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ABSTRACT

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The aim of this investigation was to examine the neuropsychological aspects of the model of information integration presented by Das et al. (1979). According to this model, information can be processed either simultaneously or successively and the domain for these modes of processing is, respectively, hypothesized to be in the posterior and anterior (fronto-temporal) divisions of the brain. Empirical verification of the model is provided in three studies: (1) adult neurological patients (N=121), (2) adult brain damaged patients (N=106), and (3) normal 75-84 years old people (N=58). Also, one case study is reported where the interactive nature of simultaneous and successive processing was observed in the sudden recovery from a profound aphemia.

The factor analyses of simultaneous and successive tasks showed that the modes of processing were clearly identifiable but also showed differentiation according to the code content (verbal/nonverbal). In brain damaged sample, a two-way ANOVA revealed no interaction of laterality and anterior/posterior division in simultaneous or successive processing but instead two main effects of laterality on simultaneous verbal ($p < .01$) and successive ($p < .05$) processing. A very weak ($p < .10$) main effect of anterior/posterior division appeared on simultaneous nonverbal processing. In the third study, the neuropsychological factors were able to predict in regression analyses from 26 % to 43 % of the variance of the modes of processing. Also, it was observed that successive processing seemed to associate more with those neuropsychological tasks characterizing the functioning of the anterior lobe and simultaneous processing with that of the posterior lobe. Also, the results tentatively suggested the existence of separate units for simultaneous and successive processing in each hemisphere according to code content. Of related interest, it was found that educational level was the most influential background variable in relation to simultaneous and successive processing while the variables related to CNS disease showed no relationship to the modes of processing. Age correlated significantly with the modes of processing in each sample although weaker with simultaneous verbal processing. - The results gave support for construct and predictive validity of the model of simultaneous and successive processing.
Keywords: simultaneous-successive processing, neuropsychological functions, cognition, neurological patients, brain dysfunction, elderly, asymmetry, anterior-posterior, aphemia, cross-validity, concurrent validity

PREFACE

The present study summarizes some of my continued interests in clinical neuropsychological work which trace back to the 1970's. It all started with the friendly help of Professor Aatto Sonninen who invited me to investigate his aphasia patients and who later introduced me to other patient clinics of the Central Hospital of Central Finland. I owe him a great debt of gratitude for his efforts, encouragement, stimulation and belief in me at the beginning of my career. Due to our successful co-operation I have maintained my neurolinguistic interests in tandem with the present study.

During the course of this study I have accumulated many different obligations. I am indebted to Professor Martti Takala, the Rector of the University of Jyväskylä, who when Chairman of the Department of Psychology lent his support and made arrangements for me to pursue clinical and scientific work simultaneously. I am also very grateful to Associate Professor Lea Pulkkinen who, when I was an undergraduate student gave the very first glimpse into scientific thinking. Since those times, she has showed a continuous interest in my work offering encouragement, advice and comments and being available when I needed help. The present Head of the Department of Psychology, Associate Professor Carl Hagfors, deserves my warmest thanks for several reasons. He introduced me to neuropsychological issues and provided ideas, support and guidance both before, during and after the initial research work. Both he and Professor Risto Näätänen of the University of Helsinki, to whom I am also indebted, read the manuscript and generously offered helpful comments interwoven with encouragement to continue.

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The following colleagues deserve my sincere thanks: Docent Juhani Vilkki for advising and commenting my earlier work on the same topic, Anna-Riitta Putkonen for supervising and advancing my clinical skills, and Ritva Hänninen whose friendly and pleasant co-operation in Study 2 of the present research work finally lead to our joint report. I also want to thank Neuropsychologist Anne-Lise Christensen for discussions and for her comments on drafts of the manuscript as well as extend my thanks to all my other colleagues.

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I finally wish to thank my husband and my daughter for their patience and unfailing support throughout my work.

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In Jyväskylä, December 1986 Seija Äystö

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1. INTRODUCTION

Information processing models have been a widely used approach in cognitive psychology for the last three decades (e.g., Miller, Galanter & Pribram 1960; Neisser 1967; Lindsey & Norman 1972; Newell & Simon 1972). In recent years, intelligence, memory and associated abilities have been approached from the perspective of information processing (e.g., Das, Kirby & Jarman 1975, 1979; Hunt E. 1980; Kail & Pellegrino 1985; Klatzky 1984; Sternberg 1985). The static and fixed nature of abilities is challenged by a more flexible and dynamic approach which attempts to study shared qualities in human intellectual functioning and to measure individual cognitive differences. This shift in theoretical positions has new practical implications for education by laying more emphasis on instructional methods than the outcome of performance or achievement (Molloy & Das 1980a). Studying the underlying mechanisms of intelligence common to all people is a more fundamental explanatory approach to information processing than the simple measurement of intelligence.

According to Palmer and Kimchi (1984), the foundations of information processing have been rather computational or philosophical than psychological. Lachman et al. (1979) mention that the intellectual antecedents of the information processing paradigm can be found in such diverse areas as neobehaviorism, verbal learning, human engineering, communication engineering, computer science and linguistics. The main idea in this approach is that people behave in certain cognitive acts like an information processing system and thus can be seen rather technically as symbol-manipulating system. Intelligence and cognitive processes are thought to be explained adequately by a relatively few basic computational operations i.e., encoding, comparing, locating, storing, and retrieving information (Lachman et al. 1979). The simulation of mental processes in computers has also been understood as information processing and the computer as a model has provided one possible explanation for performing psychological functions such as memory, attention, perception etc..

Basically a molar and molecular distinction which resembles the top-down and a bottom-up approaches, although not identical to it, has been available a possible way of testing the theories of information processing in humans and computers. The molar approach assumes that the overall plans, strategies and goals (frames, schemas and scripts) must be dealt with first, after which it is possible to proceed to a molecular approach. Thus, the high level cognitions are decomposable and reduceable to smaller units. The computer simulation of mental processes has dealt with issues mainly at the molecular or micro level although the need for molar level descriptions of the functional organization of the system is recognized (Palmer & Kimchi 1984). Gardner (1985, p. 135) mentions that in the information processing research a growing interest in psychological investigations at a molar level has recently emerged.

In dealing with the issues of information processing common to both computers and humans Palmer and Kimchi (1984) discuss five assumptions which all need to be analyzed when studying the relation of information processing to cognition. These are listed as (1) informational description, (2) recursive decomposition, (3) flow continuity, (4) flow dynamics and (5) physical embodiment. The first of these assumptions includes the spccification of the nature of the input, operations and output. The second assumption addresses the issue of how the informational event can be decomposed into subcomponents and how its flow through the system can be specified. This assumption is, according to the above authors, the most controversial one. The third and fourth assumptions concern the availability of certain inputs to the production of output. As one of the most important issues related to flow dynamics the above authors see the problem as whether a given pair of operations is executed sequentially (serially) or simultaneously (parallel processing). The assumption of physical embodiment refers to the place where the processing actually takes place (i.e., hardware of the computer, the human brain). Palmer and Kimchi (1984) mention that there are no good functional descriptions available as to how the brain works within the context of the environment.

If humans and computers are seen as general information-processing systems they must be able to represent (1) events in the external environment and (2) their own set of operations (Lachman et al. 1979). The characterization of information is not an easy task in psychology and it is obvious that the relevant description of external phenomena and events together with the internal properties of cognitive systems and structures form the basis for cognitions. An adequate and appropriate theory of information processing should be able to deal with information reception (perception) and selection, with the flow of information in cognitive systems, and with different forms of information output. The complexity of cognitive systems itself creates other problems with the form and content of representations, retention, retrieval and recall of memory traces etc.. Also, afferent information in the central nervous system can originate in the external environment, from the receptors within the body, or from other neural or mental systems (LeDoux 1984). The information received from direct perception or from memory can mainly be processed in two different ways, either sequentially or simultaneously. Therefore, the characterization of information content and its flow through the information processing system is important in any theory of information processing.

In the present study, the issue of information processing is viewed from the aspects of cognitive and clinical neuropsychology. The structure of attitudes as determinants of the levels of information processing is excluded because these more personally oriented characteristics define the selection of actively sought information, the organization of dimensional (affective, cognitive and behavioral) values, and the nature of conceptual rules. In the present study the modes of information processing are seen as if as a set of latent variables or underlying properties defining the basic operations of cognitions as has been proposed by Das et al. (1975, 1979). The main principles are simultaneous and successive synthesis which organize and further encode information from the environment or from the internal knowledge base. In addition, the focus in the definition and identification of the modes of processing is based on a careful analysis of the stimulus material and its supposed interaction with the central nervous system. Such a broad definition of the modes of processing includes global features of both important issues described earlier in this chapter (i.e., information description and flow dynamics) although the details of every side of processing (like retention, retrieval, output features etc.) cannot be included. The approach selected here is a molar level (top-down) analysis of information processing.

The definition of information in the present study is not based on mutual agreement or a contract between the sender and the receiver of information. The issue in the present study does not address informational equivalence as a transfer from one representation (head) to another person but how people act when required to perform certain tasks and how they deal with information in these situations.

The information processing perspective taken here considers the brain as a flexible and dynamic processor of information in interaction with the stimulus environment. The dynamic nature of information processing suits well the idea of dynamic localization in neuropsychology (Luria 1973) where the mental and functional systems are seen as dynamic and changing due to environmental influences. Therefore, the integration of neuropsychology and information processing theory is considered to provide invaluable insights into the nature of cognition. One such model which combines the clinical neuropsychological findings of Luria (1966a, 1966b, 1973) with information processing has been presented in educational psychology by Das, Kirby and Jarman (1975, 1979).

2. COGNITION AND INFORMATION PROCESSING

Cognition can be viewed as effectiveness in dealing with information (Arenberg 1973) and as a broad category it includes intelligence, memory, problem solving, learning etc.. In explicit theories of intelligence the ability factors are described as verbal comprehension, fluency, spatial visualization, numerical, reasoning, perceptual speed, etc.. These are claimed to comprise a fixed and static structure of different hierarchical organizations, levels or other dimensions (e.g., Cattell 1963; Guilford 1967; Horn & Cattell 1967; Jensen 1973, 1982; Spearman 1927; Thurstone 1938). The study of individual differences in cognition is especially emphasized in educational psychology where the content- or structure- and process-oriented approaches would suggest different applications to the learning process.

The information processing model provides an alternative way of viewing cognitions and their possible structure. E. Hunt (1980) has distinguished the structural, process and knowledge base of any information processing machine, be it the brain or a computer. By structural aspects Hunt means the mechanical properties of the machine (or brain). The process aspect takes advantage of the mechanical properties of the machine in executing the task or solving problems. Coordination of the present situation and the problem-solvers's memory of previously acquired information forms the knowledge base ın the information processing system.

Comparisons between the computer and the brain have dealt a lot with the structural and physical properties of both. It is more important, however, to describe the operations performed on both. The computer and the brain deal with symbol manipulation. Without going into a detailed discussion of the comparison between the computer and the brain the similarities between them according to Lachman et al. (1979) can be briefly summarized as the following: 1) both can follow instructions put in appropriate symbolic form, 2) they can store instructions and groups of instructions, 3) they can follow conditional instructions, and 4) they can store programs and data in the same symbolic form and operate on programs as data.

The dissimilarities between the computer and human brain have been extensively discussed by Cohen (1983), who concludes that the computer is a better abstract competence model of the human mind than the actual performance or working model of the human mind itself. The computer is not capable of self-programming and the computer is sensitive to the function of the machine itself or the program. One of the constraints on computers is that information is processed step-by-step or serially. Humans are able to process information from many sources simultaneously or in parallel fashion (e.g., Arbib 1972; Boden 1977; Dreyfus 1979; Shallice 1978; Webster 1973; Weiskrantz 1974).

Conventional flow chart theories of information processing have been criticized as dehumanizing, too mechanistic and narrow, and lacking in ecological, social interactional, and cultural aspects (e.g., Norman 1981). Strong criticism has particularly been directed toward a computational emphasis in explaining information processing. It is, however, a challenge to cognitively oriented clinical neuropsychology to attempt to develop a global and integrated picture of human cognitive processes.

3. DIFFERENT TYPES OF THEORIES OF INFORMATION PROCESSING

Three basic types of information processing theories view the flow of input from receptors to the brain 1) from the distinction of the peripheral-central dimension (where the elementary level sensory processing is said to differ from higher level semantic processing), 2) as a hierarchical sequence of functions and stages and 3) as the effort or attention required to perform the effort, that is, how the resources for the purposes of information processing are allocated.

The general model of the flow of information includes three different processes, namely reception or registration of information, coding and retrieval or output, and efferent mechanisms. These phases in information processing can be viewed separately, although here the main emphasis is on differences in coding and on the modes of processing. The traditional memory centered models of information processing are excluded from closer inspection due to their different orientation and emphasis to the problems considered in the present study.

The efferent mechanisms of information processing have received less interest in research than the registration units (how the information or sensory input is registered in brain). The behavioral and autonomic manifestations of the end result of processing have not been carefully specified.

3.1. The modes of processing

In cognitive psychology and in theories of information processing dichotomized modes of thought have fundamentally been presented by labelling them differently (Blumenthal 1977). The content of pairs of concepts like parallel-serial (Neisser 1967; Cohen 1973), appositional-propositional (Bogen 1977), simultaneous-successive (Luria 1966a, 1966b , 1973; Das et al. 1975, 1979), holistic-synthetic and analytic (Levy-Agresti & Sperry 1968; Nebes 1974; Bever 1975; Bradshaw & Nettleton 1981), primary process versus secondary process (Martindale 1981), perceptual-associative (DeRenzi et al. 1969) and, controlled versus automatic processing (Shiffrin & Schneider 1977) all refer to the polar types of cognition but obviously do not include the same core matter of information processing.

Experimental, clinical and educational psychology apply the above mentioned concepts of information processing differently and emphasize different sides (contents) of processing. The concept of hemispheric specialization has been seen as reinforcing the cognitive dichotomy of thought and this has given a rationale for the attempts to verifify it empirically.

The definition of the above mentioned concept pairs is a fundamental in constructing a paradigm of information processing and the mere labelling of the processes as belonging to either category of the modes of processing is unjustified without carefully specifying the task demands. Without considering here all the above mentioned concept pairs, only those having most similarity with the simultaneous and successive processing (parallel and serial) are dealt with.

Bradshaw and Nettleton (1981) consider serial and parallel processing as special cases of analytic and holistic dichotomy. The primacy of this distinction is questioned by Cohen (1981) and it seems to be the case that the exact content of the concept pairs described above is poorly understood (i.e., Nottebohm 1979, for commentaries see Bradshaw & Nettleton 1981).

Palmer and Kimchi (1984) relate the issue of the modes of processing to flow dynamics as a question of whether a given pair of operations are executed sequentially (serially) or simultaneously (parallel processing). The distinction between serial and parallel processing is theoretically quite clear according to Palmer and Kimchi (1984) but empirically in experimental settings both modes of processing can make predictions which are indistinguishable from each other. Theoretically, a lot of controversy about the nature of serial and parallel processing has appeared. Anderson (1976) thinks the issue to be empirically unresolvable.

Townsend (1972) has given a theoretical description of serial and parallel systems by relating the stimulus to the "black box" assumptions so that in a serial processor only one element is focused upon any given time and the output appears in the same order as the processing. In parallel systems, the elements to be processed are operate simultaneously so that the processing begins and proceeds simultaneously although it may terminate at a different time. Interaction or correlation between the elements is possible in the parallel processor contrary to the operating of the serial processor where interaction is not assumed. Townsend (1972) is not interested in defining the serial or parallel nature of certain psychological processes but is interested in the systems of serial and parallel processes. The need for constructing hybrid models for serial and parallel processing systems is expressed by Townsend (1972), Luria and Simernitskaja (1977), Gazzaniga and LeDoux (1978), Ben-Dov and Carmon (1976) and Moscovitch (1979) although not specified. The general trend in published literature on information processing up to recent times has been to look at the extreme ends of the processing dichotomy without emphasizing the possible interactive nature of the modes of processing.

Neisser (1967) distinguishes between serial and sequential processing so that the former means a certain number of actions taking place in a temporal order and unrelated to each other, whereas in sequential processing each action in the temporal order is dependent upon the organization of actions. This definition makes it clear that the notion of sequentiality is especially important in studying planning or goal-directed behavior, but if the problem on hand is limited to studying the modes of processing at a certain point of time the concept of serial or successive processing is appropriate. Perceptions can also happen, according to Neisser (1967), in sequential order.

Concepts of serial and parallel processing are closely related to attention and to the notions of controlled vs. automatic processing. There is evidence in the psychophysiological literature (e.g., Näätänen 1982; 1985; 1986) that at the level of sensory processing serial and parallel processing are differentially related to attention. If selective attention is not required in task-unrelated processing, the processing occurs in parallel, preconsciously and automatically. If the processing is related to the task at hand and thus requires task-related attention, it becomes selective, serial, controlled and conscious. With practice, task-related processing may become automatic, but then it is acquired through controlled processing and is different from the basic-level automatic processing. Thus, there is differentiation between automatic processing which is conscious (acquired through practice) and unconscious (the basic-level processing).

3.1.1. Operationalization of the modes of processing

In experimental literature, the serial and parallel processes have been identified on the basis of reaction time measures. In a visual search task the time required for decision making (same/different) in response production is considered unchanged in parallel processing regardless of the number of items in the set whereas in serial processing the reaction time increases as a function of the number of items in the set. A different way of defining and operationalizing the two modes of processing, i.e. simultaneous (parallel) and successive (serial) processing is presented by Das et al. (1975, 1979).

Simultaneous and successive processing are the principles by which the central nervous system organizes and integrates the incoming input into the system. The outcome of these two modes of processing is cognition (Das et al. 1979), or, they are seen as processing abilities which determine a successful performance in certain tasks (Biggs & Kirby 1984). Simultaneous processing means the integration of information into quasi-spatial groups where the elements of information are relatable each other and surveyable at any one time. Successive processing refers to the integration of information into temporal sequences. The elements in the temporal series are not surveyable at any one time but only at the end of the sequence. The elements also are separate from each other. Both forms of information integration - simultaneous and successive - can appear in verbal and nonverbal tasks.

The modes of processing in Das et al. are operationalized by the help of a number of psychometric marker tests (i.e., Raven's (1947) Coloured Progressive Matrices, Graham and Kendall's (1960) Memory-for-Designs, Figure Copying Test (Ilg & Ames 1964), Digit Span, Visual Short-Term

Memory, Serial and Free Recall) using factor-analysis. The differences in definitions of successive (serial) and simultaneous (parallel) modes of processing in the model of Das et al. compared to the reaction-time definitions operationalized in experimental literature lie in the different emphases of theoretically based stimulus analysis and its empirical verification. The main dimensions obtained in factor-analysis are thought to describe the underlying common properties of cognition which are the simultaneous or successive syntheses made on task material.

The definitions of simultaneous and successive modes of processing are specifically dealt with in more detail in pages 48 - 52.

3.1.2. Domain of the modes of processing

The processor of information in humans is generally considered to be the central nervous system or brain (e.g., Luria 1973), but also, less materially, the cognitive mind (LeDoux 1984). LeDoux (1984) has suggested that there are three kinds of functional and anatomically separate processing mechanisms in the brain, one for cognitions and the other for affects and emotions. These cognitive and affective processing systems may have interconnections through neural subsystems but they can also function on their own. In the present study, only cognitive processing is dealt with although it is acknowledged that the interactions between the two processing systems may well be possible.

The existence of the two hemispheres in the brain has provided a useful basis for testing hypothesis about different dichotomies of thought and cognition although the work on the hemispheric specialization of information processing is evaluated by Davidoff (1982) as limited. Neuropsychologically, a more plausible model for the domain of the two modes of processing would be an anterior/posterior division of the brain

(Luria 1966 a, 1966b; Das et al. 1975, 1979) with visual, auditory and tactile afferents in the posterior part of the brain and the motor efferents in the anterior region of the brain. In the theory concerning the hierarchical organization of cognitive functions, Luria (1973) states that more modality specificity is required at the lower level of the hierarchy corresponding anatomically to the primary zone, less specificity at the secondary level and the lowest specificity at the tertiary zones. The highest level of amodality is thought to be included in the hemispheric speciality of cognitive functioning.

Parallel processing is not subject to temporal constraints and so it is possible to take in more information during a certain period of time. According to Martindale (1981) neither functional theories (linguistic versus spatial) nor processing theories (temporal versus spatial ordering) are sufficient to explain the domain of emotion which is not easily categorized as being either spatial or temporal. Therefore, he suggests a theory of secondary versus primary process as a more general formulation with affect and emotion in a continuum ranging from one polar type of cognition to another. Primary process, which is characterized by dreams, reveries, and altered states of consciousness (e.g., mystical experience and psychosis), is by nature synthetic, irrational, autistic (unrelated to reality), and devoted to wish fulfillment rather than to the planning of practical action. Secondary process thought occurs in normal waking states and is analytic, rational, reality-oriented, and devoted to problem solving. The left and right hemispheres are said to control the secondary and primary process, respectively.

Based mainly on empirical evidence from experimental psychology, it has been stated (Cohen 1973; Nebes 1974; Bradshaw & Nettleton 1981; Martindale 1981; Davidoff 1982; Hammond 1982) that serial processing is typical of the left hemisphere which deals with temporal ordering, sequencing, and rhythm whereas the right hemisphere processes information in parallel fashion with spatial ordering. The empirical evidence for the hemispheric differences in processing is provided in studies using different stimulus material (e.g., Bever & Chiarello 1974; Carmon & Nachshon 1971; Cohen 1973; Consoli 1979; Hellige & Webster 1979; Kimura & Vanderwolf 1970; Nebes 1978; Patterson & Bradshaw 1975; Polich 1982; Rizzolati, Umilta & Berlucchi 1971; Youngjai, Royer, Bonstelle & Boller 1980). Goldberg and Costa (1981) have proposed a mode of "descriptive systems" which takes account of the "old" and "novel" codes in processing. According to the same authors the processing in the left and right hemisphere differs in terms of well-routinized and novel codes respectively.

Cohen (1973) obtained shorter reaction times for visual letter stimuli in the left visual field (LVF) than in the right visual field (RVF). An increase in set size did not affect the reaction times of right hemisphere (RH) processing (LVF), but did so in case of left hemisphere (LH) processing (RVF). Cohen concluded that the RH processes information in a parallel mode and the LH in a sequential or serial mode. However, White and White (1975) found parallel processing to both hemispheres when they replicated Cohen's (1973) study by using letter and configurational stimuli. Contrary to White and White, Polich (1982) observed tendencies to serial processing in both visual fields. Davidoff (1982) concluded that there is little supportive evidence for Cohen's (1973) hypothesis and that the hypothesis concerning holistic processing and hemispheric specialty lacks empirical evidence.

The hypothesis suggesting that serial and parallel processes are characteristics of left and right hemisphere functioning, respectively, has not proved to be consistent across different types of stimuli and tasks (Bradshaw & Wallace 1971; Madden & Nebes 1980). The mere fact that sequential presentation of stimuli can elicit a holistic Gestalt at a later stage of processing (i.e., melodies, sentences) makes the rigorous positions questionable. Patterson and Bradshaw (1975) have suggested that it is only in tasks of a certain level of difficulty that the serial-analytic processing advantage of the left hemisphere is evident. The neuropsychological statement about serial versus parallel processing differences corresponding to the left versus right hemispheres seems, according to Davidoff (1982), ill-founded. Also, it has been cautiously stated by Madden and Nebes (1980) that it is difficult to make any precise statement about the relationship between serial-parallel processing and the hemispheres until more is known about hemispheric interaction as a function of stimulus material, the practice effect, and short- and long-term memory. Kim et al. (1980) have found empirical evidence that verbal sequencing abilities are impaired by left hemisphere lesions and nonverbal sequencing abilities by right hemisphere lesions.

Bradshaw and Nettleton (1981) state that there is a continuum of function between hemispheres rather than a rigid dichotomy (i.e., verbal/nonverbal) and the differences between the hemispheres are quantitative (in degree) rather than qualitative (in kind) and concern more the way the information is processed. These processing differences can vary according to sex, dominant hand, etc..

An alternative neuropsychological hypothesis for successive (serial) and simultaneous (parallel) processing is expressed in Das et al. (1975, 1979) and Luria (1966a, 1966b) so that simultaneous processing is linked more with the functioning of the occipito-parietal lobes and successive processing with the fronto-temporal regions of the cerebral cortex. The structural basis in the model of Das et al. thus consists of a distinction between the anterior and posterior divisions of the brain. The neuropsychological assumptions of the model of Das et al. have remained untested thus far. Pribram (1978) has suggested that the anterior lobe of the cortex processes episodic or situational information employing a successive strategy of organization, and the posterior lobes process automatic information employing a simultaneous strategy of information organization.

3.2. The stage theories of information processing

Information processing, it is suggested, occurs in different stages which include such processes as attention, categorization, encoding, storage, and retrieval of memory traces. One way to isolate the processing stages has been to measure the reaction times in the mental chronometry paradigm (e.g., Posner & McLeod 1982) where it is assumed that perception is an accumulative process that involves specific describable stages which can be defined in chronometric studies.

The stage theory of information processing (Moscovitch 1979) states that in the early stage processing is preattentive, non-strategic, and parallel, and in the later stage it is more attentional, flexible, strategic, and serial. The early processing stages are similar in the two hemispheres and so there are no laterality effects on processing. Sensory processes, iconic storage, and judgments based on perceptual characteristics are considered as occurring at an early stage of processing as well as simultaneous comparisons of letters, shapes, and faces based on physical appearance. Successive comparisons are lateralized and this becomes possible after the stage of processing where hemispheric asymmetries emerge. Thus, the cerebral hemispheres are equivalent for intial registration but differ at some later processing stage. Neisser (1967) thinks that parallel preattentive processing is followed by sequential attentional processing.

The existence of different stages in processing has been reported for tactile (somesthetic) information (Oscar-Berman et al. 1978). When a memory component was involved in the somesthetically presented information the processing showed hemispheric lateralization. Moscovitch (1979) emphasizes the memory and categorical perception (higher order abstraction) rather than sensory level phenomena in eliciting the hemispheric difference. Moscovitch's position on hemispheric differences is not very rigid because some amount of sequential processing is possible in the right hemisphere due to its linguistic properties.

3.3. The dual-coding approach of Paivio

Paivio (1971, 1978, 1979) makes a sharp distinction in his dual-coding theory between the perceptual and cognitive processing of verbal and nonverbal information. Both systems are represented and processed in independent, but interconnected symbolic systems. He assumes that perceptual and nonverbal information are represented in a more analogue-like fashion and are associated with an imagery system which organizes elementary images into higher-order structures of a spatial or synchronous character. Verbal information takes the form of propositional representation by organizing linguistic information and is serial by nature. These two different representations are differentially accessible depending on the task. Both systems are selectively aroused either by instruction, by previous experience, or by manipulation of task demands. The verbal system includes predominantly auditory-motor components, although it may also be able to process visual-motor and haptic components which basically are thought to be the properties of the nonverbal system. Because of these sensory distinctions, it is assumed that the verbal and nonverbal systems are orthogonal to each other. In other words, symbolic modality (verbal versus nonverbal) is orthogonal to sensory modalities (auditory, visual etc.). These symbolic systems are also considered to have separate processing systems for dealing with verbal and nonverbal stimulus information in various sensory modalities.

It has been stated that imagery operates in parallel fashion. The dual-coding approach has attracted those researchers interested in hemispheric specialization and Paivio (1977, p. 62) views the lesion studies and visual hemifield studies as evidence of the dual-coding theory. However, Madden and Nebes (1980) give a general caution about identifying the two independent systems of perception with hemispheric specialization. Instead, theoretically it might be more fruitful to attempt to define the complex and interrelated stages involved in verbal and nonverbal events and to try to trace the hemispheric contribution for each detailed aspect of perceptual function.

One assumption is that the two systems are functionally independent but partly interconnected. When the one system is active, it implies that the other system is inactive. Also, both modes can be active concurrently but without interference. The two systems are said to be interconnected when activity in one system can activate the other in a nonrandom fashion. According to Paivio (1978) this implies a partial mapping of one system onto the other, so that there is communication at particular points. These interconnections may be psychological or neuropsychological. Evidence for this is suggested by the direct interconnections between representations corresponding to concrete objects on the one hand, and their corresponding names on the other. The exact way in which the interaction occurs is not clear, and perhaps some conceptual confusions must be resolved.

Paivio (1978) further thinks that ın addition to dual coding (imaginary/verbal) theory, there is a need to postulate some kind of common coding system in order to account for other empirical evidence which is not explained by dual-coding theory.

Criticism of Paivio's dual-coding theory is articulated by Kirby and Das (1976) who emphasize the following points. Imaginal coding is also seen to consist of successive and not only simultaneous processing as is indicated by Paivio's definition. According to Kirby and Das the imagery construct does not fully describe the nature of simultaneous processing. Also, the cognitive processes are emphasized in the Das et al. model instead of the task materials and instructions as in Paivio's model. Imagery and verbal information might be coded either in images or in verbal processes.

Generally, Paivio (1976) regards the Das' et al. model as undistinguishable from his dual-coding approach. Paivio replies to criticism by referring to misunderstanding and misrepresentation of his model. Based on stimulus analyses of the tests used in Das' et al's study, Paivio argues that simultaneous processing actually includes imagery coding and successive processing verbal coding. Thus, according to him both assumptions (the amodal simultaneous-successive and a dual coding one) are consistent with the empirical findings.

The dual-coding model neuropsychologically favors the hypothesis of hemispheric differences in the modes of processing (Dean 1984).

3.4. Theory of attentional resources

Human beings have a limited amount of processing capacity available at any one time. All perceptual processes have two limitations, temporal, and spatial ones. We can not attend to all possible things at any one time. These limitations are seen as structural (Underwood 1978), and even highly automatized skills do not negate the concept of limited capacity.

The concept of attentional resources is introduced into the information processing by Kahneman (1973). All human information processing requires the allocation of some attentional resources for executing a certain task. This resource allocation may not necessarily be associated with cognitive abilities or performance, but may also be demanded by non-intellectual tasks (e.g., signal detection). Friedman and Polson (1981) consider each hemisphere as a multiple resource pool of limited-capacity information processing. The two pools of resources (one in each hemisphere) are mutually inaccessible.

Because of structural differences and limitations information processing differs when contrasting different subgroups of individuals (mental retardation, brain damage, talented individuals). Consistency in modes of information processing may change because individuals vary from time to time (fatigue, illnesses) or allocate resources differently between different tasks (strategic choices) (E. Hunt 1980).

In the registering of information there might also be the possibility that some central process (e.g., concurrent activity, anticipation of activity) activates the hemispheres. Kinsbourne (1970) has suggested attentional factors affecting hemispheric arousal.

At present, the models emphasizing differences in resource allocation (Friedman & Polson 1981; Kinsbourne 1970) seem to refer to the hypothesis of the existence of hemispheric differences in the modes of processing. Näätänen (1986) has reviewed the literature on attention and stimulus processing and suggests that on the basis of Risberg and Prohovnik's (1983) study, the right frontal cortex is perhaps more important in the control of selective attention than the left frontal cortex.

3.5. The Das, Kirby and Jarman model of information integration

A very comprehensive theory which integrates the theoretical concepts associated with information processing and neuropsychology has been presented by Das, Kirby and Jarman (1975, 1979). Because the neuropsychological aspects of this model are the main theme of the present study, the model and supporting research deserves a detailed presentation.

The Das, Kirby and Jarman (1975, 1979) model of information integration is based on Luria's (1966a, 1966b, 1973) theory of clinical neuropsychological functioning where the three basic functional units (arousal, coding and storing of information, and planning) interact with three anatomically different divisions of the brain. The associated processes can take the form of simultaneous or successive synthesis. Planning utilizes the coded information for purposeful and organized action (Das 1980; Das & Jarman 1981) and becomes identifiable from the coding factors when competence in these has been increased (Molloy & Das 1980a). Das et al. distinguish four basic components in information processing, namely the input, sensory registration, central, and output units. In the central unit the simultaneous and successive cognitive processes may take place in three varieties of cognition, namely perceptual, conceptual and mnestic. The input may arrive at the senses in simultaneous or successive order. From sense receptors the input proceeds, if attended to, through the sensory register to the central processing unit. In the central unit the planning and executive programming function uses simultaneously or successively coded information. In the output unit, the response may be organized either simultaneously or successively.

Processes and strategies are separated in the model so that processes include the performance component or the actual encoding, transforming and storing of information whereas strategies involve the control and planning function of these processes. Das et al. (1979) distinguish the processes from strategies by claiming that strategies are plans for behavior, a way to select, store, manipulate, organize and produce information. Processes are components of the strategy which is formed by an individual's experiences and culturally or genetically determined habitual responses. Through experience individuals learn to recognize the most appropriate strategy for a particular task. Strategies can be inferred from human behavior (Ashman et al. 1981). Simultaneous and successive processing are components of strategies which are the functions of the third block in Luria's model. The distinction between strategies and processes is acknowledged as a "slightly blurred one" (Kirby 1984a, p. 5).

The basic outline of the model by Das et al. (1975, 1979; Das 1984a) can be summarized thus.

(1) The simultaneous and successive as well as planning processes occur at all three levels of cognition which are perceptual, mnestic and conceptual.

a) Simultaneous and successive processes operate on information presented through any receptor. Thus, both modes of information processing are amodal and they overlap different sense modalities. Luria (1966a, 1966b) makes a modality distinction in the processing modes by emphasizing the role of motor and acoustic stimuli in successive synthesis and visual and tactile stimuli in simultaneous synthesis.

b) Simultaneous and successive processing operate on verbal as well on nonverbal information. The model deals with basic cognitive processes cutting across the sensory modalities and polarities, such as visual-perceptual, verbal-nonverbal, reasoning-memory (Ashman 1984). Information is obtained through transformations which may happen either in a successive or simultaneous way and thus intelligence does not prefer either mode over the other.

c) The same task (test) may be approached either simultaneously or successively (and within each mode of encoding, there may be variations in solution strategies). The approach would be determined by the interaction of the subject's degree of (a) competence in the dominant mode of encoding; (b) habitual mode of encoding when competent in both modes; and (c) task demands that can be modified by instructions.

