in these pages.

Since Broca and Wernicke first laid the foundations of neuropsychology a century has passed; since Goldstein first attempted a scientific interpretation of its fundamental facts only fifty ~~50~~ years have elapsed. However, it is hard to appreciate two fundamental changes that have taken place during this period and that are characteristic of modern neuropsychology, primus inter pares of the neurosciences: the radical change in the basic approach to the cerebral organization of complex human psychological activity, and the radical replacement of the original propositions. At the same time it would be difficult to exaggerate the contribution made by the data of neuropsychology to modern scientific psychology, to the theory of knowledge, and to linguistics. (I deal

specially with this last problem in a book entitled Basic Problems in Neurolinguistics ~~, now in preparation.~~ (in press) I shall not deal further with the discovery of the relevant facts in this field, but will devote the remaining pages to a brief account of facts not previously published and to problems that have remained unsolved and require further investigation.

#1

CURRENT RESEARCH AND ITS PROSPECTS

For many years I have been engaged in an examination of the role of individual brain systems in cognitive processes, and in an ~~the~~ analysis of perception, speech, writing, reading, calculation, and problem solving. ~~which was the result of these investigations.~~ A no less important aspect of my research has been the ~~an~~ analysis of ~~the~~ mechanisms that are at the basis of voluntary action and conscious activity. However, during the many years spent on these investigations, I had to put aside ~~for the time being~~ some problems which seemed to me difficult to submit to neuropsychological analysis, and to which I hoped to ~~could~~ devote my full attention later.

#2

The Neuropsychology of Memory

When studying patients with local lesions of the convexital part of the cerebral hemispheres, I never

observed a single case of a patient disoriented in space and time, who exhibited an oneiroid state of consciousness, and massive, modality-nonspecific disorders of memory resembling the picture of Korsakov's syndrome. In order to make a neuropsychological analysis of those disturbances it was necessary to change the test object , to study patients with deep lesions of the brain.

Investigations of memory in the last decade have become a favorite topic in physiological and psychological laboratories. However, although the study of memory at the molecular and neuronal level has introduced an enormous flow of new information, in most cases it has suffered from a serious defect: memory has been understood by most investigators as the simple imprinting, storage, and reproduction of traces, and the whole wealth and variety of the different levels of organization of memory and its different components have usually been disregarded.

The ~~much~~ greatest wealth and complexity of the structure of memory ~~was~~ is found not only in psychological investigations, which have numbered in the hundreds in the last decade, ~~the number of which in the last decade amounts to many hundreds~~, but also in observations on disturbances of modality-nonspecific forms of memory arising in patients with deep brain lesions. These investigations, which

began with the classical observations of Penfield, Scoville, and Milner (see Milner, 1958, 1962, 1966, 1970), showed that lesions of both hippocampi can give rise to lasting and modality-nonspecific disorders of memory that have the character more of difficulties of reproduction than of difficulties of impression. Later investigations, conducted at the neuronal level, showed that this region in fact possesses a particularly powerful system of nonspecific neurons, which respond to every change in incoming stimuli and which can be regarded with every justification as the nervous mechanism of comparison or as "neurons of memory" (Vinogradova, 1970).

All these facts compelled me to make a careful study of the changes in memory that result~~ing~~ from local lesions of the deep brain structures that form the "circle of Papez"[2], and that affect~~ing~~ hippocampal structures and lead~~ing~~ to marked general disturbances of memory and sometimes also to disturbances of consciousness. I considered three fundamental questions: What is the character of these disturbances of memory? At what functional level of organization of mnestic activity do they occur? What is the mechanism of the pathologically increased forgetfulness which these patients show?

FOOTNOTE

2. Circle of Papez: hippocampal nuclei, fornix, and mammillary bodies.

The results of these investigations are described in the two volumes of my Neuropsychology of Memory, ~~which is at present in pres~~s and the contents of which I shall summarize here only very briefly.

