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Luria's Neuropsychological and Neurolinguistic Testing

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ABSTRACT

In this paper Luria's neuropsychological and neurolinguistic theory is briefly reviewed in order to relate it to his neuropsychological testing. Luria's neuropsychological and neurolinguistic testing is based on his general theory of brain-behaviour relations, which emphasizes the overlap between different functional systems. Luria's goal was to provide a principled approach to testing and rehabilitation, based upon an understanding of the factors underlying complex psychological activities and derived from observations and studies of normal and pathological populations. A case history illustrates these principles.

LURIA'S NEUROPSYCHOLOGICAL AND NEUROLINGUISTIC THEORY

In his last manuscript edited and published by Michael Cole "The Making of a Mind" (Luria 1979), Luria argued that different parts of the brain are responsible for different components of verbal activities and that different components of verbal communication suffer as a consequence of different localized brain lesions. Consequently, neuropsychology is valuable not only as a specific branch of science in and of itself, but also as a special means for studying components of verbal communication. New insight may be brought to basic linguistic problems that cannot be solved by pure linguistic analysis, if they are approached from a neuropsychological point of view.

Luria's early work with Vygotsky in the psychology of development and language had given impetus to his medical studies and built the background for his work in neuropsychology. In Luria's own words, the observations made during the Second World War resulted in a much better understanding of the "morphology" of higher psychological processes in terms of both their inner structure and of the role that separate parts of the brain play in their neural organization. Much insight was gained by way of a new method of investigation that had been developed by Luria. The goal of the investigation was to understand the symptoms of disturbances of higher cortical functions but also to "qualify the defects", i.e. to analyze the factors underlying behavioural disturbances.

The concept of the higher psychological processes as being social in their origins, structured through initiation of speech and functioning consciously in a selfregulated manner set the framework for the investigation. The observation that separate parts of the brain played specific roles in behaviour was taken into account in building the stages of the investigation. Behavioural acts were considered complex functional systems not localized in narrow circumscribed brain areas, but rather depending upon the coordinated participation of groups of interrelated functional areas, each making its own particular contribution to the entire functional system. A voluntary movement, a visual observation or a speech act represent such functional systems in which cerebral structures participate in an integrated and complex way. Every functional area gives its own contribution to the whole functional system. Depending upon which area is damaged, the specific disturbance of the functional system will manifest itself in different ways and the structure can be identified only after a detailed analysis of the symptom.

In concordance with this, Luria's work represents an attempt to develop a theory of language as a functional system and a concern with the component processes involved in the uses of language. Luria's approach has much in common with and seems an important precursor of modern neurolinguistic analyses of aphasic language disturbances. Neurolinguists view the language capacity as decomposable into components or modules whose nature and interactions are the objects of study (Fodor 1983). In both Luria's approach and in modern neurolinguistics, dissociations and associations of impairments arising after brain damage constitute data for componential analyses of psychological functions.

However, Luria differs from modern neurolinguistics in some important respects. Neurolinguists consider language to be special in the sense that it requires its own descriptive vocabulary and cannot be fully accounted for in sensorimotor or general cognitive terms. Within modern neurolinguistics, hypotheses about the components of language are therefore derived from psycholinguistic models or linguistic theory.

While Luria advocated the introduction of linguistic analyses as a powerful tool

in the study of aphasic language deficits, his position regarding the special nature of language appears to be intermediary between the modern neurolinguistic position and so-called holist positions, as exemplified by Goldstein, who viewed language as a second-order symbol system (Arbib and Caplan 1979). In Luria's theory, psycholinguistic activities (e.g. reading, word recognition, naming, etc.) constitute complex functional systems whose subcomponents can be characterized to a large extent in sensorimotor or general cognitive terms. Although there may be subcomponents which are special to language, Luria's general approach is to emphasize the association and interaction between linguistic and non-linguistic functional systems.

It seems that in the final analysis Luria's goal was to be able to relate linguistic behaviour to sensorimotor and to cognitive non-language behaviour. However, it may be precarious to do so without an intermediary level of psycholinguistic description, because one is apt to ignore the complex structure of language. Luria has been criticized on this account, i.e. for a preoccupation with sensorimotor aspects and a simplification of linguistic behaviour (Hatfield 1981).

