# CHAPTER 3

# LURIA'S NEUROPSYCHOLOGICAL THEORY OF FUNCTIONAL ORGANISATION IN THE HUMAN BRAIN

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## 3.1 Historical Background

Attempts to understand and explain the cerebral mechanisms of human cognitive activity can be generally classified, prior to the last 20 or so years, as stemming from two basic lines of enquiry, each with its own theoretical assumptions.

In 1861 Broca demonstrated that lesions of the posterior sector of the inferior frontal convolution of the left hemisphere in the human brain were associated with disturbances of articulated speech and argued in consequence that this particular area was the centre of motor speech-forms. Wernicke in 1874 described a case where disturbances in speech comprehension, but not expression, were associated with a lesion in the posterior third of the superior temporal gyrus of the left hemisphere, and concluded in like manner that sensory images of speech were localised in that cortical zone, naming it the centre for the understanding of speech (see Fig. 3.1). These discoveries stimulated considerable subsequent research concerned with identifying the specific functions located in different areas of the brain.

At the same time physiological investigations began to reveal the cellular complexity of the cerebral cortex. Fritsch and Hitzig in 1870 showed that electrical stimulation of the cortex of the anterior central gyrus in the brain of a dog produced the repeated contraction of certain muscle groups. Soon afterwards Betz (1874) identified large pyramidical-shaped cells in that area and their presence thus came to be associated with the control of motor functions. Further research utilised the technique of extirpating selected areas of the cerebral cortex in animals and then observing subsequent gross disturbances in behaviour. As a result, the existence of distinct cortical centres for a variety of motor and sensory functions came to be accepted.

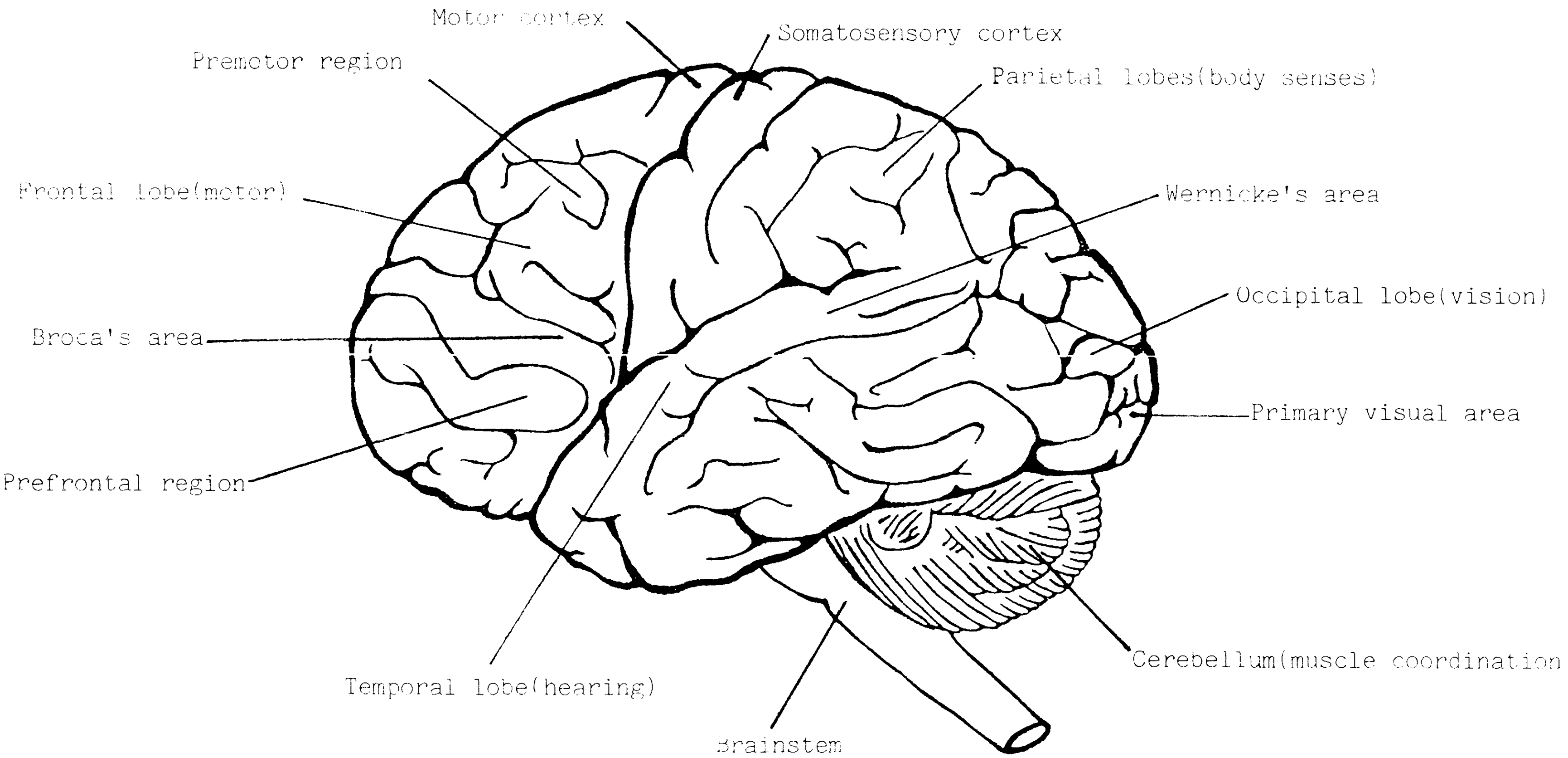



Figure 3.1 Gross anatomy and major areas referred to in the text(left hemisphere view of the brain).

Not surprisingly disturbances in complex mental functions, following Broca and Wernicke, were similarly attributed to lesions in specific areas of the brain and on that basis the principle of localisation of functions was established. Centres of "visual memory" (Bastian, 1869), of "writing" (Exner, 1881), and a "calculation centre" (Henschen, 1920) were charted and described. The culmination of this narrow localisationist approach, in which complex mental functions were rigidly consigned to clearly delineated cortical areas, is exemplified in the writings of Kleist(1934) with the presentation of detailed brain "maps". In these the cortex has been precisely demarcated into segments with labels such as "sentence construction", "memory of place", "visual attention", and "reading".

Hughlings Jackson (1869, 1884) had warned however of the dangers inherent in identifying the localisation of a particular function with the localisation of symptoms associated with the impairment of that function through area-specific lesions. His studies had indicated that in fact a lesion of one circumscribed area rarely produced the total loss of a function. He argued instead that complex mental processess were not the responsibility of a locally-defined group of cells but rather represented the interaction of different levels of neurological organisation, hierarchically-structured within the brain. Each function was initially activated at the 'lowest level' in the brain-stem, was then represented in the motor and sensory areas of the cortex, and was finally organised at the 'highest level' in the frontal brain divisions. Jackson's theory was far in advance of other neurological hypotheses current at that time.

The continued analysis of brain functions through association with lesion location had in the meantime come upon an apparent contradiction. It seemed that in certain cases the location of the lesion was less important in terms of consequent functional impairment than the size of the brain area destroyed. These findings, together with a limited interpretation of Jackson's stance against the principle of narrow localisation, gave rise to the holistic or gestalt line of enquiry with its opposing principle of equipotentiality. This stated that the brain works as a single entity, that different cortical areas contribute equally to higher mental functions, and that if damage occurs in one section of the brain then impaired functions are recoverable through utilisation of other areas (Goldstein, 1948).