The answer to the first question was quite evident: modality-specific disturbances of memory can be produced only by lesions of the convexital zones of the hemisphere, and in their character they are more ~~a~~ prolongations of gnostic disorders than true disturbances of memory. Conversely, lesions of the deep zones of the brain lead to modality-nonspecific disturbances of traces which, if the lesion extends to the anterior zones of the brain, assume the character of disturbances of mnestic activity and may be accompanied by distinctive disorders of consciousness.

The answer to the second question was equally evident: In massive brain lesions in different situations, modality-nonspecific disturbances of memory can differ in structure and can occur at different functional levels. For instance, t hypophysis tumors of the ~~pituitary gland~~, extrasellar in their location and influencing the region of the hippocampus, often evoke~~d~~ only disturbances of memory for a chain of isolated elements (sounds, traces, numbers, pictures); but the change to a higher level of organization (the remembering of phrases or stories) compensate~~d~~s for these difficulties (Kiyashchenko, 1973). Conversely, massive tumors of deep

parts of the brain, spreading to the thalamic and hypothalamic nuclei and also affecting the hippocampal structures, disturb~~ed~~ equally the recalling of discrete series of elements and of well-organized material (Popova, 1972; Luria, 1971b, 1974). Finally, lesions of the deep parts of the brain extending to the frontal regions ~~led~~ lead to disturbances of mnestic activity in that the active goal-directed recalling of any organized material ~~was~~ is generally impossible and ~~could~~ can be replaced either by the uncontrollable production of random associations or by the inert reproduction of the same rigid stereotype (Luria, 1971b, 1974).

Perhaps the most interesting answer was that to the last question: What are the physiological mechanisms of the pathologically increased forgetfulness which so often occurs in local brain lesions?

Some psychologists have explained all increased forgetfulness by trace delay, whereas others have regarded it as the result of the inhibitory influence of interfering factors. Numerous observations on patients with local brain lesions have shown conclusively that the pathologically increased forgetfulness observed in such cases is not so much the result of direct trace decay as of pathologically increased inhibitability of traces by random interfering factors, and that this mechanism lies at the basis both of the modality-specific

disturbances of memory arising in local lesions of the convexital zones of the cortex and of the modality-nonspecific disturbances of memory observed in patients with deep brain lesions (Luria, 1971b, 1974). This fact is proved by a simple test in which the patient easily retains a given series of traces (words, phrases, the meaning of a story) after an "empty" pause of 1-1.5 minutes, but immediately "forgets" them if the pause is filled by any type of irrelevant, interfering activity (cf. Peterson & Peterson, 1959)

Facts such as these clearly demonstrate the complex character of memorizing and recalling, and they show the great variety of phenomena concealed behind such an apparently simple concept as "memory."

The Neurodynamics of the Disturbance of Psychological Processes in Local Brain Lesions

The facts I have just mentioned lead us to the last region of neuropsychology, one which has so far received very little attention: the study of the neurophysiological mechanisms of disturbances of psychological processes arising through local brain lesions.

The classical neurologists were fond of saying that the result of a local brain lesion is the loss of a certain function. However, Monakow (1914) first

emphasized that a pathological focus can cause only temporary blocking (diaschisis) spreading over the cerebral cortex, ~~(diaschisis)~~ of a particular function, and Pavlov established a series of important neurodynamic laws, which are reflected in the function of the pathologically changed cortex.

Although more than half a century has elapsed since the description of these laws of the "pathophysiology of higher nervous activity," we are fully justified in turning to them once again to see whether they can explain the real forms of change in psychological processes which neuropsychologists observe in patients with local brain lesions. The phenomenon of forgetfulness, which I understand as a pathologically increased inhibitability of traces by interfering factors, is one example of this neurodynamic explanation of symptoms; the replacement of selective trace recall by reproduction of a pathologically inert stereotype is another ~~such~~ example.