(2) Simultaneous and successive processes are not hierarchical. Neither one is dependent upon the other. Simultaneous and successive processes are seen as operating upon cognitive structures which can be hierarchical and thus the two modes of coding can be involved to different degrees in the levels of abstraction within the hierarchy of cognitive structures. This point distinguishes this model of information processing from those emphasizing the level of processing, e.g. Jensen (1970, 1973). Level I (rote learning) in Jensen's model is considered to be dependent on level II (reasoning and abstraction) hierarchically.

In Das' et al. model (1975, 1979) both modes of processing are available to the individual and the choice of either depends on the factors specified above (1c).

(3) Either one of the processes may appear earlier than the other and have a distinct pattern of development that is not shared by the other. Developmentally, it is uncertain which of the processes appears earlier. Kaufman et al. (1982) imply that perhaps there appears phases when one is preferred over the other during development.

(4) Planning subsumes (a) the generation and selection of plans and strategies; (b) decision making; (c) execution of decisions and plans.

(5) Planning and coding are interdependent. Planning operates on coded information.

(6) Simultaneous processing is linked with the functioning of the posterior (parieto-occipital) regions and successive processing with the functioning of the anterior (frontal or fronto-temporal) regions of the brain (Luria 1966a, p. 125). Planning is mainly the functioning of the third unit (the frontal lobe) of Luria's theory.

Das (1984b) mentions that the factor of speed has appeared as separate from the factor of planning. In addition, the factor of planning has emerged independently from the coding factors (Ashman & Das 1980; Ashman et al. 1981; Das & Jarman 1981) and has been reported to include different clusters (e.g., search, rehearsal, clustering, and metacognition) as well as that the planning skills can be taught (Kirby 1984b). Planning is characterized as decision making and as a set of relatively distinct operations such as generating, selecting and executing plans and programs. Although coding and planning have been stated to be independent from each other theoretically in the model it is, however, certain that coding is not possible without some amount of planning. This issue is discussed more extensively in Das and Jarman (1981) and in Das (1980).

3.5.1. Comments on the Das' et al. model of information integration

The model of information processing by Das et al. assumes that symbols can be represented in perceptual, mnestic and conceptual forms. The model is sympathetic to the systemic approach to human cognitions as an interrelated set of capacities. Innate capacities and learning experiences are included in the model. As an information processing model it is more broad, comprehensive, integrative and covers many more human behavioral aspects than the general information processing models (e.g., Broadbent 1958; Newell & Simon 1972) which often are more oriented toward processing from the perspective of a computer.

If successive and simultaneous processes are seen and redefined in the terms used by E. Hunt (1980), the process base and knowledge base would somewhat overlap in the Das et al. model An additional component of planning remains in the Das et al. model which is hardly dealt with in other models of information processing. Instead, E. Hunt (1980) suggests two problem solving strategies which can have a linguistic or spatial-imaginal representation. The relationship between task performance and information processing capabilities depends on a subject's choice of either strategy for performing the task.

The model also deals more with the neuropsychological realities by assuming that the coding of information in the central nervous system is done differently and in different loci depending on task demands. However, the neuropsychological nature of simultaneous and successive processing remains further unspecified. The creative and constructive processes are emphasized in the form of planning, the capacity to create new structures on the basis of the workings of the first and second unit of Luria (1973).

In the Das et al. (1975, 1979) model the unit of information processing is considered more from the functional neuropsychological than from the neurophysiological level. Thus, the gross division of the brain according to its anterior and posterior parts is taken to represent the anatomical basis of information processing. This is in opposition to those supporters of the theory of hemispheric asymmetry (see chapter 3.1.2.), or, for example, Maron (1965) who claims that the basic unit of information processing in the brain is the neuron.

The Das et al. model is a flow chart model of information which emphasizes the role of the modes of processing (simultaneous and successive synthesis) and these concepts have been adopted from the philosophical writings of Sechenov and Kant (cf. Das et al 1979), not from communications-channel or engineering terminology. The identification of simultaneous and successive modes of processing lies not in distinguishing between processes that are simultaneous or successive, but between processing that treats information as a simultaneous event and processing that treats information as a series of events.

The concept of 'schema' or cognitive structure which is central in other theories of information processing (e.g., Anderson 1977) does not appear in the Das et al. model. Also, in a way, there appears a lack of attention to the content being processed and the issue of content is regarded as irrelevant.

The speed of processing is emphasized in cognitive theories, but in the Das et al. model it is not considered theoretically, although empirically speed has appeared as a third factor in addition to simultaneous and successive processing.

The conventional theories of human information processing (e.g., Broadbent 1958, 1963; Atkinson & Shiffrin 1968) also emphasize the role of short- and long-term memory which is not dealt separately in the Das et al. model. Memory is treated as one of the other cognitive functions and working in co-operation with these. Kirby (1980) has elaborated the coding unit (the second unit in Luria' theory) by separating the short- and long-term memory which both are controlled by the planning unit (the third unit in Luria's theory) through the intermediate-term (contextual) memory. Those structures where information is stored from moment to moment, held intact and preserved in order that any processing can happen, are responsible for memory. These short- and long-term storages should be dealt with in any theory of information processing but in the Das et al. model the emphasis is on the nature of the synthesis made of the material in the S-T M or L-T M store.

Jensen's (1970, 1973) level I (associative memory or rote learning) and level II (reasoning) model of cognitive abilities has been identified respectively with successive and simultaneous modes of processing. However, empirical research has shown that simultaneous factors also load as well on successive (memory) tests as on simultaneous tests (reasoning). Also several reasoning tests have loaded on successive factor (e.g., Kaufman et al. 1982). Thus, it seems plausible that the concepts of modes of processing are not equal to level I and level II abilities.

The hierarchical structure of simultaneous and successive processing is not hypothesized in the Das et al. model, although a hierarchical organization between the three functional units of the brain is assumed to exist (Luria 1973). No general factor has been found empirically in the studies of Das et al. (1975, 1979), and the best g-factor measure has been a mixture of simultaneous and successive tests (Kaufman et al. 1982).

The Das et al. model of information integration is an internally coherent model - like other conventional theories of information processing - but also it is externally linked to the environment and neuropsychological realities. The model takes account of individual differences and has remedial suggestions built-in to it — unlike in most conventional models of information processing. The biggest difference between conventional models of information processing and the Das et al. model lies in methodology. Both are interested in studying what happens between input and output and the underlying mechanisms behind cognitive functioning, but using different techniques. According to Zaidel (1978) the evaluation of brain function (and hemispheric differences) with the use of factor analytical theories of human intelligence might be a more fruitful approach than just to label different styles of the brain functioning. One of the objectives of the present study is to apply this approach for analyzing the relationship between the modes of processing and brain function. The emphasis in the present study is on the inferred relationship between the stimulus input and its encoding at the central nervous system, not so much on specifying the response modality.

FIGURE 1 represents the nature of simultaneous and successive processing, modified on the basis of the literature presented in earlier chapters. The elements of information to be processed can be ordered in presentation either simultaneously or successively, and the synthesis formed at the level of the central processor can also be of both types depending on the location of synthesis formation. The notions of hemispheric asymmetry have been included in the model by acknowledging that the verbal and nonverbal stimulus material have different functional localizations.

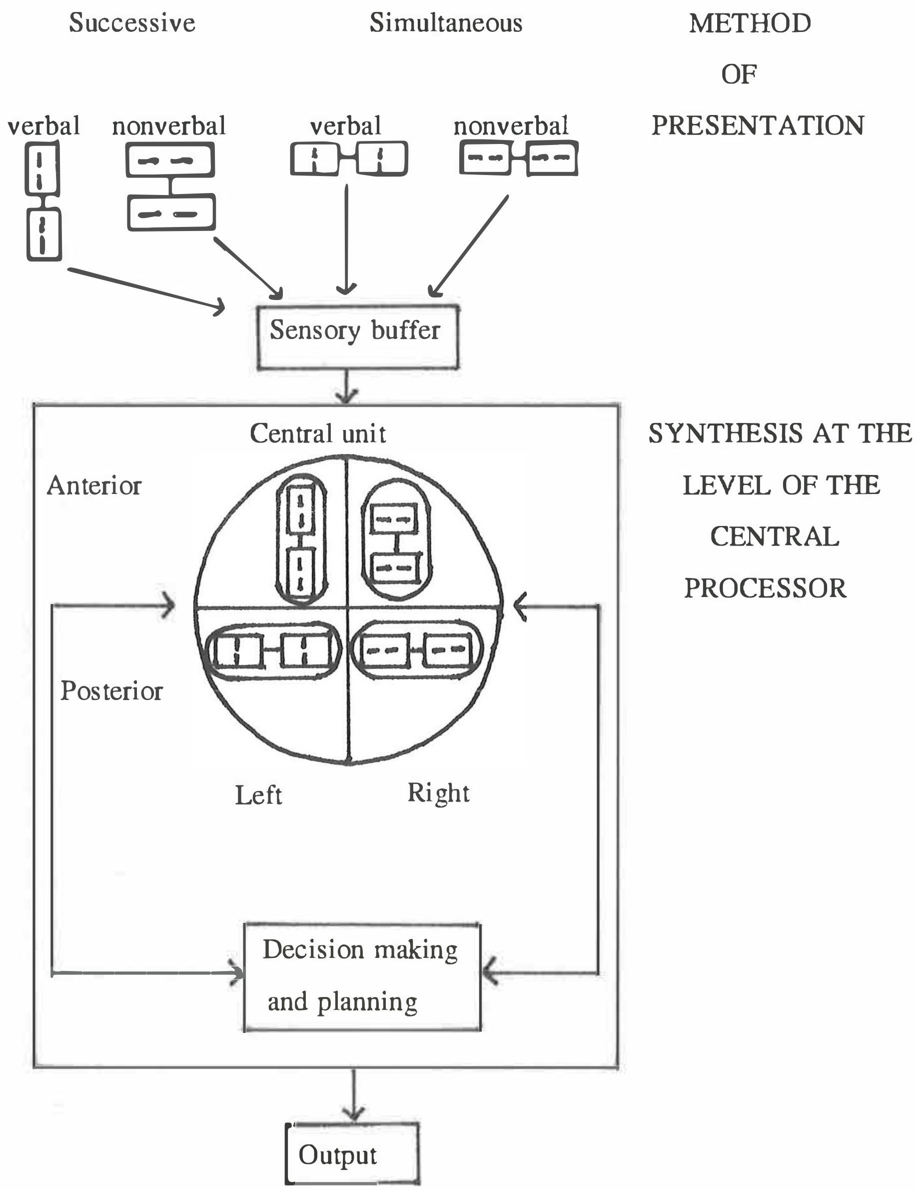


FIGURE 1. The nature of simultaneous and successive processing modified according to Das et al. model and hemispheric asymmetry.

4. EMPIRICAL RESEARCH ON THE DAS ET AL. MODEL

Empirical research on simultaneous and successive processing has focused on the validation of processing factors in different ability, age, socioeconomic, cultural, and diagnostic groups as well as on studying the relationship between cognitive processes and learning difficulties, school achievement, hyperactivity etc. Also, developmental changes in simultaneous and successive modes of processing have been studied across the preschool and elementary school age range (2 1/2 - 12 1/2 years old children) by using the K-ABC test battery (Kaufman et al. 1982; Kaufman & Kaufman 1983).

The samples studied have varied among child populations, with only a relatively few on adult populations.

4.1. Cognitions and simultaneous-successive processing

A brief review of the results of research on simultaneous and successive processing and cognition offers the following findings and conclusions.

1) Simultaneous and successive processing relate to intelligence (Kirby & Das 1977; Jarman & Das 1977; Ryckman 1981).

2) Simultaneous and successive processing can operate on the same linguistic functions, e.g. in the task of comprehending ambiguous sentences successive processing operates on the surface and deep structures but simultaneous processing is related to lexical ambiguity (Das, Cummins, Kirby & Jarman 1979; Cummins & Das 1978). In reading, successive processing is involved in the development of elementary

decoding skills, whereas simultaneous processing is related to advanced levels of comprehensive skills (like text organization, lexical access). The relation between narrative speech and the modes of processing has showed (Cummins & Mulcahy 1979) that syntactic complexity loads on the successive factor and speed of speech output on simultaneous factor. In children, the change from syntagmatic ("horse - run") to paradigmatic ("dog - horse") associations between the age 7 to 9 in free associations (Jarman 1980) has been found to correspond to the change in factor loadings from successive to simultaneous processing at the same age (Cummins & Das 1978). This finding could point to the possibility of the developmentally determined order of the earlier appearance of the other processing mode, in this particular case the successive mode (Das 1984c).

3) Simultaneous processing relates significantly to spatial ability, inductive reasoning and associative memory. Successive processing also relates significantly to associative memory (Kirby & Das 1978).

4) Arithmetic performance loaded on the simultaneous factor in samples of educable mentally retarded (EMR) children, but reading, spelling and syllogistic reasoning on the successive factor (Das & Cummins 1978). However, different results have obtained in normal samples where mathematics loaded mainly on the factor of school achievement and moderately on simultaneous processing (Das, Kirby & Jarman 1979).

5) School achievement (elementary and secondary schools) correlated (r's mainly between .30 and .40) with the factor scores of simultaneous and successive processing but where the achievement measures were factor analyzed together with the simultaneous and successive tasks then an achievement (verbal-educational) factor has appeared as an orthogonal factor to the modes of processing and speed (Das et al. 1979; Das 1973).

6) There is no clear relationship between hyperactivity and cognitive processes per se (Das, Leong & Williams 1978), although hyperactivity

may be more related to the functioning of the arousal unit (Molloy & Das 1980b).

7) Simultaneous processing is related to incidental learning (D. Hunt 1980) and the long-term retention of verbal material (Hunt & Randhawa 1983).

8) Simultaneous and successive processing seem to relate to reading so that beginning readers rely more on successive processing but advanced readers more on both modes of processing (Das, Kirby & Jarman 1979; Das, Leong & Williams 1978). Das, Cummins, Kirby and Jarman (1979) mention that in low SES (socioeconomic status) groups, reading has been shown to be related to successive processing but in high SES groups to both modes of processing.

9) Both simultaneous and successive processing are necessary for reading competence (Das et al. 1979). However, successive (or sequential) processing has been found to be more powerful in discriminating between normal and dyslexic readers (ranging in age from 8 to 12) (Hooper & Hynd 1985). In the same study, both simultaneous and successive scales were unable to discriminate among subgroups of reading disabled children.

10) Simultaneous and successive processing and achievement are related to sustained attention so that if all three (= modes of processing and attention) have high status, then reading and spelling scores are high, too (Hunt & Randhawa 1983). Sustained attention does not seem to be related to achievement in mathematics.

11) Factors of simultaneous and successive processing have emerged orthogonally to the factor of planning in studies on normal 14-year-old, gifted and mentally retarded samples (Das 1980; Ashman & Das 1980; Karnes & McCallum 1983).

12) There is no empirical evidence (Biggs & Kirby 1984) to relate meaningful learning to simultaneous processing and rote learning to

successive processing. However, the study on 15-year-old students demonstrated that students who differed in processing abilities (high sim. & succ., low sim.-high succ., high sim.-low succ., low sim. & succ.) also differed in how they perceived and organized their learning process.

13) Simultaneous and successive processing are related to grade point average (GPA) in college students (Merritt & McCallum 1984) but simultaneous processing is relatively more important for high ACT performance (American College Testing composite score).

14) The independence of the factors of simultaneous and successive processing has been demonstrated among non-retarded, retarded, and learning disabled children. Whether the children differ in the use of these modes of processing depends on their spontaneous use of strategies or combinations of these processes in the tasks to be performed in the planning unit (the third unit in Luria 1973) (Molloy & Das 1979).

15) The simultaneous, successive and speed factors were obtained for each group of fourth grade (10-year old) pupils of low-socioeconomic status and high-socioeconomic status (Molloy & Das 1979). The task of Cross-Modal Coding loaded, however, differently in these two SES groups. In the low SES group, successive synthesis was more significant in the solution of the task whereas in high SES group simultaneous synthesis contributed more to solving the task.

4.2. Cultural differences in simultaneous and successive processing

Comparing the factor scores for white Canadian children (10 years old) and for high-caste children from India Das et al. (1975) found the same Raven Progressive Matrices Test to load on both simultaneous and successive factors. He concluded that there might be a cultural preference for the succcessive mode so that the Indian children make greater use of successive strategies when resolving tasks which are simultaneous to white Canadian children.

Canadian native children (grades 3 and 4) have been found to benefit from the intervention program designed mainly to improve their strategy of successive processing (Das, Kirby & Jarman 1979). The shift in factor loadings before and after intervention changed in the intended direction. The higher loadings of the Raven Progressive Matrices on the successive factor shifted to the simultaneous factor after intervention. Also, the Visual Short-Term Memory Test loaded on the speed factor in the beginning, but after treatment the loadings were distributed over the simultaneous, successive and speed factors. The results showed that cognitive strategies can be taught to children and that optimal performance can be reached as a result of intervention.

Some cultural differences appearing on the factor loadings of simultaneous and successive processing have been reported. The clearest support for the two-process coding model (simultaneous-successive) comes from the patterns of loadings for the low-contact aboriginal group as compared to the patterns of high-contact aboriginals and nonaboriginals (Davidson 1979). Klich and Davidson (1984) concluded from their studies that there was no apparent difference in the underlying pattern of cognitive processing between Australian aboriginals and nonaboriginals as 8 to 17 years-old children. Simultaneous and successive factors were identified in both of aboriginal and nonaboriginal samples. When the means of these simultaneous and successive tasks were compared it was found that aborigines and nonaborigines performed equally well on five (Matrix A and B, Figure Copying, Form Assembly, KIO or Kim with Imagery Orientation) of the seven simultaneous processing tasks and on one of these tasks (Kim) the aborigines had a superior performance and on the another task (CF3 or Flexibility of Closure) an inferior performance. However, nonaborigines were significantly better on all four of the successive processing tasks (Number Span, Letter Span, Beads, Revised Beads) than aborigines. The interpretation of the result is presented rather in terms of contextually inappropriate and insufficient use of strategies by aborigines than as an inherent deficit. The use of appropriate strategies facilitates attention and memory functions and is primary to coding and integrating information in problem solving situations (Ashman 1984).

Neurosociological findings (e.g., Thompson et al. 1979; TenHouten 1982) have suggested the existence of cultural differences in two modes of thinking. The appositional mode of cognition (that is, the right hemisphere type of cognition which is assumed to be configurational, responsible for gestalt-formation and independent of time, Bogen 1977) has been found to be more developed in black people than whites, and, also in females compared to males. The finding has to be considered cautiously because of an inadequate operationalization of the appositional mode of thinking (the Street Test and five items from the Mooney Closure Test).

4.3. Information processing and mental retardation

Some tests of simultaneous and successive processing on mentally retarded pupils have obtained different loadings from the nonretarded group (Das 1972). The separation of both modes of processing seems to be less clear in retarded pupils than in nonretarded, but both modes of processing can still be found across different intelligence groups.

Das et al. (1979) have characterized mental retardation as deficits in planning and coding. The factor structures of retarded and nonretarded people appear to be stable across groups with intelligence as low as 50 (Das 1980). In retarded people with IQs in 20 - 50 range Ashman (1984) observed simultaneous and successive factors but not the factor of planning and concluded that these institutionalized moderately and severely retarded persons did not have the necessary coded information available to them to deal with complex planning tasks. This group also seemed to prefer simultaneous processing due to the fact that successive processing has not developed comparably with simultaneous processing. Also, the results showed that both simultaneous and successive processing play an important role in effective cognition.

Das (1984b) mentions that on mildly mentally retarded adults the factor of planning or the organizational aspects of cognition was clearly separate from the coding factors, and two other studies (Snart, O'Grady & Das 1982; Snart & Swann 1982) on borderline and moderately mentally retarded subjects seem to support the separation of planning from coding factors.

4.4. Information processing and sex differences

Randhawa and Hunt (1979) have found that for 10-year-old boys and girls the factor structures of simultaneous and successive processing are fundamentally the same. No sex-related mode of processing differences have been found in studies on adults (Merritt & McCallum 1983).

Attempting to clarify differences in female and male cognitive functioning has been an important controversial issue for over a decade (e.g., Maccoby & Jacklin 1974; McGlone 1977, 1978, 1980).

One conclusion drawn from neuropsychological literature has been that in the female brain the functions are more symmetrically or bilaterally organized than in the male brain and this notion is believed to explain some observations concerning differential ability structure and the relative rates of neuropsychological rehabilitation of males and females. Thus the language and spatial functions in female hemispheres are supposed to be more equally or bilaterally represented as well as the processing strategies of the hemispheres, too (Levy 1980, p. 292).

As a general conclusion about sex differences in brain functioning Levy (1980) points out that females surpass males in those functions which depend on the rapid encoding of unstructured information and on the retention of that information for use of adaptive output. Females have a general memory advantage over males when the information cannot be placed in a well-formed logical structure. This broad conceptualization can be understood from the point of view of the present study more as a female superiority in successive processing (due to their better coding of the rote learning type material or memorization) and in social communicative skills. On the other hand, the superiority of males in spatial and logical relation refers to their better mastery of simultaneous synthesis. It can be assumed that the coding of information is more contextual and memory dependent in females and more denotative and derivational in males.

It is incorrect, however, to consider the sex differences in terms of hemispheric asymmetry (Levy 1980). It might well be possible that the within hemispheres organization is different in males and females. Further Levy considers that the left hemisphere in females exceeds males in rote verbal memory, in fluency, and in being free from associative connections, while in males the left hemisphere is superior in analytic reasoning and abstraction of denotative meaning. The right hemisphere of females perceives information fast, remembers unstructured incidents and integrates contextual situations, whereas in males the right hemisphere is independent of perceptual field and good at forming formal spatial relationships.

4.5. Information processing in relation to age

The simultaneous-successive processing model has mainly been tested and verified on child samples where the model has proved to be of predictive value in language and reading functions.

For two groups of school children (6 years and 10 years old) the factor structure of simultaneous and successive processing was shown to be quite similar (Das & Molloy 1975). A third factor obtained was labelled as speed. An age difference was found in the two age groups in respect of the speed factor (Molloy & Das 1980a) so that the younger group is more limited in this capacity. The existence of strategic differences has also been proposed in this respect.

The factor structure for high-school students has provided a simultaneous, successive and divergent factor when given a battery of different tests than usual (Das, Kirby & Jarman 1975).

In a university student sample (N =91) Vernon, Ryba and Lang (1978) have shown 14 different tests to yield only partial support for the Das' model of information integration. The factor of successive processing resembled that of rote memorizing, but the other five factors were labelled as ability factors like number-spatial, perceptual, reasoning, and digit memory. The authors equated successive processing with associative memory or rote learning, but this has been a controversy to which Das, Cummins, Kirby and Jarman (1979) object. Vernon et al. did not find a general g-factor either, but concluded that their results tended to follow a hierarchical or multiple-factor model rather than a dichotomous simultaneous-successive model. When the second subanalysis was performed with the aid of 8 selected tests, the factors obtained became closer to those observed in studies by Das et al. (1975).

In another study by Naglieri et. al (1981) the factor structure of college students was similar to that observed by Das et al. (1975, 1979).

Although the two modes of processing have been stated to exist across different age groups, the simultaneous and successive model has not been tested in old people. Feinberg et al. (1980) see explaining the changes in information processing with aging and making distinctions between normal and pathological functioning in old age as a primary goal in the neuropsychology of aging. The elderly population is interesting from the point of view of information processing because various impairments or declining abilities have been reported in cognitive performance as a function of age. In the 65-years-old and over age group the ratios of cognitive disturbances vary so that from one to seven percent will experience severe dementia, 2.6 - 15 % mild dementia and 10 - 18 % intellectual disturbances (Eisdorfer & Cohen 1978). Some researchers (Benton et al. 1981; Kinsbourne 1980) have emphasized that age-associated changes in cognitive functions are differentiated unequally. In the elderly the effect of environmental factors like general health status, education, socioeconomic status on intelligence is more noticeable than age (Neri et al. 1980).

There is evidence from factor-analytical studies on normal adults that neuropsychological test batteries yield factors resembling simultaneous and successive factors. Aftanas and Royce (1969) found with normal 16 - 74-year-old subjects (N =100) in factor-analyzing 34 neuropsychological variables from 29 neuropsychological tests including the Halstead battery (without the WAIS) factors of perceptual organization characterized as an ability to integrate or organize relevant aspects of the perceptual field (simultaneous processing ?), temporal resolution (successive processing?), and speed which requires an integrated perceptual-motor response. The 9 other factors obtained were uninterpretable or unique to the battery. The factor of temporal resolution in particular was found to associate with age in the above-mentioned study.

4.6. Information processing and neuropsychological rehabilitation

Das (1984a) states that any good measure of cognitions should comprise three aspects including competence, processes, and remediation or the effects of training. The first of these points deals with age norms and cultural facts, the second with coding and planning, and the third with the interventional effects.

At least two successful intervention studies in children with learning disabilities have been reported (Krywaniuk cited from Das et al 1975; Kaufman & Kaufman 1979) and one partially successful in grade 4 children (Leasak et al. 1982). Some illustrative suggestions for remedial training in reading have been proposed on the basis of sequential and simultaneous processing by Gunnison et al. (1982). The execution of programs for process training in reading have been planned (Das, Snart & Mulcahy 1982).

Theoretically, a description of the modes of processing is not enough if one cannot at the same time specify the conditions under which a change in the modes of processing brings about change in behavior. Therefore, if the foundations of information processing are neuropsychological, it should be possible to point to different neurobehavioral outcomes as a result of variously applying the modes of processing. The reverse situation also holds true; the neuropsychological factors should be able to predict differentially the status of the modes of processing. The value of the information processing perspective in describing and interpreting neuropsychological dysfunctioning might offer new scope for neuropsychological rehabilitation if applied more frequently than has been done in the area of clinical neuropsychology.

Information processing psychology acknowledges the distinction between competence and performance and tries to seek out those factors bridging the gap between unused potential and actual achievement (Buffery & Burton 1982). The cognitive processes are complex skills which have to be relearned and we have to assume that brain functioning is flexible enough for this. Buffery and Burton (1982) see solid arguments in favor of developing a neuropsychological science of functional restoration based on information processing psychology.

4.7. Further need for research on simultaneous and successive modes of processing

The model of information integration (Das et al 1975, 1979) has been mainly studied from the perspective of coding, less from that of planning and hardly at all from that of arousal. A certain amount of arousal is needed as a prerequisite for the adequate functioning of the coding and planning units. It is inevitable that conclusions drawn on the basis of different samples (normal children, mentally retarded, college students) affect the clarity of the factor structure. The need for a more detailed picture of the complex relationship between different cognitions and simultaneous-successive processing is recognized by Das et al. (1979).

There are no studies available on simultaneous and successive processing in elderly people. The Das et al. model, based on neuropsychological findings, has not been tested on neurological samples either. The extension of the Das et al. model towards these two adult groups, namely neurological patients and elderly people, is one of the aims of the present study. The extension of the research from child samples in adult and elderly samples would demonstrate the appropriateness of the model as a general human information processing model. Also, the neuropsychological aspects of simultaneous and successive processing need to be clarified.

The need for cross-validating the Das et al. model of information integration by using different tasks has been expressed by Naglieri et al. (1981) and Ryckman (1981). Would it be possible to validate the Das model by giving traditional psychometric tests a new interpretation on the basis of their assumed properties of information processing ? Goetz and Hall (1984) mention that there have been no attempts to integrate an information processing perspective into standardized measures of intelligence.

Although the model of information integration is based on Luria's clinical neuropsychological findings no research on the neuropsychological correlates of the model has appeared thus far and therefore it is in high demand (Das 1984a). The applicability and usefulness of the model in the treatment of learning disabilities has been aknowledged as one of the possible approaches particularly in cases of neurological etiologies (e.g., Hartlage & Telzrow 1983).

The processing of information is stated (Das et al 1975, 1979) to be either simultaneous <u>or</u> successive and less concern is devoted to the possible interactional nature of the modes of processing. Randhawa and Hunt (1979) suggest that school achievement and complex tasks are, perhaps, dependent on the two processes working together interactively. D. Hunt (1980) further proposes that long-term retention plays an interactive role in the simultaneous-successive systems. Kamphaus and Reynolds (1984) mention the two modes of information processing as constantly interactive but they do not give any specification as to how.

5. PROBLEMS OF THE PRESENT RESEARCH

The empirical aims of the present study can be stated as the following problems which deal with the cross-validation, construct, concurrent, and predictive validation of the model of information integration (Das et al. 1975, 1979). The general outline of the modified model of Das et al. model is presented in FIGURE 1 (page 30).

1) Whether it is possible to integrate information processing perspective into standardized measures of intelligence and, thus, validate simultaneous and successive modes of processing by using novel tasks.

2) Whether it is possible to extend the model of information integration (Das et al. 1979) on the part of coding (simultaneous-successive processing) to include adult samples and the extent to which the model of information integration of Das, Kirby and Jarman (1975, 1979) can be cross-validated in different adult samples such as neurological patient groups and elderly people. Included here is the problem of how background variables like sex, education, occupation, socioeconomic level, and age relate to the modes of processing, whether simultaneous and successive processing cluster meaningfully around the neurobehavioral measures and identifying and accounting for those neurological variables which are associated with the modes of processing.

3) Whether it is possible to validate the model of Das et al. according to the neuropsychological characteristics (the theory of three functional units claimed by Luria) and whether there is any hemispheric superiority for

preferring a certain kind of mode of processing over the other. This involves identifying the neuropsychological variables which have the closest relationship with the modes of processing and which of them predict the level of simultaneous and successive processing. If there were a close relation between brain and cognitive functions at the behavioral and psychological levels this would suggest the importance of studying the role of neuropsychological variables in the relationship between brain and cognition.

4) The usefulness of the model of information integration (Das, Kirby & Jarman 1975, 1979) in understanding cognitive dysfunctions and whether the model of information integration can be applied to explain behavioral changes appearing in cases of disturbed cognitive functioning.

5) Whether it is possible to define the interactional nature of the modes of processing and the likely nature of such possible interaction.

6. STUDY 1

The aim of study 1 was (1) to cross-validate the model of information integration (Das et al. 1975, 1979) in a sample of adult neurological patients by using novel tasks, and, (2) to examine the relationship between the modes of processing and certain background variables, like sex, age, education, socioeconomic level, handedness, place of habitation and some factors associated with the neurological disease itself (i.e. the length of the time since the onset of injury, the number of clinical syndromes, the length of unconsciousness following trauma or injury, the evaluated need for neuropsychological rehabilitation and the degree of organic alteration).

6.1. Method

6.1.1. Subjects

The subjects were 121 mainly adult patients with different neurological diagnoses from the Central Hospital of Central Finland. The patients were sent for neuropsychological examinations by neurologists and physicians who evaluated the necessity for a neuropsychological assessment in each individual case. The distribution of patients according to their ethiopathogenesis, sex, age, education (score 1 = lowest, 9 = highest level) and socioeconomic status (score 1 = highest, 9 = lowest according to Rauhala 1966) is presented in TABLE 1. The age range of subjects was between 9 and 67 years. Only two subjects were under 16 years old. There were no aphasics in the present sample.

The sample means for verbal, performance and total IQ (WAIS) were respectively 93.52 (sd = 13.86), 83.79 (sd = 23.94) and 89.30 (sd = 14.56). The mean MQ (WMS) was 94.79 (sd =16.86). In some cases the IQ was evaluated on the basis of four (verbal) or three (performance) subscales of WAIS.

TABLE 1. Patient distribution according to etiopathogenesis, sex, age, education and socioeconomic status (N =121).

Etiopatho- @ genesis	M	F	Age x̄	Age sd	Education x̄	Education sd	Socioeconomic status x̄	Socioeconomic status sd
	(N)							
Congenital		1	19.0	0.0	3.0	0.0	8.0	0.0
Vascular	6	3	42.0	11.5	3.1	1.4	5.4	1.5
Infection	1	3	29.0	20.2	2.8	1.7	7.8	1.9
Trauma, head injury	39	11	35.0	15.1	3.2	1.5	6.2	1.5
Tumor	3	1	35.3	12.8	4.0	1.6	4.5	1.0
Degenerative	2	1	32.0	8.7	3.7	2.1	5.0	2.0
Metabolic-toxic	2		41.0	2.8	2.5	0.7	7.0	0.0
Epilepsy	15	3	30.4	12.2	3.2	1.7	7.1	1.6
Headache, migraine	2	3	42.0	13.0	2.2	0.8	7.0	1.6
Neuromusc.	1	-	20.0	0.0	2.0	0.0	7.0	0.0
Psychiatric	7	3	48.1	10.8	3.9	3.1	5.5	2.0
Other than neurological	9	5	36.9	13.2	2.3	0.6	7.0	1.1

@ According to Chusid (1973) except the last category.

Most of the patients (48 %) had been injured during the year before the investigation was performed, although the average time from injury to the time of neuropsychological assessment was four years and three months due to a few very old injuries.

The etiology of most of the patients (41 %) was head injury. The second largest patient group consisted of epileptics (18 %).

In the present sample, there were 92 % right-handed, 4 % left-handed and 4 % ambidextrous subjects.

In the sample 84 patients were classified as neurological patients as a result of clinical, electro-physiological and neuro-radiological examinations (including different combinations of EEG, PEG, brain scan, angiography and neurosurgical operation). There were no neurological findings on the basis electro-physiological or neuro-radiological measurements in 15 patients and no such data available for 22 patients. The latter group was considered to reflect diffuse psycho-organic syndromes on the basis of syndrome descriptions.

6.1.2. Procedure

All the subjects were individually interviewed and tested in the hospital. The psychometric tests were performed in a standard manner, although the test administration varied individually. Thus, there was no predetermined order of test presentation. The test battery included parts of the WAIS (Wechsler Adult Intelligence Scale, 1955) and the WMS (Wechsler Memory Scale, 1945), the Benton Visual Retention Test (1963), some personality tests (e.g. Wartegg Zeichnungstest, Rorschach (1948), Sentence Completion Test, drawing tests) and a qualitative neuropsychological investigation (e.g. different subscales of Luria's investigation by Christensen 1974 or part of the Finnish version of Maruszewski's 1972 battery). In some cases the motor performance was also investigated (tapping) as well as nonverbal intelligence (Ravens's Progressive Matrices, 1958).

The individual missing data on some variables was substituted for by the mean of the respective sample value before performing statistical calculations. The effect of these corrections was tested in a smaller sample with complete data on all test items (Äystö 1983). Because no differences were found in results between samples consisting of complete data and by group means substituted for missing data the data for the whole sample is reported here.