The resolution of the conflict generated by these supposedly irreconcilable theoretical principles was achieved in Soviet neuropsychology by a revision of the concept of mental function. This in turn led to the recognition that higher psychological functions in man are not simply the result of innate cortical structures in designated centres of cells, nor of abstract symbolic activity within an undifferentiated brain mass, but rather are dynamic functional systems involving the joint operation of various constituent units within the brain, and are formed through interaction with the environment.

## 3.2 Functional systems

Luria (1966a; 1966b; 1973) considered that a major reason why the principle of narrow localisation become untenable in relation to higher mental functions was confusion over the meaning of 'function'. Anokhin (1940) and Vygotsky (1934) had discerned two distinct applications of the term.

One use in physiology relates to the purpose of a particular tissue. In this sense it is the function of the kidney to eliminate urine, the function of a muscle to contract, and the function of the pyramidical Betz cells in the cortex to generate motor impulses. Such functions specify direct activity and are not generally amenable to change.

However, in the physiolcgy of higher nervous processes, in biology and in psychology, 'function' is used to denote a complex system within a living organism resulting from adaptation to environment and directed towards the fulfilment of an interactive task. Examples are the respiratory function, the digestive function, the functions of perception and voluntary attention. Such intricate adaptive systems rely on the combined actions of different structural units.

The function of respiration, for instance, normally involves a dynamic arrangement of nerve cells differentially employed within the nervous system. A rise in the concentration of carbon dioxide in the blood stimulates cells in the brain stem which in turn produce excitation in corresponding cells at lower levels in the spinal cord, a consequence of which is that the intercostal muscles and diaphragm are caused to contract. As the contractions increase in strength and frequency, breathing becomes faster and more oxygen is absorbed. Once the concentration of oxygen in the blood stream is sufficient to meet the demand from those areas of the body which are expending it as energy, a similar network of nervous connections reduces respiration to a slower cycle.

In this sense, then, it is more correct to speak of a functional system (Anokhin, 1940; Vygotsky, 1934) based on the interconnected operation of diverse components. This concept of 'function' has been comprehensively applied to the analysis of higher mental processes by various Soviet researchers, and has led to a radical reappraisal of evidence concerning the cerebral basis of cognition. In particular four pivotal implications have emerged.

### 3.2.1 Variable interaction of components

Bernstein (1947) made the case that one of the basic features of a functional system was the presence of a constant task which led to an invariant result, but through the variable interaction of component mechanisms.

In the example of respiration, the constant task is the maintenance of equilibrium in the face of changing conditions i.e., homoeostasis. The ultimate and invariant result is the absorption and delivery of oxygen by the bloodstream. However, the components of the system may achieve that effect in a number of ways, for although there may be a regular chain of interactions between them, this is not immutable. Interference or damage to links in the chain produces adaptation within the system through substitution or reorganisation of the intermediate links between components. Impairment of the diaphragm's motor nerve, for example, may lead to the compensatory mechanism of increased activity among the intercostal muscles. Thus if the invariant end-product is not achieved through 'normal' system functioning, feed-back signals attempt to reactivate the functional system as a whole through an amended contribution from components.

Luria (1963) extended this work to encompass the examination of complex mental functions, especially the restoration of higher psycho-physiological functions after the destruction of localised brain areas. It became evident that, despite irreversible damage to brain substance, autoregulatory capacity ensured that in many cases some restitution of the impaired functional system occurred through the reorganisation of component processes within the cerebral cortex. While initially executed with difficulty, and rarely achieving the operational flexibility and smoothness of the original systematisation, such recovery from functional disorder was possible, and Luria (1963; 1966a; 1966b; 1970b; 1973a; 1976a; 1976b) demonstrated that it could be greatly assisted once the concept of a functional system had been understood and applied in neuropsychology.

### 3.2.2 Dynamic localisation

Functional systems within the human brain involve constellations of widely-dispersed ganglion cell connections responsible for integrative activity which varies according to the nature of task demand (Luria, 1973a). Such recognition obviously contradicts the ideas of both narrow localisation and brain equipotentiality, and goes a considerable way towards clarifying why neither approach was sufficient to explain the data on functional impairment following local lesions.

For example, the pursuit of isolated brain 'centres', while reasonably productive in the domain of elementary motor and sensory functions, was plagued with speculation and what at times appeared to be almost capricious uncertainty when it came to complex functional systems, since what was being sought was a precise location for a diffuse but coordinated performance. Pavlov, describing the quest for a 'respiratory centre' in the brain wrote:

> "From the very beginning it was thought that this was a point the size of a pin-head in the medulla. Now, however, it has slipped about a great deal, climbing up into the brain and falling down the spinal cord, so that nobody knows its precise limits." (Pavlov, 1949, Vol. 3, p. 127).

Luria himself used the analogy of a pendulum clock to illustrate the fallacy of assuming localisation for a complex function following the appearance of certain symptoms resulting from damage to a confined area.

Interference with or destruction of the pendulum will undoubtedly cause the clock to run inaccurately or to cease running altogether, but it is wholly inappropriate to localise the 'running' function of the clock in the broken pendulum (Luria, 1970b). He therefore argued that 'localisation of symptoms' should be considered only as the starting point to determine the dynamic localisation of the components involved in the whole function. Nevertheless, while a complete system drew upon different cooperating zones of cortical and subcortical structures, "each of the areas makes a highly specific contribution to ensure the operation of the functional system" (Luria, 1975b, p. 17).

Dynamic localisation of functional systems therefore has some important consequences for the study of disturbances in higher cortical processes. Damage to any component will disrupt the normal operation of a system. Damage to different components within the same system however will mean that a system will be disturbed in differing ways. Equally important is the realisation that since components may contribute differentially to a range of functions, a local brain lesion is likely to result in more than the mere disturbance of a solitary psychological function. Rather, a number of psychological activities are likely to be affected in different ways, while others remain intact.

Luria's important conclusion was that the detailed, qualitative analysis of the disintegrative systems amongst groups of cognitive functions following local brain lesions would identify the contribution of functional components from the damaged areas.

> "All processes the function of which is disturbed by a local brain lesion have a common factor, which is intimately connected with the function of the affected cerebral areas, while other intact 'functions' do not include this factor. Thus lesions in the lower parietal regions in the left hemisphere result in disturbance in spatial orientation...The opposite is the case in lesions of the temporal regions, where we find disturbances in understanding of language and in operations including successive processes, whereas the simultaneous (spatial) schemes are intact. These facts show that neuropsychological analysis opens up new ways to single out the factors on which the complicated psychological processes are based." (Luria, 1975b, p. 19).

### 3.2.3 External influences on development

Vygotsky (1934, 1960) considered that earlier attempts to understand the functional organisation of the brain had oscillated ineffectually between the principles of narrow localisation and equipotentiality not only because of an improper awareness of the dynamic localisation of functional systems, but also due to a disregard for their developmental aspects. Higher psychological processes distinguish man from the animals, and while elementary sensory-motor activities are direct functions of nervous tissue, this clearly cannot be the case for processes such as intentional memory and abstract thought. In order to fully understand these specifically human cognitive processes, argued Vygotsky, it is necessary to look outside the neurological limits of the human brain and to examine the adaptive mechanisms and "extra-cerebral connections" that were involved in their development.

Deliberate attempts to control psychological processes appear to be the preserve of human beings e.g., the tying of a knot in a string or handkerchief is a premeditated act to influence the process of memory (Luria, 1966a). The use of marks or objects to record quantity or time, the application of tools to create symbols, and the representation of images and signs for purposes of communication are not the result of 'natural' brain procedures, but are the complex products of social life which themselves will further influence the development of relevant cognitive functions.