The question naturally arises: can we explain many pathological phenomena in the working of the brain by pathophysiological mechanisms such as these? I shall examine only one, ~~but~~ decisively important series of phenomena. The course of psychological processes in the normal cerebral cortex is known to be characterized by very high selectivity and mobility: the necessary systems of connections are easily formed, and irrelevant random

systems of connections are just as easily inhibited. The opposite situation applies in oneiroid states and in pathological states of the cortex: in such cases both the required and the irrelevant connections arise with equal probability, and the process of choosing from different alternatives (or, as it is now expressed in psychology, the process of decision making) is severely disturbed.

The explanation of this fact evidently lies in the altered cortical neurodynamics produced by the pathological focus. As Pavlov showed many years ago, factors such as fatigue or a pathological focus can reduce the cortex to a pathological state, which is reflected in a disturbance of the normal "law of strength" on the one hand, and of the normal mobility of nervous processes on the other. Whereas in the normal state of the cortex strong (or important) stimuli evoke strong responses and weak (or unimportant) stimuli evoke weak responses, in a pathological state of the cortex the situation is different: in the first, "equalizing" phase strong and weak stimuli (or their traces) begin to evoke equal responses, while in the second, more severe, "paradoxical" phase responses to weak stimuli are actually stronger than those to strong stimuli. ~~Under these conditions~~ the main condition of

selectivity of psychological processes ~~thus~~ is thus naturally disturbed, all connections begin to arise with equal probability, and the organized course of psychological processes becomes impossible.

In deep brain lesions this loss of selectivity of psychological processes may be global in character (Luria et al., 1967); in local lesions of the convexial zones of the cortex this pathological state of the cortex can be localized or regional in character and can lead to the "equalization of excitability of traces" either in the visual or in the audio-verbal sphere (Luria et al., 1967). The difficulties that a patient with aphasia experiences when attempting to find an essential word and the phenomena of literal and verbal paraphasias, ~~which~~ that arise with the same probability as the desired word, can very likely be explained by this equalizing phase of the pathologically changed speech area of the cortex (Luria, 1972). L, 1975

A factor that is just as important for the neurodynamic explanation of pathological forms of brain activity is a disturbance of the normal mobility of nervous processes, observed particularly clearly in lesions of the anterior zones of the brain. It is manifested as perseverations, which may assume different forms and may arise at different levels (Luria, 1965) and which disturb the normal course of psychological activity. The role of pathological inertia

in the clinical picture of local brain lesions is very great, and this phenomenon has been studied in detail in many neuropsychological investigations (Luria, 1966a,b, 1967, 1969, 1970b, 1973a,b; Luria and Homskaya, 1966).

All I have said goes to show that the introduction into neuropsychology of criteria elaborated in the pathology of higher nervous activity is one of our most important tasks, and one that has so far received inadequate attention.

The Prospects

I have discussed very briefly the sources, principles, and basic facts of neuropsychology. It now remains for me to say a few words about its prospects. As in any new branch of science the facts at our disposal are only the beginning, and to use Pavlov's expression, "The mountain which remains unknown is immeasurably larger than the small heap taken from it which is known." I shall attempt to summarize this mountain of the unknown in a few short words.

The first and the longest period of time was occupied in formulating the basic principles of neuropsychology as a science, in describing the symptoms found in lesions of the basal zones of the human brain, and in characterizing the principal neuropsychological

syndromes arising in local lesions of this part of the brain.

The last few years have brought with them the urgent necessity of studying the pathophysiological mechanisms lying at the basis of these syndromes. This work has only just begun and in all probability it will occupy a whole generation, linking neuropsychological observations with neurophysiological analysis. Workers in my laboratory, including E. D. Homskaya and L. A. Filippycheva, have already set out along this road, and much can be expected from their investigations.

The next step, without which any further development in neuropsychological research would be impossible, is a careful clinical analysis of the nature of the facts observed. Whereas in the first stages it was sufficient to indicate the location of the focus and to analyze the symptoms produced by it, it is now necessary, in the present state of the science, to correlate the discoveries obtained by modern methods of investigation of the living brain with the data of angiography, with a careful investigation of the compensatory capillary circulation, and with analysis of the relations between local and general cerebral factors involved in every local brain lesion. Without this work no further development of neuropsychology

could take place, and its results would rest on an imperfect clinical basis. However, the work has now begun and much is expected from it.