6.1.2.1. Classification of the tests

Tests of simultaneous synthesis

The criteria for the tests of simultaneous synthesis were defined according to Luria (1966a,1966b), Das, Kirby and Jarman (1975,1979) and Townsend (1972). The task was considered to require more of the simultaneous than the successive mode of processing where the elements of information were surveyable at once and relatable to each other (Luria 1966a, 1966b; Das, Kirby & Jarman 1975, 1979) or equally present at the time of processing, or correlatable at the level of the central processor (Townsend 1972) (see FIGURE 1). The following tasks were considered to meet these criteria.

1. WAIS - Similarities (S)

Adequate performance in the task of Similarities requires the successful integration of two components of verbal input. In other words, the correlation or integration of the input at the level of central nervous processor is necessary for the production of correct response. Tasks which require an understanding of the relations between concepts and subconcepts are considered by Cummins and Das (1978) to be examples of simultaneous verbal processing. Das, Kirby and Jarman (1975) used the task of Similarities as a marker test of simultaneous synthesis.

Score: the scaled score of WAIS Similarities.

2. WAIS - Information (I)

Luria (1966a, p. 74) states that the recall of earlier experiences or their organization demands the integration of separate elements into simultaneous groups. The task of WAIS Information is an example of recalled memorized knowledge as a reaction to the criteria (or question) specified by the experimenter. The question asked by the investigator requires the re-integration or organization of already experienced or acquired knowledge. This condition elicits the correlation of stimuli at the level of the central processor.

Score: the scaled score of WAIS Information.

3. WAIS - Block Design (BD)

The task of Block Design is a typical test of simultaneous synthesis (Luria 1966a, 1966b) which demands the production of complex spatial relations. The task corresponds closely to the simultaneous task of Spatial Manipulation used by Vernon, Ryba and Lang (1978).

Score: the scaled score of WAIS Block Design.

4. The Benton Visual Retention Test (BVRT) (Benton 1963)

The Benton Visual Retention Test (series C) requires that simple geometric figures are drawn immediately from memory after a 10 seconds' presentation. All the figures in a display card are presented at the same time. This condition meets the criteria of parallel processing in Townsend (1972). Although drawing calls for successive pencil movements the fundamental demand of this task is, however, the ability to draw the elements in their relative positions. The test items also have a resemblance to Graham-Kendall's (1960) Memory-for-Designs Test which has been used as a marker test of simultaneous synthesis in studies by Das, Kirby and Jarman (1975). The test also shares certain common features with the Figure Copying Test, although it is more complex due to immediate memory performance. Figure Copying has been classified as a test of simultaneous synthesis (Luria 1966a, 1966b; Das, Kirby & Jarman 1975; Vernon, Ryba & Lang 1978).

Score: the number of correctly remembered drawings (max. 10).

5. WMS : the subscale of Visual Reproduction (VR)

The test items in the Visual Reproduction subscale of the WMS and the method of presentation are similar to the above-described Benton Visual Retention Test. The test requires short-term nonverbal memory and its correct reproduction by drawing. The task demands retention and recall of geometric figures and their relations and thus has characteristics of simultaneous synthesis. Possibly the test of Visual Reproduction of WMS is somewhat more difficult to perform than the Benton Visual Retention Test because of the more complex nature of the visual items in the WMS.

Score: the score of correctly reproduced elements (max. 14).

Tests of successive synthesis

In the temporal order of processing the elements to be processed are presented one by one and the whole sequence is not surveyable at any one time (Luria 1966a, 1966b; Das et al. 1975, 1979) (see FIGURE 1). The information components are not necessarily related to each other in any systematic way, but may acquire meaning as the result of the whole sequence. A correlation (or a direct association) between stimuli is not required at the level of the central processor (Townsend 1972), although this may well happen in some cases. The issue is then no longer one of successive synthesis but a reflection of the appearance of strategic differences in the actual performance (e.g. chunking, memorizing). The interpretation of successive processing in a case of serially organized and presented material is obscured because the subject may use strategic approaches in resolving the tasks of successive synthesis and in this way the processing might acquire the characteristics of simultaneous synthesis. The following tasks were employed as tests of successive synthesis.

6. WMS: the subscale of Digit Span (DSp)

The subject is asked to reproduce immediately an aurally presented series of numbers. The forward and reverse series were both presented in two trials if the subject failed on the first one. Digit span or serial recall is a typical example of successive synthesis (Luria 1966a; Das, Kirby & Jarman 1975; Vernon, Ryba & Lang 1978).

Score: the sum of the maximum number of digits repeated correctly forward and reverse.

7. WMS: the subscale of Associate Learning (AL)

A list of ten pairs of words is presented to the subject aurally in three trials. After each presentation the recall of pairs of words is requested. Every presentation of the list follows a different order and the recall of pairs of words is also varied. Six pairs of words are easy associates and four pairs difficult or hard associates. Generally, paired -association learning is thought to be an example of successive synthesis (Luria 1966a; Das, Kirby & Jarman 1975, 1979; Vernon, Ryba & Lang 1978).

Two scores were derived:

1) number of correctly remembered associations in hard associates (ALh) (max. 12);
2) number of correctly remembered associations in easy associates (ALe) (max. 18) (Wechsler 1945).

8. WMS: the subscale of Logical Memory (LM)

Two short stories are read aloud by the experimenter. After the first reading is over the subject is asked to tell as much as s/he can recall from the story. The number of ideas as marked off in the memory passage are coded as record of verbatim. After the first story is read and recalled the investigator reads the second story and proceeds as before. The order of recalled ideas is not important, only the amount of correctly produced ideas matters.

The mode of presentation is organized serially, but at the stage of recall simultaneous synthesis is quite likely to happen. Luria (1966a, p. 76) states that the remembering of any logical text requires simultaneous synthesis. However, Vernon, Ryba and Lang (1978) have used the task of Logical Memory as a marker test of successive synthesis. If one follows the criteria described by Townsend (1972), it is clear that the story repetition does not require the combination of the story with the substance learned earlier and so the correlation at the level of the central processor is not necessarily assumed.

Score: the average number of ideas correctly reproduced on both passages (max.23).

9. WAIS - Digit Symbol (DSy)

Nine visual symbols are simultaneously presented on paper in numerical organization so that each number and symbol correspond to each other. The symbols must be copied on the paper as fast as possible according to the numbers randomly presented. Although in principle the symbols are surveyable at any time it is unlikely that the symbols and their corresponding numbers are mastered completely even after a brief training period. Rather, it is probable that the subject proceeds serially and sequentially checks the display symbols and their corresponding numbers when performing the task (the so called "multiplexing-phenomenon"). The task demands of Digit Symbol include the successive synthesis of kinesthetic-motor and visual functions associated with speed and accuracy of the performance.

Score: the scaled score of WAIS Digit Symbols.

6.2. Results and discussion

6.2.1. Factors of simultaneous and successive processing

The intercorrelations among ten cognitive variables are presented with means and standard deviations in TABLE 2. The calculations were made by using the Finnish HYLPS-program (1979).

TABLE 2. Intercorrelations, means and standard deviations among ten cognitive variables in a sample of neurological patients (N =121).

Tests	2	3	4	5	6	7	8	9	10	x	sd
1. BVRT	.15	.06	.43	.31	.34	.31	.45	.04	.27	5.89	1.8
2. I		.47	.14	.24	.33	.22	.18	.26	.28	8.97	3.0
3. S			.22	.27	.23	.33	.17	.31	.27	10.17	1.9
4. DSy				.64	.38	.49	.45	.32	.47	6.60	3.4
5. BD					.26	.45	.53	.24	.34	7.67	3.5
6. LM						.32	.43	.41	.65	8.75	4.1
7. DSp							.37	.29	.27	9.05	1.7
8. VR								.26	.36	8.36	3.4
9. ALe									.58	15.07	3.6
10. ALh										6.10	3.2

$r = .18$ ($p < .05$) $r = .23$ ($p < .01$) $r = .29$ ($p < .001$)

Factor analyses by the principal axial method were performed separately for two, three, and four factor Varimax-solutions (Äystö 1983). The four Varimax-rotated solution was selected for interpretation because this solution separated the simultaneous and successive components clearly and gave the interpretatively simplest factor structure. The eigenvalues were respectively 3.592, 0.916, 0.608 and 0.402 with the four factors accounting for 18.4 %, 15.5 %, 10.7 % and 10.5 % of the total variance respectively. The four factor Varimax- solution accounted for 55 % of the total variance. Due to similar factor loadings both in a sample of verified neurological patients with brain dysfunctions (N =84) and the total group of patients (N =121), the rotated Varimax factor results for the total sample are presented in TABLE 3.

TABLE 3. Varimax-rotated factor matrix for the neurological patients (N=121).

Test	Factors I Sim.n-v.	II Succ.	III Sim.v.	IV Sim. mem.	Communality h^2
BVRT	.320	.039	.024	.597	.461
I	.059	.167	.653	.156	.482
S	.218	.173	.641	-.050	.490
DSy	.707	.290	.035	.254	.649
BD	.752	.116	.168	.174	.638
LM	.111	.573	.221	.496	.635
DSp	.596	.153	.269	.165	.421
VR	.471	.203	.089	.477	.498
ALe	.208	.691	.230	-.082	.581
ALh	.224	.722	.159	.255	.662
% of total variance					55.1

The first factor can be labelled as simultaneous processing. Both simultaneous (BD, VR) and successive (DSy, DSp) tests have high loadings (over .47) on the first factor. Common to the loadings on the first factor is their concentration on nonverbal tests except in the case of Digit Span. The structure of the first factor resembles the number-spatial factors obtained in the study by Vernon, Ryba and Lang (1978), which was considered with reservation by the same authors largely to describe the content of the simultaneous factor.

The second factor has high loadings (over .57) only on the memory tasks which were classified as tests of successive synthesis and low loadings (under .30) on the other tasks. The factor describes successive processing, although not all successive tasks are loaded on this factor.

Information and Similarities are the only high loadings (over .64) on the third factor, which received low loadings (under .27) from the other test items. These simultaneous verbal tasks give the factor the characteristic of content specific simultaneous processing in addition to the mode of processing specificity. Thus, the first and third factor are both labelled as simultaneous processing but with different content, the first nonverbal, and the third verbal. This dissociation of the processing factors according to code content has not been demonstrated in earlier studies on child samples. Due to possible inherent characteristics in the present mainly adult neurologically impaired sample it is to be assumed that such characteristics might be responsible for the result obtained. The verbal and nonverbal functions are found to be dissociated in cases of aphasias or other differently localized brain injuries (e.g. Luria 1966a, 1966b, 1973) and so it is hypothesized that simultaneous and successive processing might further be specified according to the characteristics of the neurological patient sample. The two contradictory propositions concerning the gross level systems of brain organization responsible for preferring a certain mode of processing need to be tested in the light of simultaneous and successive processing in future studies.

The fourth factor comprised the successive (LM) and nonverbal simultaneous (BVRT, VR) tasks (loadings over .47). All these tasks demand either verbal or nonverbal recall. It was mentioned earlier that the task of Logical Memory has a dual nature requiring simultaneous and successive processing. Also, the use of different strategies in performing the task can vary individually and bring difficulties in interpretation. Common to all memory tasks loaded on fourth factor is the recall of holistic designs or images created temporarily during the testing situation. The fourth factor represents simultaneous recall and refers to one possible way of extracting information from memory storage independent of its content or code. The fourth factor might thus describe the simultaneous properties of the memory components suggested in the model of Das et al. (1975, 1979). The fourth simultaneous factor differs from the other two simultaneous factors (namely I and III) only on the basis of content characteristics. The other alternative interpretation for the fourth factor suggests that it reflects the organizational components of cognition or planning. The factor may reveal the underlying planning component included in the memory tasks which were originally defined as demanding both successive and simultaneous processing.

The four factors described above each have a special nature and in principle they reflect the same properties as have been found in earlier studies by Das and his collegues. Two tasks, namely Logical Memory and Visual Reproduction of the WMS had high loadings on two factors. The covariance of LM on the factors of successive processing (.57) and simultaneous memory factor (.50) is interpretable as due to the characteristics of the task. Also, the VR subscale covariances in simultaneous nonverbal (.47) and memory factor (.48) are easily interpretable for the above reasons, as well as the BVRT covariances in the same factors (loadings respectively .32 and .60). The hypothesized simultaneous tasks (I, S, BD, VR, BVRT) had on some of the three simultaneous factors loadings of .47 to .75 and all loaded under .21 on the successive factor. Respectively, three of the successive tests had high loadings of .57 to .72 on the successive factor, but low loadings under .25 on simultaneous factors except the LM covariate on the simultaneous memory factor. The role of two hypothesized successive tasks, Digit Symbol and Digit Span, was emphasized on the simultaneous nonverbal factor perhaps due to sample characteristics and differences in strategic solutions.

In summary, it can be stated on the basis of the data presented in TABLE 3 that no substantial overlapping occurred between the tasks selected to measure simultaneous and successive processing. In the present study, no g-factor was found. The refinements made in the interpretation of factors in the present study can be explained adequately by the information integration model of Das, Kirby and Jarman (1975, 1979). Whether the use of content-based interpretations of the simultaneous-successive dimension is needed or not depends on the actual problem under study and on the interpretative specification thus suggested. If the objective is to study the relationship between modes of processing and brain function, content-based interpretations might be appropriate. However, content-based interpretations of factors in addition to the process-based interpretation might contribute to resolving the disagreement between the processing model (Das, Kirby & Jarman 1975, 1979; Kirby & Das 1976) and the dual-coding approach (Paivio 1971, 1976).

6.2.2. The relationship between the modes of processing and background variables

The relationship between factor scores for simultaneous and successive processing and some individual and background variables is presented in TABLE 4. The factor scores were calculated by the regression method.

Education was the only background variable correlating positively and significantly ($p < .05 - .001$) with all the processing factors. The more education the individual had the more higher the factor scores in all modes of processing tended to be. If the two modes of processing are assumed to form the basis for cognition, then these correlations suggest the importance of the role of education (or intervention, rehabilitation) ın improving

TABLE 4. Correlations between factor scores for simultaneous and successive processing and some background variables in the neurological patient group (N =121).

Variable / Factors	I Sim.n-v.	II Succ.	III Sim.v.	IV Sim. memory
Age	-.38***	-.20*	.10	-.37***
Socioeconomic level	-.03	.10	-.23**	-.06
Education	.29***	.23**	.27**	.21*
Occupational incapacity #	-.45***	-.25**	-.10	-.36***
Need for neuropsychological rehabilitation #	-.06	.01	-.06	-.02
Organic alteration and deterioration #	-.40***	-.09	-.12	-.29***
Length of time since injury/disease #	-.01	.06	.03	-.02
Amount of clinical symptoms #	-.15	-.11	.05	-.05
Length of period of unconsciousness following trauma #	.15	-.15	.02	.17

* p< .05 ** p< .01 ***p< .001

\# high scores indicate a high value on the variable

the basic processes of cognition (and consequently cognition itself).

Age correlated negatively and in a predictable way with three of the factor scores for processing but not with the factor for simultaneous verbal processing. The verbal functions or "crystallized intelligence" have been found to be most resistant to the effects of aging in studies concerning the ability structure of intelligence (Cattell 1964). In the present study the correlation between age and verbal simultaneous synthesis remained nonsignificant.

Socioeconomic status correlated only with the factor of simultaneous verbal synthesis indicating that the higher the socioeconomic level the higher the scores for simultaneous verbal factor. The relationship between the modes of processing and socioeconomic status (SES) did not reach statistical significance in the cases of successive and other simultaneous factors I and IV. One explanation for the lack of correlations in these cases might be that the mean of the socioeconomic level in the present sample was quite low and the distribution of the values of the SES variable was skewed at the lower end. However, despite the skewedness of the distribution, socioeconomic status was powerful enough to influence significantly factor scores for simultaneous verbal processing. The role of high socioeconomic status has been found (e.g. Mussen, Conger & Kagan 1974, pp. 261-267) to associate with higher language ability in children. The weak correlation between simultaneous verbal processing and the SES variable points to a possible existence of one potential external mediator (SES) in the simultaneous mode of processing, but not in the case of successive processing.

The degree of occupational incapacity and inefficiency following trauma or disease - which was evaluated on the basis of clinical psychological assessment - correlated negatively with all the processing factors, although not significantly in the case of the simultaneous verbal factor. There were more defects in successive and simultaneous nonverbal (factors I and IV) processing the greater was the involvement of occupational incapacity.

One of the striking findings in the present study was that the external variables associated with the disease itself did not seem to correlate with the processing factors at all. The length of time since the onset of injury, the number of different clinical symptoms or the dysfunction of the nervous system, the presence and the length of unconsciousness following trauma or injury and the evaluated need for neuropsychological rehabilitation did not correlate significantly with the modes of processing. The degree of psychologically evaluated organic alteration or deterioration correlated negatively and significantly with simultaneous nonverbal factor I and recall processes (factor IV), but not with successive or simultaneous verbal processing. This observation might indicate that one of the most profound changes after the occurrence of brain dysfunction is to be seen first in the impairment of simultaneous nonverbal and recall processes. This finding in adults is in reverse pattern to the observations found by Das et al. (1979) according to which simultaneous synthesis plays an important role when children learn to read. The role of simultaneous processing is emphasized as much in the process of cognitive skill acquisition as in the breakdown of cognitive systems as a result of brain dysfunction.

There was an interesting finding between sex and the modes of processing when testing the means of factor scores in t-tests (TABLE 5). Males seemed to perform better than females in the tasks of simultaneous synthesis, but less well in successive synthesis. However, sex-related differences became significant ($p < .05$) only in simultaneous verbal and memory factors and this was probably partly due to functions at occupational level which were significantly higher in males than females ($p < .05$). The other background variables were not represented significantly differently in the groups of males and females. No sex-related mode of processing differences have been found in studies on adults elsewhere (Merritt & McCallum 1983).

TABLE 5. The relationship between sex and information processing (N =121).

Sex		Factor scores I (Sim. n-v.)	II (Succ.)	III (Sim.v.)	IV (Memory)
Male (N =87)	$\bar{x}$	505	491	513	514
	sd	(93)	(103)	(95)	(98)
Female (N =34)	$\bar{x}$	488	522	466	464
	sd	(116)	(90)	(107)	(97)
		ns.	ns.	$p < .05$	$p < .05$

The male superiority on simultaneous processing and the tendency for female superiority on successive processing (although non-significant) is a tentatively interesting finding because both modes of processing are seen theoretically as polarities or orthogonal to each other.

Left-handedness and place of habitation (city or countryside) bore no relationship to simultaneous and successive processing.

6.3. Conclusions

The present study was an attempt to independently cross-validate with novel tasks the model of information integration of Das, Kirby and Jarman (1975, 1979) in an adult neurological sample. Support for the model was generally found. The four factors obtained in the present study, however, included simultaneous and successive factors so that simultaneous processing could be interpreted either with or without code content. Simultaneous verbal (factor III) and nonverbal (factor I) processing could be interpreted as separate factors and as appearing independently of simultaneous memory (factor IV). The three simultaneous factors with different content support the existence of different varieties of cognition.

The interpretation of the processing factors was not restricted by code content, because all simultaneous factors cut across different varieties of cognition (e.g., mnestic, conceptual, perceptual). Thus, the interpretation of simultaneous and successive factors containing various codes is consistent and well in accordance with the theoretical constructs of the model of Das et al. (1979). It is quite possible that the properties of the study population (adult neurological patients) influence the differentiated nature of the processing factors.

In the present study, no g-factor was found, either. It was felt that factor interpretation may obtain deeper meaning when the modes of processing and code content are taken into consideration simultaneously. Interpretations of this kind might be needed in studies concentrating on the relationship between modes of processing and the brain. The combined interpretation of the modes of processing and the content might partially contribute to resolving the disagreement between the model of Das et al. (1975, 1979; Kirby & Das 1976) and Paivio's (1971, 1976) dual-coding approach.

The role of education was emphasized as the most influential background variable correlating highly with the modes of processing. A weaker advantage in favor of males in the simultaneous verbal and memory factors was also observed.

7. STUDY 2

The two hypotheses concerning the relationship between the modes of processing and their neuro-anatomical structure (Luria 1966a, 1966b; Das, Kirby & Jarman 1975, 1979; *versus* Cohen 1973; Bradshaw & Nettleton 1981) has not been tested empirically thus far. The present study aimed (1) to cross-validate the Das's model of information integration (Das, Kirby & Jarman 1975, 1979) in a brain dysfunctional sample, (2) to test the relationship between the modes of processing and their proposed neuroanatomical structure, and (3) to study tentatively the distribution of the modes of processing according to sex.

Kimura (1983) has proposed that the sexual dimorphism is not only between the left and right hemisphere but also between anterior and posterior cerebral locations. Futher, sex differences in cerebral verbal functional organization and the processing of visuospatial tasks have been observed elsewhere (McGlone 1977, 1978, 1980; McGlone & Kertesz 1973).

7.1. Method

7.1.1. Subjects

The subjects were 106 adult neurological patients (males 73, females 33) selected from 192 recently and comprehensively tested neurological patients from two regional hospitals in Central Finland and North Carelia, Finland. The mean age of the patients was 35.8 years ranging from 16 years old up to 67 years old. All subjects except three of the older ones had completed elementary education (seven years in school). Ten of the subjects had college level education, and 93 had high school or vocational school education. The data on education was missing in three cases.

The mean verbal, performance and full scale IQ scores (the WAIS) for the sample were respectively 102.5 (sd =16.9), 94.8 (sd =21.1) and 99.7 (sd = 17.3). In some cases, IQ was evaluated on the basis of four (verbal IQ) and three (performance IQ) test scales. The Memory Quotient (of the WMS) for the sample was 99.0 (sd =16.7).

There were no severe aphasics among the subjects. Almost all of the subjects (96 %) were right-handed.

Six of the patients (5.7 %) had visual field defects and 18 of the patients (17 %) had hemiparetic syndromes.

The patients were assigned to one of the brain-damaged groups on the basis of the following criteria: (1) clinical anamnesis and diagnosis of head trauma or injury and (2) positive findings on one or more of the following: electroencephalography, angiography, brainscan, pneumoencephalography, computerized axial tomography and/or neurosurgical operation. The classification of patients into groups was performed unanimously by two neuropsychologists or by the same neuropsychologist at two different times. All cases of equivocal diagnosis were excluded as well as severely aphasic patients who were not testable psychometrically.

Unilateral left hemisphere dysfunction was found in 33 cases and unilateral right hemisphere dysfunction in 39 cases. The lesions located anterior to the Fissura Rolandi (in front of the central sulcus) or in fronto-temporal areas were separated from the posterior lesions (cerebral dysfunctions behind the central sulcus). An anterior lesion was observed in 29 cases and a posterior lesion in 40 cases (appendix 1). There were seven cases with bilateral lesions. Focal lesions were found in 67 cases and these distributed as follows: left anterior damage (N =12), right anterior damage (N =17), left posterior damage (N =17) and right posterior damage (N =21). The diagnoses of specific lesions are described in TABLE 6.

The control group consisted of 32 patients (males 24, females 8) who were examined neurologically with neuroradiological and electro-physiological measures and were found to be without CNS-dysfunction.

7.1.2. Procedure

All the patients were interviewed and tested by neuropsychologists who used psychometric tests (WAIS, WMS, BVRT, SCT, Rorschach, Raven Matrices, Wartegg-Zeichnungstest, tapping) and a qualitative neuropsychological test battery (parts of Luria's investigation by Christensen 1974 and items from the Finnish version of Maruszewski's neuropsychological test battery). The test was administered individually and so there was no predetermined order of test presentation. The psychometric tests were performed in a standard manner according to the test manuals.

The tests of simultaneous and successive synthesis are the same as presented in the Study 1 (pages 48 - 52).

TABLE 6. The diagnoses of specific damages (N =67)

Left anterior (LA) (N =12)	
Contusio cerebri	2
Contusio cerebri cum subdural hematoma or hemiplegia l. dx.	2
Focal epilepsy	4
Hemorrhage	1
Meningeoma (operated)	1
Tumor (operate)	1
Occlusion	1
	12

Right anterior (RA) (N =17)	
Neurosurgical operation	9
Contusio cerebri cum focal atrophy	3
Contusio cerebri cum subdural hematoma	1
Focal epilepsy	1
Atrophy	1
SAV	2
	17

Left posterior (LP) (N =17)	
Thrombosis	3
Contusio cerebri cum subdural hematoma	1
Contusio cerebri	3
Infarct	1
Glioma (operated)	1
Atrophy (temporal & parietal lesion)	4
Embolia	1
Tumor	1
Focal epilepsy	1
SAV	1
	17

Right posterior (RP) (N =21)	
Contusio cerebri cum hemiparesis l.sin.	2
Contusio cerebri cum focal atrophy	6
Infarct	1
Focal epilepsy	6
Neurosurgical operation	3
Thrombosis	1
Occlusion	1
Edema	1
	21

7.2. Results

All nine simultaneous and successive tests were intercorrelated and factor-analyzed by the principal-axial method with Varimax rotation (TABLE 7). The eigenvalues for three factors were respectively 3.361, 0.949 and 0.853. All three factors were submitted to Varimax-rotation because the total variance accounted for by the last two factors was

TABLE 7. Varimax rotated principal factors for the total group of neurological patients (N =106) including the control group (N =32).

	Factors			
Test	I	II	III	h^2
BVRT	.491	.110	.069	.258
I	.085	.798	.151	.667
S	.203	.748	.233	.655
DSp	.413	.529	.075	.456
DSy	.725	.179	.236	.613
BD	.733	.231	.052	.593
LM	.250	.298	.531	.433
VR	.637	.050	.211	.453
ALe	.057	.149	.663	.465
ALh	.183	.057	.731	.571
% of total variance				51.6

quite large (31 %) and equal in size, 17 % and 14 % respectively. The three factor Varimax-solution explained about 52 % of the total variance (TABLE 7). It was thought that factor structures for simultaneous and successive processing would be basically similar in patient and control groups (as observed in Study 1) and so the factor analysis was performed for the whole group. The possible differences between groups were considered to appear in the level of performance. Also, the group sizes were too small to allow separate factor analyses. All calculations were performed by using the Finnish HYLPS-program (1979).

The first factor was interpreted as nonverbal simultaneous processing. The first factor has loadings mainly from tests of simultaneous synthesis. However, the simultaneous tests split their loadings over two factors so that verbal simultaneous tests also have significant loadings on factor II. Also, factor I has high loadings from two successive tests, namely Digit Symbol (.73) and Digit Span (.41). Both these tests include number content to some extent, and the factor closely corresponds to the number-spatial factor of Vernon et al. (1978) which was interpreted by the authors as simultaneous factor with reservation. The only verbal test to load on factor I is Digit Span, but the highest loadings on the first factor are due to nonverbal tasks.

The second factor represents all the verbal subscales of the WAIS. Information (.80) and Similarities (.75) were defined as simultaneous tasks and Digit Span (.53) as a successive task. The overlapping of Digit Span between the two factors (I and II) might be explained by differential use of individual strategies in resolving the problem (e.g., different memorizing aids, chunking etc.) or by the fact that the scaled score of the sum of Digit Span forward and backward reflects more simultaneous than successive synthesis. It has been suggested (e.g., Naglieri et al. 1981) that Digit Span Backwards requires the memory of Digit Span Forward and so the demand for simultaneous synthesis is greater in the task of Digit Span total. Certain properties of brain damaged groups in the present study might have influenced the covariation in factor loadings of Digit Span. The overlapping of Digit Span between simultaneous and successive factors has not been found in child samples (Das, Kirby & Jarman 1975, 1979) or in university students (Vernon et al. 1978). The difference in the use of strategies between children and adults is understandable from the aspect of expert-novice difference where adults have already learned the effective use of strategies compared to children in the process of learning different cognitive strategies. The dissociation of simultaneous verbal synthesis (factor II) from the simultaneous nonverbal synthesis (factor I) in the present study might well arise from the characteristics of the sample and therefore, a more careful study of the effects of cerebral dysfunction on simultaneous and successive processing is indicated.

The third factor can be labelled as successive processing. It has loadings mainly on memory tasks which were classified as successive tests. However, not all of the tests believed to measure successive processing have loadings on factor III. The Digit Span and Digit Symbol have only low loadings. All those tasks which load highly on the third factor demand immediate repetition or the rote learning type of memorizing relatively independent of earlier experiences.

The three factor Varimax-solution gave clearly interpretable simultaneous and successive factors. All hypothesized simultaneous tasks had loadings of .49 to .80 on simultaneous factors and failed to load above .23 on the successive factor. However, some hypothesized successive tasks (Digit Span and Digit Symbol) failed to load on the successive factor, whereas the other successive tasks (LM, ALe, ALh) got high loadings of .53 to .73 and low loadings under .30 on simultaneous factors.

The factor scores for three factors were calculated by the regression method and the means of factor scores were compared in groups of patients with left anterior (LA), left posterior (LP), right anterior (RA) and right posterior (RP) lesions. The results of the two-way variance analysis (ANOVA) are presented in TABLE 8, where F-values are presented for laterality, anterior-posterior main effects, and the interaction. The mean ages for the groups were respectively 33.5, 31.6, 39.3 and 32.7 years. For comparison, the means and standard deviations of control group (N =32) are also given in TABLE 8. The comparisons in simultaneous and successive processing between the brain damaged groups and the control group are presented in appendix 1.

TABLE 8. Simultaneous and successive processing in anterior and posterior locations of left and right hemisphere dysfunction (N =67). Summary of the results of two-way ANOVA: laterality (L, R) x anterior/posterior (A, P).

	Factor I Sim. nonverb.		Factor II Sim. verb.		Factor III Succ.	
Lesion group	x	sd	x	sd	x	sd
LA (N =12)	543	106	452	86	474	122
RA (N =17)	500	83	508	88	493	105
LP (N =17)	487	90	452	81	446	140
RP (N =21)	469	114	508	81	535	63

	F	df	p	F	df	p	F	df	p
General means	1.48	3/63	ns.	2.47	3/63	.07	2.24	3/63	.09
Laterality	1.40	1/64	ns.	7.52	1/64	.01	4.82	1/64	.05
A/P	2.97	1/64	.10	0.00	1/64	ns.	0.21	1/64	ns.
Interaction lat. & A/P	0.26	1/63	ns.	0.00	1/64	ns.	1.70	1/64	ns.

	x	sd	x	sd	x	sd
Control (N =32)	506	105	514	117	509	80

The two-way ANOVA showed some slight differences ($p < .07$ to $p < .09$) among the four groups in factor scores for simultaneous and successive processing (TABLE 8). There were no interactions between laterality and anterior-posterior division in any of the processing factors. The main effects of laterality were significant in factors of simultaneous verbal processing (factor II) ($p < .01$) and successive processing (factor III) ($p < .05$). The main effects of the anterior - posterior division of the brain was only significant at the level of $p < .10$ in the factor of simultaneous nonverbal processing (factor I).

In the first factor both posterior groups performed worse than either of the anterior groups. The weak statistically significant difference appeared only between the LA and RP groups ($t = 1.81$, $df = 31$, $p < .10$). This tentative finding is consistent with neuropsychological evidence that assumes visuospatial functions are processed by the posterior regions of the hemispheres.

In the factor of simultaneous verbal processing (factor II) the LP group differed significantly from the RP group ($t = 2.13$, $df = 36$, $p < .05$); the LA group differed slightly from the RP group ($t = 1.87$, $df = 31$, $p < .10$) and the LP group from the RA group ($t = 1.93$, $df = 32$, $p < .10$). The performance of all the left hemisphere groups (either with anterior or posterior dysfunction) was poorer than the performance of the respective right hemisphere groups. The result for factor II indicates the vulnerability of simultaneous verbal processing as a result of left hemisphere dysfunction compared to right hemisphere damage. The result is well in accordance with the classical notions concerning the superiority of the left hemisphere where verbally presented material dominates.

In the factor of successive processing (factor III) the LP group performed significantly lower than the RP group ($t = 2.61$, $df = 36$, $p < .05$). Another weak difference in the same factor emerged in comparisons between the LA and RP groups ($t = 1.90$, $df = 31$, $p < .10$). In both comparisons successive processing was more affected by left than by right hemisphere dysfunction, and in one comparison the left anterior group was more deficient in successive processing than the right posterior group.

7.2.1. Sex differences and information processing

There were no differences between males and females on any of the factors of simultaneous and successive processing in the brain dysfunctional group ($N = 67$) as a whole or in the control group ($N = 32$). However, there was a statistically significant difference between the sexes in the case of the left hemisphere so that the females did better than the males in factor III ($t = 2.56$, $df = 31$, $p < .02$). In the case of right hemisphere dysfunction the males and females did not differ. In the groups of anterior or posterior dysfunction the sex differences were also nonsignificant. Further, it should be noted that there were no differences between males and females in background variables such as age, occupation, education, intelligence (WAIS IQ) or memory (MQ of the WMS).

7.2.2. Age, education, socioeconomic status, and information processing

Education (TABLE 9) correlated significantly with all three processing factors and SES only with the simultaneous verbal factor. The more education the individual had the better the factor scores in processing. Also, the higher the socioeconomic status, the better the performance in simultaneous verbal factor.

The correlation of age with the modes of processing was nonsignificant in the case of simultaneous verbal processing, but reached .01 level in factor of successive processing and .001 level in the factor of simultaneous nonverbal processing. The correlations were consistent and in the same direction as the earlier findings published on the differential decline of verbal and visuospatial functions with aging (e.g. Schludermann et al. 1983).

When the sample was divided into groups of younger (under 36 years old, $N = 55$) and older subjects (36-67 years old, $N = 51$) the only difference between these two groups appeared in the simultaneous nonverbal factor ($t = 4.00$, $df = 104$, $p < .001$). The difference in this first factor was to the advantage of the younger subjects. In the third factor, the successive processing of the older subjects was worse with $p < .10$.

TABLE 9. Correlations between the modes of processing and age, education and socioeconomic status (SES) (N =106)

Variable	Factor scores I Sim.n-v.	II Sim.v.	III Succ.
Age	-.40***	.15	-.28**
Education	.23*	.53***	.29**
SES @)	.03	-.41***	.09

@) a high score indicates low status in SES
* p < .05
** p < .01
*** p < .001

In the localized brain-damaged group, the left hemisphere subjects of the younger group performed better than the respective older group in the simultaneous nonverbal factor (I) (t between anterior groups =2.18, df =27, p < .05; t between posterior groups =2.31, df =38, p < .05). In the successive factor the younger group also performed better than the older group (t =2.01, df =27, p < .10).