Modern neurolinguistics is based on sophisticated models of language and is not likely to be met with the same criticism. However, in the preoccupation with structural descriptions, neurolinguists sometimes neglect the performance or processing perspective on the language capacity which Luria showed a clear awareness of in his writings. In recent years, systematic empirical studies of aphasic subgroups have brought new evidence about the nature of the normal language processing system. As this research progresses, Luria's neurolinguistic work may be expanded.

Luria also differs from modern neurolinguistics on another important question, pertaining to the level of theory construction. In Luria's theory, the neural substrate of functional systems is a constellation of activated areas and interactions between these. The components of a functional system are psycho-physiological in the sense that they are assumed to have a discrete and specific localization in the brain. Recent developments in neurolinguistics create distances to any specific theory of localization or neurophysiology. The components sought are psychological rather than psycho-physiological and their neural instantiation is considered to be a separate issue. Blood flow studies (Lassen et al. 1978) show that many areas of the brain are activated during complex psychological activities and therefore support Luria's notion of a whole working brain and dynamic patterns of activity across different cortical zones. However, recent findings concerning neurochemical circuits of cortical areas (Finger and Stein 1982) suggest that changes in our understanding of the relationship between anatomy and function may be under way. As our knowledge in this area increases, Luria's theory about anatomy and function may have to undergo revisions.

LURIA'S NEUROPSYCHOLOGICAL EXAMINATION

Luria's neuropsychological testing is described in *Higher Cortical Functions in* Man (Luria 1966) as well as in Luria's Neuropsychological Investigation (Christensen 1974). His neurolinguistic testing and its theoretical background are also described in Traumatic Aphasia (Luria 1970) and in Basic Problems of Neurolinguistics (Luria 1976).

The first stage of the investigation is a preliminary conversation. In this stage, attention is focused first on the state of consciousness of the patient and his orientation with respect to time and place. The areas of the brain which need to be active in order for these functions to be performed are primarily the reticular formation and the deeper structures. Next, as much information as possible is obtained regarding the patient's premorbid level. Here mnestic functions play an important role. In the third part of the conversation self-awareness and self-evaluation (primarily frontal lobe functions) are concentrated upon. The fourth part, illuminating the subjective complaints of the patient, has a varied localizing value depending upon the specific symptoms noted by the patient.

In the second stage of testing, attention is directed to the primary areas, the motor, the auditory, the visual and the tactile areas. In order to provide the most extensive information, these tests have to be simple and short. The purpose is to clarify the integrated components through a qualitative analysis.

In the third stage the testing will be selective. The tests are chosen to illuminate and determine the disturbances that have been shown in the earlier stages of the investigation. In the selection of the tests, awareness of the components is necessary in order to secure the qualitative analysis of the patient's performance. Thus, the general strategy is to test complex activities and to vary mode of response, rate or mode of stimulus presentation, memory requirements or stress-factors such as time limits on responses in order to establish the circumstances under which the patient fails and succeeds.

The final part of the investigation is stage four, where the formulation of a clinical-neuropsychological conclusion is made. The disturbed, as well as the intact functions, have to be discerned. The fundamental defects must be identified; the influence of the defects on various forms of mental activity must be illuminated in order to discriminate the pathopsychological factors underlying the defects.

The reliability of the conclusion can be ensured by syndrome analysis, i.e. by a comparative analysis of the results of the group of assorted tests and a determination of the general signs among these results which converge on a specific syndrome. Through this method of administration and analysis, the neuropsychological examination becomes an experiment conducted by the examiner; the results

are thus obtained, not only by distinguishing the functional mental defect, but also by demonstrating how this defect manifests itself in changing activities and symptoms.

In the investigation of the *motor* function, first the motor function of the hands is examined. Secondly, an examination of oral praxis follows. The more complex motor functions where speech can regulate the motor act are examined last.

The initial tests are simple, i.e. the patient is instructed to touch each finger in turn with his thumb. In a more complex variation of the test the patient can be instructed to count the fingers at the same time. The task of the investigator in this test is to pay attention to the muscle power and tone, to the kinesthetic afferent impulses that direct the motor efferent impulse to its proper destination and to observe the motor control of the movements. Inclusion of coordinates of external space (up, down, right, left, near, far) will provide information about the opticspatial components of the system. The same procedure is followed in the examination of the tongue, lips and face. The main purpose is to differentiate disorders of the peripheral innervation of the articulatory apparatus from aphasic disturbances. Simple movements such as to show the teeth, to puff the cheeks or to frown, kinesthetic movements and dynamic organization as well as integrative oral praxis are examined. An example of a more complex task in the examination of speech regulation of movement is conflict reactions: the patient is asked to show his finger when the examiner shows his fist and vice-versa.