> "Forming his behavior in association with adults, reconstructing it on the basis of using objects and speech, mastering knowledge, the child not only acquires new forms of relations to the external world, but even develops new means of regulation of his own behavior; he forms new functional systems permitting him to master new forms of perception and memory, new forms of thinking, new means of organization of voluntary acts." (Luria, 1965, p. 389).

The evolvement of new functional systems does not imply the growth of nerve cells or of additional groups of cells, but instead new tasks are effected through the development of reformed inter-areal relations between highly differentiated cortical zones. The progression of language use, for example, would presumably require new, complex functional relations between the auditory and sensori-motor cortical areas. The design and wielding of tools and instruments would likewise involve new systematic links between visual and sensori-motor zones. Higher psychological functions therefore come to be recognised as social phenomena in their origins (Luria, 1971a), derived from gainful participation in environmentally and historically determined experiences.

### 3.2.4 Functional change in development

Knowledge of the dynamic localisation of mental functions helped to resolve the previously enigmatic finding that damage to completely different areas of the cerebral cortex occasionally produced apparently indistinguishable disturbances. Having realised the social basis for the development of higher psychological activities, Vygotsky began to compare the organisation of functional systems in children and adults. Not only was it confirmed that identical syndromes in both cases may result from differently localised lesions, but conversely it appeared that lesions with identical localisation in children and adults could produce very dissimilar impairments.

Vygotsky postulated that if lesions of the same brain area at different stages of ontogenesis lead to different consequences it is because the relationships between individual components of the higher mental functions do not remain the same. In the early phases of development relatively elementary forms of mental activity e.g., direct visual or auditory perception, are the basis for the formation of higher mental functions. During subsequent stages, more complex systems of connections are formed as higher cognitive functions come to be influenced by external mediation and the development of speech, itself dependent on earlier elementary sensory analysis and integration.

So damage to a cortical zone responsible for components of an elementary mental activity in the brain of a child will not only directly affect that particular function, but will as a secondary result disturb the development of all the higher mental functions proceeding from it. The descriptor 'higher' can thus be taken to mean 'developmentally reliant on more elementary functions' (Luria, 1966b).

In the adult, however, in whom more complex functional systems are already operative, the same lesion will have a more limited effect, and this may eventually be compensated for by other differentiated systems of connections.

> "A lesion of the secondary areas of the visual cortex in early childhood may lead to systemic underdevelopment of the higher zones responsible for visual thinking, whereas a lesion of these same zones in the adult can cause only partial defects of visual analysis and synthesis, and leaves the more complex forms of thinking, formed at an earlier stage, unaffected." (Luria, 1973a, p. 33).

Elsewhere, Luria (1966a) described an adult patient with a circumscribed lesion in the occipital region of the cortex, which left a disturbance of visual synthesis such that the patient was unable to integrate discrete elements into a whole visual image e.g., to comprehend the subject-matter of a complete picture. Luria's investigation showed how this adult was able to utilise components of other already developed functional systems (e.g., speech) which had remained intact to make up for the visual defect. The patient attempted to 'decipher' the meanings of pictures by setting up hypotheses based on the verbal labelling of individually-perceived elements, and then confirmed or rejected them through comparison with subsequently identified individual features. A pair of spectacles, for example, might be only fragmentarily perceived initially as a circle, then another circle, and possibly a cross-bar. Hypotheses of a bicycle or spectacles at this stage might both be reasonable, with subsequent elimination as further separate features were identified.

In children, however, lesions of the occipital cortex gave rise to optic agnosia (disturbed visual perception) which also inevitably hindered the formation of higher forms of mental activity involving visual information processing. The restitution of the original function was therefore considerably more difficult, since other compensatory functional components not only were not already available, but may indeed have been causatively delayed in their development as a consequence of the selfsame lesion.

### 3.2.5 The example of writing

The process of writing may be used to illustrate functional systems whose complex operations consist of integrative tasks dependent on the interconnected organisation of cortical zones (Luria, 1966a; 1973a; 1979b).

The development of literary activities was undoubtedly linked to the progressive refinement of man-made tools and socially-defined need for transcribed communication. Different languages utilise different sound systems for communication which have arisen largely from socio-historical circumstances (Jakobson, 1971). To my knowledge for example, there are no words in the English language that begin with the sound dl, although in Polish there are a number of such words. Thus an English speaker attempting to learn the Polish language will often hear the more familiar 'gl' for 'dl' until taught to accoustically recognise the difference (one suspects that much intracultural humour dealing with the speech problems of outsiders reflects similar problems of transfer from a familiar sound system to an unfamiliar one). The procedures for writing down such diverse sound systems as well as the symbols to be used are again variable and culturally determined (see Gibson and Levin (1975) for an excellent cross-cultural survey of writing systems).

Analysis of the phonetic composition of speech flow is the usual starting point for the function of writing. Discrete phonemes need to be identified, and specific functional components in the cerebral cortex are responsible for the analysis and identification of acoustic-verbal information. If these are rendered inoperative, then errors in writing appear (Luria, 1970a) which can be accurately traced back to confusion in the process of phonetic analysis e.g., in English, the substitution of letters representing voiced as opposed to unvoiced consonants, such as b for p, g for k, v for f or d for t. Thus, although writing from dictation may be disrupted, the act of copying which does not require phonetic analysis will remain undisturbed.

Damage to cortical segments responsible for motor operations in speech may produce superficially similar errors in writing which can, however, with a more detailed examination, be traced back to problems of articulatory analysis. In these cases the patient's difficulty lies in distinguishing the differential articulation involved in pronunciation of required phonemes. Errors in writing therefore will occur due to transposition of phonemes with similar pronunciation e.g., 'articulatory' errors such as substitution amongst the labials b, p, m, or amongst the palato-glossals d, l, n, t.

Some cultural groups have bypassed the need for this kind of phonetic analysis in writing altogether, using instead ideographic transcription in which concepts are directly represented as symbols. In Chinese, for example, graphic ideograms or logographs, commonly called 'characters', are used to represent words, or more correctly, conceptual meanings. Each has a particular spatial configuration, they may be written from top to bottom and from right to left (although some modern stylists advocate a more Europeanised horizontal left to right order), and symmetrical rhythm in the flow of the written or 'painted' strokes is a critical feature of presentation. An individual concept may be composed of other symbols displayed in conjunction e.g., the character for 'medicine' can be made up of three visual components representing (a) a wound enclosing an arrow, (b) the extraction of foreign bodies with an instrument, and (c) the treating of wounds with a tincture (Leong, 1974).

It is not difficult to appreciate the greater emphasis on holistic pattern recognition in this system without the actual representation of sounds. Luria (1970a) has documented the fact that Chinese patients with severe damage to the cortical areas responsible for accoustic-verbal analysis have none of the difficulties described above in relation to their writing skills. In other words, writing, in their terms, does not designate specific sounds of speech but rather relies on a direct link between the ideas behind spoken words and a conventional graphic sign used to evoke them.

Naturally this has major implications for the process of learning to read and to write within such systems. Leong (1974) has drawn the distinction that whereas in English learning to read is learning by eye and ear, "learning to read in Chinese is largely learning by eye and hand" (p. 328). It is also not unusual for English-speakers to articulate a word out loud in order to assist with the process of accurately transcribing it, particularly in the early stages of learning to write. Luria (1970a) cites the case of a class of Russian elementary schoolchildren who during an early writing lesson were simply asked to immobilise their tongues with their teeth while they wrote. The results showed six times as many spelling mistakes compared to writing undertaken when the children were free to formulate words which, even allowing for the disruptive effect of a novel procedure, suggests strong links between articulation and transcription.