There was no significant correlation between the length of time since injury and the modes of processing.

7.3. Discussion

The model of information integration (Das, Kirby & Jarman 1975, 1979) was successfully cross-validated in the present sample of brain dysfunctional adult patients. Simultaneous and successive factors were clearly verifiable according to the earlier findings. However, simultaneous processing loaded two separate factors depending on the verbal or nonverbal nature of the task. This result had earlier (Äystö 1983) been concluded as influenced by the particular characteristics of the brain-injury sample. In cases of the left hemisphere dysfunction the verbal simultaneous and successive processing factors were impaired as compared to the right hemisphere dysfunction. In the neuropsychological literature, left hemisphere damage is known to have a deteriorative influence on verbal rather than nonverbal functions, and vice versa in right hemisphere lesions. In the present study, a right hemisphere dysfunction did not significantly impair simultaneous nonverbal processing. On the contrary, the results tentatively suggested that there is an anterior/posterior division effect on the factor of simultaneous nonverbal processing.

It can be concluded that both main hypotheses (that is, the hypothesis emphasizing the importance of the anterior/posterior division of the brain and that of hemispheric asymmetry) were partially supported.

The proposed distinction between successive and simultaneous processing according to anterior (fronto-temporal) and posterior (parieto-occipital) locations of cerebral dysfunction was weakly supported only in case of simultaneous nonverbal processing ($p < .10$), but not so clearly in case of successive synthesis. The results showed that the means of the factor of simultaneous nonverbal processing tended to be lower when there was posterior rather than anterior damage. The result is consistent with the neuropsychological findings often observed in clinical settings that impaired performance at the level of visuospatial functions is associated with temporo-parietal or parieto-occipital lesions (e.g., Christensen 1974; Lezak 1976). In case of successive processing, only the left anterior group was more deficient ($p < .10$) than the right posterior group. However, the overall main effect of the anterior/posterior dimension did not reach statistical significance in successive processing.

The hypothesis concerning the existence of different modes of information processing in both hemispheres was also only partially supported. As evidence for the assumption of differentially distributed modes of processing in each hemisphere a significant impairment ($p < .01$) was observed in simultaneous verbal processing and successive processing ($p < .05$) due to left hemisphere damage. The multiple nature of successive processing can be considered theoretically as the interdependence of the anterior/posterior regions or of the hemispheres. Also, theories concerning hemispheric specialization are quite controversial (e.g., Cohen 1977, p. 198) as well as it being premature to think that processing systems divide themselves in an arbitrary manner according to hemispheres or anterior/posterior division of the brain. It is reasonable to think that where hemispheric specialization or specialization according to an anterior/posterior division of the brain exists, this is neither absolute, simple, nor constant.

Contrary to the hypothesis of the existence of hemispheric differences in information processing it was found that simultaneous (parallel) verbal processing was impaired after left rather than right hemispheric dysfunction. The above finding is more acceptable when one considers the explanations combining code content and mode of processing which are obviously needed when interpreting results found in neurological patient samples. Also, the dissociation of function (e.g., verbal - nonverbal) and the modes of processing in a brain-damaged population points to the need for an interpretatively more complex model of information integration if the structural basis (neuroanatomy) is to be taken into account. The issue concerning the code or quality of information (e.g., auditory, visual) mediated in its processing is controversial, because the functional and processing theories of hemispheric specialization often tend to ignore each other's contributions.

Another factor adding complexity to interpretations of modes of information processing in brain-damaged samples concerns task complexity and task difficulty. Tomlinson-Keasey and Kelly (1979) have found the left hemisphere better than the right hemisphere in processing difficult, sequential tasks even when the material was pictorial.

The various stages in information processing are emphasized by Moscovitch (1979). The pre-categorical perceptual processes are said to be common to both hemispheres and only higher-order processing is stated to be hemispherically differentiated. The exact point where these hemispheric differences emerge is difficult to locate in individual tasks beforehand and at present is largely unknown. According to Moscovitch (1979) the organizing principle might well be determined by the situational context.

Luria (1980) emphasizes the co-operation between hemispheres in information processing. It might well be the case that there are different levels operating in psychological processes, i.e. one being more primary and under the control of the other when it functioning in the background and in charge of performing some other aspect of the process.

The problems associated with the brain factors are manifold. In order to get comparable samples in different subgroups of brain damaged subjects, groups need to be matched according to the size and site of the lesion, the nature of the lesion, and brain disease. Matching concerning the external factors like sex, education, age, and socioeconomic level is also preferable. In the present study, the subgroups were considerably homogeneous with regard to certain external factors like education, age and socioeconomic level and thus this point did not become as problematic as the control of internal factors, i.e. central nervous system variables.

In respect of neurological patient groupings it is generally more reliable to determine unilateral brain damage than to separate more specifically localized injuries. The lack of strong evidence for the anterior/posterior hypothesis may be due to this anatomical fact. Also, the exact nature and extent of the brain injury was difficult to establish in neurological subpopulations in the present study. Luria (1966a, 1966b) considers the fronto-temporal areas especially critical for performing successive synthesis. In the present study, although some clear fronto-temporal injuries were included, there was also some more extensive frontal damage included in anterior groups. However, the role of the frontal lobe according to Luria (1973) deals more with the overall function of planning and decision making and is not characterized merely by successive synthesis.

In conclusion, both neuropsychological approaches (namely, the theory of hemispheric asymmetry and the Luria-Das model of the anterior/posterior division of the brain) in human information processing were supported and neither to the exclusion of the other. The complexity of the interpretative issues and the interdependence of hemispheres or anterior/posterior regions from each other make strong statements about the direct relationship between the modes of processing and the brain premature. The interactive and complementary role of the modes of processing in cases of disturbed brain functions needs further to be explained. It may well be the case that both hemispheres share properties of simultaneous and successive processing which are represented differently in the anterior and posterior parts of the brain. However, the sex differences in the modes of processing were not significant in the dysfunctions of anterior and posterior locations but instead a minor difference was found on factor scores in superior successive processing in the left hemisphere group of females. This finding partially supports the conclusions of Kimura (1983) that there are sex differences in the organization of speech and praxis within the left hemisphere, and supports indirectly the existence of a differential sex effect according to anterior or posterior involvement. As Kimura (1983) states, the role of the left anterior region is important in females for the control of speech and praxic function, and so the female superiority in successive processing in the present study might indirectly reflect this assumption.

8. STUDY 3

The relationship between information processing and aging has not been studied in the light of the Das et al. model of information integration (Das, Kirby & Jarman 1975, 1979).

As one of the primary goals in the neuropsychology of aging Feinberg et al. (1980) have put forward the study of changes in information processing. Simultaneous and successive modes of information processing are the elementary cognitive operations forming the basis for other mental activities (like intelligence, memory, problem solving etc.) in the model of information integration proposed by Das, Kirby and Jarman (1975, 1979). The model is based on the neuropsychological findings of Luria (1966a, 1966b, 1973), but the neuropsychological correlates of the Das et al. model have not empirically been studied thus far.

Evidence from factor-analytical studies (e.g., Aftanas & Royce 1969) on normal adults shows that neuropsychological test batteries yield factors resembling simultaneous and successive factors. The factor of temporal resolution (successive processing ?) in particular was found to associate with age in the above mentioned study.

The object of the present study is: (1) to verify and cross-validate the model of information integration (Das et al. 1979) in a sample of normal elderly people, and, (2) to study the relationship between neuropsychological variables and simultaneous - successive processing. If the assumptions concerning the neuropsychological domain of simultaneous (posterior divisions of the brain or alternatively the right hemisphere) and successive (fronto-temporal and anterior divisions of the brain or alternatively the left hemisphere) processing hold any truth then the neuropsychological functions aimed at measuring different sides and lobes of the brain should according to theoretical assumptions correlate and predict differently the modes of processing.

8.1. Method

8.1.1. Sample

A representative stratified sample of 100 women and 100 men was randomly selected from the 75 - 85-years-old population (N women = 2665, N men =1307) of Jyväskylä and surrounding communities. In the sample of 200 people 12.5 % were living in convalescent homes or hospitals. From the sample of 200 77 elderly people were selected randomly for neuropsychological interviews and examinations. The final sample consisted of 58 elderly people (females 32, males 26), because five of the selected people died before the study started, two persons were unreacheable at the mutually agreed time, and 12 people refused to participate because of poor health, lack of time or other such reasons. The neuropsychological sample was fairly healthy, although every person had on average one or two chronic diseases (mostly diseases of the circulatory system and of the musculoskeletal system and connective tissue). The drop-out ratio in the neuropsychological sample was 25 %. On the basis of drop-out analysis the final neuropsychological sample was not biased as regards to age, education, sex, institutionalization and marital status, but was slightly overrepresented by urban dwellers. The educational level was less than elementary school (under 7 years of education) in 14 % of the elderly, elementary in 79 % and secondary or more education in 7 %.

8.1.2. Procedure

The tests for measuring simultaneous and successive processing are described above in Study 1 (pages 48 - 52). However, in the present Study 3 the score for the easy associates of the WMS Associate Learning was:

WMS VII ALe: raw score divided by two (max. 9).

8.1.2.1. Neuropsychological variables

The battery of neuropsychological variables was created to reflect a wide range of perceptual, motor, sensory, memory and cognitive functions on the basis of Luria's (Christensen 1974, 1975) or of the Lurian type of neuropsychological battery (the Finnish version of Maruszewski's battery 1972). A short form of the Facial Recognition Test (Benton et al. 1975) was also used. The organicity and reality index was calculated on the basis of the Rorschach Test (Rorschach 1948, 1981), but a detailed analysis of personality is not reported here.

The neuropsychological tasks were selected to measure different levels of difficulty in a given function, to reflect any neurobehavioral characteristics of brain dysfunction and to be sensitive to the functioning of different brain areas (e.g., lobes and sides). One of the assumptions underlying Luria's qualitative neuropsychological battery is the notion that performance disturbances in the task indicate brain dysfunction at some level compared to undisturbed normal brain functioning in respect to the same task. An extensive neuropsychological battery of the Lurian type favors the maintenance of therapeutic contact during the process of investigation and is flexible to the needs of the subject. An important factor in the neuropsychological testing of elderly people is to ensure that the battery is as harmless and unrestrained as possible and not time consuming. In the present study the evaluation of qualitative neuropsychological functions hardly exceeded an hour, and as a whole the examination lasted about three hours.

A brief description of each neuropsychological task is given below.

8.1.2.1.1. Motor functions

The motor functions in the present study involved the analysis of various praxias, viz. the reciprocal coordination of both hands, hand praxis, oral praxis, spatial praxis, dynamic praxis, constructional praxis and symbolic praxis. The speech regulation of the motor act, tapping, and drawing a design composed of two alternating components (ornaments) were also tested as associated with the motor functions. Because there were no signs of the existence of oral apraxia among the subjects, this task was excluded from the analysis.

Reciprocal coordination. The simple dynamic organization of movement was studied by asking the subject to place both hands on the table and to change the positions of both hands (making a fist with one hand and stretching the another) simultaneously (Christensen 1974, p. 42) repeating this for some time and accelerating the speed of the activity gradually. The performance was also shown to the subject by the experimenter. The task of reciprocal coordination measures the coordinated performance of both hands and the successive organization of movement and demands frontal lobe functioning and especially the anterior zones of the corpus callosum (Luria 1973, p. 254). Sometimes a disturbed performance (e.g., neglecting one hand completely) may well point to a dysfunction in the right hemisphere.

Score: undisturbed performance = 0; slightly disturbed = 1; moderately disturbed = 2; strongly disturbed or unable to achieve or maintain the movement = 3.

Dynamic praxis. Following the experimenter's modeling the subject had to place both hands successively in three positions (Christensen 1974, p. 44: "fist", "edge" and "palm") and to change the positions flexibly five times after which the subject was asked to continue alone. The dynamic movements were studied for both hands separately, but in a slightly changed order. Dynamic praxis is considered by Christensen (1974, p.176) to reflect the functioning of the frontal lobe.

Score: as described above. Scored for both hands separately.

Ornamental drawing. The subject had to continue a given pattern by drawing it (Christensen 1975, card D 1. See the pattern in FIGURE 3 up left, p. 147). Performance was evaluated on two grounds: 1) changes in pattern was noticed (score = 0) or not noticed (score = 1), and, 2) the subject showed perseverance (score = 0 for no perseverance; score = 1 for perseverance). The sum score of the above-mentioned evaluations (ranging from 0 to 2) indicating a degree of disturbed performance in ornamental drawing was used in the present study to measure the assumed functioning of the frontal lobe (Luria 1973, pp. 206-210; Christensen 1974, pp. 44, 51).

Hand praxis. The kinesthetic basis of movement was investigated by placing the position of the fingers according to the experimenter's model as described in Christensen (1974, p. 39) supplemented by four other finger movements. The performance of both hands was investigated separately with visual feedback for the subject. The task when done blindfolded mainly measures the sensory areas (kinesthetic) of the opposite hemisphere providing pathological inertia is not present (Christensen 1974, p. 164); otherwise the motor and visual components also affect performance.

Disturbances in the motor functions of hand praxis were scored separately for both hands 0, when no disturbances were present; 1, if slight disturbances were present; 2, if the performance was moderately disturbed; 3, if the performance showed strong disturbances.

Optic-spatial organization or spatial praxis. Optic-spatial organization of movement was investigated according to Christensen (1974, pp. 40-41) with supplementary movements (altogether 8 movements by each hand) taken from Maruszewski's procedure (1972). The spatial praxias were investigated in a face-to-face situation by emphasizing the different positions of the gross-level movements of the right and left hand and, thus, the mental rotation of movements was required. The task is generally considered to measure the functioning of the parieto-occipital lobes (Luria 1973, p. 36; Christensen 1974, p. 49; Goldberg 1976). However, if the echopraxia (the tendency to mirror-image movements) can not be overcome the disturbance relates dysfunctioning of the frontal lobe (Christensen, 1974).

Score: as described above.

Constructional praxis. Construction tasks demand spatial components in perception and motor execution. Lezak (1976, p. 331) claims that inclusion of both construction and drawing tests in a neuropsychological test battery will help to discriminate between the spatial and visual aspects of practic ability (e.g., by including the WAIS Block Design and Object Assembly). Luria (1973, pp. 331-335) considers construction tasks as a form of thinking where the spatial relations among the elements must be attended to. Here the constructional praxis was evaluated indirectly on the basis of level of success in the honeycomb drawing (Christensen 1975, card G 28).

Constructional praxis is considered mainly to reflect the functioning of the parieto-occipital cortical areas if the spatial synthesis in the performance of a construction task is emphasized (Luria 1973, p. 332; Christensen 1974, p. 157) but it can appear in different forms depending on the hemispheric side of the lesion (Lezak 1976, p. 54).

Score: the level of drawing in the honeycomb task; 0 = very poor or unable to construct anything ; 1 = bad; 2 = moderate; 3 = good.

Speech regulation of the motor act. Two tasks were used for studying the speech regulation of the motor act (Christensen 1974, pp. 46-47). First, the selectivity of motor response to a given instruction in a repeated series of successive movements was investigated by a task where the subject had to make a fist when the investigator pointed with a finger. Secondly, speech regulation was more clearly emphasized in a task where a signal A (knocking once) and signal B (knocking twice) requiring different responses (raising the right arm and left arm respectively) were repeatedly changed. Both tasks were evaluated separately.

The speech regulation of the motor act is considered to reflect the functioning of the frontal or fronto-temporal areas (Christensen 1974, pp.

53-55; Luria 1973, pp. 195-197).
Score: as described above in reciprocal coordination on page 81.

Tapping. In finger tapping the subject held an instrument and used the thumbs of the dominant hand and of the nondominant hand in turn to press a lever as rapidly as possible. Three trials of 10 seconds were given to both hands.

Asymmetries in motor functioning can be easily detected from the results of the task.

Score: the average number of tappings for both hands (rescaled 0 - 6).

8.1.2.1.2. Tactile functions

The investigation of stereognosis and tactile perception consisted of three different tasks.

Stereognosis. An object was placed in the subject's hand (left and right hands in turn) who, blindfolded, had to identify the object when actively fingering it. The objects were a coin, a key, an eraser, a piece of comb and a pencil sharpener. The difficulties or disturbances in the performance of this task mainly reflect dysfunction of the parietal lobe of the contralateral hand or disturbances in the motor segments of the sensorimotor region of the cortex (Christensen 1974, p. 67).

Score: the number of correctly identified objects (max. 5).

Tactile perception and recognition. Subjects were blindfold and attempted to read numbers (8, 2, 6, 0, 3, 1) and letters (S, H, R, T) drawn on the palms of their hands as if they themselves were drawing them. The task requires the successful combination of incoming tactile information with earlier learned visual signs and, thus, the appropriate functioning of the parieto-occipital cortical areas. Usually the non-dominant hemisphere (in right-handed people the right hemisphere) has been deemed to be responsible for the tactile recognition of shapes and forms (Lezak 1976, p. 43).

Score: the average number of correctly identified figures in both hands (max. 10). Right and left hand performances were scored separately.

Skin writing. A skin writing procedure similar to Rey's skin writing (Lezak 1976, pp. 308-309) was applied to both the subject palms simultaneously. The numbers 5, 1, 8, 4, 3 and 2 were drawn in large figures one after another the palms being held one centimeter apart (see Lezak 1976, p. 308, figures c - h). Defective performance in this task is considered to implicate a tactile perceptual disability. The task was assumed to be a somewhat more complex one than the task of tactile perception and recognition described above due to its greater demands for simultaneous synthesis of slightly different tactile patterns on both hands. Also, the coordinated tactile perception of both hands was required.

Score: the number of correctly identified numbers (max. 6).

8.1.2.1.3. Higher visual functions

The visual functions were investigated by studying the perception of objects and pictures (Poppelreuter's figures, clock recognition), spatial orientation (spatial localization and directions on a map, items of Raven's Progressive Matrices), visual search where the subject had to identify a target embedded in the background, and intellectual operations in space (constructing and completing a pattern resembling a honeycomb). The following tasks for visual functioning were taken from Christensen (1974, 1975).

Visual perception. The tasks mentioned below are supposed primarily to measure the elementary visual functions of the parieto-occipital lobes, although, especially in cases of clear brain pathology, the qualitative interpretation of visual task performance can sometimes indicate dysfunction in other regions of the brain (e.g., the frontal lobe, the right hemisphere).

A. Silhouette photos (Christensen 1975, cards G 10-11). Score: the number of correctly identified silhouettes (max. 2).

B. Figure - ground identification. The task of identifying a figure in a complex background (Christensen 1974, card G 15) was evaluated as correct (score = 1) or incorrect (score = 0) and this score was added to the score of the Silhouettes above (max. 3). The task resembles that of the Embedded Figure Test (Witkin 1950) and requires the subject to identify and trace a simple figure embedded in a more complex design. Ryckman (1981) argues that this kind of task requires simultaneous processing.

C. Poppelreuter's figures (Christensen 1975, cards G 12-14). Score: undisturbed = 0, disturbed = 1.

D. Raven items (Christensen 1975, cards G 17-19). Score: the number of correct responses (max.3).

Spatial orientation. The tasks described below are considered mainly to reflect the functioning of the parieto-occipital lobes (Christensen 1975, pp. 73-74). In some cases qualitative analysis (= a particular type of error) can show signs pointing to lesion in the anterior lobe.

A. Clock recognition (Christensen 1975, card G 26). Score: undisturbed performance = 0, disturbed performance = 1. This task was excluded from the analysis due to very few cases of disturbance.

B. Directions on a map. The subject had to give the approximate location of seven well known and differentially situated cities on an empty map of Finland. Score: the number of correctly located cities on the map (max. 7).

Intellectual operations in space.

A. Honeycomb (Christensen 1975, card G 28). The subject had to complete on a separate paper a pattern that resembled a honeycomb (Rupp's test). The task requires breaking up the homogenous parts of a pattern into their component spatial elements and it is assumed to be sensitive to parieto-occipital functioning (Christensen 1974, p. 74).

Performance was evaluated according to the four following dimensions: (1) geometric form of a honeycomb cell: score 0 = no errors; 1 = error(s) or cannot complete, (2) the vertical parallel lines: score 0 = lines are attended to (meaning no disturbances present), 1 = lines are not attented to (meaning disturbed performance), (3) the structure of the organization of honeycomb cells in relation to each other: score 0 = no errors, 1 = cells are drawn as situated along the same vertical line and the varied pattern of the cells is not noticed, and (4) the figure is correct (score = 0) or incorrect (score = 1). The final score was formed by combining the scores from the above four dimensions (max. 4).

8.1.2.1.4. Language functions

Receptive speech. The investigation of receptive speech was focused on phonemic discrimination and the understanding of the instructions used in the investigation procedure throughout.

The ability to discriminate similar sounding phonemes (e.g., /b/- /p/, /t/ - /d/ , /f/ - /v/) was evaluated. Score: 0 = no difficulties, 1 = some difficulty. Difficulties in differentiating speech sounds usually refer to dysfunction of the temporal lobe (Luria 1973, pp. 134-138, 310).

The overall ability to understand various instructions (the standard instructions of psychometric tests and of qualitative investigation procedure) was scored thus: 0 = no difficulties, 1 = difficulties. The obvious attentional disorders demanding the repetition of instructions were not interpreted as primarily exhibiting difficulties in understanding unless some cognitive based difficulty (e.g., blocking, difficulty in comprehension or reception etc.) appeared. This general measure of difficulty in understanding instructions is based on phonemic hearing and consequently could be interpreted neuropsychologically as primarily demanding well-functioning temporal lobes (Luria 1973, pp. 138-139). As high level cognition, the understanding of instructions might well indicate the frontal lobe or overall functioning of the brain and, therefore, it is difficult to give any exact neuropsychological interpretation for such a over-all measure.

Expressive speech. Besides repetition tasks (e.g., the Digit Span of the WMS) or narrative repetitive memory tasks (e.g., the Logical Memory of the WMS) which were evaluated quantitatively, three qualitative tasks of expressive speech were arranged.

A. Fluency and automatization of speech

The fluency of speech output was evaluated on the basis of tape-recorded responses on the Mental Control subscale of the WMS. The Mental Control consists of three sub-tasks: (1) counting backward from 20 to 1, (2) spelling alphabets quickly and (3) counting by 3's as quickly as possible and beginning with 1 (e.g., 1, 4, 7, 10 .... 40).

Difficulty in fluency and automatization of speech is generally thought to be influenced more by dysfunctions in the anterior than posterior divisions of the brain (Caramazza & Berndt 1978; Lassen et al. 1978; Christensen 1974, p. 97).

Score: 0 = if output was fluent, smooth and automatic; 1 = non-fluent and disintegrated in sequential operations. Possible errors were not observed.

B. Naming

The nominative function of speech was assessed by an object naming task. Thirty different pictures from the Cronholm and Molander (1957, 1961; Cronholm & Ottoson 1963) KS-Minnesprovet Test (memory test) were shown to the subject with the request to name the objects. Due to many sensory difficulties in vision (e.g., cataract) in the sample it was difficult to assess the naming difficulties independently from visual defects and, therefore, the performance scored 0 if cognitively based difficulties were absent, and 1 if the naming difficulties were cognitively obvious. The latter disorders were inferred with the help of auxiliary methods (e.g., giving more information verbally about the visual features of the object) to facilitate the process of naming.

The naming difficulties of visually presented objects are neuro-psychologically considered to reflect parieto-occipital or parieto-temporo-occipital functioning (Luria 1973, pp. 156-160; Christensen 1974, pp. 95-96). But also, if fatigue and mnestic problems are present in the process of word naming or in tracing the words, the possibility exists of a generally diminished activity.

C. Narrative speech

The coherence of narrative speech was evaluated on the basis of spontaneously told tape-recorded stories about three different scenes from Christensen's photos (1975, cards M 11 -beach scene, M 20 - horse racing and H 22 - children playing). The instruction to the subject was to tell what was happening in the picture and what the picture expresses. The story told scored 0 if the narrative output was coherent and elaborated, and 1 if the output was abbreviated and non-coherent.

Due to the non-specific scoring of speech output for the present purposes a neuropsychological interpretation can only be given at a very general level as an ability to synthesize on spontaneously produced output (the presence of simultaneous synthesis in the end result or output).

8.1.2.1.5. Memory functions

Two psychometric memory tests, namely the Finnish version of the WMS and the KS Memory Test (Cronholm & Molander 1957, 1961; Cronholm & Ottoson 1963) were used for the assessment of memory functions.

The WMS. The subscales of the WMS were scored according to a Finnish translation of the WMS (Wechsler 1945) with the exception of Logical Memory in which only story A was scored (and thus story B rejected from presentation) and was requested to be recalled both immediately after presentation and after a two hours' interval.

The index of organic memory signs was calculated by summing up the following three comparisons of the subscales of the WMS (max. 3).

1) The sign of organicity was scored as 1 if a subject's performance in the subscale of Visual Reproduction was 9 or under. Otherwise, a score of 10 or more was considered as a non-organic sign (Bachrach & Mintz 1974).

2) The two equations below were both scored as 1 showing organic responses if the comparison of scores in the subscales was in the following direction: (a) Digit Span - 1 > Associate Learning , and
(b) Information + Orientation ≥ Associate Learning.

The non-organic signs were scored as zero in both comparisons above (Kljajić 1975).

The KS Memory Test includes three subsets of different memory material. Only two of these sets were used here: a) thirty figures of familiar objects (KS-objects) and b) five fictitious facts associated with each of six drawings of persons (KS-persons). In both subsets the number of correctly identified responses were scored (maximum score in both scales 30). Immediate recall and delayed recall (2,5 hours) were both scored separately as well as the errors. The reliability of the test has, according to the authors (Cronholm & Molander 1957, 1961; Cronholm & Ottoson 1963), been found to vary between .84 - .91 in immediate recall and .66 - .89 in delayed recall (usually 3 hours). The reliabilities of the subscales have varied in immediate and delayed recall between .72 and .91.

8.1.2.1.6. Other intellectual processes

The investigation of intellectual activities consisted of two concept formation tasks (analogies and classification) and one task of discursive intellectual activity (solving arithmetical problems).

Classification. The task of classification was from the Finnish version of the Maruszewski (1972) battery. Four pictures each including four familiar objects (e.g., a pen, a typewriter, a car and a pencil) were shown to the subject who was asked to point to the object which did not share the characteristics of the other three giving reasons.

Christensen (1974, p. 130) considers the task of classification similar to that of categorical intelligence but does not make any clear statements about its brain functional representation.

Score: the number of correct classifications (max. 4).

Analogies. The task of analogies was similar to that described in Christensen (1974, p. 130). Four items were presented where the subject was asked to find a word ("X") bearing the same relationship to a given word ("good") as is another relationship between two other words ("high" - "low"). This task is considered neuropsychologically to reflect frontal and temporal lobe functioning (Christensen 1974, pp. 134-135).

Score: the number of correct responses (max. 4).

Arithmetical problems. Two sets of orally presented arithmetical problems (an elementary "Sam has 7 apples and he gives 3 to Mary. How many apples will he have left ?" and a more complex one "On the shelves there are 18 books. One has twice as many books as the other. How many books there are on each shelf ?") were presented to the subject according to Christensen (1974, pp. 131, 135-137).

The elementary arithmetical problems are considered to reflect dysfunction of the parietal and temporal lobes if there are difficulties in forming simultaneous synthesis (e.g., comprehending the problem) or in memorizing the problem statement. The frontal dysfunctions are seen for example when the subject cannot analyze the elements properly and cannot hold on to the logical plan of the problem (Luria 1973, pp. 335-340).

The ability to solve complex arithmetical problems is usually deficient with diffuse brain lesions.

Score: 1) the number of correct solutions to the elementary arithmetical problems (max. 3).

2) the task of complex arithmetical problems scored 0 if the subject did not resolve them, and 1 if the subject was able to resolve either one of the presented extra problems.

8.1.2.1.7. Organicity index and reality index

Piotrowski's index of organicity was calculated from the Rorschach test (Piotrowski 1937; Ames et al. 1973). The maximum score of 10 indicated a highest amount of organicity.

Another index calculated from the Rorschach test was Neiger's reality index (Bohm 1960, p. 24). Rorschach test responses in older people are regarded as characterized by inaccurately perceived forms and highly restricted thought control. Older people have difficulties mastering wholes and seeing relations as well as in thinking in the same way as other younger people (Ames et al. 1973). The maximum score (8) on the reality index is considered to reflect overcontrolled reality testing, whereas scores between 0-4 indicate impaired and the scores from 5 to 7 adequate reality testing. It should be emphasized that generalizations from this index about real life situations should be accompanied by other variables of personality and their patterns of interactions.

The increased amount of Piotrowski organic signs and the lowered amount of Neiger's reality index have been stated to be among the charateristics of brain damaged subjects (Mattlar, Knuts & Alanen 1985).

8.2. Results

All statistical analyses were performed by using the SPSS-statistics (Nie & Hull 1981).

Factor-analyses for the elderly group (N =58) were calculated differently from the scaled scores and raw scores of the WAIS subscales. Because there are no Finnish norms in the WAIS available for age groups over 75 years, the reference group used for norms in the age group of 75 - 85-years-old was the next oldest one of 60 - 75-years-old. The factor structure in both cases when using scaled scores or raw scores was very similar and the amounts of total variance accounted for by the different types of factor calculations corresponded well to each other.

TABLE 10 presents the four factor Varimax-solution based on the raw scores of the WAIS test because in the age group studied and in regard to the study problem the general norms (and thus the need for scaled scores) are of less relevance. The four-factor solution explained 78 % of the total variance. The eigenvalues for factors before rotation were respectively 5.06, 1.06, .96 and .71. It can be mentioned here that the four-factor solution with oblique rotations consistently gave the same factors as obtained using orthogonal rotations.

The four-factor Varimax-solution gave the following factors: factor I - successive verbal processing (with high loadings on the subscales of the WMS test), factor II - simultaneous verbal processing (with high loadings on the verbal scales of the WAIS), factor III - simultaneous nonverbal (or spatial) processing (with high loadings on the BVRT and the VR of the WMS) and factor IV - successive nonverbal processing (high loadings on Digit Symbol and Block Design). The fourth factor may reflect a special qualitative property in elderly people's performance in their use of serial processing strategies in resolving tasks mainly demanding simultaneous

TABLE 10 . Varimax-rotated factor structure of simultaneous and successive tests in the age group 75 - 85-years old. Calculations based on raw scores in the WAIS. (N =58).

4 - factor Varimax-solution

Test	I	II	III	IV	h^2
BVRT	.366	.169	.716	.344	.794
I	.433	.634	.320	.217	.739
S	.177	.731	.062	.240	.627
DSy	.306	.197	.293	.776	.821
BD	.197	.376	.320	.489	.521
LM	.578	.250	.242	.093	.464
DSp	.152	.494	.402	.031	.430
VR	.147	.208	.531	.360	.477
ALe	.758	.313	.181	.132	.723
ALh	.787	.064	.129	.366	.774
% of total variance					78.0

synthesis (e.g., Block Design). Block Design also loaded on the simultaneous nonverbal factor but not as clearly as has happened in other samples (Study 1 and 2). The interpretation of the loading of Block Design suggests that some elderly people also use successive strategies in resolving the task and in the elderly the manipulospatial skills play an important role in Block Design performance. It would be interesting to study whether this particular characteristic is correlated in any way for example with qualitative neuropsychological findings like spatial and constructional praxias. Only two of the tasks shared covariation on two different factors where their loadings exceeded .40. The Information loaded mostly on the simultaneous verbal factor but also loaded on the successive verbal factor. The Digit Span split loadings half on simultaneous verbal and half on nonverbal factors.

The fourth factor can also be seen as a counterpart of successive verbal processing (factor I) which has not appeared in earlier studies (Das et al. 1975, 1979; Äystö 1983; Äystö & Hänninen1986). Another small detail in the four factor Varimax-solution on the elderly sample is that the easy and hard associates in the WMS subscale of Associate Learning seem to load on different factors with the easy ones on the simultaneous verbal and the hard ones on the successive nonverbal factor.

The result here is in accordance with the findings by Cummins (cf. Das et al. 1975) who observed that concrete words had loadings on the simultaneous factor and abstract words on the successive factor. Paired-associate tasks have loaded on simultaneous and successive factors in another study on 9-year old children by Kirby and Das (1978).

According to Das (1984b) verbal and nonverbal tests are related to simultaneous and successive factor scores and so there is no need to classify the two coding processes in terms of categories of abilities. In the present study, if the two-factor solution had been selected for Varimax-solution, it would have given a factor structure of simultaneous and successive coding although the factor structure then would not become "pure" (e.g., high loadings over .40 in successive marker tests like Digit Symbol and Digit Span on the simultaneous factor). Also this two factor Varimax-solution was easily interpreted as verbal memory and nonverbal factors. However, because above (Study 1 and 2) it was weakly indicated that in cases of neuropsychological interpretations there is need for a more specific definition of simultaneous and successive processing by taking into consideration the possible code content, the four factor Varimax-solution was selected here for later analyses.

8.2.1. Sex and the modes of processing

There were no significant differences in the factor scores for simultaneous and successive modes of processing between males and females. Similarly, the means on individual subscales of the WAIS, the WMS and the BVRT also showed no differences between the sexes. A small number of subjects in each group may not have been enough to reveal any sex differences if they exist.

8.2.2. Neuropsychological variables and the modes of processing

8.2.2.1. Correlations between the modes of processing and neuropsychological variables

Correlations between the factor scores of the modes of processing and qualitative neuropsychological variables are presented in TABLE 11. The four factor scores of simultaneous and successive processing are calculated from the raw scores of the WAIS test and Varimax-rotated factors.

All modes of processing correlated significantly ($p < .05$ or $< .01$) with the same task of speech regulation of the motor act. The better the performance in the task in question, the better the score in the processing modes, too. The role of speech in the regulation of human cognitive development and behavior has been emphasized by Luria (1961; Luria and Yudovich 1959) . The speech regulation of motor act is considered to reflect frontal lobe functioning, and so this result might reflect the overall importance of frontal lobe functioning in processing or possibly the planning component which is a superordinate organization for both modes of processing.