The subtests included in the investigation of *acoustic-motor* organization have to do with perception and reproduction of pitch relationships and rhythmic patterns. Implied in these tasks are a precise serial organization and a "motor" melody, in which the sequence is based on time intervals, acts for which the convexity of the temporal lobe is considered especially important.

Investigation of *cutaneous sensation*, muscle and joint sensation and stereognosis is performed in order to clarify the state of the structures responsible for cutanco-kinesthetic functions. Usually, vision is excluded to prevent participation of the visual receptors.

The investigation of the higher *visual* functions is not only aimed at the primary visual area but also at the complex processes inherent in visual analysis and synthesis. Included in this section are tests of perception of objects and pictures and of spatial orientation and intellectual operations in space. A number of variations in the testing method can ensure insight into the directions and implications of specific processes taking part in the subject's performance and in this way the need for a qualitative analysis can be obtained.

The examination of *language* is organized into subtests corresponding to the classical psycholinguistic faculties: impressive speech (auditory comprehension), expressive speech (production), reading and writing. This organization is didactic NEL 4/1-J

rather than theoretically motivated. In Luria's theory a psycholinguistic ability such as auditory comprehension does not have a discrete localization in the brain, but constitutes a dynamic and highly complex functional system which requires the participation of several (cortical and subcortical) areas. Furthermore, the functional systems underlying psycholinguistic activities like speech perception and speech production may share components with each other and with some nonlanguage behaviours. In accordance with this, the investigations of mnestic and intellectual processes include subtests which are highly language-dependent and of interest from a neurolinguistic perspective.

In the investigation of *impressive speech* (auditory comprehension), four levels are examined: phonemic hearing, word comprehension, understanding of simple sentences and understanding of so-called logico-grammatical structures.

The subtest of phonemic hearing varies the complexity and memory load of a speech discrimination task by requiring the patient to repeat single sounds or a series of these and to distinguish consonants differing in one (e.g. "p" and "b") or in several distinctive features. To determine articulatory errors, alternative modes of responding are explored: asking the patient to write or point to letters, making same-different judgements either by responding "yes"/"no" or by a specific hand movement conditioned to occur to one of the sounds.

There are some points, however, on which this task may be criticized. For one thing, Luria's suggestion to have the patient discriminate isolated consonants is impracticable since the phonetic realization of consonants depends on the following vowel. It would be preferable to have the patient repeat and discriminate syllables instead. Secondly, since Luria intends to test the discriminative abilities of the areas involved in auditory analysis, it would be in concert with his theory to test a wider and more systematic range of acoustic correlates of phonetic structure. It is outside the scope of this paper to review Luria's theory of "phonemic hearing" and his claims about its disruption in sensory aphasia. It should be noted, however, that this theory has been criticized (Blumstein 1981) and that it remains unclear how speech discrimination ability relates to measures of general auditory comprehension.

The test of word comprehension requires the patient to point to objects representing the meaning of a single word spoken by the examiner. The difficulty of the task is graded by varying the number of words spoken at a time, the number of alternatives from which the patient must choose or by naming objects which are not within his immediate view. One of the word identification tasks requires careful phonetic discrimination (e.g. "cat" — "bat"), which according to Luria would be expected to cause difficulty for sensory aphasics. The inclusion of a task requiring subtle semantic discriminations might be a useful addition (Baker *et al.* 1981).

The test of understanding simple sentences includes matching phrases or sen-

tences with pictures and carrying out verbal commands. Most of the items are constructed so that their meaning cannot simply be inferred from the individual words, but require an appreciation of the sentence structure (e.g. pictures of stove, firewood and matches: "Show me what is used to light the fire").

The comprehension of more complex linguistic structures are examined in the subtest of logico-grammatical structures. The subtest examines the patient's ability to understand relationships signalled by word order or prepositional phrases (e.g. "point to the key with the pencil"), as well as genitive constructions (e.g. "point to the daughter's mother"), comparative constructions (e.g. "John is taller than Peter — which boy is shorter?") and prepositional constructions involving spatial relationships ("draw a circle beneath a cross"). Finally, the patient is asked to interpret reversible passives (e.g. Peter struck John — who was the victim?"), before-after sentences ("I had breakfast after I read the newspaper — what did I do first?") and complex sentences with embedded relative clauses (e.g. "The woman who worked at the factory came to the school where Margaret studied to give a talk — what did Margaret do?").