In alphabetic languages once correct phonetic analysis has been completed the appropriate visual unit or grapheme must be assigned to the identified phonetic stimulus. An injury to the occipito-parietal region of the cortex which is responsible for spatial operations (Luria, 1959; 1970b) will not affect the preceding stage of phonetic analysis but on the other hand errors will be evident in selecting the correct spatially-organised symbol to match a phonemic unit. Letters which share a comparable spatial design e.g., d, b, p, q, may be confused with each other and mirror-image misjudgements may occur.

The nominated visual images of letters must be recoded into a series of movements by means of which they may be recorded. Separate but co-ordinated motor acts are required to produce the shape of just one letter. With experience, movements become less discrete and more automated so that a whole letter is produced as an integrated sequence, then combinations of letters, and eventually familiar words are transcribed in a complex but unified movement without awareness of their original step-by-step collocation. A lesion of the temporal and fronto-temporal cortical regions responsible for serial integration will interfere with this sequential linkage so that the smooth transfer of one movement to another may be disrupted and the correct order of letters in a word may not be retained. Earlier stages may also be affected e.g., although able to correctly differentiate between the articulation of individual sound units, a patient with this kind of lesion may not be able to reproduce the right order of sounds to be coded, so creating positional errors in writing due to articulatory disarrangement.

Maintaining the purpose of any activity is essential for its adequate completion. Writing requires constant attention during the various stages of the task, continuous feedback concerning the results of actions, and in particular a plan or sustained set of intentions pertaining to the desired outcome. Luria (1970b, 1973a, 1979b) has described the effect of frontal lobe lesions where patients lose their stability of purpose, and in being unable to maintain the required vigilance do not adhere to original task intentions, and may lose track completely of what they are supposed to be doing. In the process of writing this emerges primarily as confusion of meaning and content, with apparently aimless intrusions of irrelevant material or stereotyped associations, and sometimes the repetition of individual word elements.

Writing therefore relies on the variable interaction of diverse components in many different cortical regions, whose activities are integrated according to the demands of an immediate task within a particular context. It is a social phenomenon in origin, and its procedures were arrived at in the course of historical development. The psycho-physiological processes of writing may vary from one cultural group to another, and between states in the development of the skill in differing languages. In Luria's neuropsychological terms, writing is the product of intricate functional cognitive systems.

## 3.3 Derivation of the theory

MacDonald Critchley (1970), assessing Luria's research contribution to the study of higher nervous activity, suggested that "In neurology, as in Art, on est toujours le fils de quelqu'un" (p. 1) and Luria himself has consistently acknowledged his indebtedness to the ideas of his mentor and colleague Vygotsky (Luria, 1965, 1966a, 1971a, 1971c, 1979a). However, if it is primarily to Vygotsky that we owe the reinterpretation of cognitive activities as culturally-mediated dynamic functional systems, it was Luria's commitment to the study of specific neuropsychological processes in the human brain which has provided detailed evidence of the cerebral organisation of cognitive functions.

It should be stressed that Luria was a prolific researcher and writer (Cole, 1977, 1979; Pribram, 1978) whose productivity covered publications in the areas of cultural differences in thinking (1928, 1931, 1976c), mental development in twins (1936, 1971c), the verbal regulation of behaviour (1960, 1961a, 1961b, 1969), mental retardation (1963b), and two notable psychological case studies: one of an individual with exceptional memory (1960, 1975a), the other of an adult who, despite extraordinary sensory and psychological disarray as the result of a devastating head-wound, kept written details of his thinking during the remaining 25 years of his life, and thus provided a unique first-hand account of the attempt to cope with cognitive dysfunction after brain injury (Luria, 1975b).

Luria had always emphasised "the necessity for building psychological theories on a sound physiology of brain activity" (Cole, 1979, p. 219), and the disastrous effects of the Second World War escalated dramatically the need to develop scientifically-based techniques for the restitution of damaged brain mechanisms. The response to that need led to Luria's most prodigious research (Luria, 1963, 1966a, 1967, 1970a, 1970b, 1973a, 1973b, 1976a, 1976b, 1979 ) which was significant in establishing neuropsychology, "a new branch of science with the specific and unique aim of investigating the role of individual brain systems in complex forms of mental activity" (Luria, 1973a, p. 16).

Luria's major tasks were to study the nature of functional change following brain lesions, to identify the factors underlying disturbance amongst groups of cognitive processes, and finally, where possible, to encourage rehabilitation of brain-injured patients by devising programmes to restore impaired functions. Without an adequate conceptualisation of the functional organisation of the brain it would be clearly impossible to carry out the last task of directing the restoration of cognitive systems through functional reorganisation, so the nature of cortical and sub-cortical components in the co-ordination of mental activities came to be painstakingly inferred from persistent observation of brain-behaviour relationships. Many years after the war had ended, Luria was finally prepared to publicise a succinct neuropsychological theory of functional organisation in the human brain (Luria, 1970a).

## 3.4 Three principal functional units

According to Luria, (1970a, 1973a, 1975b, 1976c, 1979a), the functional organisation of the brain can be understood in terms of three basic units, or blocks. Unit 1 is responsible for regulating the energy level and tone of the cortex i.e., for optimal arousal, and is located in the brain stem and reticular formation. The second unit is highly specialised for the analysis, coding and storage of information, and Luria (1966a, 1970b) considered that it operated through two forms of integrative activity: simultaneous synthesis, or the integration of stimuli into maintained spatial groupings, and successive or sequential synthesis, where serially perceived stimuli are temporally ordered such that each element exists only as part of a retraceable sequence. The occipito-parietal zones are responsible for simultaneous synthesis, and the temporal and fronto-temporal regions for successive synthesis. The third unit of the brain, comprising the frontal lobes, is involved in the organisation of conscious activity through the programming, regulation, and verification of behaviour (Luria, 1973a). The three principal functional units as described by Luria are illustrated in Figure 3.2.

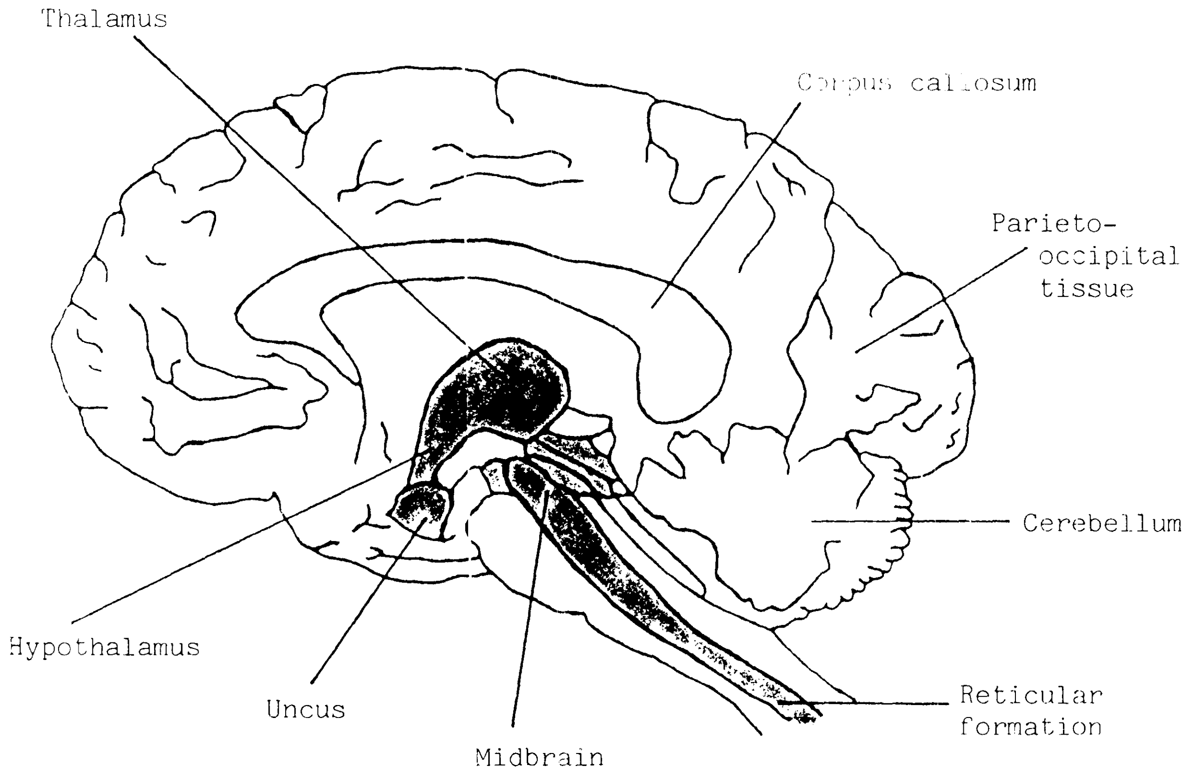
An important feature of these basic units is their hierarchical structure. Each consists of a 'primary or projection area' which receives impulses, a secondary region 'of projection-association' where accessed information is organised, and finally, the tertiary 'zones of overlapping' where the complex integrative activities of each unit are carried out (Luria, 1973a).