The other neuropsychological functions with overlapping correlations

TABLE 11. Correlations between the modes of processing and qualitative neuropsychological variables (N = 58). @

Neuropsychological variable	Factors I succ.v.	II sim.v.	III sim. nv.	IV succ. nv.
Face recognition	-.05	.11	.45***	.27*
Reciprocal coordination#	-.38**	-.26*	-.22	-.44***
Hand praxis: left hand #	-.09	-.20	-.20	-.34*
Hand praxis: right hand #	-.12	-.23	-.20	-.35**
Spatial praxis: left hand #	-.32*	-.32*	-.11	-.38**
Spatial praxis: right hand #	-.35**	-.33*	-.09	-.38**
Dynamic praxis: left hand #	-.18	-.31*	-.41**	-.46***
Dynamic praxis: right hand #	-.07	-.29*	-.37**	-.27*
Honeycomb: level of drawing	.16	.33*	.52***	.38**
Sp. reg. mot. act.: fist #	-.38**	-.38**	-.20	-.44***
Sp. reg. mot. act.: knocking #	-.47***	-.40**	-.29*	-.41**
Touch: writing on palm	.27*	.35**	.21	.20
Stereognosis	.42**	.27*	.38**	.21
Rey's Skin writing	.31*	.30*	.23	.22
Spatial orientation: map	.23	.49***	.32*	.42***
Raven items	.12	.37**	.35**	.19
Understanding of instructions #	-.45***	-.38**	-.12	-.32*
Naming difficulties #	-.24	-.37**	-.31*	-.24
Auditive discrimination #	-.04	-.15	.02	-.24
Automatisms #	-.25	-.34*	-.32*	-.27*
Narrative speech #	-.26	-.30*	-.19	-.36**
Arithmetic: easy oral	.14	.49***	.34*	.26
Arithmetic: difficult oral	.22	.48***	.20	.05
Classification	.37**	.50***	.16	.29*
Analogies	.17	.24	.34*	.25
Visual functions (S, F/G)	.01	.03	.24	.37**
Attention, concentration # ø	-.19	.26	-.36**	-.33*
RO: Piotrowski-index #	-.01	-.01	-.14	-.47***
RO: reality index	.22	.02	.15	.21
Ornaments #	-.15	-.01	-.45***	-.47***
Honeycomb disturbances#	-.17	-.30*	-.59***	-.36**
Tapping: right hand	.21	.33*	.24	.24
Tapping: left hand	.23	.21	.28*	.21

@ Because of pairwise deletion of missing neuropsychological data, some correlations only are calculated for N = 56.

A high score indicates poor or disturbed performance

ø evaluated on the scale 0 (no disturbance) - 3 (very disturbed)

* $p < .05$ ** $p < .01$ *** $p < .001$

among both modes of processing included some of the praxic tasks (reciprocal coordination, spatial praxis, dynamic praxis, constructional praxis and ornament drawing), tactile perception and recognition (stereognosis), spatial orientation (map), intellectual operations in space (honeycomb) and some language tasks (classification, understanding of instructions, narrative speech and automatisms). Praxic tasks correlated mainly and more intensively with successive processing (either verbal or nonverbal) than with simultaneous processing although the task of dynamic praxis also correlated strongly with simultaneous nonverbal processing. The claimed successive nature of any motor act agrees with the results obtained here.

Simultaneous verbal processing had significant correlations with most of the neuropsychological functions. Both simultaneous (verbal and nonverbal) factors were found to correlate significantly with the Raven items, naming, and the easy arithmetical tasks. These tasks seem to have a strong simultaneous component independently of their content.

The task of reciprocal coordination correlated most significantly with both successive processing factors (verbal and nonverbal) but not with the simultaneous factors. The above mentioned task requires a serial and gradually accelerated motor performance with well coordinated hands. This neuropsychological task seems clearly to be associated with nonverbal, motor, successive processing and despite its nonverbal nature it also seems to have underlyingly verbal components. This interpretation of the result is in accordance with other studies (Lapsley & Enright 1983) concerning rigidity and inflexibility ın elderly people. Temporal disorganization, shifting from one pattern to another - a typical sequential and successive processing task - seems to be affected but not simultaneous processing. Rigidity in this motor-cognitive task of reciprocal coordination accords well with the findings reported by Schaie (1958) that a greater decline in rigidity was observed in motor-cognitive rather than in personality-perceptual rigidity or in psychometric speed.

One unexpected correlation appeared in relation to the task of narrative speech which correlated significantly ($p < .01$) with the successive nonverbal processing but not with the successive verbal factor (although almost $p < .05$). Also, the dichotomized scoring of narrative speech obviously was not enough powerful to reveal the real nature of the relationship. In case of these variables a more suitable approach for the analysis of the relationship would have been polychoric or polyserial correlations.

The Piotrowski index of organicity in the Rorschach test correlated significantly ($p < .01$) with the successive nonverbal factor. The lower the organicity index was, the better the performance in successive processing. In older people one of the first effects of aging on neuropsychological functioning has been found to be in difficulties in dealing with the tasks of Digit Symbol and Block Design (Bak & Greene 1980) both of which tasks loaded here on successive nonverbal processing.

8.2.2.2. Correlations between memory tasks and the modes of processing

The other subscales of the WMS which were not used for assessing simultaneous and successive processing correlated quite strongly with the modes of processing (TABLE 12). The overall raw score of the WMS correlated highly with each type of processing as expected, but the combined score of organic signs in the WMS correlated significantly only with the successive verbal factor. The fewer organic signs the individual had, the better the performance on the successive verbal factor was.

The KS-Memory Test correlated with successive verbal and simultaneous nonverbal factors, but non-significantly with the simultaneous verbal

TABLE 12. Correlations between the modes of processing and some memory tasks (N = 58).

Memory task	Factors I succ. v.	II sim. v.	III sim.nv.	IV succ. nv.
WMS I	.43***	.41**	.22	-.01
WMS II	.36**	.17	.32*	.16
WMS III	.23	.62***	.30*	.53***
WMS raw score total	.72***	.47***	.47***	.37**
WMS organic signs (N)	-.74***	-.25	-.12	-.24
KS-objects S-TM	.33*	-.05	-.39**	.24
KS-persons S-TM	.39**	.12	.32*	.51***
KS-objects L-TM	.30*	.05	.31*	.14
KS-persons L-TM	.46***	.19	.40**	.53***
KS-objects S-TM errors	-.26	-.13	-.15	.13
KS-objects L-TM errors	-.20	-.23	-.30*	-.03
KS-persons S-TM errors	.01	-.03	-.05	-.04
KS-persons L-TM errors	.01	-.19	-.05	.01

* $p < .05$ ** $p < .01$ *** $p < .001$

factor. Those of the elderly who were good processors of information in the successive verbal and simultaneous nonverbal modes were better able to recall objects and persons from short- and long-term memory. The KS-subscale of remembering facts concerning fictitious persons correlated significantly ($p < .001$) with the successive nonverbal factor.

The error scores in short- and long-term memory in the KS-Memory Test correlated with the modes of processing only in one case, namely errors in the KS-objects of long-term memory which correlated with the simultaneous nonverbal factor. The explanation for the lack of correlations in error scores is the observation that in very few, if any, recalled objects were there still fewer errors.

On the basis of TABLE 12 it can be concluded that subscale I of the WMS is more a content- than process-oriented task, but the other subscales of the WMS and the KS-memory test studied are both process- and content-oriented tasks.

Those elderly persons who were good processors of information in the successive verbal and simultaneous nonverbal modes were better able to recall objects or persons from short- and long-term memory.

8.2.2.3. Individual neuropsychological variables as predictors of the factor scores of the modes of processing

Multiple stepwise regression analyses (Nie & Hull 1981; SPSS-statistics: new regression) were performed for the factor scores associated with each of the obtained four factors of simultaneous and successive processing. Basically, in each of these regression analyses the same neuropsychological variables were used as predictor variables, but the stepwise procedure selected only the most significant predictors among them. Multiple stepwise and fixed model (all variables included) regression analyses were performed for individual neuropsychological variables because the role of chance in multiple regression analyses usually requires cross-validation. Also, the potentiality of each individual neuropsychological variable as a predictor of simultaneous and successive processing was important to study. The use of regression analysis analyses here is, of course, an exploratory one.

The neuropsychological variables selected for predictors are presented ın TABLE 11, however, so that all dichotomically scored variables are excluded from the regression analysis (understanding instructions, naming, auditive discrimination, automatisms, narrative speech and difficult arithmetical problems).

Regression analyses ın which the factor scores of the modes of processing were used as dependent variables and substantive neuropsychological variables as predictors were all significant. The number of variables in the regression equation was limited so that only those variables with a significance level of $p < .05$ were selected. The variables in TABLES 13 - 16 are presented in the same order as they entered the stepwise regression analyses. The residual diagnostics were found to be normal.

The best single predictor on the first factor (successive verbal processing) was the speech regulation of the motor act ($R^2 = .2248$, $F (1, 54) = 15.662$, $p < .0002$). The above mentioned task accounted for 22 % of the total variance on the first factor. The regression coefficient for the task was -.4792 indicating that a change for better in successive processing happened when speech regulation was less disturbed.

The set of the two most predictive neuropsychological variables (the speech regulation of the motor act and face recognition) predicted 28 % of the total variance of the successive verbal factor (TABLE 13). These tasks can be interpreted as representing the components of successive processing. Face recognition is thought neuropsychologically mainly to reflect the functioning of the the right hemisphere (e.g., Benton et al. 1975; Lezak 1976). Its appearance as a predictor of successive verbal processing in the present study may result from the characteristics of the sample, so that elderly people may prefer verbal and serial strategies when matching different faces. The third variable to enter the regression equation in the next step would have been dynamic praxis of the right hand, but this variable as a single predictor would then have become nonsignificant although the overall equation of the three variables was nonetheless significant. However, the nature of dynamic praxis as a predictor of successive verbal processing is in accordance with the serial organization of speech and motor performance and thus neuropsychologically with the functioning of the anterior lobe and as such is consistent with the nature

TABLE 13. Selected statistics for multiple regression. Factor scores of successive verbal processing as dependent variables and individual neuropsychological variables as predictors.

Analysis of variance		Source of var.	df	F	p
Multiple R	.533	Regr.	2	10.525	.0001
R^2	.284	Residual	53		
Standard error	.765				

Predictor	Regression coefficients unstand. b	st.error b	beta		p
1. Speech reg. of motor act	-.578	.127	-.572	-4.568	.0000
2. Face recogn.	-.044	.021	-.263	-2.098	.0407
Constant	1.177	.421		2.798	.0072

of the factor structure of successive processing.

The factor score for simultaneous verbal processing was best predicted by the single neuropsychological task of classification, which accounted for 25 % of the total variation on factor II (R^2 = .2494, F (1, 54) = 17.944, p <.0001). The regression coefficient for the classification task was +.4010. The relationship between simultaneous verbal processing and the classification was in the same direction. Increase in scores for classification predicted an increase in the mode of simultaneous verbal processing.

Stepwise multiple regression analysis produced three overall regressions so that every individual neuropsychological predictor of simultaneous verbal processing included in the equation became significant. The set of three variables (classification, easy arithmetical tasks and spatial orientation on a map) in the regression equation accounted for 42 % of the variation in simultaneous verbal processing (TABLE 14). The multiple correlation in the set of three variable combinations became .65.

The simultaneous nature of the factor is reflected in the neuro-

TABLE 14. Selected statistics for multiple regression. Factor scores for simultaneous verbal processing as dependent variable and individual neuropsychological tasks as predictors.

Analysis of variance		Source of var.	df	F	p
Multiple R	.646	Reg.	3	12.392	.0000
R^2	.417	Resid.	52		
Standard error	.665				

	Regression coefficients				
Predictor	unstand. b	st.error b	beta		p
1. Classification	.206	.099	.257	2.073	.0431
2. Arithm. easy	.411	.151	.314	2.730	.0086
3. Sp. orient. map	.119	.051	.278	2.309	.0250
Constant	-2.054	.368		-5.585	.0000

psychological findings. The task of classification requires the simultaneous synthesis of different conceptual relations and a response selection on the basis of the correct synthesis. As a verbal task, arithmetic requires simultaneous synthesis and retention of the problem statement in order to be correctly performed. The task of recalling familiar places and locating them on the map demands a spatial orientation associated with verbal content and this task is claimed mainly to require the functioning of the parieto-occipital lobes (Luria 1973; Christensen 1974). All three neuropsychological predictors are characterized by the simultaneous synthesis of verbal or spatial imagery and so the neuropsychological predictors of the second factor are well in accordance with the nature of simultaneous verbal processing.

On the third, simultaneous nonverbal factor, the best single neuropsychological predictor was the constructive task of the honeycomb (R^2 = .3418, F (1, 54) = 28.044, p < .0000) which explained nearly 34 % of the variance in the factor scores for simultaneous nonverbal processsing. The regression coefficient -.2735 indicated that a change towards fewer disturbances in honeycomb drawing predicted a better performance in simultaneous nonverbal processing.

The regression model with a combination of the two best predictive neuropsychological variables jointly explained about 40 % of the total variance (TABLE 15) of simultaneous nonverbal processing and then both predictors in the model were individually significant. The multiple correlation of this set of two variables rose to .63.

TABLE 15. Selected statistics for multiple regression. Factor scores for simultaneous nonverbal processing as dependent variables and individual neuropsychological tasks as predictors.

Analysis of variance		Source of var.	df	F	p
Multiple R	.630	Reg.	2	17.439	.0000
R^2	.397	Resid.	53		
Standard error	.646				

	Regression coefficients				
Predictor	unstand. b	st. error b	beta	t	p
1. Honeycomb:					
disturbances	-.249	.051	-.532	-4.864	.0000
2. Attention	-.252	.115	-.241	-2.200	.0322
Constant	.675	.144		-4.701	.0000

The factor scores for simultaneous nonverbal processing were predicted by disturbances in the honeycomb test and inability to concentrate and direct attention to the task at hand. The decreased number of disturbances in honeycomb drawing and concentration predicted better scores in simultaneous nonverbal processing.

The task of the honeycomb reflects, according to Christensen (1974), the functioning of the parieto-occipital lobe and requires breaking up the homogenous parts of a pattern into their component spatial elements. The other task demand in the honeycomb test is that the end result must be a correct synthesis of the analytically evaluated component parts brought together again. Thus, the honeycomb as a neuropsychological predictor of simultaneous nonverbal processing is in accordance with the nature of the simultaneous mode of processing. The appearance of attention and concentration as another significant predictor here possibly reflects a special characteristic of a sample of elderly people. Therefore, an interpretation of its significance more generally for simultaneous processing is uncertain.

The fourth and weakest factor characterized as successive nonverbal processing was best predicted by the single task of ornamental drawing (R^2 = .2201, F (1, 54) = 15.237, p < .0003). This single variable predicted 22 % of the total variance. The regression coefficient -.4997 showed that the fewer disturbances in the ornamental drawing, the better the score in successive processing.

The regression model for four neuropsychological variables jointly predicted 51 % of the total variance on factor IV (TABLE 16) so that all the individual predictors in the model were significant. The multiple correlation of the four variable combination with the successive nonverbal processing factor became .71.

The factor scores for successive nonverbal processing tended to increase with correct (=undisturbed) performance in ornamental drawing and with a decreasing Piotrowski-index of organicity as well as with good performance in tasks of spatial orientation and visual function. The role of ornamental drawing can be interpreted here as reflecting the dynamic organization of movements necessary for successful manipulospatial performance. Thus the dynamic successive nature of ornamental drawing is also in accordance with the nature of individual loadings (Digit Symbol and Block Design) on the fourth factor. Because the neuropsychological

TABLE 16. Selected statistics for multiple regression. Factor scores for successive nonverbal processing as independent variable and individual neuropsychological tasks as predictors.

Analysis of variance		Source of var.	df	F	
Multiple R	.714	Regr.	4	13.251	.0000
R^2	.510	Resid.	51		
Standard error	.619				

	Regression coefficients				
Predictor	unstand. b	st. error b	beta	t	p
1. Ornament: disturbances	-.478	.106	-.448	-4.510	.0000
2. Piotrowski-i.	-.150	.054	-.285	-2.793	.0073
3. Sp. orient. map	.112	.044	.260	2.540	.0142
4. Visual function #	.326	.139	.243	2.340	.0232
Constant	.005	.350		0.001	.9989

Silhouette and figure-ground identification.

interpretations of dynamic movement have dealt with the anterior lobe function (Christensen 1974; Luria 1973) and when Block Design especially has been considered to be one of the marker tests for detecting dysfunctioning in the right hemisphere (e.g., Lezak 1976, p. 220) it might be possible that the content of the fourth nonverbal processing factor reveals the underlying nature of the functioning of the right anterior lobe.

The interpretation of the Piotrowski-index of organicity here reflects the overall characteristic of the amount of organic involvement in the visuo-perceptual function evaluated on the basis of the Rorschach personality test. The negative direction of the regression coefficient shows that the less organic impairment there was, the better the scores in successive nonverbal processing tended to be.

The other neuropsychological tasks predicting successive nonverbal processing were spatial orientation (maps) and visual functions (silhouette and figure-ground identification). The task of spatial orientation also became a significant predictor of the second factor, simultaneous verbal processing. The spatial orientation task predicted in the same direction for both factors, but probably for different reasons. In the case of the second factor, the simultaneous nature of processing was more emphasized via the spatial orientation, whereas in case of the fourth factor, the role of spatial orientation as predictor plausibly stressed the code content of successive processing.

When fixed model (forced entry) regression analyses were performed for the criterion variables of simultaneous and successive processing it was found that in cases where the verbal content was included in the modes of processing all the individual neuropsychological tasks jointly were nonsignificant as predicting either successive (R^2 = .5896, F (27, 28) = 1.490, n.s.) or simultaneous verbal processing (R^2 = .5335, F (27, 28) = 1.186, n.s.). But in the case of nonverbal code content, simultaneous nonverbal processing was predicted by the same individual neuropsychological tasks in 77 % (F (27, 28) = 3.399, p < .0010) and successive noverbal processing in 74 % (F (27, 28) = 2.947, p < .0029). The multiple correlations for the same neuropsychological tasks combined were for successive verbal processing .77, for simultaneous verbal processing .73, for successive nonverbal processing .86 and for simultaneous nonverbal processing .88. From these results it seems plausible that in the elderly sample the same neuropsychological tasks were more associated with the code content than the processing modes themselves. The process of aging has been found elsewhere (e.g., Horn & Cattell 1967; Horn 1970) to relate more to the functioning of nonverbal or fluid intelligence than to verbal or crystallized intelligence. The results obtained in the present study are not incongruent with these findings.

8.2.2.4. Individual memory tasks as predictors of factor scores of the modes of processing

In multiple stepwise regression analyses (Nie & Hull 1981; new regression) the memory tasks investigated (same as in TABLE 12) were treated separately from the neuropsychological Lurian-type tasks. The memory tasks in TABLE 17 are presented in the same order in which they entered the stepwise regression analyses which were all significant. Residual statistics were found normal.

TABLE 17. Selected statistics for multiple regression. Factor scores of the modes of processing as dependent variables and the memory tasks as independent variables.

A. Successive verbal processing

Analysis of variance		Source of var.	df	F	p
Multiple R	.881	Regr.	3	62.245	.0000
R^2	.776	Resid.	54		
Stand. error	.432				

Predictor	Regression coefficients unstand. b	st.error b	beta		p
1.WMS-organic signs	-.355	.084	-.383	-4.245	.0001
2. WMS-raw score	.065	.009	.865	7.244	.0000
3. WMS-Mental Control	-.248	.042	-.560	-5.872	.0000
Constant	-1.685	.454		-3.710	.0005

(continues)

TABLE 17 (continues)

B. Simultaneous verbal processing

Analysis of variance		Source of var.	df	F	p
Multiple R	.714	Regr.	3	18.718	.0000
R^2	.510	Resid.	54		
Stand. error	.609				

	Regression coefficients				
Predictor	unstand. b	st.error b	beta	t	p
1. WMS-Mental Control	.286	.047	.679	6.148	.0000
2. WMS-Inform.	.401	.134	.296	2.999	.0041
3. KS-persons (S-T M)	-.032	.013	-.270	-2.473	.0166
Constant	-3.029	.724		-4.181	.0001

C. Simultaneous nonverbal processing

Analysis of variance		Source of var.	df	F	p
Multiple R	.552	Regr.	2	12.077	.0000
R^2	.305	Resid.	55		
Stand. error	.693				

	Regression coefficients				
Predictor	unstand. b	st.error b	beta	t	p
1. WMS-raw score	.052	.011	.747	4.803	.0000
2. WMS-organic signs	.339	.132	.399	2.566	.0131
Constant	-3.054	.689		-4.433	.0000

(continues)

TABLE 17 (continues)

D. Successive nonverbal processing

Analysis of variance		Source of var.	df	F	p
Multiple R	.607	Regr.	2	16.085	.0000
R^2	.369	Resid.	55		
Stand. error	.689				

Regression coefficients

Predictor	unstand. b	st.error b	beta		p
1. KS-persons (L-T M)	.059	.021	.351	2.840	.0063
2. WMS-Mental Control	.149	.052	.351	2.836	.0064
Constant	-1.057	.210		-5.033	.0000

The Mental Control subscale of the WMS appeared most often as a significant predictor of the modes of processing. The other three significant predictors were the number of organic signs in the WMS test, raw scores for the WMS and the KS-persons (either short-term or long-term memory). The appearance of the raw scores for the WMS as a predictor of simultaneous and successive processing is understandable because it has some covariation with the memory tasks (LM, VR, ALe and ALh as well as DSp) used for the operationalization of the modes of processing.

There seemed to be no clear systematic clustering of different memory tasks with the modes of processing. The raw score for the WMS predicted only verbally accentuated processing (either simultaneous or successive) but WMS organic signs and Mental Control predicted both verbal and nonverbal processing. The associative memory (such as KS-persons) did not seem to be linked to successive processing and the visual memory (such as KS-objects) with simultaneous processing. In fact, the KS-objects did not even appear as a significant predictor of simultaneous processing.

In fixed regression models (where all the memory variables were included in the equation) all the regression analyses became significant (p ranging from .028 to .0000). The respective R^2 values were: for successive verbal processing .808, for simultaneous verbal processing .594, for simultaneous nonverbal processing .390 and for successive nonverbal processing .478. Thus, all the memory variables investigated seemed to predict more powerfully the verbally accentuated content of processing (be it simultaneous or successive).

8.2.2.5. Summary

Individual neuropsychological tasks as predictors. The four processing factors were appropriately predicted from the individual neuropsychological variables and neuropsychological tasks were able to provide some clear distinctions between factor content. The four factor solution was found to be neuropsychologically rational. Further, it can be tentatively suggested that the more general neuropsychological characteristics of the modes of processing seemed to be differentiated in such a way that the most significant predictor of the successive factors (either with verbal or nonverbal content) were associated more with tasks characterizing the functioning of the anterior lobes. On the other hand, the most significant predictors of the simultaneous nonverbal factor were associated with tasks characterizing the functioning of the posterior lobes. The neuropsychological nature of verbal simultaneous processing pointed more to a general overall brain functioning, although the third predictor (spatial orientation) in the regression equation as a more elementary variable has been connected with functioning of the posterior lobe. The assumption that modes of processing can reflect different degrees of verbal or nonverbal involvement (e.g., the factor loadings on Block Design and Digit Span) was supported as well as claims that the same neuropsychological test can require different modes of processing depending on the strategy used in resolving them (e.g., spatial orientation). Many of the significant correlations between the modes of processing and neuropsychological tasks overlapped and so these neuropsychological tasks cannot be classified as purely simultaneous or successive tasks.

Memory tasks as predictors. The results indicated a stronger relationship between memory variables and verbally accentuated processing (in either the successive or simultaneous mode) than nonverbally accentuated processing. There seemed to appear no clear clustering of associative memory with successive and visual memory with the simultaneous processing.

8.2.3. Neuropsychological factors

8.2.3.1. Qualitative neuropsychological factors as predictors of modes of processing

The 21 qualitative mostly Lurian-type neuropsychological variables were factor analyzed by the principal axial method and by Varimax-rotation (TABLE 18). The six factor solution was more clearly interpretable than the five factor solution although then the eigenvalue dropped to .977. The six factor solution explained 73.9 % of the total variance and the single factors respectively 59.7 %, 12.0 %, 9.8 %, 7.7 %, 6.2 % and 4.6 % of the common variance.

The frequency distribution of the neuropsychological variables noted in TABLE 18 showed a declining smooth curve to the right side end of normal distribution in most of the cases. In the tasks of honeycomb (level of drawing), stereognosis, map, analogies, classification and honeycomb disturbances the distribution was smoothly skewed to the left end. In case

TABLE 18. Varimax-rotated factors of the neuropsychological variables (N = 56).

Variable	Factors I	II	III	IV	V	VI	h^2
Recipr. coordination @	.44	-.15	-.45	.15	.16	.03	.48
Left hand praxis @	.39	-.10	-.05	.14	.79	.18	.84
Right hand praxis @	.36	-.20	-.04	.16	.77	.10	.79
Spatial praxis: left @	.33	-.19	-.23	.82	.16	.15	.92
Spatial praxis: right @	.22	-.18	-.29	.87	.23	.11	.99
Dyn. praxis: left @	.31	-.20	-.22	.15	.32	.71	.81
Dyn. praxis: right @	.20	-.22	-.11	.15	.32	.72	.74
Honeycomb: level	-.17	.83	.14	-.06	-.09	-.05	.75
Sp. reg. motor act: fist @	.77	-.18	-.02	.43	.15	.12	.86
Sp. reg. motor act: knock.@	.68	-.22	-.26	.42	.11	.32	.86
Tactile perception	-.11	.07	.71	-.24	-.06	-.25	.64
Stereognosis	-.65	.17	.24	-.06	-.30	-.06	.60
Skin writing	-.29	.00	.81	-.06	-.02	-.12	.76
Map	-.22	.72	-.02	-.16	-.13	-.09	.62
Raven items	-.11	.38	.23	-.25	-.20	-.16	.34
Easy arithmetic	-.44	.22	.22	-.25	.05	-.26	.43
Classification	-.26	.37	.15	-.26	-.09	-.16	.33
Analogies	-.06	.19	.66	-.12	-.05	.02	.49
Visual perception (S,F/G)#	.12	.15	.08	-.09	-.47	-.25	.33
Ornaments disturb. @	.51	-.19	-.14	.05	.10	.09	.33
Honeycomb disturb. @	.13	-.79	-.11	.05	.13	.16	.71
% of total variance							73.9

@ a high value indicates poor or disturbed performance
# Silhouette and figure-ground identification

of easy arithmetics the distribution was curvig very slightly to the left. In the task of visual perception both extreme classes had equal size of cases with most of the cases concentrating in the middle of the distribution.

It can be mentioned that the six-factor solution with oblique rotations consistently gave the same factors as obtained using Varimax-rotation.

In TABLE 18, only the task of reciprocal coordination and speech regulation of the motor act seemed to have a covariation on two factors (loadings over .40). Otherwise, the factor structure of neuropsychological variables was rather pure.

The first factor got high loadings (over .40) on the variables of reciprocal coordination, the speech regulation of the motor act, stereognosis, easy arithmetical problems and ornamental drawing. The speech control of movements is emphasized in the first factor as is the dynamic organization of movement (ornamental drawing) and both reflect the neuropsychological functioning of the frontal lobe. The first factor was labelled according to its highest loadings as the speech regulation of the motor act.

The second factor loaded mainly on variables of the visuospatial functions, like a good performance level in honeycomb or constructional praxis tasks (.83), good spatial orientation on the map (.72) and no bad disturbances in honeycomb drawing (-.79). Most of the other tests loaded only slightly (under .25) on this factor and only the Raven items (.38) and classification (.37) loaded moderately. The factor describes rather clearly the good performance of visuospatial functioning. Neuropsychologically the second factor is associated most clearly with the functioning of the posterior lobe.

The third factor loaded mainly on tactile perception (.71) and skin writing (.81) which was assumed to be a more complex version of the task of tactile perception and recognition. However, the third tactile task, namely stereognosis did not load on this factor but was loaded on the first factor which was interpreted as the speech regulation of the motor act. This is understandable because earlier it was mentioned that the task of stereognosis is found to be linked more with the motor segments of the sensorimotor region of the cortex than the other two tactile tasks. The task of analogies also become highly loaded (.66) on the third factor as did the reciprocal coordination (-.45). The loadings of the other neuropsychological variables remained under .25 and thus the factor represents tactile perception and recognition. Both highly loaded tactile tasks require the simultaneous synthesis of somesthetic information with number/letter identification and thus the neuropsychological basis of the content of this factor is more in the posterior than anterior divisions of the brain.

On the fourth factor the tasks of spatial praxis (ranging from .82 - .87) and the speech regulation of the motor act (ranging from .42 - .43) were the only high loadings. The factor is a task specific factor of spatial praxis and due to the scoring it has to be interpreted as reflecting apractic disturbances in spatial praxia. The role of speech is emphasized as if underlying the performance. If the aspect of spatial dominance over performance is more emphasized ın neuropsychological interpretations then the fourth factor represents more the functioning of the posterior lobes. But the loading of the speech regulation of the motor act gives the factor the dual neuropsychological nature of the combined activity of both the anterior and posterior divisions of the brain.

The fifth and sixth factor also represent task specific factors. The fifth factor reflects disturbed performance of hand praxis (ranging from .77 - .79) and poor visuoperceptual ability (-.47). Also the loadings of stereognosis (-.30) and the dynamic praxis (.32) were moderate on the fifth factor, which was interpreted as the factor of disturbed hand praxis. The neuropsychological interpretation of the fifth factor refers here more to the functioning of the frontal lobe than the posterior lobe because of the high and moderate factor loadings in cases of disturbed praxias (hand and dynamic). It can be considered that here the successful tactile and visuospatial functions which are more typical of the functioning of the posterior lobe are required for the good performance in the above mentioned praxias.

The sixth factor was labelled as the disturbance of dynamic praxis where the more difficult task of speech regulation of the motor act was also loaded moderately (.32). It is noteworthy that the other test loadings were quite low on this factor. Neuropsychologically the content of the sixth factor is believed to refer to the working of the anterior lobe.

Interpretation. Considering the nature of the six factors from the view point of Luria's theory about three functional units of the brain it can be approximately stated that the first, fifth and sixth factor characterize more the workings of the third unit (the frontal lobes or the anterior division of the brain) and the second, third and fourth factors mainly feature the workings of the second unit (temporo-parieto-occipital lobes or the posterior division of the brain). In the case of the fourth factor which was the disturbance of spatial praxias the distinction of its belonging to the workings of the second or third unit is unclear because if motor regulation and performance is emphasized it would describe more the workings of the third (anterior) unit and if the visuospatial and organizational aspects of the performance are emphasized more then the fourth factor would mainly characterize the workings of the second (posterior) unit. In the present study, the speech regulation of the motor act was moderately (.42 and .43) loaded on the fourth factor of spatial apractic disturbance and so the fourth factor might reflect the functioning of the anterior as well as the parietal lobes. However, disturbed spatial praxis has typically been associated with parietal lobe damage (Luria 1973; Christensen 1974).

8.2.3.2. Correlations between factor scores for qualitative neuro-psychological variables and modes of processing

The correlations between the factor scores of neuropsychological variables and simultaneous and successive processing are presented in TABLE 19.

TABLE 19. Correlations between neuropsychological factors and simultaneous and successive factors (N =56).

Mode of processing	Neuropsychological factors I sp.reg.	II vis.sp.	III tact.	IV sp.prax.	V hand pr.	VI dyn.pr.
I succ. verbal	-.34**	.16	.25	-.22	.06	.04
II sim. verbal	-.27*	.41**	.22	-.12	-.02	-.16
III sim. nonverbal	-.20	.48***	.30*	.10	-.12	-.29*
IV succ. nonverbal	-.32*	.27*	.20	-.25	-.26*	-.21

* $p < .05$ ** $p < .01$ *** $p < .001$

TABLE 19 shows that simultaneous processing (either with verbal or non verbal content) correlates most significantly with a good level of visuospatial functioning. The neuropsychological interpretation of the visuospatial factor refers to the workings of the second unit of Luria's theory and so the model of Das et al. is indirectly supported in a normal sample of elderly people when it comes to associating the simultaneous factor (either verbal or nonverbal) with the workings of the posterior division of the brain. Also, good tactile perception and recognition relates to good simultaneous (nonverbal) processing ($r = .30$, $p < .05$) and the tactile functions were earlier specified neuropsychologically as more reflecting the workings of the posterior than the anterior division of the brain so that the Das et al. model is further supported by simultaneous processing. It is noteworthy that only one of the motor factors relates to simultaneous processing i.e., the fewer there are disturbances in the dynamic praxis (factor VI) the better is a persons's simultaneous (nonverbal) processing ($r = -.29$, $p < .05$). Here the dynamic praxis is interpreted as being an important condition for successful performance in tasks demanding simultaneous synthesis, for good performance in tests loading highly on the simultaneous nonverbal factor (the BVRT and the subscale VR of the WMS) requires dynamic organization in recalling the simultaneously presented and coded visual memory traces in the output phase of drawing. It might well be the case that the correlation of dynamic praxis and simultaneous nonverbal processing points here more to the working of the output unit than the coding unit. This interpretation seems plausible because old people are usually found to be more deficient in performances demanding the use of manipulospatial skills.

The speech regulation of the motor act correlates more clearly with successive processing (either verbal or nonverbal) than simultaneous processing. Only in simultaneous verbal processing did the correlation between the speech regulation of the motor act and processing become significant ($p < .05$). The negative correlations here mean that the more disturbed the speech regulation of the motor act the worse is the processing. Because the speech regulation of the motor act was interpreted neuropsychologically to describe more the functioning of the anterior division of the brain then it can be stated that the assumptions behind the Das' model concerning the linkage between successive processing and the functioning of the anterior part of the brain acquired empirical support.

The role of the hand and spatial praxias in relation to the modes of processing became quite insignificant. The factor of spatial praxis did not correlate with the modes of processing at all and the factor of disturbances in hand praxis correlated weakly (-.26) only with successive nonverbal processing which loaded on tasks requiring manipulospatial skills (e.g., the Block Design and the Digit Symbol of the WAIS). However, the spatial praxis as an individual variable (TABLE 11) correlated with all the processing factors except the simultaneous nonverbal one. In the factor structure of neuropsychological tasks (TABLE 18) also the variable of the speech regulation of the motor act also loaded quite highly (over .40) together with the spatial praxis on the fourth factor. The neuropsychological interpretations of the variables of speech regulation of the motor act and spatial praxis are in a way contradictory, the former featuring more the workings of the anterior division of the brain and the latter the posterior division of the brain. It might be that the lack of a relationship between the factor scores of spatial praxis and the modes of processing is the result of these counterbalancing effects and thus by definition mirrors the balancing effect of the separately distributed domains of the modes of processing in the brain. Also, the factor of hand praxis showed a dual neuropsychological nature due to the high loadings on tasks featuring the functioning of the anterior lobes and due to the moderate loadings on tasks typical for the functioning of the posterior lobes.