Although it remains unclear how deficits in the short term retention and retrieval of verbal material intersects with knowledge of language and its uses, it is generally assumed that a restricted verbal short term memory may be the source of some aphasic impairments. Luria's investigation of *mnestic processes* includes subtests which examine memory functions in specific modalities (e.g. acoustic, verbal and visual) and at different levels of coding. In the verbal subtests, the patient is required to remember and reproduce a series of unrelated words and the results can be compared with similar tasks in other modalities, e.g. the retention and retrieval of sequences of rhythmic taps, a series of hand shapes or of geometric shapes.

The investigation of *intellectual processes* does not provide subtests of non-verbal intelligence (these are included in the investigation of higher visual functions), but it is a useful test of disturbances in lexical-semantic knowledge which have been shown to occur in many aphasics with posterior lesions (Grober *et al.* 1980) and of conceptual inferences, which many linguists consider part of language comprehension. Thus, the patient is asked to listen to or read a short story or a fable and afterwards the examiner asks questions about the content. The patient may also be asked to explain the meaning of metaphors and proverbs or choose a sentence or phrase to match the meaning. The integrity of semantic concepts is tested by requiring the patient to give an explanatory definition of words denoting common objects or entities (e.g. "bed" or "island"), to state what two such words have in common or to indicate how they differ (e.g. "fox" and "dog"). Other tests require the patient to state the super-ordinate term for words like "a rose" or, conversely, to produce instances of members when given the super-ordinate category, e.g. "furniture". Further tests include the production of antonyms (e.g. tall: "short") and

naming of the parts of an object when given its name (e.g. knife: "blade", "handle") and vice versa. For patients with expressive difficulties, the examiner may adjust the mode of responding by providing alternatives from which the patient may choose.

The investigation of *expressive speech* also comprises four subtests: articulation of speech sounds, repetitive speech (repetition), the nominative function of speech (naming) and narrative speech.

The test of articulation requires the patient to repeat vowels and consonants, consonant clusters and open or closed syllables. As in the test of phonemic hearing, syllables would be a more felicitous choice rather than attempts at isolated sounds. The examiner notes the clarity and ease of transition in the patient's pronunciation and examines whether the patient can make use of auxiliaries such as a mirror or comparisons between sounds and non-verbal oral gestures (e.g. blowing out a match). For some patients with anterior lesions, repetition is usually less distorted than spontaneous speech (Goodglass and Kaplan 1983). Accordingly, it would be preferable for the examiner not to restrict observations of articulation to this task, but also to note the patient's pronunciation in the subtests on naming and narrative speech.

In the repetition test with single words, length and familiarity of meaning are varied. The patient is also asked to repeat short lists of unrelated words, which can be compared with repetition of sentences of varying length and complexity. The examiner may vary the rate or mode of presentation (letting the patient read the words) and he may allow the patient to repeat promptly or only after a brief pause.

In the naming test, the patient must name visually presented objects, pictures of objects and parts of the body. He is also asked to provide the name after listening to the examiner's description of an object and to produce the super-ordinate or category term when shown some of its members. The examiner is instructed to take note of the usefulness of different methods of cueing such as prompting by initial sound, silent mouthing of the word and providing a semantically appropriate context.

The investigation of so-called narrative speech tests the preservation of automatic sequences, simple conversational answers to questions pertaining to the patient's situation, the patient's description of a picture and his retelling of a short narrative which has been read to him. In more advanced tasks, the patient may be asked to tell a story which he knows, e.g. "Little Red Riding Hood" or to make a speech on a selected topic. The preservation of grammatical structure is tested more formally by asking the patient to select the correct form of missing words in sentences or short phrases from grammatically acceptable and unacceptable alternatives. He may also be asked to construct a sentence incorporating some words chosen by the examiner and he may be asked to do an anagram task, where he has to rearrange words on cards into a complex sentence.

The investigation of *reading and writing* is preceded by an examination of "phonetic analysis and synthesis of words". This is in accordance with Luria's theory that the functional systems of both reading and writing depend crucially upon phonological skills and knowledge of the phoneme-grapheme correspondence. The patient is asked to indicate how many sounds there are in a given word, which sounds occur and in what order they occur in relation to each other. The synthesis of phonemes into syllables is tested by asking the patient to say what syllable or word is made by a series of isolated sounds (e.g. "s" and then "o" and then "n"). The examiner is instructed to note if the patient carries out these tasks immediately "in his head" or if he does it in a piecemeal fashion while saying the word.