### 3.4.1 Unit 1

The brain's first functional unit is comprised of those structures which maintain and regulate cortical tone. Magoun (1963) and Moruzzi and Magoun (1949) were the first to clarify the activities of the nervous structures lying below the cortex in the sub-cortex and brain stem whose form and functions are adapted to allow modulation of excitation levels in the cortex itself. While the cortex consists of isolated neurons that operate on a seemingly 'all or nothing' basis (Luria, 1973a) where individual neurons either are or are not generating or receiving and relaying impulses along their long axons, the structures of this unit of the brain can be better described as a non-specific nerve net. Bodies of nerve cells are linked by short fibres so that excitation, as a rule, spreads gradually throughout the whole mesh of interconnections.

Since the unit is responsible not just for arousal but also for regulation of cortical tone, it is capable of inhibition as well as activation. Hernandez-Peon (1969) demonstrated that while electrical stimulation of some of these nuclei produced greater alertness and activation, stimulation of others led to decreased cortical activity and eventually to the onset of sleep.

a) Midline view: Unit 1(shaded)




b) Surface view: Unit 2(shaded); Unit 3(dotted)

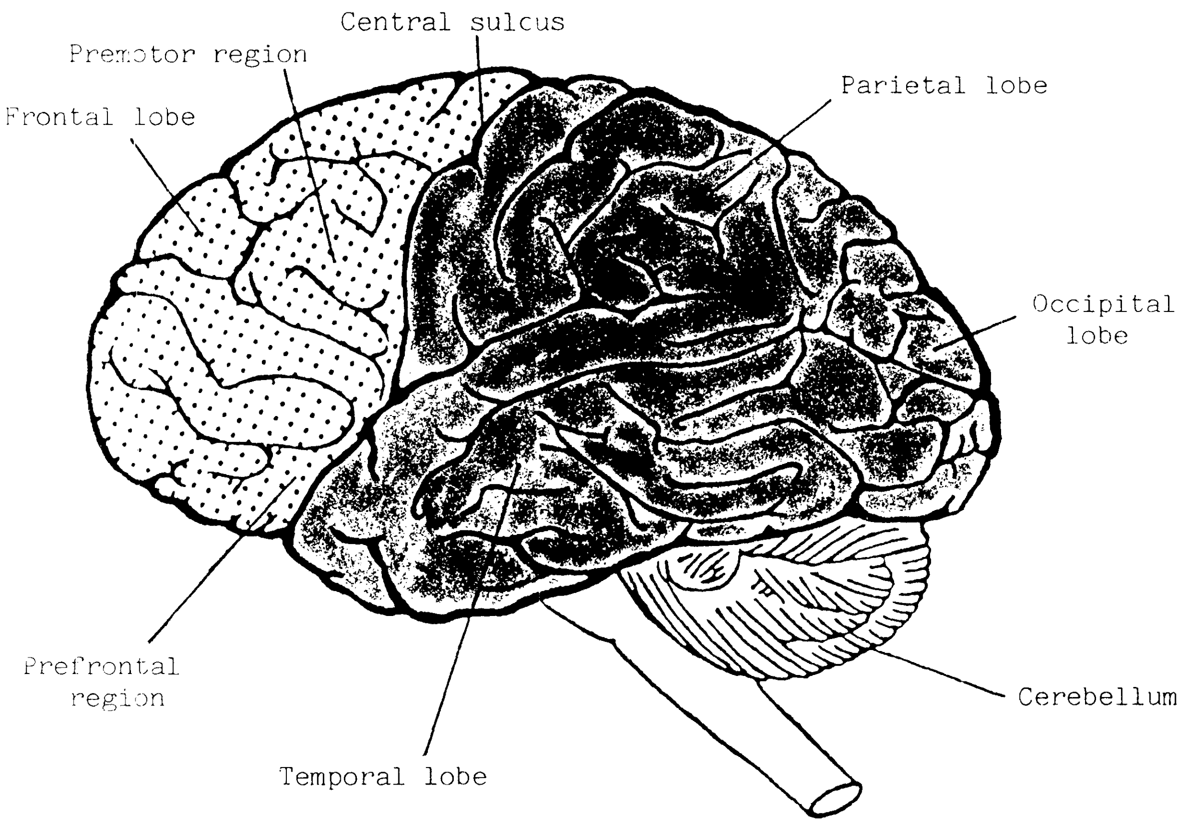



Figure 3.2 Principal functional units of the brain(after Luria 1970a).

This nervous network or reticular formation functions in two directions. Fibres of the _ascending_ reticular system proceed upwards and terminate in the thalamus and neocortex. On the other hand, fibres of the _descending_ reticular system begin in the higher nervous structures such as the neocortex and the caudate body and run down to lower structures in the hypothalamus and brain stem. Thus the reticular formation not only functions to change the tone of the cortex but is itself under cortical influence, providing an autoregulatory capacity in which levels of arousal can be mediated by higher mental functions.

Luria (1973a) considered that three principal sources could be distinguished which activated the reticular formation: (1) the 'internal economy' of the human organism i.e., the normal metabolic processes involved in retaining internal equilibrium or homoeostasis; (2) the arrival of stimuli from outside, which may require instinctive reaction or voluntary response to external situations that are being constantly monitored through incoming sensory information. In general, it is by means of the ascending reticular system that any necessary re-orientation is effected. (3) The formulation of programmes in the higher cortical levels which may rely on optimal arousal and activation for their fulfilment. By means of the descending reticular system

> "the higher levels of the cortex, participating directly in the formation of intentions and plans, recruit the lower systems of the reticular formation of the thalamus and brain stem, thereby modulating their work and making possible the most complex forms of conscious activity." (Luria, 1973a, p. 60).

Lesions vary in their disruptive impact on the operation of this unit according to their specific location and severity, but common syndrome features are the slowing down of reactions, a definite lowering of tone leading in some cases to an akinetic state, and a tendency towards rapid fatigue. Complex sensory-motor and cognitive functions may be impaired in so far as they depend on the maintenance of energy levels or the inhibition of response to irrelevant stimuli e.g., simple non-modally specific memory defects may become apparent which are due to the continuous interference of newly-arriving information on existing memory traces, for the patient seems unable to selectively control reaction to irrelevant features or events.