8.2.3.3. Qualitative neuropsychological factors as predictors of simultaneous and successive processing

A multiple stepwise and a fixed (all variables included) regression analysis was calculated (Nie & Hull 1981; SPSS: new regression) for neuropsychological factor scores as independent variables and the modes of processing as dependent variables. Due to the orthogonal factor structures the intercorrelations between neuropsychological factor scores were almost zero as was the case between the factor scores of the modes of processing. Thus, there was no multicollinearity among predictors. The multiple stepwise and fixed (forced entry) regression analyses performed separately on individual neuropsychological tasks and on neuropsychological factors were considered important for eliminating the role of chance in multiple regression analyses. The results of these regression analyses are summarized in TABLE 20. The residual statistics were found to be normal in all cases.

All regression analyses in which the simultaneous and successive factor scores were used as the criterion variables were significant. The order of the variables entered in the stepwise regression model is numbered. The inclusion of predictors in the multiple stepwise procedure was continued until the significance limit reached the .05. TABLE 20 presents basically the same results as presented in TABLE 19 but from a different perspective. The additional information is derived from the R^2 -values, the coefficients of regression and significant combinations of predictors.

With all the predictors included in the fixed regression model the successive verbal factor is predicted about 26 % by the neuropsychological factor scores. In the multiple stepwise regression analysis the only significant ($p < .009$) single factor of the speech regulation of the motor act predicted 12 % of the variance in successive verbal processing. The next variable to enter the stepwise regression analysis would have been tactile perception and recognition but it slightly ($p < .051$) exceeded the criterion limit set for inclusion here. The result in multiple stepwise analysis is consistent with the finding presented in TABLE 13, although the value of R^2 is now .117 instead of the value .225 when the individual task of speech regulation of the motor act was used as a predictor.

TABLE 20. Summary of the fixed and multiple stepwise regression analyses: Neuropsychological factor scores as independent variables and the factor scores of the modes of processing as dependent variables (N = 56).

A. Fixed model

Dependent variable: Successive verbal processing

Independent variables	b	s .e. b	Beta	t	p	R^2
Speech reg. motor act	-.333	.117	-.350	-2.834	.006	
Visuospatial functions	.142	.120	.145	1.180	.243	
Tactile perc. & recogn.	.232	.121	.235	1.907	.062	
Spat. praxis disturb.	-.193	.110	-.215	-1.748	.086	
Hand praxis disturb.	.076	.121	.077	.627	.533	
Dyn. praxis disturb.	.074	.126	.073	.589	.558	
Constant = -.006						
F = 2.839 , p = .0188						.257

B. Stepwise regression						R^2
1. Speech reg. motor act	-.326	.121	-.343	-2.684	.009	.117
Constant = -.006						
F = 7.205, p = .0096						

A. Fixed model

Dependent variable: Simultaneous verbal processing

Independent variables	b	s.e. b	Beta	t	p	R^2
Speech regul. motor act	-.217	.106	-.243	-2.034	.047	
Visuospatial functions	.363	.109	.395	3.322	.001	
Tactile perc. & recogn.	.183	.110	.197	1.658	.103	
Spat. praxis disturb.	-.101	.100	-.120	-1.006	.319	
Hand praxis disturb.	.010	.110	.011	.096	.924	
Dyn. praxis disturb.	-.122	.114	-.128	-1.068	.290	
Constant = -.002						
F = 3.611, p = .0048						.306

(continues)

TABLE 20 (continues)

B. Stepwise regression	b	s.e. b	Beta	t	p	R^2
1. Visuospatial functions	.370	.110	.402	3.344	.001	.170
2. Sp. regul. motor act	-.223	.107	-.250	-2.081	.042	.232
Constant = -.022						
F = 8.047, p = .0009						

<u>A. Fixed model</u>

Dependent variable: Simultaneous nonverbal processing

Independent variables	b	s.e. b	Beta	t	p	R^2
Speech reg. motor act	-.127	.090	-.152	-1.406	.166	
Visuospatial functions	.392	.092	.457	4.227	.000	
Tactile perc. & recogn.	.251	.093	.290	2.681	.010	
Sp. praxis disturb.	.088	.085	.112	1.031	.307	
Hand praxis disturb.	-.081	.093	-.094	-.871	.387	
Dyn. praxis disturb.	-.212	.097	-.238	-2.189	.033	
Constant = .037						
F = 6.073, p = .0001						.426

<u>B. Stepwise regression</u>						R^2
1. Visuospatial funct.	.397	.093	.464	4.251	.000	.226
2. Tactile perc. & recogn.	.245	.094	.283	2.598	.012	.313
3. Dyn. praxis disturb.	-.232	.097	-.260	-2.386	.020	.381
Constant = .037						
F = 10.670, p = .0000						

(continues)

TABLE 20 (continues)

A. Fixed model

Dependent variable: Successive nonverbal processing

Independent variables	b	s. e. b	Beta	t	p	R^2
Speech reg. motor act	-.250	.100	-.290	-2.503	.015	
Visuospatial functions	.217	.102	.245	2.119	.039	
Tactile perc. & recogn.	.158	.103	.177	1.532	.131	
Sp. praxis disturb.	-.196	.094	-.241	-2.085	.042	
Hand praxis disturb.	-.200	.103	-.224	-1.937	.058	
Dyn. praxis disturb.	-.154	.107	-.166	-1.433	.158	
Constant = .046						
F = 4.326, p = .001						.346
B. Stepwise regression						R^2
1. Speech reg. motor act	-.269	.105	-.312	-2.567	.013	.098
2. Sp. praxis disturb.	-.208	.099	-.255	-2.102	.040	.165
3. Visuospatial funct.	.227	.108	.255	2.101	.040	.230
Constant = .046						
F = 5.205, p = .003						

In the fixed regression model the neuropsychological variables together predicted about 31 % of the total variance in the simultaneous verbal processing factor. The two-variable stepwise model including the visuospatial functions and the speech regulation of the motor act in this order could alone predict 23 % of the variance in simultaneous verbal processing ($p < .0009$). The third variable to enter the regression analyses would have been tactile perception and recognition. The finding here emphasizes more the role of the visuospatial function in simultaneous verbal processing than was the situation in TABLE 14, where the individual language tests also appeared as predictors. However, the nature of the simultaneous processing factor is supported in both results.

The simultaneous nonverbal processing factor was 43 % predicted by the neuropsychological variables together and the best individual predictors in the multiple stepwise procedure were, in this order, the visuospatial factor, tactile perception and recognition, and undisturbed dynamic praxis. Together these three variables were able to explain significantly 38 % of the variance in simultaneous verbal processing ($p < .0000$). The result here describes more manysidedly the nature of simultaneous processing than those presented in TABLE 15 in the case of single neuropsychological variables as predictors.

About 35 % of the total variance of successive nonverbal processing was accounted for by the fixed regression model including all independent variables. Together the three variables became significant predictors and in the fourth step the variable of hand praxis slightly exceeded the inclusion value ($p < .055$). The order of individual predictors in multiple stepwise regression was the speech regulation of the motor act, spatial praxis, and the visuospatial functions, which, as a whole, predicted 23 % of the variance in successive nonverbal processing ($p < .003$). The nature of the successive processing factor when the combination of neuropsychological predictors was used is well in accordance with the findings observed in cases of using single predictors.

8.2.3.4. The left and right hemisphere tasks and the modes of processing

One mean for internal validation is to classify the tasks according to theoretical statements and to compare the consistency in results. Here the neuropsychological tasks were reclassified according to their assumed indications of measuring more or less either the left (mainly verbal) or right (visuospatial, nonverbal) hemisphere functioning (e.g., Cohen 1977; Galin 1976; Kinsbourne 1978; Krashen 1976; Lesser 1978; McGee 1979; Segalowitz 1983; Sinatra & Stahl-Gemake 1983; Williams 1983; Wittrock 1978). The motor performance of the contralateral hand was attended to. The LH and RH tasks were factor-analyzed by the principal axis method with Varimax rotations (TABLES 21 and 22) and the rotated factor matrices used for factor score calculations. Eigenvalues were greater than 1 in both cases. Some dichotomized variables (such as naming difficulties, understanding instructions, automatisms, discrimination of phonemes, narrative speech) were included in the left hemisphere factor analysis due to their language content although a more powerful measurement scale would have been better and more correct for factor analysis.

The "LH and RH factors" (conceptually latent factors by definition) seemed to be relatively pure (simple) as far as the factor loadings (over .40) of the tasks were concerned. Of the LH factors, the task of verbal intelligence and right hand spatial praxis loaded on two different factors. Performance IQ and stereognosis happened to load on two different RH factors.

The factor analyses of LH tasks yielded three factors which were interpreted as speech regulation of the motor act (factor I), verbal reasoning and memory (factor II) and disturbed praxias (factor III). The RH factors included factors of memory for personal facts and motor fluency (I), successful praxias (II), visuospatial functions (III), tactile perception and recognition (IV) and memory for objects (V). The LH factor explained about 54 % of the total variance and the RH factors 67 % respectively.

The praxias obviously form their own dimension and differ from the higher level LH or RH factors or from the simple motor performance level (i.e., tapping did not load on the factor of praxias).

TABLE 21. 'Left hemisphere' (LH) factors in the elderly (N =56).

Test	Factors I	II	III	h^2
Verb. IQ	-.49	.66	-.12	.69
Tapping: right	-.51	.26	-.28	.40
WMS IV delayed	-.26	.59	-.09	.43
WMS VII delayed	-.16	.84	-.08	.74
Hand. prax. right	.35	-.12	.60	.50
Sp. prax. right	.55	-.26	.41	.53
Dyn. prax. right	.35	-.22	.50	.42
Sp. reg. (fist)	.73	-.26	.24	.65
Sp. reg.(knock)	.77	-.35	.27	.78
Underst. instr.	.36	-.43	.32	.42
Naming diffic.	.40	-.31	.12	.27
Aud. phon. discrim.	.02	.02	.75	.56
Automatisms	.68	-.21	.35	.63
Narrative speech	.14	-.47	.36	.37
Arithm. prob.solv.	-.31	.34	-.03	.21
Classificication	-.38	.46	-.19	.39
Analogies	-.19	.35	-.11	.17
WMS III: 20-1	-.77	.33	-.09	.71
" : abc	-.34	.29	-.08	.21
" : 1,4,7,..40	-.18	.29	-.40	.28
% of total variance				53.8

TABLE 22. "Right hemisphere" (RH) factors in the elderly (N =55).

Test	Factors I	II	III	IV	V	h^2
Perf. IQ	.54	.50	.26	.25	.06	.67
Tapping: left	.61	.28	.05	.02	-.11	.47
KS-objects (S-T M)	.22	.33	.04	-.09	.86	.91
KS-persons (S-T M)	.84	-.18	.23	.18	.08	.83
KS-objects (delayed)	-.18	.12	.13	.23	.60	.48
KS-persons (delayed)	.76	-.06	.30	.29	.12	.77
Face recognition	.02	.58	.13	.13	.26	.44
Hand praxis: left	-.21	-.73	-.11	-.01	-.10	.60
Spatial praxis: left	-.27	-.51	-.23	-.35	.02	.52
Dynamic praxis: left	-.18	-.51	-.28	-.37	-.18	.54
Honeycomb (level)	.31	.06	.86	.08	.14	.86
Tactile perception	.15	.23	.09	.81	.02	.74
Stereognosis	.50	.51	.10	.08	.24	.58
Skin writing	.38	.10	.01	.67	.18	.64
Map	.25	.29	.68	-.05	-.04	.61
Raven items	.06	.39	.39	.20	.01	.34
Arithmetic: easy	.43	.23	.21	.28	-.09	.36
Visual functions	-.09	.35	.20	.09	.12	.20
Ornament disturb.	-.49	-.33	-.10	-.09	-.14	.38
Honeycomb disturb.	-.13	-.26	-.77	-.11	-.13	.70
% of total variance						67.1

TABLE 23. Intercorrelations between two sets of neuropsychological variables (the "left and right hemisphere" tasks) (N =55).

L H factor scores	R H factor scores 1	2	3	4	5
Factor 6	-.47***	-.53***	-.22*	-.19	.06
Factor 7	.33**	.08	.34**	.40***	.25
Factor 8	-.19	-.54***	-.10	-.07	.02

* p < .05 ** p < .01 *** p < .001

L H - factors:

6. Speech regulation of the motor act (disturbances)
7. Verbal reasoning and memory
8. Disturbed praxias

R H - factors:

1. Memory for personal facts and motor fluency
2. Successful praxias
3. Visuospatial functions
4. Tactile perception and recognition
5. Memory for objects

The intercorrelations of LH and RH factor scores in TABLE 23 showed that the speech regulation of the motor act did not correlate significantly with the factors of tactile perception and recognition or memory for objects. The factor of verbal reasoning and memory had significant correlations with the RH factors except with praxias. The disturbed praxias of the LII tasks correlated significantly only with thc RH praxias. The covariation between the LH and RH factors seemed to be most remarkable in the case of verbal reasoning and memory, and speech regulation of the motor act.

TABLE 24. Correlations between two sets of neuropsychological variables ("left and right hemisphere scale") and simultaneous-successive processing (N =55).

Mode of processing	L H factors 6	7	8
Succ. verbal	-.26*	.65***	-.01
Sim. verbal	-.39**	.55***	-.11
Sim. nonverbal	-.34**	.28*	-.10
Succ. nonverbal	-.36**	.27*	-.36**

	R H factors 1	2	3	4	5
Succ. verbal	.44***	.06	.15	.16	.19
Sim. verbal	.14	.27*	.38**	.27*	-.05
Sim. nonverb.	.26*	.22	.44***	.19	.27*
Succ.nonverb.	.46***	.32**	.26*	.25	.01

* $p < .05$ ** $p < .01$ *** $p < .001$

The correlations between the factor scores for RH and LH tasks and the modes of processing in TABLE 24 indicated that the higher level functions of the LH factors (verbal reasoning and memory, speech regulation of the motor act) correlated significantly with simultaneous and successive modes of processing. The factor of verbal reasoning and memory correlated higher with verbal than nonverbal code content a finding consistent with statements suggested in the theory of functional asymmetry. The LH factor of disturbed praxias correlated ($p < .01$) only with successive nonverbal processing. In case of RH factors, the visuospatial functions correlated clearly with simultaneous processing. Tactile perception and recognition as well as memory for objects both had significant ($p < .05$) correlations with simultaneous processing. Successive processing correlated highly and most noticeably with the RH factors of memory for personal facts and motor fluency and with a successful performance in praxias.

The overall results of correlation matrix 24 further confirm the internal validity of the research measurements, because the different combinations of psychometric and qualitative variables were able to give results consistent with earlier findings in the present study, and also, at the same time, to be in accordance with the basic assumptions of the Das et al. model. The differentiation of the modes of processing at the level of neuropsychological variables was apparent. Simultaneous processing associated more closely with the factors of visuospatial functions and tactile perception and recognition, whereas successive processing had more connections with praxias and motor fluency. Verbal reasoning and memory seemed to overlap both simultaneous and successive processing, although the correlations were more significant ($p < .001$) in the case of verbal than nonverbal code content ($p < .05$). Thus, it can be seen that the verbal or conceptual variety of cognition appears also in simultaneous processing and not only in successive processing.

8.2.3.4.1. The left and right hemisphere factors as predictors of factor scores of simultaneous and successive processing

The claims of the theory of hemispheric asymmetry concerning the relationship between successive (serial) processing and left hemisphere functioning and between the simultaneous (parallel) processing and right hemisphere functioning suggest that there should be a stronger relationship between simultaneous and successive verbal processing with left hemisphere factors than between simultaneous and successive nonverbal processing. A contrary relation should hold true for behaviors associated with right hemisphere processes where simultaneous and successive nonverbal processing should have a stronger relationship with that hemisphere. If this turns out to be the case it would suggest that there are both simultaneous and successive units inside each hemisphere and these are separable in terms of code content. TABLE 25 presents a summary of the separate multiple stepwise and fixed regression (all variables included) analyses for the factor scores for the left and right hemisphere tasks as predictors and the factor scores for successive and simultaneous processing as dependent variables. Only the significant steps of the multiple stepwise regressions are presented in TABLE 25. The residual statistics were found to be normal.

TABLE 25. Results of the multiple stepwise and fixed regression models: the factor scores of simultaneous and successive processing as dependent variables and the factor scores of the left and right hemisphere tasks as predictors. The regression analyses are performed separately for the left and right hemisphere factors.

	LEFT HEMISPHERE FACTORS	
	Stepwise regression	Fixed model (all variables incl.)
<u>A. Successive verbal processing</u>		
1. Speech regulation of the motor act	R^2 = .419 R = .646 F (1, 54) = 38.878, p < .0000	R^2 = .452 R = .672 F (3, 52) = 14.298, p < .0000
<u>B. Simultaneous verbal processing</u>		
1. Verbal reasoning and memory		
2. Speech regulation of the motor act	R^2 = .406 R = .637 F (2, 53) = 18.093, p < .0000	R^2 = .410 R = .640 F (3, 52) = 12.026, p < .0000

(continues)

TABLE 25 (continues)

C. Simultaneous nonverbal processing		
1. Speech regulation of the motor act	R^2 = .116 R = .341 F (1, 54) = 7.085, p < .010	R^2 = .176 R = .420 F (3, 52) = 3.703, p < .017
D. Successive nonverbal processing		
1. Disturbed praxias		
2. Speech regulation of the motor act	R^2= .232 R = .482 F (2, 53) = 8.003, p < .0063	R^2 = .284 R = .533 F (3, 52) = 6.863, p < .0006

	RIGHT HEMISPHERE Stepwise regression	FACTORS Fixed model (all variables incl.)
A. Successive verbal processing		
1. Social memory and motor fluency	R^2 = .192 R = .438 F (1, 53) = 12.615, p < .0008	R^2 = .263 R = .513 F (5, 49) = 3.498, p < .0088
B. Simultaneous verbal processing		
1. Visuospatial functions		
2. Tactile perception and recognition		
3. Successful praxias	R^2 = .275 R = .524 F (3, 51) = 6.436, p < .0009	R^2 = .288 R = .536 F (5, 49) = 3.960, p < .0043
C. Simultaneous nonverbal processing		
1. Visuospatial functions		
2. Memory for objects	R^2= .265 R = .515 F (2, 52) = 9.377, p < .0003	R^2 = .380 R = .616 F (5, 49) = 6.005, p < .0002
D. Successive nonverbal processing		
1. Social memory and motor fluency		
2. Successful praxias		
3. Visuospatial functions	R^2 = .359 R = .599 F (3, 51) = 9.515, p < .0000	R^2 = .399 R = .631 F (4, 59) = 6.499, p < .0001

In TABLE 25, the results of the correlation matrix (TABLE 24) are presented from a different perspective with added information concerning the R^2 -values and the relative contribution of the left and right hemisphere factors as predictors of simultaneous and successive processing.

The prediction percentages of the left hemisphere factors varied from 41 % to 45 % for the verbally emphasized modes of processing (either simultaneous or successive), but only from 12 % to 28 % for nonverbal content of modes of processing. Thus, the left hemisphere factors were better able to predict those modes of processing which included a verbal code content whether simultaneous or successive. Respectively, the right hemisphere factors predicted more exactly the nonverbally accentuated modes of processing. The percentages for the best combinations of the right hemisphere factors predicting the nonverbally emphasized codes of processing varied from 27 % to 40% , whereas the modes of processing including verbal content were predicted to a somewhat lesser amount varying from 19 % to 29 %.

On factors of simultaneous and successive processing, the multiple correlations of the left hemisphere factor combinations remained higher (.64 and .65) on verbally than nonverbally accentuated content (.34 and .48) and the multiple correlations of the right hemisphere factor combinations were slightly higher (.52 and .60) on nonverbally than verbally accentuated modes of processing (.44 and .52).

These results suggest conceptually that there are inside each hemisphere the units for successive and simultaneous processing which are differentiated from each other according to their code content.

TABLE 26 gives a summary of the regression analyses (multiple stepwise and forced entry) where the modes of processing were used as criteria and the left and right hemisphere factors conjointly as predictors. Here some of the predictors correlated significantly with each other (see

TABLE 26. The factor scores of simultaneous and successive processing as criteria and the left and right hemisphere factors conjointly as predictors : a summary table.

Criteria	Predictor	R^2	R
Successive verbal	1. Verbal memory and reasoning (LH)	.43	.65
	2. Social memory and motor fluency (RH)	.48	.70
	All LH and RH factors	.52	.72
Simultaneous verbal	1. Verbal memory and and reasoning (LH)	.30	.55
	2. Speech regulation of motor act (LH)	.41	.64
	3. Social memory and motor fluency (RH)	.46	.68
	All LH and RH factors	.51	.72
Simultaneous nonverbal	1. Visuospatial (RH)	.19	.44
	2. Memory for objects (RH)	.27	.51
	3. Speech regulation of motor act (LII)	.33	.58
	All LH and RH factors	.42	.64
Successive nonverbal	1. Social memory and motor fluency (RH)	.21	.46
	2. Successful praxias (RH)	.31	.55
	3. Visuospatial (RH)	.36	.60
	All LH and RH factors	.42	.65

TABLE 23). The main point was to evaluate the overall relative significance of the combination of the left and right hemispheric factors as predictors of the modes of processing. It was thought that the results might suggest

something about the importance of the content vs. process interpretations of the modes of processing. All the regression analyses reported in TABLE 26 were highly significant.

The factor of verbal memory and reasoning appeared as the most powerful predictor of both verbally accentuated modes of processing whether simultaneous or successive. Social memory and motor fluency (the RH factor) predicted also verbal simultaneous and successive processing. These both factors together were able to account for 48 % of the total variance in successive verbal processing.

The best predictors of simultaneous and successive processing with nonverbal content were the right hemisphere factors. Only in one case did the left hemisphere factor (i.e., speech regulation of the motor act) emerge as one of the predictors of simultaneous nonverbal processing.

The predictive power of the left and right hemisphere factors together was slightly higher for the modes of processing with verbal content (ranging from .51 % to 52 %) than was the predictive power of the same factors for simultaneous and successive processing with nonverbal content (42 %). Naturally, the multiple R in combinations of the predictors was also larger in the case of the verbal modes of processing than the nonverbal.

8.3. Conclusions

The results of the regression analyses for both levels of prediction (i.e., individual neuropsychological tasks and neuropsychological factors) support the Das et al. statements concerning the neuropsychological definitions of simultaneous and successive processing. Although the results of the regression analyses are meaningful and in accordance with theoretical notions, it should be remembered that there still remains considerably more unexplained variance. Also, this study was conducted with a small number of subjects so these conclusions should be interpreted with caution.

Firstly, at factor level simultaneous processing (with either verbal or nonverbal content) was best predicted by the visuospatial functions which alone could explain 17 % of the total variance of verbal and 23 % of nonverbal simultaneous processing. The visuospatial functions are generally considered to reflect more the functioning of the posterior than anterior division of the brain and so the empirical results here demonstrating the linkage between simultaneous processing and Luria's second unit are well in accordance with the assumptions presented in the Das et al. model. It should be noted here that in more specific neuropsychological analyses of brain damaged persons the qualitative analysis of the visual performance tasks might point to frontal lobe functioning as well, but this is usually supported by syndrome analysis showing the typical features (errors) of qualitative frontal lobe dysfunctioning in other cognitive domains as well. The speech regulation of the motor act was also a significant predictor of the simultaneous verbal factor, although not of the nonverbal simultaneous factor where the absence of any disturbance in dynamic praxis was more emphasized. It can be inferred that underlying the simultaneous mode of processing is a motor component of performance which by its nature in either the verbal or nonverbal content of simultaneous processing is dynamic movement. This dynamic property of movement is seen basically to be the function of Luria's third unit having at least two possible alternative interpretations one reflecting the motor executive component and the other exhibiting the emergent property of planning.

Secondly, at factor level successive processing (either verbal or nonverbal content) was best predicted by the speech regulation of the motor act which characterizes the functioning of the frontal lobe. Spatial praxis and the visuospatial factor also emerged as significant predictors of successive nonverbal processing. Spatial praxis and the visuospatial functions are typically considered to express the workings of Luria's second unit but here in the multiple regression analysis their order of appearance was after the task characterizing Luria's third unit. It can be stated that simultaneous processing underlies successive processing in contrast to the situation mentioned in the above paragraph. The interdependence of the workings of Luria's second and third unit is thus conceptually reflected in the results of the regression analyses.

Thirdly, the prediction percentage of the significant variable combinations of the individual neuropsychological tasks varied from 28 % (successive verbal processing) to 51 % (successive nonverbal processing). The prediction percentages of the significant variable combinations of one, two or three neuropsychological factors were slightly lower ranging from 12 % to 38 %. Also, the multiple correlations of the variable combinations of individual neuropsychological tasks with simultaneous and successive processing were slightly higher (ranging from .53 to .71) than those of the significant combinations of neuropsychological factors (ranging from .34 to .62). All together the individual neuropsychological variables were able to explain from 53 % to 77 % of the total variance in simultaneous or successive processing, although the overall equation did not then become significant in two cases (namely simultaneous and successive verbal processing). The combination of six neuropsychological factors accounted for 26 % to 43 % of the total variance of simultaneous and successive processing and then all the regression equations became significant. The multiple correlations of all the individual neuropsychological tasks with simultaneous and successive processing were higher (from .73 to .88) than those of all the neuropsychological factors taken together (from .51 to .65).

Thus, the best predictors were found at the level of individual neuropsychological tasks which is understandable because fewer tasks were selected for factor-analyses (only Lurian type qualitative tasks).

Fourthly, the results showed that the verbal content of the modes of processing was mainly predicted by the task factors of the left hemisphere and the nonverbal content by the task factors of the right hemisphere. The finding supports the statements associating hemispheric specialization and the modes of processing differentially but it also points to the need to take content-based interpretations into account when dealing with the neuropsychological aspects of simultaneous and successive processing. These results suggested tentatively the existence of separate units inside each hemisphere for the modes of processing so that simultaneous and successive verbal processing are more efficiently mediated via the left hemisphere and simultaneous and successive nonverbal processing through the right hemisphere.

Fifthly, the memory tasks investigated predicted better the verbally than the nonverbally accentuated content of processing.

8.4. Discussion

In the present study psychometric and qualitative research approaches were combined together within the perspective of information processing. Some of the traditional psychometric tests (WAIS and WMS subscales, BVRT) were interpreted from the view point of information processing and the findings obtained were further examined in terms of neurobehavioral observations. The qualitative neuropsychological tasks used were adapted from the Lurian neuropsychological battery (Christensen 1974) which made it possible to test the usefulness of the information processing theory in the light of Luria's (e.g., 1973) neuropsychological theory. The research emphasis was now transferred from the brain damaged patient to the normal subject in the present study and so the functional systems which are claimed to be highly interdependent were studied as a set.

The simultaneous and successive processing of elderly people (75 - 85 years) seems to be somewhat clearer than the empirical findings on a neurological patient group (Äystö 1983; Äystö & Hänninen 1986). Schludermann et al. (1983) mention that normal aging produces more alterations in the factor structure of intelligence tests like the WAIS than does brain damage.

In the present study, the four factor Varimax-solution dissociated the modes of processing of elderly people so that simultaneous verbal and nonverbal processing as well as successive verbal and nonverbal processing were clearly separable from each other. In fact, the mode of processing (simultaneous-successive) was orthogonal to code content (verbal/nonverbal) as has been assumed by Das at al. (1979). It has not been possible to differentiate the successive nonverbal factor in a neurological adult sample (Äystö 1983; Äystö & Hänninen 1986) using the same tests. The differentiation of successive verbal and nonverbal factors may be a sign of the age effect or there may be some kind of strategic property in the processing of elderly people which distinguishes content and code specific processing as clearly as it does in this particular age group.

In the elderly sample, the easy items on the Associate Learning subscale of the WMS got residual loadings on the simultaneous verbal factor whereas the hard items had residual loadings on the successive nonverbal factor. In the neurological patient sample, the easy and hard items of Associate Learning subscale were not distinguishable from each other on the basis of factor loadings (Äystö 1983). The concrete-pair word associations have been found to load on the simultaneous factor in fourth graders (Cummins cf. Das et al. 1975). Whether the more specific factor structure of the modes of processing in an elderly normally-aged sample indicates the differential nature of aging was tentatively studied by investigating the relationship between simultaneous and successive processing and neuropsychological tasks.

The neuropsychological tasks selected for the present study mainly included qualitative tasks of the kind commonly used in investigations of brain-damaged and aphasic samples. Although the elderly sample in the present study was rather healthy and without known brain damage or dysfunction, the factor structure of the neuropsychological tasks constituted the composition of the test battery such that factor content resembled quite consistently and systematically the main characteristics and dimensions observed in locations of various brain dysfunctions. The result of the factor analysis of neuropsychological qualitative tasks was as if a syndrome analysis of a whole sample of elderly people and thus comparable to the Luria's clinical-anatomical method of performing a syndrome analysis inside a brain injured individual. An important aspect of syndrome analysis is the qualitative and multidimensional evaluation of the performance (i.e., how the task was resolved), especially in cases of focal brain damages. However, its use in investigating normal samples is much more questionable. Therefore, only the degree of severity in neuropsychological functioning (undisturbed - strongly disturbed) was scored and the qualitative type of error neglected as a nonrelevant dimension in the relatively healthy elderly sample. Scoring the severity of the performance made the neuropsychological variables unidimensional and, thus, better suitable for factor-analytical treatments. The clear neuropsychological implications of the factor structure contributed to testing the neurobehavioral properties of simultaneous and successive processing. If simultaneous and successive processing systematically correlate and predict the hypothesized relationship between the modes of processing and qualitative neuropsychological functions, a more confident statement about the differential nature of normal aging is possible. At the same time, at the neurobehavioral level it was also possible to study both hypotheses concerning the relationship between the modes of processing and their corresponding neuropsychological domains (anterior/posterior and the left/right hemisphere).

In fact, it was found that those neuropsychological tasks or factors featuring the workings of the anterior division of the brain more highly correlated with and predicted successive processing (either verbal or nonverbal). In a similar way, the neuropsychological variables characterizing the workings of the posterior divisions of the brain correlated with and predicted better simultaneous processing (either verbal or nonverbal). The simultaneous factor was best predicted by those neuropsychological factors or variables containing the visuospatial or tactile functions which, in neuropsychological literature, are assumed to reflect the functioning of Luria's second unit (posterior parts of the brain). The speech regulation of the motor act was the most powerful predictor of successive processing and so this finding points to a close connection between successive processing and Luria's third unit (anterior parts of the brain). The results tentatively suggested that there are separate units inside the hemispheres for the modes of processing. Successive processing seemed to be differentiated in the left and right hemisphere tasks so that successive verbal processing was more closely related to left hemisphere tasks and successive nonverbal processing to right hemisphere tasks. On the other hand, simultaneous verbal processing was better predicted by left hemisphere tasks, whereas the right hemisphere tasks more significantly predicted simultaneous processing in general.

The observations above would tentatively suggest a model where the anterior left hemisphere would be most closely associated with successive verbal processing, and the posterior left hemisphere with simultaneous verbal processing. Also, according to the same findings, the anterior right hemisphere would have the most important connections with successive nonverbal processing and the posterior right hemisphere with simultaneous nonverbal processing. It might be possible to test the model as a simultaneous equation where the degree of the interdependence of the four units (modes of processing residing inside hemispheres) could also possibly be clarified.

9. STUDY 4

The aim of the present study is (1) to apply the modes of processing in understanding cognitive dysfunction (aphemia) and a sudden and complete recovery from it, and (2) to discuss the likely nature of the interaction of the modes of processing associated with the behavioral change observed in the recovery phase.

9.1. Introduction

Aphemia is described according to Broca (Schuell et al. 1964, p. 12) as "a loss of the faculty of articulated speech in the absence of paralysis of the tongue, impairment of comprehension or loss of intelligence." However, this syndrome was later called motor aphasia (Broca's aphasia) and as a syndrome it is different from aphemia.

Usually aphemia has referred to a very specific syndrome with labels like subcortical motor aphasia (Lichtheim 1885), cortical dysarthria (Bay 1964), pure word dumbness (Brain 1965), pure motor aphasia (Brown 1972) and anarthria (Marie 1906; citation from DeRenzi et al. 1966). The inability to articulate (Goldstein 1948, pp. 190-216) or to coordinate the movements of phonation (DeRenzi et al. 1966) or in the sequencing of articulatory movements without a real language deficit (Nebes 1975) is generally seen as a defect in aphemia.

Aphemia is said to be an extremely rare disorder (Boller et al. 1977; Schiff et al. 1983) with a very distinct clinical picture (Benson 1979). Benson (1979) has described the clinical picture of aphemia in the following way. The patient becomes actually and temporarily mute being unable to produce vocal expression. Naming and repetition fail because they demand vocalization, but the patient is able to understand speech, to read (silently) and to write. Sometimes a patient with aphemia may have difficulties in performing on command such acts as whistling, coughing, blowing, sucking and winking. Apraxia associated with the use of limbs (e.g., waving goodbye, making a fist, imitating the use of a comb etc.), is not necessarily present, although hemiplegia or paralysis on the right side associated with the onset of aphemia often occurs. Bucco-facial apraxia is demonstrated in many cases.

According to Benson (1979), laryngeal pathology does not cause aphemia, and most cases of aphemia follow large cerebral infarctions,hematomas or traumas. The neuropathology of aphemia may directly involve Broca's area or the subcortical tissues immediately below this area (Benson 1979; Mohr 1976). Heilman (1978) suggests that the anatomical pathway between the motor encoder (Broca's area) and the primary motor area (area 4) does not function thus causing the syndrome of aphemia. It has also been speculated (e.g., Nebes 1975) that the possibility of disconnection between the cortex and speech organs may elicit the aphemic syndrome.

It is, as yet, an unresolved terminological issue as to whether aphemia is a form of speech apraxia, dysarthria or a disorder of phonologic (sound) production (Schiff et al. 1983), although "aphemia represents the interaction between normal lexical and syntactic language with a motor system impaired in sound production."