Writing is examined by asking the patient to copy letters and words from a model within view or after exposure to a model which is subsequently removed. Automatized writing skills such as the patient's signature are tested. The subtest of reading reflects Luria's view that reading involves phonetic recoding. It is predominantly a test of reading aloud rather than reading comprehension without vocalization. This appears to be a weakness, also in the light of Luria's own view that the association of semantic content with visual word images plays a role in the functional system underlying advanced reading. A subtest of reading assessing whether any skills of this kind might be preserved, e.g. in patients with expressive aphasia, would make a useful addition.

Luria's subtests of language cover a wide range of linguistic levels, including speech discrimination and articulation, syntactic knowledge in comprehension and production, semantic-conceptual knowledge, comprehension of metaphors and stories and creative narrative abilities. From a psycholinguistic perspective, however, Luria does not bring his analysis of linguistic abilities as far as to consider how the different components interact. Thus, a more detailed and precise analysis of the contribution of each component is lacking. Finally, although Luria has adopted many of Jakobson's hypotheses about aphasic language impairment (e.g. Jakobson 1973) and frequently referred to a differential breakdown of syntagmatic and paradigmatic processes, his language tests do not evaluate these factors specifically.

Luria's neuropsychological and neurolinguistic teaching is based on his general theory of brain-behaviour relations, which emphasizes the overlap between different functional systems, the difficulty of testing isolated components and the necessity to examine the complex and dynamic interrelations between components. Although Luria's subtests often appear to confound different skills with one another, e.g. by requiring the patient to repeat/articulate to show that he has discriminated or to produce an explanation to show that he has comprehended, the

sources of failure are established by varying the task parameters and by making the subsequent syndrome analysis of the patterns of breakdown across different subtests. In Luria's approach, the crucial point is not whether or not a patient succeeds on a given task; rather, the manner of administration requires the examiner to pay attention to *how* the patient fails and *how* he may succeed. Thus, the most characteristic aspect of Luria's neurolinguistic and neuropsychological testing is the manner of administration and the theoretical interpretation made by the examiner.

It is especially with a view to rehabilitation that Luria's methods offer the examiner a valuable tool. In the following we shall present a case to illustrate the principles of testing and rehabilitation.

CASE PRESENTATION

History

The patient was born in 1945 in Denmark. He worked as a teacher at a training college for nursery school teachers and was employed periodically as a co-director at different theatres. His main interest was music and he also worked professionally as a composer. He had been married twice and had 3 children from his two marriages. In 1975 he was separated from his second wife and began consulting a psychiatrist due to periodic depression. The following year, without any previous illness, he suddenly developed an occlusion of the left carotid artery resulting in right-sided hemiparesis and severe aphasia. A psychological examination concluded that his non-verbal intellectual functions were preserved and that he handled his situation in an emotionally adequate manner. He was treated with physiotherapy and was seen by a speech pathologist but decided rather quickly to give up his speech training. He then began living alone in his own home with daily assistance provided by the municipality.

He has devoted his time to music and has been successful in redeveloping his skills as a composer. Although he has been able to use music as a means of expression, the lack of language gave him a deep sense of loss. Ten years after the stroke at the age of 41 he made the decision to begin a language rehabilitation program at the Center for Rehabilitation of Brain Damage, University of Copenhagen.

Neuropsychological Examination

After initial examination with Luria's Neuropsychological Investigation and consequent periodic (due to geographic distance) treatment for one year, a recent

re-evaluation was performed and regional cerebral blood flow (rCBF) measurements were taken at the Neurophysiological Laboratory at Lund University.

From the first stage of the investigation it became clear that awareness and orientation were normal. The premorbid level of function was judged to have been above normal, given his interests and energy. Furthermore, motivation and feelings were illuminated.

Investigation of the function of the primary motor areas showed a paretic right hand while the motoric function of the left hand was natural in all respects. The patient was handling all practical and functional activity effectively with his left hand. The tactile, kinesthetic functions in the left hand were normal with respect to sensation and differentiation whereas more fluent functions could not be voluntarily performed. In drawing, every line in a pattern was completed separately; a fluent melody of movement was not possible and the same was true for the patient's writing, where every letter was printed separately. There was no perseveration and an initiated movement was carried through in a determined and controlled manner.