### 3.4.2 Unit 2

The second functional unit is responsible for information integration or the reception, coding and retention of stimuli. It covers the posterior divisions of the cerebral hemispheres, incorporating the visual (occipital), auditory (temporal) and general sensory (parietal) regions of the cortex (Luria, 1973a).

High modal specialisation characterises neurons in the primary or projection area of this unit e.g., neurons of the cortical visual system respond only to the qualities of visual stimuli such as the character of lines, shades of colour, and the direction of movement.

> "Neurons which have undergone such a high degree of differentiation naturally preserve their strict modal specificity, and virtually no cells which respond only to sound can be found in the primary occipital cortex, just as no neurons responding only to visual stimuli can be found in the primary temporal cortex." (Luria, 1973a, p. 68).

The secondary cortical zones of this unit convert incoming elements into necessary functional patterns. While retaining their modal specificity they operate as a system which organises stimuli recognised by the primary areas. Thus in the temporal cortex, neurons of the primary area respond only to the highly-differentiated attributes of accoustic stimuli, but the secondary auditory cortex located in the outer parts of the temporal region synthesises these discrete auditory impulses into combined formations. Similar receptive and organisational activities are carried out in the primary and secondary areas of the general sensory cortex located in the parietal region.

However, complex cognitive functions do not rely on the isolated processes of one modality, be it vision or hearing, touch, taste or smell, but are the consequence of comprehensive polymodal activity dependent on the combined operations of separate cortical areas. The tertiary zones of the second unit are responsible for such integrative functions, which also promote the transition from modally-specific syntheses to the level of symbolic processes. Concrete percepts may thus be transformed into more abstracted thinking through internally synthesised schemata, and the memorising or storage of experience is facilitated by this re-organisation of incoming stimuli.

Luria (1973a) states three principles which govern the structures and work of the second brain system. The functional relationship between the three zones outlined above is one example of the law of hierarchical structure. However, changes in the course of ontogenetic development (see section 3.2.4) mediate the nature of those relationships. In infants and children the development of functional organisation in the tertiary and secondary zones is dependent on the efficient operation of the modally specific primary zones. Once the higher psychological functions are fully formed in adults then the tertiary zones begin to influence the work of the areas subordinated to them e.g., prior schematic frameworks may determine the ways in which new percepts are recognised, coded and retained.

In addition, the law of diminishing specificity expresses the already mentioned gradual coalescence of modality-restricted functions, with the maximal specificity of neurons in the primary area giving way to the largely supramodal symbolic operations of the tertiary zones.

The law of progressive lateralisation of functions is considered by Luria (1973a) to apply to the cortex as a whole, including the second functional unit. The primary areas of both hemispheres have the same roles. However, with the development of handedness and speech, some lateralisation of functions begins to occur involving the secondary and predominantly the tertiary zones. Thus the differential effect of localised hemispheric lesions suggests that in right-handed patients the left hemisphere plays a more dominant role not only in the cerebral organisation of speech, but of all those cognitive functions connected with speech, though nevertheless with some right hemisphere involvement (Luria, 1970a, 1973a), whereas in left-handed patients the control of linguistic functions appears to be more evenly distributed across both hemispheres.

The activities of the second brain unit can then be summarised as the recording, analysis, coding, synthesis and storage of perceived information achieved through intermodal integration and accompanied by a developmentally reliant progressive lateralisation of functions. Luria further addressed the question of how these analytico-synthetic functions are accomplished, and argued that there was convincing evidence to distinguish two basic forms of integrative activity in the cerebral cortex

(Luria, 1966a, 1970b). These he categorised as simultaneous and successive syntheses, employing terms originally applied by Sechenov (1878).

By simultaneous synthesis Luria means the integration of discrete elements perceived one after the other into simultaneous or quasi-spatial schemes, thus bestowing the property of surveyability to the accessed information. Conversely, successive synthesis refers to the sequential organisation of arriving stimuli such that "each link integrated into a series can evoke only a particular chain of successive links following each other in serial order" (Luria, 1966a, p. 77), without being wholly surveyable at one point in time.

It is clear from the work of Sechenov (1878) that earlier conceptions of these processes were derived from the association of simultaneity with the visual, kinetic and vestibular functions which orient the body in space, while successive processes were seen as characteristic of operations in the motor systems and the accoustic domain. Luria's neuropsychological research however demonstrated that these two integrative processes may function across modal spheres and at different levels within the zones of the second brain unit.

### 3.4.2.1 Simultaneous synthesis

The synthesis of discrete elements into simultaneous spatial schemes, according to Luria (1966a, 1970b), may occur in the course of direct perception, during the process of memorising previous experience, and as part of the performance of complex higher cognitive functions.

At the perceptual level this may involve the combining of essential optical elements to produce a unified visual structure. An example would be the manner in which the individual components of a picture are incorporated to produce an integrated visual image which is consequently distinguishable from other such conglomerates of similar information (see also section 3.2.4 on problems in perceiving a pair of spectacles). So too in the tactile modality, separate elements may be identified initially in isolation, but are at some point fused simultaneously to generate complete representation, or, with the aid of memory traces, recognition. Defects from lesions may result not only in the inability to synthesise elements of any modality into an entire whole, but may also lead to disorientation through loss of bearings in a system of spatial co-ordinates.

At the <u>mnestic</u> (i.e., concerned with memory) level, retention of prior traces of experience may require a simultaneously surveyable scheme of organisation e.g., the reproduction and mental manipulation of spatial relationships, or the recognition of an array of modally-specific information. Construction of target designs or models from specified units such as blocks, recall of spatial locations, recognition or reproduction of relative spatial positions of items on a map, or even the schematic depiction of time on a clock through relative hand positions, are further practical examples of simultaneous synthesis of information in recall.

In the realm of <u>intellectual</u> processes, the comprehension of any system of relationships, such as the grammatical rules of a language or an assembly of interrelated mathematical concepts, is impossible in Luria's view without the maintenance of a simultaneously surveyable scheme which may on occasions assume the form of a quasi-spatial array. Thus basic arithmetical operations may be performed mentally through actions reliant on an internal spatial arrangement with a structure similar to externally organised tables of numbers.

Patients with lesions of the parieto-occipital cortical regions, for example, may have little difficulty understanding simple narrative speech or communications of events (such as 'father and mother went to the cinema') but will be unable to disentangle the more complex logico-grammatical relationships evident in a sentence such as 'a lady came from the factory to the school where Nina was a pupil' (Luria, 1973a). In such cases verbal constructions using similar words will tend to be classified as having the same meaning (e.g. 'my father's brother' and 'my brother's father'). Verbal expressions of relationships in space ('the cross below the circle' or 'the circle below the cross') and in time ('spring before summer' or 'summer before spring') may be likewise confounded, as indeed will any statements in which the word order departs from the order of meaning e.g. 'I had breakfast after I had read the newspaper' (Luria, 1973a).

The measures used by Luria to examine simultaneous syntheses of information therefore corresponded to these perceptual, mnestic and intellectual levels of operations exemplified above:

> To investigate the simplest forms of simultaneous syntheses the patient is asked to copy a series of geometrical figures, possessing a particular orientation in space. When copying these and also reproducing them from memory, the subject must retain not only their shape, but also the spatial direction of their elements ... Disturbance of spatial syntheses is especially prominent in those cases when the patient is asked to invert a presented figure in his mind and to draw the resulting shape." (Luria, 1966a, p. 84).