The prognosis for recovery from aphemia is excellent (Schiff et al. 1983). However, there are no explanations concerning what might happen in the process of recovery from aphemia. Jackson (1958, pp. 169-170) supposedly gave a description of aphemia when he wrote about the pseudo-speechlessness, or non-utterance of patients who could not speak yet wrote perfectly. This pseudo-speechlessness might remain for months and frequently there was loss of voice. According to Jackson the kind of not-speaking was caused by emotional excitement. After months of not-speaking patients might recover absolutely and immediately after some treatment which could have no therapeutical effect (e.g., a liniment rubbed on the back, a single faradic stimulation of the vocal cords or of the neck). Jackson also mentions that sometimes the so-called speechless patient spoke inadvertently when suddenly asked a question; the speech was "surprised out" of the patient. In Jackson's opinion there was no particular cure in cases of this kind.

Nebes (1975) has described an aphemic case with a severe articulatory defect which remained unchanged over the four months investigation period. Benson (1979) argues that recovery from a mute state in aphemia happens sometimes within a few days but more often it takes some weeks before verbalization begins to return. In the first stage the verbal output is hypophonic, slow, breathy and poorly articulated as to be almost incomprehensible. However, the morphological and syntactic structure of the language is intact from the earliest stages of recovery and a full lexicon is present in writing. Even when aphemia has gradually moderated there are almost invariably signs of residual dysprosody and the altered speech can show a foreign accent. Thus far, speech therapy has been the only therapeutic approach in the treatment of aphemia.

Schiff et al. (1983) have described four cases of aphemia with notable dysarthria after a follow-up period of eight to 30 months. The only persistent deficiency in these four aphemia patients was dysarthria, which persisted up to two years and longer. However, there were no deficiences in language content.

Goldstein (1948) explains the rapid recovery from peripheral motor aphasia anatomically as the preservation of "the connections through the corpus callosum between the operculum Rolandi and the central speech mechanisms of both hemispheres." Mohr (1976) mentions that proposals have been made concerning the possibility of prompt recovery from aphasia, but the means by which such improvements occur has been only broadly suggested.

Warren and Datta (1981) have described a case of head injury, where speech returned suddenly and unexpectedly 4 1/2 years after the trauma as a result of the use of a speech synthesizer (Handi-Voice 110). However, their case was not without voice, but was mutismic. Also, according to the authors, their case does not verify the effect of such treatment or encourage generalization to the recovery of other such patients. Although the authors present several alternative interpretations for the recovery, they imply that the Handi-Voice apparatus obviously facilitated speech by stimulating phonetic patterns subvocally. The apparatus enabled the patient "to select, sequence, and encode elements of language into a covert, comprehensible form, which in turn encouraged him to use his residual language skills."

Aphemia is different from functional aphonia in its clinical picture. The most successful method in voice therapy has been the direct symptom-modification proposed by behavior therapists (Boone 1971). The therapist focuses on a symptom and gradually "conditions it away." It also appears that the aphonic patient in voice therapy often recovers during the first treatment. However, the clinical symptoms in functional aphonia are different from aphemia as the patient can manage by whispering in most situations.

If the basic disorder in aphemia is in the sequencing of phonemic articulation (Luria 1966a) or of articulatory movements (Nebes 1975), recovery from the aphemic syndrome could be explained in terms of information processing. The following case illustrates such an explanation, but also points to the need for multilevel explanations as to recovery from aphemia.

9.2. Case history

9.2.1. Neurological examination

Case K.H. Recently, a 15-year old schoolboy was brought to hospital unconscious from a motorbike accident. During the first week in hospital he was treated in the intensive care unit where he slowly regained consciousness and began to respond to verbal commands. Hemiparesis on the right with a positive Babinski sign and gaze paresis also to the right were evident from the beginning. The left carotid angiogram was normal. Ten days after the accident the patient was transferred to the neurological department. He was still somnolent but easily arousable, able to open his eyes, but did not speak. There was spastic paresis of the right extremities and facial weakness on the right side. EEG one month after the accident showed a large focal slow-wave disturbance in the parieto-occipital region on the left.

For several weeks the patient was tired but improved steadily. Speech therapy was started about two and half weeks after the accident. The only form of voice production was crying and the patient was totally unable to produce expressive speech. The patient also had great difficulties in concentrating. His understanding of speech seemed to be unimpaired and he was able to write words and short sentences on dictation as well as to communicate short expressions spontaneously in writing.

About three weeks after the accident he regained his ability to speak during neuropsychological testing. For a few weeks after this his behaviour was uncontrolled and uncritical but before discharge 1 1/2 months after the accident his mental state had significantly improved, and he was motivated for rehabilitation. At discharge he was able to walk without assistance and some slight movement had reappeared in the right arm.

He has since made a steady improvement with regard to his neurological status. At the most recent examination at the outpatient department in September 1982 he still had signs of hemiparesis on the right with distal accentuation. His ability to walk was satisfactory with only a slight limp but the right arm had not improved as satisfactorily. His behaviour seemed slightly uncontrolled.

All the neurological symptoms and signs were compatible with a cerebral contusion primarily affecting the posterior parts of the left cerebral hemisphere.

9.2.2. Neuropsychological examination

Prior to recovery. A neuropsychological examination was carried out on the 19th day after the accident and three days after the first speech therapy session. K. H.'s over all behavior was uncontrolled, uncritical, and regressive (e.g., during the investigation he urinated twice on the floor). During the initial bed-side investigation K. H. was alert only for periods of 5-10 minutes during which the testing was then possible. The patient yawned continually and often turned away for a short nap. Resistance to the treatment was obvious as well as his labile and fluctuating mental state. It was also evident that verbal performance in an intelligence test such as the WAIS would be zero if tested in the standard way owing to the absence of voice. Naming, singing, repetition, reading aloud, producing verbal automatisms or phrases, narrative or spontaneous speech were all absent. When asked to cough the patient lifted his arm in front of his mouth and opened his mouth with no blowing or sound. An ideational apraxia was thus not present. He was also unable to imitate coughing. The patient was unable to whisper or whistle on request or to imitate those acts. However, he was able to write his name as well as to express his desires by writing and pointing with his hand. His writing performance was impulsive, for example he performed rapidly and might omit the last syllables from words (FIGURE 2). However, the writing was preserved. K. H. recognized most letters and numbers correctly, but made a few mistakes. Otherwise, he was uncommunicative.

K. H. understood normal speech and was able to react nonverbally to simple yes or no-questions. He could calculate simple addition and subtraction correctly on paper, but was unsuccessful in complex calculations like multiplication or division. He did not resolve any dictated arithmetical problems.

FIGURE 2. Example of writing.
(Haluan luI... he.. *pro* Haluan lukea heti)
(I want re.. on.. *pro* I want to read at once)

There were some perseverative tendencies in the overall behaviour of K. H. (e.g., he pointed to the same place when answering different questions concerning the content of pictures and copied the same part of a sequence in drawing). Flexible shifting from one visuomotor pattern to another was difficult (FIGURE 3). According to clinical descriptions given by Benson (1979) K. H. had a profound and typical aphemia.

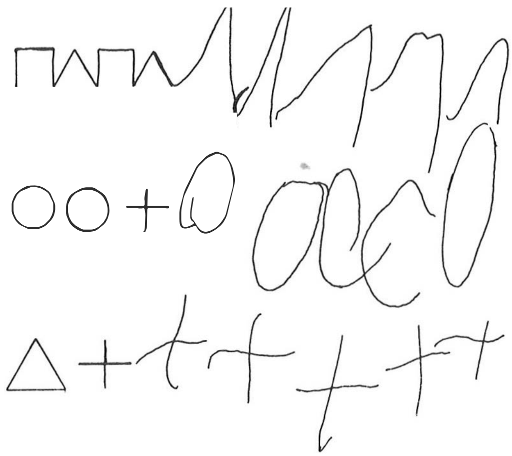


FIGURE 3. Example of copying. The model on the left.

Recovery process. K. H.'s nonverbal intellectual level was investigated using Raven's Coloured Matrices (1947). In the bed-side investigation K. H. showed signs of aggression and impulsiveness in toying to get the investigator to turn the pages of the Raven test more rapidly. K. H. succeeded correctly in 8 out of 12 items in the easiest series (A) but only 1/12 correct in the second series (A_B) . K. H. tended to point impulsively and perseveratively at alternatives on the left-hand side in the Raven test. The investigation was briefly discontinued because of fluctuations in concentration and attention. About after 5 minutes' rest K. H. was again shown the Raven designs from the beginning of the serie A_B with the instruction "Lets look at these again." At this point K. H. seemed to remember something of the earlier instruction because he started to point rapidly and repeatedly at the left-hand alternatives. When confronting picture A_B 6 K. H. was asked at the same time as he was pointing to the wrong alternative "What is the color of this?." He answered suddenly in whispering voice "red" (which was the correct answer) and seemed to be very surprised. Uncooperatively he turned away from the investigator but a supportive and reinforcing talk brought him soon back into discussion.

Immediately after the sudden return of vocalization and speech occurring coincidentally with the instructional change in the investigation procedure, K. H.'s speech was fluent and of a high pitch with a full lexicon and appropriate syntax. Sometimes his speech became whispering but without errors. The articulation of the sounds 's' and 'r' was not totally complete but this might have been the case before the accident. K.H. was able to tell of his past experiences and give his anamnesis but was amnesic toward trauma and accident. The patient thought that he was in the hospital "because of his voice," although he had been told earlier by the personnel about the accident. There were, however, no remarkable defects in K. H.'s spontaneous speech immediately after the return of his voice and no signs of aphasia. Some word finding difficulties were present (e.g., finger naming) as well as confusion in directional orientation. Cursing was also notable.

Later recovery. After the neuropsychological examination K.H. had intensive speech therapy sessions daily. Here he spoke with a high pitched voice and hypophonically. Spontaneous expressions were sparse. He tired easily and had a low motivation for treatment. His performance fluctuated from time to time and his behaviour was labile and uncontrolled. There were signs of impaired short-term memory. Some echolalic reactions occurred in his answers and the construction of logical sentences from the pictures failed from lack of motivation. However, his ability to reason and categorize started to improve concurrently with auditory memory. On the 44th day after the accident K. H. realized that "now I have got back my reason and memory", and subsequently, rapid improvement from a regressive state began. Two months later he went back to school (the final grade in secondary school), where he performed somewhat below average.

Follow-up. In the follow-up neuropsychological examination a year after the accident K.H.'s intellectual level was about average (WAIS full scale IQ = 94, WAIS verbal IQ = 96 and WAIS performance IQ = 91). He ranked on the 25th percentile among age fellows in the Raven Progressive Matrices (1958). He performed 7/10 correct in the Benton Visual Retention Test (series C). The psychomotor response (tapping) of the right hand was severely impaired (mean 11/10") but the left hand performance was good (mean 45/10"). There were no noticeable qualitative neuropsychological defects as investigated by Luria's battery (Christensen 1974). His use of language was appropriate with no alterations, no dysarthria or marked language deficits. At the time of the follow-up investigation K. H. was planning to enter vocational school from where he graduated two years later as a welder.

9.3. Discussion

According to clinical symptoms described by Benson (1979) the case K. H. represents a profound aphemia. The neuropsychological deficits were compatible with frontal lobe dysfunction. The EEG suggested left posterior lobe involvement as well. Two other syndromes, namely, mutism and post-traumatic mutism resemble aphemia. The total lack of voice (mutism) is usually affected by local inflammation of the larynx (which was not observed in K. H.) but is also observed in brain lesions (Benson 1979, pp. 163-164). However, the mute patient is hypophonic and can manage whispering which was not observed in this case prior to the recovery process. The clinical symptoms in aphemia (Benson 1979) are a more consistent entity than has been described to be in those various cases of post-traumatic mutism (e.g., Levin et al. 1983). From the 9 cases of mutism after closed head injury Levin et al. describe only one case (#2) which resembles aphemia as found in K. H.. However, there are important differences between these two cases. The case of Levin et al. (1983) was a 12 year old girl who was struck by a car, had no phonation and remained mute for three weeks (which well corresponds to the initial situation in case K. H.). However, their case recovered gradually from the mute state and after two years follow-up still experienced linguistic deficits. There were also signs that their case had initially difficulties in writing (uninterpretable jargon), and this fact differs from aphemia (and from the case K. H.) where writing factually and initially is preserved. A more complete comparison between the cases is difficult to perform due to the lack of neuropsychological details characterizing the initial mute period of the case presented by Levin et al. (1983). Their case also had a CT scan which showed subcortical pathology. On the basis of the EGG findings, the pathology of K. H. was different. Levin et al. (1983) suggest that there are two types of mutism after closed head injury, one with subcortical patholgy and the other with severe diffuse brain injury. This latter type usually leads to residual linguistic disorders.

In this case, K. H. recovered suddenly and completely and without any residual linguistic disorders. The return of speech in post-traumatic mutism has not been observed to be sudden and complete. Rather, the typical recovery has been gradual. Levin et al. (1983) report two cases (numbered as 6 and 9 and both without CT evidence of subcortical lesions) who still after a follow-up period of more than six months, remained mute. In other cases of aphemia, the recovery has also not been complete (e.g., Nebes 1975). This report tentatively suggests a mechanism for a sudden and complete recovery from aphemia as observed in unusual case.

A young patient with cerebral contusion experienced a sudden, unexpected and complete recovery from aphemia coincidentally with an instructional change in the investigation procedure. Confrontations where the psychological process undergoes an immediate change in front of one's eyes might be viewed broadly from the perspective of situationally operative factors. The issue is then to determine the relevant factors and principles and how they operate in the process of sudden behavioral change. The task is to analyze the essential features of the stimulus input and situation and their possible interaction with the individual's internal (e.g, central nervous system) state. Here the process of sudden recovery from aphemia caused by cerebral contusion is discussed in terms of modes and stages of information processing and their association with the demands of a given task.

The information process is a two-stage process: 1) the nature of the initial stage of information processing is preattentive, non-strategic and parallel, whereas 2) in the later stage it is more attentional, flexible, strategic and serial (Lachman et al. 1979). Moscovitch (1979) assumes that the early processing stages are similar in the two hemispheres but beyond the point where the hemispheric asymmetries emerge the processing will be different in the left than in the right hemisphere. According to Moscovitch (1979) the hemispheric asymmetries emerge only at a higher level of analysis in which relational or categorical features are represented. From this locus the information is transmited either serially or in parallel to a variety of structures that form integrated functional systems, one in the right hemisphere and one in the left. All the processes beyond those at which relational or categorical properties emerge will be functionally lateralized to the left or right hemisphere.

This transmitted lateralization hypothesis indicates that all stimuli which are received by the higher-order, specialized processing systems must undergo the two-stage processing. The degree to which this "dual processing" occurs will depend, according to Moscovitch (1979), on the nature of the stimulus material and the task demands. In the case of different visual object stimuli the right hemisphere processes and encodes information on the basis of appearance, whereas the left concentrates primarily on the functional and nominal aspects of the input. Taylor (1972) mentions that color naming requires identification processes, while reasoning requires perceptual processes. The identification process is associative in nature, but perceptual processes which are usually measured by shape matching are apperceptive and connected with the functioning of the right hemisphere.

As far as the stage of information processing is concerned, the qualitative behavior of the above case of K. H. before the dramatic change took place implicates first level or parallel processing in that K. H. matched the pictures in the Raven Coloured Matrices (serie A) on the basis of similarity of shape and color quite successfully (8/12 correct). Further, K. H.'s impulsive way of reacting and unattentiveness perhaps prohibited any higher level processing. Thus, the task (Colour Raven; series A) did not require any kind of synthesis at the level of the central nervous system and so processing did not proceed to the second level at all. But, in the interference situation where the memory of the earlier instruction (the Raven test instruction) was well in K. H.'s mind and where the investigator's new instruction demanded attention to be focused simultaneously on the identification process ("what is the color of this?") the ongoing, parallel processing mode interferred with the serial mode and, possibly at the point of instructional conflict, changed the hemispheric balance and shifted processing to the second stage. In the color naming situation, according to Damasio et al. (1979) "certain types of verbal information are coprocessed in (or transferred to) the right hemisphere and the visuoverbal interweaving process would take place there rather than in the left hemisphere " Because the case had more neurological dysfunctioning in the left than in the right hemisphere, the more intact right hemisphere had probably to transfer the message in the interference situation to the language dependent centers in the left hemisphere. Because color naming and pointing out are mediated by a central lexicon which accepts verbal and visual input (Davidoff & Ostergaard 1984), so in the interference situation where verbal and visual input converged on the same lexical system the verbal input was capable of activating or priming an entry in the lexicon. The interference point for the verbal (color naming) and visual inputs happened to be the same as the locus for the emergence of hemispheric asymmetries. The function of color naming and color perception converged with the modes and stages of information processing by forming the cross-over point for the emergence of hemispheric asymmetries.

The task demands of the Raven Matrices have been analyzed by Basso (et al. 1973) . Two neuroanatomical areas critical for performance in the Raven task are (1) the retro-rolandic region of the right hemisphere (for intellectual processing of visual data), and, (2) the area in the left hemisphere overlapping the language area. This analysis suggests that both linguistic and non-linguistic processes operate ın the Raven task. The convergence of these linguistic and non-linguistic task demands of the Raven Matrices in the rapid recovery of the case of K. H. at the point of interference is as an explanation congruent with the other factors discussed thus far and further supports the idea of the appropriate coincidence of multilevel phenomena in a single phase of information processing.

Goldberg and Costa (1981) have suggested that instructional biases may have a profound effect on the pattern of lateralization seen in a given experimental situation. They have suggested task novelty with respect to the representational codes preexisting in a given subjects's repertoire as an alternative explanation to hemispheric differences. Any cognitive process might be conceptualized in terms of codes which refer to preexisting codes or those which do not. In our case, the instructional change occurred when the stimulus material was the same but the codes were different. The preexisting code interferred with the novel one at the point of convergence or instructional conflict which resulted in the response ("red"). Goodglass and Baker (1976) have stated that the retrieval of a name depends on the convergence of concurrently activated associations that trigger the appropriate naming response. These explanations fit well in the case of K. H. but, also, at the same time, a change occurred in the modes and stages of processing (from first stage parallel processing to second stage serial processing) and in the content of information (from color perception to color naming). It is difficult to point to a separate factor responsible for this behavioral change and therefore, it is more plausible to regard the sudden and complete recovery as a coincidence of many convergent factors in an interference or conflict situation. The resolution of the conflict at the level of the central nervous system was appropriate and sufficient in K. H. to elicit the hitherto inhibited vocalization or articulation and all the cognitive skills associated with the aphemic syndrome.

The process of recovery in K. H. can also be considered as a dual-task situation. Here, the investigator defined both tasks (the first, the shape and color identification requiring parallel processing and the second, color naming requiring serial processing), but the patient processed automatically and unattendly being initially conscious only of the first task. The patient had to respond so as to create the second task by changing the mode of processing from automatic (parallel) processing into conscious and controlled (in this case serial) processing at the point of instructional change. Externally, the situation and both tasks were the same to the patient all the time. Internally, the change in the modes of processing required a differential allocation of motivational resources and obviously the reallocation of motivational resources in the interference situation according to the instruction influenced the selection of the appropriate response pattern. If the resource supply of each hemisphere is considered to be fixed, limited, inaccessible to the other hemisphere and undifferentiated (Friedman & Polson 1981), so in the interference situation the competition for resources as well as for a particular mechanism to perform the task coincided and the two tasks independently performed by each hemisphere converged. At the same time and point unattended automatic processing changed to attended and controlled processing. The described change in K.H.'s processing can be viewed as a shift from automatic processing to controlled processing from the plateau level to the hierarchical, and from parallel (simultaneous) to serial (successive) processing. Sternberg (1984b, p. 173) states that controlled processing is primarily hierarchical and serial, and automatic processing preconscious and not under voluntary control of the individual. Information processing at the first stage was in K. H. automatic and occurred only at the sensory level, but the transmission of information into the internal code required attentional resources to be allocated differently and in this way the transformed information became controlled.

As far as neuroanatomical factors are considered, it is known that failure at self-initiated efforts to begin speaking has occurred in parietal- and temporal-lobe electrical stimulation (Penfield & Rasmussen 1968). Friedman & Polson (1981) state that the posterior part of the left inferior frontal gyrus is responsible for speech production (i.e., vocalization) in most right-handed individuals and especially males, and that speech production demands mechanisms that are specific to the left hemisphere. The neuroanatomical areas responsible for eliciting vocalization have been described as located along the central (Rolandic) fissure and at the supplementary motor area or even possibly connectionally from the posterior Sylvian regions to the opposite inferior frontal region (Mohr 1976). Thus, the neuroanatomical description of vocalization is not very close anatomically to those areas in the parieto-occipital lobe functionally responsible for color perception and naming expect for the lastly mentioned connection from the posterior Sylvian regions to the opposite anterior lobe. Also, it has been reported by Caramazza and Berndt (1978) that posterior aphasics are able to name on the basis of perceptual features so that the selection of a color naming task in the case of K. H. happened to be successful despite the left posterior dysfunctions observed in his EEG. It has also been stated by Friedman and Polson (1981) that there are probably few, if any, cognitive tasks with hemispheric resource demands in addition to simple lateralized motor tasks or the act of speech production. The same authors claim further that by instructional manipulation one can likely affect a particular resource composition and a particular hemispheric advantage. Thus, neuroanatomically it might be possible that the point where the color perception process (with the first stage parallel unattentional mode of processing and the preexisting code in mind) interferred with the color naming process (with the demand for second stage serial and controlled processing and for a novel code) by bringing the hemisphere-specific resources into collision or convergence created a state in the central nervous system which "stimulated" the critical brain areas responsible for eliciting vocalization and speech. Although it is inappropriate to argue the neuroanatomical localization of the convergence point here, the onset of speech (vocalization) during the color naming task correlated at the point of instructional change with the area normally found to be responsible for the function of color naming which area, paradoxically in the case of K. H., was found to be dysfunctional in the left hemisphere according to EEG findings. This paradox suggests the possibility that by optimal environmental manipulation the interaction of corresponding symbolic and neurofunctional systems or states in the brain can so be influenced that it changes the inactive system into an active one. The change of transition in states can be seen according to MacKay (1984) as an operational symbol of cerebral information processing. Causality is then seen as a conjoined process of complex patterns of events with the corresponding structures (forms) of other patterns or events. Nevertheless, the above explanation emhasizing the role of external and internal factors interacting in the process of recovery could as well be applied to spontaneous recoveries from aphemia given a specific internal state and the necessary external conditions (e.g., a sudden change in environment or instruction, a "surprise"). The cross-over point for the dramatic behavioral change occurred simultaneously with the change of instruction, hemisphere-specific task and resource demands, and with the emergence of hemispheric asymmetry in processing.

The case of K. H. also seems to support the notion that aphemia is a disorder of phonological (sound) production. The associative bond between any picture or any sound stimulus and the vocal response (e.g. naming, answering questions) was defective, if nonexistent, in K. H.. The correct matching of external information , either pictorial or sound, with the vocal response may have been achieved in the interference situation. Also, it is tentatively suggested that disturbance in aphemia exists not only in the verbo-articular connection but also at the level of cognitive operations. When these operations (e.g., parallel and serial processing) are brought together to converge momentarily with the demands of a task and with the neuropathology of the patient may well be recovery from aphemia. When the stimulus material, the external situation and the components of the central nervous system are viewed as parts of an integrated system we have a complicated picture where it is almost impossible to isolate a single factor as causing the behavioral change. Therefore, the neuropsychological analysis of aphemia recovery requires a multilevel approach.

Summary: The case of a young patient with a cerebral contusion experiencing a sudden and complete recovery from aphemia during neuropsychological testing is described. The process of complete recovery happened unexpectedly and coincidentally with an instructional change in the investigation procedure. The process of recovery is discussed in neurobehavioral terms emphasizing theories of information processing and hemispheric specialization. Tentatively, it is suggested that the profound behavioral change in the aphemic patient appeared as a result of the convergence of the following factors: the modes and stages of information processing, the content or code of information input, task demands and the site of the cerebral dysfunction.

10. GENERAL DISCUSSION

In this chapter the main topics of the present study are discussed from the theoretical aspects and as a cross-validation, construct, concurrent and predictive validation of the model of information integration presented by Das et al. (1975, 1979). The implications for further studies and remediation programs are also dealt with.

Integrating the approach of information processing and intelligence. The present study attempted to integrate the perspective of information processing into standardized measures of intelligence by giving a new interpretation to some traditional intelligence and memory measures. This interpretation was based on a careful analysis of stimulus characteristics according to the neuropsychological theory of Luria (1966a, 1966b, 1973), the model of information integration of Das et al. (1975, 1979) and according to statements expressed by Townsend (1972) concerning the identification of serial and parallel systems. The aspect of the manner of information presentation and its assumed interaction at the level of the central processor (the brain) was especially attended to in definitions of the nature of stimulus encoding. Kaufman et al. (1982) state that it is the type of mental processing rather than the nature of stimulus or response which determines whether a test is simultaneous or successive. However, on a theoretical basis Townsend (1972) also considers the mode of presentation important when identifying parallel and serial systems. Thus, in the present study, the modes of processing were considered as a way of structuring input and so attention was paid to the manner of stimulus presentation and its assumed way of organizing information at the level of the central processor (the brain). Based on definitions by Das et al. (1975, 1979), Luria (1966a, 1966b) and Townsend (1972) one can propose definitions of simultaneous and successive processing by taking account not only of the stimulus task, but also of the component processes within the task and their supposed (either direct or undirect) correlation at the level of the central processor.

Sternberg (1984a) has doubted the applicability of Luria's theory as a basis for theories of intelligence or information processing due to the lack of empirical support. Goetz and Hall (1984), too, conclude that at present there is no theoretical basis in information processing theory for the Kaufman type simultaneous-sequential analysis of intellectual ability. In fact, in evaluating the K-ABC battery (which aims to measure sequential and simultaneous processing in children) Sternberg (1984a) considers that the theory developed by Wechsler (1958) or Binet is far more superior to the Lurian theory on which the K-ABC test (Kaufman et al. 1983) of simultaneous and sequential processing is based. Further, Sternberg (1984a) carefully hints that such a theory might be forthcoming although he suspects, for several reasons, that this is unlikely to happen. On the other hand, Goldberg (1976) sees the Lurian "nonfactorial" and multi-dimensional ("qualitative") approach as an interesting research issue for the "factorial" approach. In the present study, a number of psychometric tests of intelligence and memory (the WAIS and the WMS of Wechsler 1958, 1945) were selected for the purposes of studying their ability to measure simultaneous and successive processing in normal elderly and adult brain damaged samples. Certain subscales of traditional and widely used psychometric tests were given a new interpretation in the light of Lurian neuropsyhological theory and this operationalization was used to study primarily the cross-validation of the model of information processing presented by Das et al. (1975, 1979). The approach here differs from that of Kaufmans (1983) who created new scales for measuring simultaneous and sequential processes instead of giving a new interpretation to old tasks. Also, the neuropsychological Lurian-type tasks were given a psychometric "quantitative" interpretation, thus, providing them with a unidimensional nature better suitable for factor-analytical calculations. These measures were thought to describe the graded differences in the functioning of the hemispheres and different areas of the brain.

The approach selected here was a molar, top-down analysis of cognitive processes and so here the presentation of the results describes global level events. The operationalization of the modes of processing was performed factor-analytically as has been done by Das et al. (1975, 1979). The empirical verification focused on adult samples (neurological patients, elderly healthy people, see appendix 2) and, thus, it was possible to extend the cross-validation of the the model of information integration into adult samples and more closely to study the neuropsychological properties of the modes of processing. There has been a marked lack of research especially on the factors to do with neuropsychological side of the Das model (1984a).

Methodological considerations. In intelligence models the choice of factor analytical method has influences the method of data handling. Typically, in ability measurements, there has not often been sufficient consideration of the underlying theoretical method. In the present study of information processing and as assumed by Das et al. (1975, 1979) the modes of processing were considered to be independent of each other and in equal relationship to each other. It is important to recognize that the use of a particular factor-analytical model will lead to particular outcomes. Principal component factor analysis with orthogonal Varimax-rotation assumes the obtained factors to be independent of each other, whereas in oblique rotation this assumption is not made and thus the factors may correlate with each other. The emphasis on orthogonal factor structure accords with the theory formulated by Das et al. (1975, 1979). The results of factor analysis (and regression analyses, too) are here, of course, explorative and thus preliminary. In further studies, it might be fruitful to study the relationship between the oblique rotated factor scores with the help of the LISREL-model (e.g., Jöreskog & Sörbom 1981) and how the both factor structures (namely processing factors and neuropsychological factors) explain simultaneously each other.

The factors in the present study were formed from the combination of such tasks (e.g., Block Design, Visual Retention Test, Digit Span and Digit Symbol) which have been found to discriminate quite satisfactorily in cases of brain pathology. The combination of single tests by means of their content analysis to measure the modes of processing can be seen as clustering the internal structure of cognition into some meaningful unit. In the present study, equivalent tasks employing a variety of stimulus material including perceptual (e.g., Block Design), memory (e.g., Logical Memory) and conceptual (e.g., Similarities) tasks were used for definitions of simultaneous and successive processing. However, by the factor-analytical method one is able to deal with the global structure of the processing, but not to separate different subcomponents or stages of the processing. The factors provide one way of organizing information and including underlying properties common to the test items included in analyses but they are less useful for specifications of the subcomponents of processing.

The highest overall values of communalities (h^2 ranging from .43 to .82 and generally over .63) were obtained in the factor analyses of the modes of processing in Study 3 (the elderly sample) and the lowest in Study 2 (the brain damaged sample: h^2 ranging from .26 to .67 and mostly over .57) and Study 1 (h^2 generally over .50). Thus, the measurement of the modes of processing seemed to be most reliable in the elderly sample if communality estimates are used as approximate estimates of the reliability. Also, it was possible to extract more specific processing factors in the elderly group than in neurological patient groups and so the communalities became higher due to increased factor number. In Study 3, the communalities in factor analyses of qualitative neuropsychological variables varied from .33 to .99 (generally over .60), the "right hemisphere" tasks from .20 to .91 (generally over .55) and the "left hemisphere" tasks from .17 to .74 (generally over .40). Thus, the Lurian-type neuropsychological factors seemed to have the highest overall reliability.

Carroll (1979) has critically dealt with the methodological and theoretical aspects of using factor analysis in studies concerning individual differences in cognition and information processing. Some of his general criticism can be directed at the present research as well. He gives some criteria concerning the size of the sample and the number of variables that may be included in factor analyses so that they become statistically satisfactory. In the present study, these criteria were rather satisfactorily met. It is felt that the sample size was large enough even in the smallest sample of elderly people (N =58) for three or four factor solutions. However, the sample size should preferably be larger to establish more reliable results. Also, the 10 variables selected for the operationalization of simultaneous and successive processing exceeded the criterion for the number of variables required to determinate three or four factors.

<u>Cross-validation.</u> Here the cross-validation of the Das model was extended to an adult population and completed with novel tasks compared to the measures used in previous child samples. It was thus considered to

achieve a better generalization and validation of the modes of processing in adult samples and to extend the research results on children to a broader age span. The results in three different samples (adult neurological patients, brain damaged adults and healthy elderly people) demonstrated that the factors of simultaneous and successive processing appeared as having similar characteristics as observed in child studies. The slight loading disparities in the three samples here might represent strategic differences rather than age differences or they could be due to the variability in sample sizes. The successful cross-validation of simultaneous and successive processing in adult samples and by using traditional psychometric tasks also showed the applicability of Lurian theory as a basis for understanding certain intelligence and memory tasks. This conclusion was further confirmed in the study on the elderly (75-84-year old) sample when Lurian type neuropsychological variables predicted meaningfully simultaneous and successive processing and vice versa.

Simultaneous and successive processing were found to be relatively independent of such background variables as sex, dominant handedness, place of habitation and certain disease variables (i.e., length of time since injury, amount of clinical symptoms, length of unconsciousness following injury or trauma, evaluated need for neuropsychological rehabilitation). Socioeconomic level correlated in Study 1 only with simultaneous verbal processing and education with all the modes of processing as expected on the basis of earlier literature. Age correlated significantly with simultaneous nonverbal, memory and successive processing but not with simultaneous verbal memory (Study 1) which finding corresponds to similar observations in other studies.

Brain functions appear to be hierarchically organized from lower level functions to higher level functions (Luria 1973). Complex psychological functions can be viewed from the level of constructions rather than from their localization. The hierarchical organization of brain functions also means that the lower levels are controlled by higher level functions but that they are also capable of functioning independently. The controversial issue concerning the hierarchical organization of the modes of processing has been much debated (e.g., Vernon et al. 1978; Das et al. 1979). In the present research, no g-factor was found and so the results are in accordance with the statements expressed by Das et al. (1975, 1979) and with their empirical findings demonstrating no hierachical structure between the modes of processing.

Construct, predictive and concurrent validity. The results of Studies 1, and 2 also demonstrated that the simultaneous and successive modes of processing were clearly differentiated according to code content. In Study 3 (elderly sample) this was particularly noticeable where the verbal and nonverbal content of the modes of processing were also closely and differentially related to the neuropsychological variables. The model of information integration was successfully applied to the description of a sudden and complete recovery from a quite rare syndrome of aphemia (Study 4), which further referred to the interaction of content- and process-based descriptions. Therefore, it was concluded that the need for content based specifications of simultaneous and successive processing would be important in remedial training where the process and content areas are practised conjointly.

The results demonstrated clearly, especially in the elderly sample that simultaneous processing cannot be equated solely with nonverbal coding and successive processing with verbal coding. On the contrary, both verbal and nonverbal content in simultaneous processing as well as verbal and nonverbal content in successive processing were observed in factor analyses. This finding supports one of the basic statements of the model of information integration about the independence of material specificity in the modes of processing but it also points to the need for separating the modes of processing according to their content (FIGURE 1). Also Willis and Hynd (in press) have observed that simultaneous and successive processing style interact with modality (i.e., auditory/vocal or visual/motor). In their opinion, particularly with regard to studies in which children or developmental populations are examined, a serious problem is related to variability in cross-task difficulty both in simultaneous and successive domains. Thus, in experimental studies, modality x task difficulty interactions are difficult to explain let alone control for (Willis & Hynd in press).