The third and equally important prospect of neuropsychological research is connected with the widening of the field of its activity. Until recently nearly all the information we ~~have~~ obtained was concerned with the function of the left, dominant hemisphere; the function of the nondominant, right hemisphere (like the function of the deep brain structures) has remained largely a closed book. Only very recently, with the work of Sperry and his collaborators ~~with~~ on the "disconnected" brain and with their observations during stereotaxic operations, has the attempt begun to make this unexplored field accessible for investigation.

In recent years we have begun to gather material from which we can hope that the functions of the right ~~(nondominant)~~ hemisphere will eventually be revealed to us. We know already that the line dividing the functions of the two hemispheres does not ~~by no means~~ necessarily follows the line of separation of speech and nonspeech processes, that the right hemisphere is intimately connected with the direct realization of its activity and with the automation of its course, that in lesions of the right hemisphere anosognosia and de-automation of the processes can arise, that residual gnostic and speech processes

may become uncontrolable ~~lose their controllability~~ in such lesions, and that the right hemisphere participates in a unique way in the consolidation of traces.

However, although these observations are still purely preliminary in character, perhaps it will not take a complete generation to collect the more informative material we require. We can look hopefully at the abundant literature now appearing and at the systematic work begun only a few years ago in my laboratory by E. G. Simernitskaya and her collaborators.

It now only remains for me to mention the last prospect for the development of neuropsychology as a science, and this time it is more technical in character. During the years I have spent on this work I have recorded many observations that have helped to provide ~~which provided~~ the foundations for a theory of neuropsychology. However, these facts still require verification of detail, ~~they require~~ careful evaluation, and, where necessary, ~~they require~~ quantification in order to establish their complete reliability. I am far from thinking that quantitative measurement is the only true criterion of science. I am not too greatly impressed by the usual methods of medical statistics, which usually amount to nothing more than stating a number of cases showing a given symptom. In a special communication

published not very long ago (Luria and Artemeva, 1970), I expressed the view that in neuropsychology, as in other fields of science where the material is comparatively limited in amount, attention should be focused on the intercorrelation of symptoms, and that a mathematical apparatus should be specially developed for use in such cases.

The time has come for a ~~more than quantitative~~ mathematical analysis of the vast amount of material gathered as a result of my observations over the last forty ~~almost 40~~ years, observations ~~which~~ that lie at the basis of the neuropsychological syndromes of local brain lesions and ~~which~~ that give these syndromes their essential reliability. I have no doubt that this work will take more than a generation, but an inspired look into the future is sometimes just as important as a sober evaluation of the present.

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28 Carleton Street
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Massachusetts Institute of Technology
617-253-5646 Telex 92-1497

23 January 1975

Aleksandr R. Luria
University of Moscow
13 Frunze Str.
Moscow G. 19, U.S.S.R.

Dear Dr. Luria,

The manuscript for The Neurosciences: Paths of Discovery has now gone to the compositor. We would like to have the book out in the fall, and so we have put ourselves on a fairly rigorous schedule. The book will be set directly into pages, and the proofreading will be done here and at the NRP. You will receive a copy of the page proofs of your chapter for your information, but, because of the distance and the uncertainty of the mails, we will not wait to hear from you before returning the proofs to the compositor. For this reason, I am enclosing a xerox of the final edited manuscript of your chapter. Please look it over carefully, and if you find any errors, please let me know immediately so that I will be able to transfer your corrections to the proofs. I have tried to be as careful and scrupulous as possible in my editing, and the final version has been checked by George Adelman and Frederic Worden of the NRP. I hope you will find it satisfactory.

I am quite excited about the book. I believe it will offer a unique insight into the functioning of an international scientific community, and will also be quite useful as an overview of and introduction to neuroscience.

With best wishes,

Larry Cohen
Associate Editor