The examination of oral praxis was affected by a slight right-sided facial paresis. Decreased kinesthetic sensitivity from the speech apparatus was demonstrated.

Auditory perception and reproduction of acoustic signals were intact and the rhythmic structuring was particularly efficient.

Testing of the primary visual areas did not give evidence of disturbance. Visuomotoric and visuo-spatial tests were performed in a careful and controlled way. However, slight difficulties with respect to evaluating relational conditions as well as sequence could not be ruled out.

In the examination of arithmetics it was shown that the patient counted automatically in a rhythmic sequence, but he could not name individual numbers. He could write numbers and wrote the date as well as his own personal data correctly. He drew a graph of his progress during treatment, reflecting the endurance of his premorbid motivational state as well as his intact spatial abilities.

The patient was very communicative and made use of intonation, pantomime, drawings and writing of visually preserved words such as names of places or institutions. Speech consisted almost exclusively of single word utterances. His vocabulary included affective words (in English: "great", "wow-wow", "bad", "auch-auch"), nouns and adjectives ("coffee", "morning", "music", "year", "sick", "tired", etc.) and uninflected verbs ("smoke", "sleep", "work", etc.). These words were produced spontaneously and without effort. The patient frequently used intonation or repetitions to modify the meaning (e.g. "year-year" was repeated in order to signify "several years ago"). A neologism [kon-nu] was used as a stereotype with various meanings, e.g. "pardon!", "wait a minute!", "okay?".

In testing voluntary speech production by repetition of syllables, the patient's

articulation was distorted and slow. Polysyllabic sequences could only be produced if the patient was allowed to observe the examiner's articulation and if he pronounced the syllables simultaneously. Repetition of single words was only successful in half of the attempts and repetition of phrases and sentences was not possible. Naming of drawings caused difficulties, articulation was slow and distorted and there were delays in responding. When failing to retrieve the proper word, the patient produced substitutions to indicate that he knew the meaning or concept in question (e.g. for chair: "table, bed, but no!"). If asked out of context to produce words, which were part of his spontaneous repertoire, articulation was laboured and distortions occurred. The patient was quite aware of and rejected these distorted attempts. Thus, his voluntary speech production was severely affected and one might suspect that his active vocabulary of largely affective words and phrases, which were fluently produced and intonationally varied, may have depended on retained right hemisphere functions.

In natural conversation it was clear that the patient exploited his adept perception of social situations and often relied on guessing rather than genuine verbal decoding. In the tests of auditory comprehension, the patient had difficulty discriminating between similar vowels and consonants. Common nouns and verbs could be discriminated in an array of pictures or objects, but parts of the body, numbers, letters and colours caused difficulty. Short commands were carried out correctly, but if the number of clements was increased or if the commands were less predictable, the patient performed based on guesses. In the comprehension of logico-grammatical relations such as genitive constructions and passives, the patient had severe difficulties.

The patient often displayed an attitude of aesthetic judgment about language and, as he attempted to learn or repeat words, he expressed pleasure or displeasure with their sound. He knew some English, a little German and French prior to his aphasia and he had lived in areas of Denmark where dialects are spoken. In spite of his severe aphasia, he quite spontaneously and very successfully imitated intonational characteristics of these languages or dialects as well as certain phonetic features which sound prominent to the Danish ear.

The purpose of testing was to uncover the patterns of lost and retained psychological functions with a view to establishing not only the extent of overt behavioural deficits but charting the remaining abilities which might be enlisted in rehabilitation.

The strategies for remediating the patient's severe speech production difficulties have been designed to capitalize on his retained intellectual, visual and musical abilities, which were demonstrated in the test. The training of the patient has involved working on a more analytical attitude to language including the development of phonological awareness. Voluntary articulation guided by visual diagrams of the vocal tract has been trained and, more recently, melodic intonation therapy has been included (Sparks and Holland 1976).

RCBF Study

The regional cerebral blood flow (rCBF) of the patient was measured on 20 October 1986. The measurements were made by the 133Xe-inhalation method using a newly developed high-resolution recording system (Cortexplorer, Scan. Detectronic Inc, Hadsund, Denmark). All superficial parts of the cerebral cortex were measured by means of 254 scintillation detectors giving a spatial resolution of about 1 cm. The reader is referred to Risberg(1987) for details about the system and the method of flow calculation. The blood flow parameter used here is called the initial slope index (ISI).