The reproduction of simple relationships on a map, depiction of relative positions of discrete elements within a familiar spatial environment (e.g. a diagram of a route through a building, or from one building to another), the replication of finger and body movements carried out by a person placed in a facing position, and differentiation between Roman or Arabic numerals composed of identical elements differing only in their spatial orientation (IX and XI, or 89 and 98, etc.) were used to further analyse mnestic levels of simultaneous synthesis. Mental calculation of simple arithmetical problems (sometimes verbalised aloud), and the decoding of logico-grammatical information through verbal operations served a similar purpose at the intellectual level (Luria, 1970b).

What became clear then was that a general syndrome of disturbance of simultaneous syntheses could be identified through such procedures, and was associated with lesions of the occipito-parietal brain regions.

#### 3.4.2.2 Successive synthesis

The synthesis of elements organised serially in time, referred to by Luria as either 'successive synthesis' (Luria, 1966a) or 'sequential integration' (Luria 1970b), while apparently left largely undisturbed by lesions of the occipito-parietal regions, was on the other hand grossly impaired by lesions of the temporal and fronto-temporal regions, which usually had minimal impact on simultaneous synthesis. Depending on the location and extent of a particular lesion, disturbances of successive integration could also occur at the sensori-motor, mnestic or intellectual levels.

Difficulties in grasping and replicating a simple tapped rhythm, or repeating a short unsophisticated melody where the essential task was to preserve the sequence of sounds, characterised problems at the basic levels of successive synthesis. Motor performance tasks employing a series of three or four movements strung together in a particular order (e.g. tapping with the palm of the hand, with its edge, and with the back of the hand) resulted either in a confusion of the required order of elements, or the inability to execute them as a smooth 'kinetic melody' (Luria, 1966a). In other cases, patients with such disorders complained of not being able to sing songs and some who had, prior to injury, known the Morse code and used it fluently, were now unable to do so (Luria, 1966a).

Although Luria makes the distinction between sensori-motor and mnestic levels of synthesis it is apparent that most of these tasks depend to some degree on the retention of memory traces. Repetitions of series of words, letters and digits, presented either visually or verbally were used as measures of successive synthesis specifically at the mnestic level, with emphasis placed on the retention of the correct order of items in the series, rather than the random recall of isolated elements. Graphic serial tasks, such as drawing a circle, then a cross, then a minus sign followed by a circle (after these stimuli had been separately presented visually or by verbal instruction) created the requirement not only to retain the correct order of stimuli in memory but also to change over at the appropriate time from drawing one symbol to the next, a task of particular difficulty for patients with fronto-temporal lesions. One patient could complete such tasks only by naming the successively presented figures out loud, but was unable at all to reproduce a similar series of digits (Luria, 1966a).

At the intellectual level, the syntactic structure of narrative speech is designated by Luria (1966a) as one of the most obvious examples of serially organised cerebral activities requiring successive synthesis. Patients who could efficiently memorise the individual components of a story were however unable to link them together into a thematically consistent narrative. Similarly, patients who listened to a poem read out to them eight or ten times could only reproduce the general sense but not the rhythmic pattern or 'melodic' structure.

The precise location of lesions within the general cortical regions associated with either simultaneous or successive syntheses affected the type and degree of impairment, explaining in part the variety of symptoms displayed. Thus lesions predominantly affecting the primary or secondary zones of the cortex might lead to disturbances in the functions of particular modal analysers, whether visual, accoustic, motor or tactile. Damage to the tertiary zones however would more likely produce more general integrative dysfunction across the sensori-motor, mnestic and intellectual levels of synthesis carried out within the second functional unit of the brain.

### 3.4.3 Unit 3

The frontal lobes of the human brain comprise up to one quarter of its total mass, and are much more highly developed than the corresponding areas of the brain among man's closest relatives in the animal kingdom. The structures of Luria's third functional unit of the brain, responsible for the programming, regulation and verification of activity, are located in the regions anterior to the central sulcus i.e., the premotor area and primarily the frontal lobes.

Luria makes the important contradistinction that although the primary, secondary and tertiary zones of this third unit are subject to the same principles of diminishing specificity and hierarchical organisation which govern the operations of the second unit, the direction of processes is reversed. The second unit is primarily an afferent (i.e., conducting inwards) system, with the flow of operations proceeding from primary to the secondary and tertiary zones. The third unit, responsible for the formation of intentions and the maintenance of plans to carry them out, is an efferent (i.e., leading outwards) system in which processes start at the tertiary level in the frontal lobes (where plans and programmes are initiated), proceed through the structures of the premotor areas (secondary zone) which play an integrative role in controlling groups of systematically-related movements, and are finally discharged as prepared impulses from the motor cortex in the precentral gyrus (Luria, 1973a). This primary zone is described as the 'outlet channel' for the third unit, an 'effector apparatus' linked by specific fibres via the spinal motor nuclei to the rest of the body (Luria, 1973a, pp. 80-82), and contains the large pyramidical-shaped cells of Betz that early in the history of neurology had come to be identified with control of motor functions (see section 3.1).

Another major difference between the second and third brain units is that the latter has no separate zones with individual modally-specific analysers, demonstrated by the fact that damage to these areas (particularly the frontal lobes) does not impair sensation, perception or speech (Luria 1970a). Structurally the primary zone of the motor cortex is characterised by the vertical type of striation that extends to the secondary premotor region in which, however, the upper layers of small pyramidical cells are better developed. The tertiary zone of the frontal lobes contains no pyramidical cells, and as a result is sometimes referred to as the 'granular frontal cortex' (Luria, 1973a).

The frontal lobes have extensive pathways of connections not only with the reticular formation of the first functional unit (see section 3.4.1) but with all other cortical regions, a point emphasised repeatedly by Luria as indicating their executive function in regulating planned behaviour through activation, modulation or inhibition of dispersed cortical activities: ".. the tertiary portions of the frontal lobes are in fact a superstructure above all other parts of the cerebral cortex" (Luria 1973a, p. 89).

Developmentally this is reflected in the fact that the frontal lobes mature comparatively late. Luria (1973a, p. 87) has graphed data from the Moscow Brain Institute on the rate of increase in area of the frontal lobes, and the rate of increase in size of nerve cells in ontogeny. These showed a sharp rise in the rate of increase of frontal brain surface area around the age of three and a half to four years with a second jump at about seven to eight years. The first rise was also accompanied by a marked increase in the rate of growth of cell bodies in the prefrontal cortex. Luria concluded that the prefrontal regions of the cortex do not become "finally prepared for action" (1973a, p. 87) until the child has reached the age of four to seven years.

Injury to the areas covered by the third functional unit produces consequences that again vary in type and degree according to extent and exact location among the three zones, but the frontal syndrome is generally characterised by difficulty in formulating a plan of action, maintaining a level of vigilance or selective attention sufficient to continue goal-directed behaviour, and inability to verify or gauge the outcomes of that behaviour.

The effect of damage to the premotor area alone, for example, may leave intact the general intention to carry out a behaviour and a plan for its execution, but may abolish the inhibitory influence on lower subcortical structures, so that an action may commence and continue, but may not be appropriately terminated. This elementary motor perseveration was illustrated by a patient who when asked to draw a circle began to do so, but kept repeating the movement over and over again. As the lesion site extends to encompass parts of the frontal lobes, loss of the assigned programme of action begins to occur, and may be replaced by the repetition of inert stereotypes. This is particularly evident with graphic tasks. Thus a patient asked to write his name may competently produce the first letter, but then continues duplicating it. The request to draw 'two circles and a cross' produced several repetitions of the digit '2', and an attempt to trace the shape of a cross became the number four (Luria, 1966b).