The first measurement (Figure 1) was made while the patient was resting with eyes covered in a silent laboratory. The global ISI-level was within the normal range. A pathologic asymmetry was, however, seen with about 15% lower flow level in the left hemisphere compared to the right. Regionally marked focal decreases of flow were seen in temporal, fronto-temporal and temporo-parietal parts of the left hemisphere. The flow distribution of the right hemisphere was normal with the exception of a small temporal-central region of focally decreased flow.

Figure 2 shows changes of the blood flow distribution from rest to activation by ordinary speech training. The therapist thus had the patient perform a 10 minute training programme while the rCBF was measured. The training task consisted in repeating short phrases of sentences spoken by the therapist. A major area of increased flow (increased neuronal function) is seen in left fronto-temporal areas most likely including the major speech area of Broca. Temporo-occipital and occipital areas of the left side are also activated together with prefrontal areas of the right hemisphere. Other parts of the right hemisphere did not show any flow increases during activation. Figure 3 shows changes of the rCBF-distribution during melodic intonation therapy, where the patient repeats phrases or sentences by chanting/singing them following the model provided by the therapist. Compared to rest again fronto-temporal areas on the left side show elevated flow together with occipital and temporo-occipital areas. The latter areas show larger increases than during ordinary speech training and a central-premotor area of the left hemisphere also shows some increases. The major difference between musical and ordinary speech training, however, seems to be an added involvement also of right temporal and fronto-temporal areas.

The rCBF-investigation thus shows marked focal flow decreases in language areas of the left hemisphere. The flow pathology found is typical for patients with cerebral infarcts due to occlusion of the left carotid artery. The changes of rCBF found during ordinary speech training show that fronto-temporal areas of the left hemisphere can still be activated during speech production. The Broca area seems thus to be at least partially functioning. The right frontal increases during ordinary speech training are a little more difficult to interpret. They might be related to activation of mechanisms for control or attention not directly involved in speaking. The most interesting finding is the greater involvement of the right hemisphere during musical speech training. This activation might indicate a greater participation of the right hemisphere during this form of speech production. The interpretation of the finding can only be tentative but might be that, for this subject, speech production according to the musical method makes the most use of the intact parts of the cerebral cortex. Whether this training method will also be the most efficient in retraining functional language is a different question.

CONCLUSION

Luria's goal was to provide a principled approach to testing and rehabilitation, based upon an understanding of the factors underlying complex psychological activities and derived from observations and studies of normal and pathological populations.

It is obvious and quite in Luria's own spirit, that as our knowledge of the psychological mechanisms underlying complex human behaviours increases, the analyses offered in Luria's work of the past decades will need revisions. Controlled empirical studies of specific deficits in brain damaged populations are providing new evidence and insight into normal and pathological function and may lead to the incorporation of more detailed and explicit models in Luria's work. Theories of anatomy and function have made progress and are changing our understanding of brain-behaviour relationships.

However, as necessary revisions of Luria's theory evolve, the value of his explicit and coherent theory of brain function and of his commitment to a principled approach to diagnosis and treatment becomes increasingly clear.

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NOTES

1. Please send all correspondence and reprint requests to: Anne-Lise Christensen, Director of Center for Rehabilitation of Brain Damage, University of Copenhagen, Njalsgade 88, DK-2300 Copenhagen, S. Denmark.



LT 41.7

RT 47.0

Figure 1. The Regional Cerebral Blood Flow (rCBF) in the Case Presented. The Measurements were made with the ¹³³Xe-Inhalation Method and a High-resolution Instrument (Cortexplorer). A Vertex View is Shown with Elevation of Frontal, Temporal and Occipital Areas Giving a Display of all Parts of the Superficial Cerebral Cortex. The Colours Show each Regional Value in Per Cent of the Mean of all Regions. The Hemispheric Means (ISI-Parameter of Cortical Blood Flow) are Shown at the Bottom of the Figure.

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Figure 2. Changes of the rCBF-Distribution from Rest to Activation by Ordinary Speech Training. Red Areas have Higher Values During Speech Training than During Resting.



Figure 3. Changes of the rCBF-Distribution from Rest to Activation by Musical Speech Training. Symbols as in Figure 2.

LT -0.7

RT -3.1

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