At the other extreme, patients with massive tumours of the frontal lobes may remain completely impassive when stimulated by direct questioning or even personal need e.g., hunger. However, more elementary forms of reaction or arousal may be unaffected, as attested to by attention and reactions to irrelevant stimuli. Luria found that the most effective way to elicit a verbal response was to start up a conversation with someone else in the vicinity of the patient who, while apparently unable to maintain attention to a direct request, would often produce seemingly involuntary replies to passing questions directed at other people (Luria, 1973a). In some cases, the purpose of a required action may be replaced by an apparently unconscious habitual response. A patient who was asked to light a candle correctly lit the match, but then instead of carrying out the original intention picked up the candle and proceeded to smoke it like a cigarette.

A significant component of all these problems is the patient's failure to recognise or check the results of an action. Since this entails the comparison of output with the original intention, if that intention is not maintained, either through distractability or uncoordinated responses to isolated elements of a programme, then no recognition of deviation from the original plan (or production error) is possible. In effect this self-regulatory or feedback mechanism is normally responsible for monitoring outcomes and adjusting prepared programmes when intentions are not fulfilled, when the requirements of a task are altered, or when necessitated by a perceived change in circumstance.

The third unit of the brain therefore, through its rich system of bilateral connections with all other cortical regions, and especially through the actions of its tertiary zones which initiate and regulate purposeful activities, functions essentially as a coordinator of all operations which govern man's conscious behaviour.

### 3.4.4 Combined operations

It should be stressed that no form of higher mental activity is the result of the isolated function of any single brain unit. Complex psychological processes such as memory, speech and verbal-logical thinking are realised through the combined operations of all three functional units, with each making its own specific contribution. A graphic illustration of functional unit interaction can be seen in the example of writing, examined in detail earlier (see section 3.2.5).

Elementary forms of attention dependent on low levels of momentary arousal are predominantly a function of the first unit generally responsible for cortical tone. However, more complex forms of attention that may require the maintenance of purposeful vigilance for longer periods, the selective recognition of particular stimuli followed by appropriate response, as well as the inhibition of responses to irrelevant stimuli are clearly the result of varying interaction between the first unit and the planning and executive functions of the third unit.

Changes in the functional organisation of the brain during development were mentioned in section 3.2.4, and training and habituation may change the nature of cortical interaction over time. Returning again to the earlier example (section 3.2.5), it is conceivable that for the experienced reader in English a word may come to be perceived as a whole conceptual unit (not unlike the Chinese ideogram), whereas the unskilled reader needs to decode the visual assembly into individual sound symbols before reassembling them into a unit of meaning. Evidence from patients with frontal lobe syndrome supports the notion that the brain comes to execute customary tasks without resorting to previously necessary analytical procedures, in other words, tasks that cannot be performed if conscious thought is required may be carried out as part of an automated kinetic response. Patients may not be able to transcribe from dictation, but have no difficulty in signing their names; a person unable to write one word serially spelled out to her could nevertheless write down a whole familiar sentence quickly (Luria, 1970a).

Culturally or experientially-based cognitive and affective blueprints (governed by unit three) may likewise influence the manner in which external information is perceived, coded, stored and retrieved (unit two), which in turn will have been determined by those features of the original context that attention was selectively directed to (units one and three), if an appropriate level of arousal existed (unit one). Luria's assessment that "one task may be performed by several different methods based on different combinations of active brain units" (Luria, 1966a, p. 65) applies not only to the range of cognitive functions and strategies that may be found between individuals, but also to those of the same individual on different occasions. Indeed, it was that very fact which enabled Luria to assist his patients to compensate for an impaired cognitive function by progressively reforming contributions from undamaged cortical regions.

## 3.5 Luria's methodology

No examination of a scientific theory would be complete without considering the means by which its supporting evidence had been accumulated, and the culmination of Luria's lifetime commitment is no exception. His task was to facilitate the rehabilitation of brain-injured persons. He set about doing this by carefully documenting the functional changes in everyday activities that followed specific brain lesions, and his eventual methods evolved from these clinical investigations of individual behaviour.

The first step in what came to be known as his neuropsychological method, or syndrome analysis (Christensen, 1975; Luria, 1966a, 1970a, 1973a), is the presentation of short standardised tests considered to be measures of basic cognitive operations. The purpose is simply to ascertain what fundamental skills previously within the grasp of the individual may have been affected, and to identify any damage in modally-specific domains e.g., optic, auditory or motor analysers.

Since a localised lesion will not produce impairment solely to one isolated function but rather to a whole system of cognitive processes that may rely on the contribution of that particular function, the second stage of investigation attempts to explore defects in groups of processes that may be involved in higher mental activities i.e., the effort is made to identify a symptom-complex (or 'syndrome') based on the data from the preliminary tests. In Luria's terms this investigation probes for the 'common factors' (see section 3.2.2) that underlie disturbances in complex cognitive behaviour:

> "By observing the secondary disturbances or the systemic consequences of these primary defects and by analysing them qualitatively and comparing them with a careful description of the mental processes remaining intact in these cases, the investigator can study in its concrete form the mutual relationship between individual forms of mental activity, and can deduce from this relationship the factor on which it is based. This method of investigation of patients with local brain lesions has many advantages and, despite the large number of complicating conditions, it may be used as an additional method of factor analysis." (Luria, 1966a, p. 52).

One of the complicating conditions is the selection of variable and flexible procedures that will nevertheless elicit evidence of intact functions as well as the type, quality and range of damaged processes - no easy task when one considers the complexity of functions involved in spontaneous and repetitive speech, reading, writing, problem-solving, comprehension, logical deduction, spatial orientation, etc. In addition, vital clues may be obtained by variation in tempo and context, observations of the development of fatigue in relation to different types of activity, analysis of the way in which a problem is approached as well as the outcome, the introduction of regulatory speech mechanisms, and analysis of any attempts by the individual to consciously reorganise processes during a task.

This is a highly sensitive stage of inquiry, geared specifically to the needs of each individual case, and success depends to a considerable extent on the knowledge, expertise and experience of the investigator involved. Das, who worked with Luria, elaborates on the metaphor used by him to describe his methods:

> "Visiting Professor Luria during the clinic was an experience worth remembering. One felt fortunate to be witnessing an outstanding clinician at work. He likened the task of correlating brain lesions with behaviour as detective work. Sometimes the site of the lesion was known but not the exact nature of the dysfunction caused by the lesion. At other times, the debilitating symptoms were all too apparent, but the lesion was yet to be found. The detective knew the criminal, but not the crime in one case, and in another case knew the crime, but not the criminal. A team of multidisciplinary experts were engaged in examining both the crime and the criminal with the supervision of its chief inspector Professor Luria." (Das, 1980, p. 141).

Structured schedules have now been produced (Adams, 1980; Christensen, 1975; Golden, 1978, 1981) that attempt to systematically incorporate Luria's procedures in order to assist other investigators to arrive at a clinical neuro-psychological assessment, the third and final step of Luria's own method. This provides a description of the underlying factor based on the assumption or knowledge of a specific local lesion, details its manifestation in a range of cognitive functions, and seeks to formulate a rehabilitative programme based on the reconstruction of damaged links in complex behaviour largely through reorganisation of intact functions.

Luria has in several instances commented on the parallels and distinctions between his own method and the psychometric procedure of factor analysis (Luria, 1966a, 1970a, 1973a), and in an important statement summarised his course of action as a qualitative, individualised variation of that routine: "With the neuropsychological technique we can now make factor analyses in individual subjects" (Luria, 1970a, p. 72).

Innumerable such 'individual factor analyses', gathered over many years of research and involving many different localised lesions, enabled Luria to gradually build a comprehensive theoretical model of the functional organisation of the human brain before his death in 1977, at the age of 75. His work remains as an important theoretical framework to be applied in psychological research beyond the clinical precincts from which it was derived.