Two hypotheses concerning the neuropsychological domain of successive (serial) and simultaneous (parallel) processing differ in their basic assumptions. Researchers in experimental psychology (e.g., Cohen 1973; Bradshaw & Nettleton 1981) have associated serial processing with left hemisphere functioning, and parallel processing with right hemisphere functioning. The theory of hemispheric specialization treats hemispheres as separate processors of information. Based on Luria's neuropsychological findings on clinical subpopulations, Das et al. (1975, 1979) have proposed that neuroanatomically the posterior unit (either in the left or right hemisphere) is more responsible for making syntheses on simultaneously processed material whereas the anterior unit (the fronto-temporal areas, frontal lobe) is specialized for handling successively presented material. The direct mapping of psychological functions onto the cerebral cortex is successful only in cases where the model and the neural system are believed to be isomorphic. Luria (1973) characterizes the cerebral cortex as a network of dynamic interactions between disparate regions and zones of the brain with each having a special role in contributing to the complex functional system. Thus, the cerebral cortex is not organizationally fixed and does not necessarily map structure isomorphically to function. However, in Study 2, the results in the brain damaged sample did not resolve the issue in favor of either hypotheses although both approaches were weakly supported. Due to many internal factors (like the difficulty of establishing and matching exactly the neuropathological factors in the lesion groups, the possibility of the complementary and interactive functioning of brain areas etc.) it was felt that experimental designs where the subject acts as own control might be more profitable. In Study 3 (normally-aged elderly sample), it was possible to study the relationship between the modes of processing and the neuropsychological variables from the perspective of syndrome analysis inside the group (as compared to the Lurian-type syndrome analysis performed inside an individual). Actually, the results in the elderly demonstrated that the neuropsychological variables characterizing more the workings of the posterior divisions of the brain correlated and predicted more accurately simultaneous processing, whereas neuropsychological variables typical of the functioning of the anterior lobe predicted more closely successive processing (FIGURE 4). The results also tentatively suggested that within each hemispheres there are separate units for simultaneous and successive processing which can be distinguished according to their code content (as described in FIGURE 1). Verbal processing content would seem to be mediated through the left hemisphere and nonverbal content through the right hemisphere. Thus, successive verbal and successive nonverbal processing would be performed in different hemispheres as would simultaneous verbal and nonverbal processing (FIGURE 5). This tentative model needs further testing in respect of the simultaneous equation but the claim is well in accordance with the principle expressed by Das et al. (1979) concerning the orthogonality of the two modes of processing and code content.

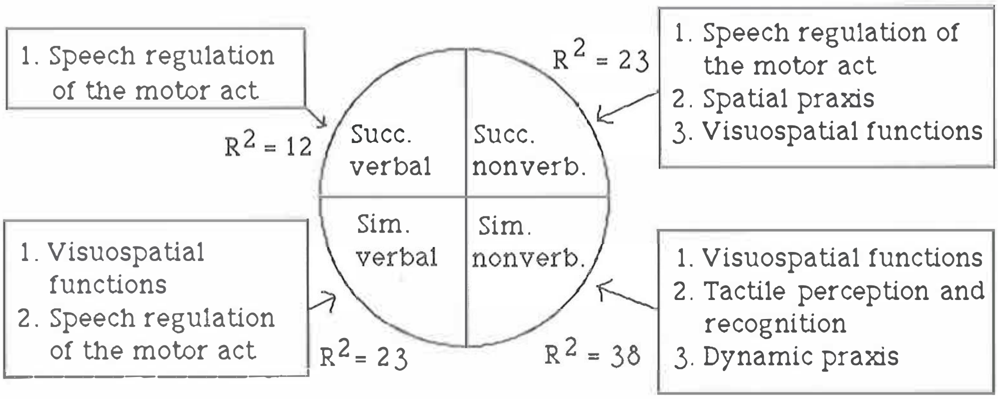
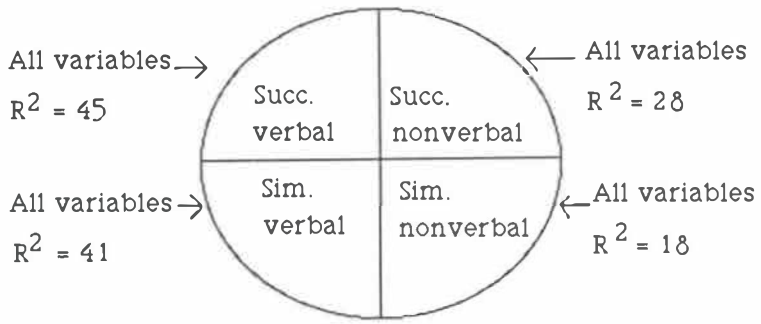
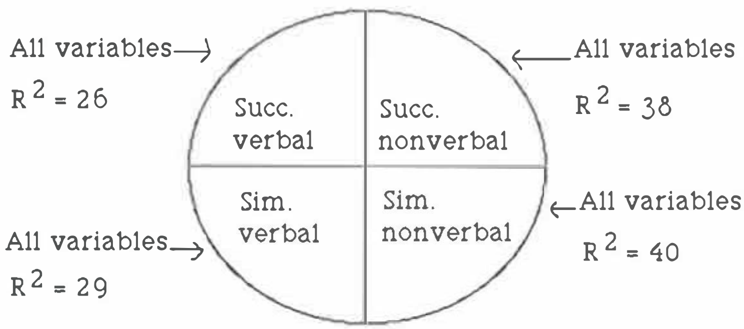


FIGURE 4. Neuropsychological variables as predictors of the modes of processing. Summary of the results in elderly sample.

The evidence in the present research suggests that the rigorous position of hypothesizing a different mode of processing for each cerebral hemisphere seems to be overstated. There seems to be some little evidence that hemispheres as such process information according to successive (serial) or simultaneous (parallel) modes of processing. Rather, there units exist inside each hemisphere capable of both types of processing (FIGURES 4 and 5). One can argue that this position also represents a continued search for dichotomized models. However, the purpose of the present study is not in reclassification but rather in providing predictive neuropsychological confirmation of simultaneous and successive processing. It is another issue as to whether there are any additional and smaller processing units inside the brain and what is their



The "left hemisphere" factors as predictors of simultaneous and successive processing (above).



The "right hemisphere" factors as predictors of simultaneous and successive processing (above).

FIGURE 5. The conceptual left and right hemisphere factors as predictors of the modes of processing. Summary of the results in elderly sample.

likely nature.

The results of Study 3 demonstrated that the theory of information integration had predictive value. Neuropsychological variables aimed at measuring the functioning of different brain areas and sides were meaningfully associated with the claimed characteristics of simultaneous and successive processing and predicted quite accurately and consistently the modes of processing in the elderly sample (FIGURE 4).

In regression analyses the independent variables as predictors are considered to be causal antecedents of dependent variables. Although in the Das et al. model it is assumed that the modes of processing form the basis for cognition, nothing, however, is stated about the causal direction of the relationship between the neuropsychological variables and the modes of processing. It might be implicitly assumed that the modes of processing also form the basis for the neuropsychological functions. The identity issue cannot be studied here, but instead it is possible to change the direction of prediction so that neuropsychological variables are used as criteria or dependent variables and the modes of processing as predictors or independent variables. The results in positing the opposite direction of prediction (where the modes of processing were used as predictors and neuropsychological variables as dependent variables) were unambiguous and consistent with the earlier findings in TABLE 20. Successive processing was closely related to those neuropsychological factors featuring the functioning of the anterior region of the brain whereas simultaneous processing associated more closely with the neuropsychological factors characterizing the functioning of the posterior division of the brain. The predictive value of the model of information integration presented by Das et al. (1975, 1979) is important and worthy of consideration when it comes to the applicability of any ability or processing theory to explain the basis of human cognitive functioning.

Implications for remediation and future studies. The present study dealt only with cognitive processing. For human behavior as a whole it is also important to understand affective processing. Whether cognitive affective processing are separate, or work in a parallel or interactive fashion is a fundamental issue to the theory of information processing, but little dealt with.

The interactive nature of simultaneous and successive processing observed in the sudden and complete recovery from a profound aphemia (Study 4) was discussed from the different theoretical approaches outlined earlier in the stage theory of information processing, the dual-coding theory and the theory of differential resource allocation between hemispheres. This case seemed explicable in terms of the unitary process, where the modes of processing and some task-specific and subject-specific factors converged simultaneously to give access to the knowledge base disrupted temporarily by the disease. Perhaps, at the point of recovery simultaneous and successive processes became controlled from a higher level organization (planning ?). Moscovitch (1979) has suggested that hemispheric asymmetries emerge at the point where the processing in each hemisphere is different. The need for specifying the control structure in the joint participation of two hemispheres or specifying the form of information-transfer that links the stages is recognized by Marshall (1981). Although the generalizability from one case study is usually limited, here its significance can be seen as providing one possible theoretical point about the nature of the functional interaction of simultaneous and successive processing. At any rate, the case demonstrates the conceptual usefulness of the modes of processing in understanding (one) cognitive dysfunction and recovery from it.

The issue of strategies is an important one to neuropsychology. People do not all approach task situations in the same way. The process-oriented model where different cortical information processing systems are specified and their (qualitative) features presented - would provide practical guidelines for educational psychology to be used in teaching plans and in methods for intervention or learning. Following brain damage to particular structures the patient may have difficulties in selecting the proper strategy or may not have access to all available strategies or may not be able to shift as easily as before from one strategy to another. The patients may have fewer strategies available and may need to relearn the earlier acquired, but lost strategies. Therefore, the recovery of function as a result of brain damage is of particular interest and if the concepts of simultaneous and successive processing can be applied to the recovery process, then these observations have important applications in the area of special education. This researcher's own experiences are that child dysphasics from 7 to 10 years old seem to have either association or dissociation between simultaneously performed verbal and motor tasks; in some cases the simultaneously performed motor act facilitates speech output whereas in other cases it clearly inhibits verbal utterances. The issue what are these individual characteristics in each case is yet to be resolved.

People are able to do many things simultaneously, and particularly, if the nature of the tasks (performances) is different enough from each other and, perhaps does not compete for the same components reflecting cerebral organization. It follows then that there probably is not much meaningful interaction between these two tasks (performances) at the neurological level. It can be assumed that if tasks with different requirements for the modes of processing are functionally proximal so the interaction between tasks and processing is more probable to occur (for example, as was observed in case K. H. where color naming and color perception required different modes of processing).

In neurolinguistic literature (Jakobson & Halle 1971; Luria 1976; Caramazza & Berndt 1978) similarity and contiguity disturbances have been separated. Syntactic disorders in language are stated as reflecting disorders of the anterior lobe of the brain and paradigmatic disorders dysfunction of the posterior lobe. By paradigmatic principle Luria (1976) means the selection processes of phonetic and semantic systems and the syntagmatic principle combines words into propositions and phrases. Other definitions have been offered, too (e.g., Lesser 1978), but common to them all is that syntagmatic and paradigmatic systems are claimed to be independent. One possible future research topic in the light of the present study would be studying these linguistic properties and information processing in an elderly sample (i.e., a more careful analysis of narrative speech).

It has been suggested by Burton (1982, pp. 4 - 5) that the information processing theories might be tested experimentally by employing computer representation. Because the stages in information processing are not directly observable, one can construct models with a different data or variable base and then try to test them in computers. Arbib and Caplan (1979; Arbib 1982) have used Lurian neuropsychological theory as one of their approaches when constructing the computational model of neurolinguistics. The model of information integration shares a number of common features with the theory of Luria (e.g.,1973) and so the model might also be suitable for computer testing if provided with more cognitive specifications. Neuropsychological theories are valuable for computer testing because they do not ignore the structural aspects and mechanisms existing in the brain and thus they allow the investigation and validation of structural models.

The educational applications of simultaneous and successive processing do not emphasize the deficits, but rather the existence of a differential preference for modes of processing in organizing information. However, for educational purposes the mere isolation of the modes of processing is inadequate without considering the content of instruction. The appropriate selection of tasks combined with its assumed processing demands seems also to be neuropsychologically open to dispute. The present results on adult samples and the case study point to the importance of having the content- and process-based interpretations tied together as complementary explanations.

If processing components are considered as underlying cognition or intelligence, then this point of view changes the emphasis from static task-oriented abilities to a dynamic, process-oriented perspective in educational psychology and in the clinical therapy of learning disorders. What then matters, is the processing components of the task performance, not the type of task. But these aspects, again, are an extreme point; the interaction of processing components with task type has not been emphasized or studied adequately. The emphasis on processing over ability factors has been put forth by Das (et al. 1979) and Sternberg (1985) whereas the contrary view is advanced by Paivio (1971, 1978) and supporters of the classical theories of intelligence or ability structure (e.g., Cattell 1963; Thurstone 1938). It has been pointed out by Sternberg (1985) that the information processing approach to intelligence is not a replacement for the "old" psychometric theories of intelligence but only a contribution to a finer and more analytical identification of tasks. The neuropsychological knowledge applied to information processing could be one possible approach in clarifying the internal structure of cognitive functions.

Future studies should address the question whether one of the organizing principles of the brain is simultaneous and successive synthesis and to what extent cognitive tasks are reducable into these two forms of syntheses. Some tentative suggestions in this direction have been presented in the present study.

Summary. The model of information integration (Das et al. 1975, 1979) was cross-validated across adult samples of different ages. The model was demonstrated to have satisfactory construct, concurrent and predictive validity in the light of investigated neuropsychological functions. The factor analysis of simultaneous and successive tasks showed that the modes of processing were clearly identifiable as described in earlier literature but also showed differentiation according to the code content (verbal or nonverbal).

In Study 1 (a sample of neurological patients), educational level was the most influential background variable in relation to simultaneous and successive processing. The disease variables investigated showed almost a zero relationship to the modes of processing. Males were better than females in simultaneous synthesis but seemed to perform less well in successive synthesis. The Study 1 and 2 also showed that the higher the socioeconomic status of the subject the better was the performance in simultaneous verbal processing. Generally, age correlated significantly with the modes of processing although weaker with simultaneous verbal processing. The young neurological patients and brain damaged people (Study 2) were better than the respective older groups in successive and simultaneous nonverbal processing.

In Study 2 (a sample of brain damaged subjects), the two-way ANOVA revealed no interactions of laterality and anterior/posterior division in simultaneous or successive processing but instead two main effects of laterality on simultaneous verbal ($p < .01$) and successive ($p < .05$) processing and one weak ($p < .10$) main effect of anterior/posterior division on simultaneous nonverbal processing. It was concluded that the results

partially supported both assumed neuropsychological models of processing. There were no differences between males and females in the modes of processing in brain damaged or control group as a whole but in the left hemisphere group the females performed better than the males in successive processing.

In Study 3 (a sample of normal elderly people), when the factor scores of qualitative neuropsychological variables were used as concurrent predictors of the modes of processing it was found that the prediction percentage varied from 26 % (successive verbal processing) to 43 % (simultaneous nonverbal processing). The prediction percentages of the significant variable combinations of individual neuropsychological tasks were slightly larger varying between 28 % and 51 %. In both cases, the results of regression analyses were rather similar. At factor level the best predictor was speech regulation of the motor act which appeared as the only predictor common to all modes of processing except simultaneous nonverbal. The above factor especially predicted highly successive verbal and nonverbal processing. The visuospatial functions were the best predictors of simultaneous verbal and nonverbal processing. Thus, successive processing seemed to associate more with those neuropsychological tasks characterizing the functioning of the anterior lobe. Simultaneous processing was more associated with that of the posterior lobe (FIGURE 4). Further, the results tentatively suggested the existence of two separate processing units within each hemisphere so that successive and simultaneous verbal processing were more associated with tasks featuring left hemisphere functioning and successive and simultaneous nonverbal processing with the tasks typical of right hemisphere functioning (FIGURE 5). The memory variables investigated seemed to predict more powerfully the verbally accentuated content of processing (be it simultaneous or successive). There seemed to appear no clear clustering of associative memory with successive and visual memory with the simultaneous processing. The results of the regression analyses are well in accordance with the statements of Das et al. concerning the neuropsychological assumptions of simultaneous and successive processing.

In Study 4 (a case study), the model of information integration was applied usefully to describe the sudden and complete recovery from a rare disorder of aphemia where one kind of interaction between simultaneous and successive processing was also interpreted.

Theoretically, the results tentatively suggested the existence of separate units for both simultaneous and successive processing in each hemisphere according to code content (FIGURE 1). In general, the results were consistent with and supported the neuropsychological premises of the model of information integration.

TIIVISTELMÄ: RINNAKKAISEN JA PERÄKKÄISEN INFORMAATION PROSESSOINNIN NEUROPSYKOLOGIASTA

1. Taustaa

Käsillä oleva tutkimus rinnakkaisen ja peräkkäisen prosessoinnin neuropsykologiasta liittyy laajemmin ymmärrettynä ns. kognitiiviseen tieteeseen, joka monitieteisesti pyrkii selvittelemään mm. niitä periaatteita, joilla älylliset olennot ovat vuorovaikutuksessa ympäristönsä kanssa. Psykologian ohella myös filosofian, kielitieteen, antropologian, neurotieteiden ja tietojenkäsittelyn voidaan katsoa olevan kiinnostuneita samoista kysymyksistä, joissa tutkitaan kognitiivisten järjestelmien (joko ihmisen tai koneen) toimintaperiaatteita ja organisaatiota. Neuropsykologia osallistuu aivojen ja käyttäytymisen välisen suhteen tutkimisella hyvin olennaisesti kognitiivisten järjestelmien teorian rakentamiseen. Neuropsykologian tehtäväkenttä on ratkaiseva silloin, kun on analysoitava, mitä rajoituksia jokin erityinen aivojen vamma on aiheuttanut kognitiivisiin toimintoihin eli meidän kykyymme vastaanottaa, organisoida, säilöä ja palauttaa informaatiota ja tietoa. Tällöin esimerkiksi neuropsykologinen patologioiden tutkimus voidaan katsoa yhdeksi avaimeksi - monien muiden ohella - normaalin kognitiivisen toiminnan rakenteen ymmärtämiseen.

Neuropsykologian ja kasvatustieteen kannalta prosessointitapoihin eli kognitioiden pohjaan kohdistuva tutkimus on opetuksen järjestämisen ja kuntoutuksen näkökulmasta ensiarvoisen tärkeätä. On esitetty näkemyksiä (mm. Luria 1979; Das ym. 1979), että kuntoutuksessa voidaan edetä kognition pohjalla oleviin periaatteisiin vaikuttamalla ja että näitä häiriöitä voidaan korjata.

Tässä tutkimuksessa on kognition pohjaa tutkittu neurologisten potilaiden ja normaalien, suhteellisen terveiden iäkkäiden henkilöiden tulosten varassa siten, että prosessointitavat on suhteutettu aivojen toimintaorganisaation keskeisiin rakenneyksikköihin. Näin pyritään hahmottamaan uutta kliinisen neuropsykologian, informaation prosessoinnin ja älykkyyden tutkimuksen pohjalle rakentuvaa kuvaustapaa, joka perustuu lähinnä Lurian (1966a, 1966b, 1973) ja sittemmin Dasin työtovereineen (1975, 1979) tarkentamaan kahden erilaisen prosessointitavan, nimittäin rinnakkaisen ja peräkkäisen synteesin malliin. Mallia on pidetty kyky- ja älykkyysteorioille vaihtoehtoisena lähestymistapana kognitioihin.

Dasin ym. informaation integraation mallissa on neljä komponenttia: syöttöyksikkö, sensorinen rekisteri (puskuri), keskusyksikkö ja tuottoyksikkö. Informaatio saapuu hermostoon aikajärjestyksessä, ja sitä voidaan Dasin ym. (1975, 1979) mukaan järjestää joko samanaikaisesti tai peräkkäisesti. Molempien prosessointitapojen lopputuloksia voidaan Dasin ym. mukaan pitää kognitioina. Ärsyke voidaan esittää mille tahansa aistimelle joko samanaikaisesti tai peräkkäisesti. Sensorinen puskuri reagoi heti informaatioon ja siirtää sen edelleen keskusyksikön käsiteltäväksi. Keskusyksikössä on kolme komponenttia. Ensimmäinen prosessoi erillistä informaatiota samanaikaisiin ryhmiin, toinen ajallisesti järjestyneisiin peräkkäisiin sarjoihin ja kolmas on päätöksenteon ja suunnittelun komponentti, joka käyttää kahden edellisen komponentin integroimaa informaatiota. Sensorisen syötteen muoto (visuaalinen, verbaalinen jne.) ei vaikuta keskusyksikön prosessointiin, joten Dasin ym. mukaan visuaalinen informaatio voidaan prosessoida keskusyksikössä peräkkäisenä ja verbaalinen rinnakkaisena tapahtumana. Molemmat prosessointimallit ovat yksilön käytettävissä eikä niiden välille oleteta mitään hierarkkista rakennetta. Jomman kumman prosessointitavan valinta riippuu kahdesta ehdosta: 1) sosiokulttuuristen ja geneettisten tekijöiden määräämästä yksilölle totunnaisesta prosessointimallista ja 2) tehtävän vaatimuksista. Kolmas suunnitteluksi (ajatteluksi) nimetty keskusyksikön komponentti käyttää hyväkseen koodattua informaatiota ja määrittelee parhaimman mahdollisen suunnitelman. Riippumatta informaation esittämistavasta rinnakkainen ja peräkkäinen prosessointi esiintyvät suorituksissa siten kuin tuottoyksikkö määrää ja organisoi reagointia tehtävän vaatimalla tavalla.

Prosessointitavat on tässä työssä päädytty tunnistamaan ärsykemateriaalin tiettyjen laadullisten seikkojen sekä ärsykemateriaalin ja keskushermoston vuorovaikutuksen luonteen perusteella. Toisin sanoen lähtökohtana on korostunut ärsykeinformaation ja keskushermoston toiminnan vastavuoroisen suhteen piirteiden erittely ja kuvaaminen sekä eteneminen tältä pohjalta laadittujen ennusteiden testaamiseen. Rinnakkainen prosessointi on määritelty informaation yhdentämisenä ns. kvasispatiaalisiin hahmoihin, joissa informaation elementtejä voidaan yhtä aikaa tarkastella ja suhteuttaa toisiinsa. Tämä ärsyke-elementtien korreloiminen toisiinsa voi tapahtua keskushermoston tasolla tai informaation esittämistavassa (jolloin elementit ovat yhtä aikaa läsnä). Samanaikaisen synteesin suorittamisesta vastaavat hermoston rakenteet sijaitsevat aivojen posteriorisissa osissa (Lurian teorian toinen yksikkö: parieto-okkipitaaliset ja temporaalialueet). Peräkkäinen prosessointi käsittää informaation yhdentämisen ajallisiin sarjoihin, joissa elementit eivät ole sisäisesti toisiinsa suhteessa, vaan saavat merkityksensä vain kokonaisesta sekvenssistä. Täten peräkkäinen prosessointijärjestelmä ei ole kokonaisvaltaisesti tarkasteltavissa milloin tahansa, eikä elementtien välille oleteta hermoston tasolla välttämättä korrelaatiota. Peräkkäinen prosessointi tapahtuu hermostossa anteriorisissa aivojen osissa eli molempien aivopuoliskojen frontaali- ja frontotemporaalialueilla (Lurian teorian kolmas yksikkö).

Informaation integraation mallia on testattu empiirisesti ja pätevyyttä tutkittu eri-ikäisillä ja eri kulttuureista lähtöisin olevilla lapsilla lukuisasti. Sen sijaan mallia on tutkittu vähemmän aikuisaineistossa yliopisto-opiskelijoita lukuun ottamatta eikä lainkaan iäkkäiden henkilöiden ryhmissä. Mallin neuropsykologisia oletuksia ei ole testattu tähän mennessä, ja tutkimuksen tarve tältä osin on tuotu julki (mm. Das 1984a). Muunneltu versio Dasin ym. mallista on esitetty kuviossa 1 (s. 30).

2. Tutkimusongelmat

Ensimmäisenä ongelmana on ollut laajentaa Dasin ym. informaation integraation mallin pätevyyden tutkiminen aikuisaineistoon. Mallin ristikkäisvalidointia on tutkittu neurologisten potilaiden sekä iäkkäiden henkilöiden otoksessa. Prosessointitapojen ja taustatekijöiden välisiä yhteksiä on pyritty kartoittamaan tässä yhteydessä.

Toisena ongelmana on ollut Dasin ym. mallin neuropsykologisten oletusten testaaminen. Tällöin on tutkittu prosessoijan eli keskushermoston häiriintymisen vaikutusta prosessointimuotoihin. Tutkimuksen tausta-osassa on esitelty kaksi selväpiirteistä toisistaan eroavaa kokonaisvaltaista neuropsykologista näkemystä prosessointitapojen yhteydestä aivojen toimintajärjestelmäkokonaisuuksiin. Nämä eriävät katsantokannat on ilmaistu aivoasymmetrian hypoteesina ja jo edellä mainittuna Lurian ja Dasin oletuksena aivojen toimintayksiköiden ja prosessointitapojen välisestä suhteesta (kuvio 1, sivu 30). Empiirisenä tavoitteena on tällöin ollut tutkia prosessointitapojen suhdetta aivopuoliskojen eroihin ja toisaalta aivojen anterioriseen ja posterioriseen tahoon sekä lisäksi pyrkiä vertaamaan näiden kahden näkemyksen keskinäistä suhdetta aivovamman erilaisen sijainnin mukaan. Tällä tavoin on pyritty selvittämään Dasin ym. mallin rakennevaliditeettia.

Mallin neuropsykologisia oletuksia on edelleen tutkittu ennuste- ja nykyisvaliditeetin osalta suhteellisen terveessä iäkkäiden henkilöiden ryhmässä, jossa neuropsykologisten muuttujien yhteyttä prosessointitapoihin on voitu tarkastella oletusten mukaisesti patologioista irrallaan, koska neurobehavioraaliset mitat valittiin aiempien teoreettisten ja empiiristen tietojen perusteella siten, että ne mahdollisimman monipuolisesti kuvaisivat aivojen eri lohkojen ja aivopuoliskojen toimintoja. Neuropsykologisia muuttujia käsiteltiin yksidimensionaalisina, jotta ne olisivat paremmin vertailukelpoisia tutkimuksen edellyttämän prosessointitapojen faktorianalyyttisen tarkastelutavan kanssa.

Kolmantena ongelmana oli alustavasti pyrkiä selvittelemään prosessointitapojen mahdollista interaktiivista luonnetta. Rinnakkaista ja peräkkäistä prosessointia on kirjallisuudessa tarkasteltu dikotomian ääripäinä kiinnittämättä huomiota mahdolliseen vuorovaikutukseen. Tällaisten vuorovaikutusmallien tarve on tiedostettu, mutta mitään tarkennuksia ei kuitenkaan ole esitetty. Eräät tutkijat (esim. Anderson 1976) jopa arvelevat kysymyksen olevan ratkaisemattoman. Käsillä olevassa tutkimuksessa on pyritty soveltamaan samanaikaisen ja peräkkäisen prosessoinnin mallia erään tapaustutkimuksen äkilliseen kuntoutumiseen ja tässä yhteydessä päädytty esittämään eräs alustava havainto mahdolliselle prosessointitapojen vuorovaikutuksen luonteelle.

Monipuolisten psykologisten tutkimusten ja haastattelujen antamaa tietoa käsiteltiin tilastollisesti seuraavilla menetelmillä; keskiarvojen ja korrelaatiokertoimien merkitsevyystestit, faktorianalyysi, varianssi- ja regressioanalyysi. Monimuuttujamenetelmien käyttö oli tässä tutkimuksessa luonteeltaan eksploratiivista.

3. Tulokset

Tutkimus osoitti kiistatta sen, että kognitioiden pohjaa voidaan perustellusti tarkastella myös aivojen toiminnallisen järjestelmän tasolla.

Dasin ym. esittämän informaation integraation mallin pätevyys oli todettavissa tutkimuksen kolmen eri otoksen (neurologiset aikuispotilaat, aivovammapotilaat sekä iäkkäät, suhteellisen terveet henkilöt, N =285) osalta samansuuntaisena. Tavanomaiset ja laajasti käytetyt psykometriset testit tulkittin informaation prosessiivisesta näkökulmasta entisten sisällöllisten ja kykyteorioiden mukaisten tulkintojen asemesta. Testien faktorointi paljasti rinnakkaisen ja peräkkäisen prosessointitavan olevan eriytynyt jossain määrin myös prosessoinnin sisällön perusteella, mitä havaintoa ei ole todettu muissa aiemmissa tutkimuksissa. Prosessointitapojen spesifiointi myös niiden sisällön perusteella ilmeisesti on tärkeä nimenomaan neuropsykologisesti painottuneissa tutkimuksissa, mutta se saattaisi olla rakentava ratkaisu sisällöllisiin (esim. Paivio 1971; 1976) ja prosessointimalleihin (Das ym. 1979; Kirby & Das 1976) yksipuolisesti painottuvien näkemysten keskinäiseen kiistelyyn.

Taustamuuttujista koulutus oli selvimmin yhteydessä prosessointitapoihin, mikä onkin ymmärrettävää. Merkille pantavaa oli, että tutkitut sairausmuuttujat, kuten sairausajan pituus, etiopatogeneesi, kliiniset oireet ja tajuttomuuden kesto eivät korreloineet prosessointitapojen kanssa (Äystö 1983). Myöskään kätisyys ja arvioitu neuropsykologisen kuntoutuksen tarve eivät olleet yhteydessä prosessointitapoihin. Miehet neurologisten potilaiden ryhmässä näyttivät suoriutuvan naisia paremmin samanaikaisessa prosessoinnissa, joskin naiset osoittivat parempaa peräkkäisen prosessoinnin tasoa (ero ei kuitenkaan merkitsevä neurologisten potilaiden ryhmässä). Aivovammapotilaiden ryhmässä miesten ja naisten välillä ei ilmennyt prosessointieroja. Kuitenkin vasempaan aivopuoliskoon vammautuneet naiset olivat selvästi parempia peräkkäisessä prosessoinnissa kuin miehet. Iäkkäät miehet ja naiset suoriutuivat prosessoinnissa yhtäläisesti. Sosiaaliluokka oli yhteydessä lähinnä rinnakkaisen kielellisen prosessoinnin tasoon siten, että mitä korkeampi sosiaalinen asema, sitä parempi oli myös prosessoinnin taso. Ikä oli yleensä yhteydessä prosessointitapoihin, mutta vähiten merkitsevästi rinnakkaiseen kielelliseen prosessointiin. Taustamuuttujien ja prosessointitapojen yhteys näiltä osin on odotusten mukainen.

Dasin ym. malli sai tukea neuropsykologisten olettamusten osalta selvemmin iäkkäiden ryhmässä kuin aivovammapotilaiden ryhmässä. Aivovammapotilaiden tulokset osoittivat nimittäin tukea kummallekin neuropsykologiselle johtoajatukselle (nim. aivoasymmetriaolettamus ja Dasin ym. sekä Lurian kanta). Aivopuoliskojen rooli oli näkyvämpi rinnakkaisessa kielellisessä ja peräkkäisessä prosessoinnissa, kun taas aivojen anteriorisen ja posteriorisen tahon osuus tuli selvemmin esille samanaikaisessa ei-kielellisessä prosessoinnissa.

Iäkkäiden ryhmässä neuropsykologiset muuttujat ryhmittyivät siten, että eräät aivojen anteriorisille osille tunnusomaiset toiminnot ennustivat merkitsevästi peräkkäista prosessointia, kun taas aivojen posteriorisille osille tunnusomaiset toiminnot ennustivat voimallisemmin rinnakkaista prosessointia. Neuropsykologisista faktoreista puheen avulla tapahtuva motoriikan säätely ennusti tuntuvimmin peräkkäistä prosessointia, kun taas visuospatiaaliset toiminnot olivat rinnakkaisen prosessoinnin parhaimpia ennustajia. Tutkitut muistimuuttujat eivät näyttäneet ryhmittyvän erityisellä tavalla prosessointitapojen ennustajiksi. Assosiatiivinen muisti ei noussut tärkeäksi peräkkäisen prosessoinnin ennustajaksi eikä visuaalinen muisti rinnakkaisen prosessoinnin ennustajaksi, mitä olisi voinut odottaa kykyteoreettisten mallien (esim.

Jensen 1973) perusteella.

Iäkkäitä tutkittaessa saadut tulokset näyttivät viittaavan siihen mahdollisuuteen, että aivopuoliskojen sisällä olisi omat yksikkönsä rinnakkaiseen ja peräkkäiseen prosessointiin ja että nämä eriytyisivät toisistaan prosessoinnin sisältöjen (kielellinen/ei-kielellinen) perusteella. Tulokset nimittäin osoittivat, että tutkimuksen kohteeksi valituilla laadullisilla neuropsykologisilla muuttujilla pystyttiin ennustamaan valikoivasti prosessointitapoja. Tämä voitaisiin jatkotutkimuksissa testata ns. samanaikaisyhtälöjen avulla, jolloin periaatteessa on mahdollista todeta mainitun käsitemallin todentuminen tutkimusaineistossa. Prosessointitavat näyttivät siis olevan valikoivasti ja tarkoituksenmukaisesti yhteydessä neuropsykologisiin muuttujiin. Eksploratiivisen analyysin tulosten pohjalta laadittu alustava rakennemalli, joka kuvaa prosessointitapojen ja neuropsykologisten yhteyksien luonnetta, on teoreettisena mallina uusi ja tarkentaa Dasin ym. luomaa informaation integraation mallia.

4. Johtopäätökset ja merkitys

Tulosten voidaan katsoa tukevan Dasin ym. informaation integroinnin mallia ja sen neuropsykologisia oletuksia mutta antavan samalla mallille perustellun tarkennuksen. Dasin ym. laatima malli oli ristikkäis-validoitavissa aikuisten eri otoksissa ja käyttämällä totunnaisia, mutta informaation prosessoinnin näkökulmasta uudelleen tulkittuja psyko-metrisiä testejä. Mallilla voidaan tulosten perusteella katsoa olevan vähintään tyydyttävästi rakenne-, ennuste- ja nykyisvaliditeettia, ja sen soveltuvuutta informaation prosessiiviseksi älykkyyden teoriaksi voidaan pitää perustaltaan jokseenkin onnistuneena. Mallin peruskäsitteiden avulla pyrittiin kuvaamaan erään kognitiivisluonteisen neuropsykologisen häiriön äkillisen kuntoutumisen luonne, joskin tällöin tuli esille jo aiemmin todettu prosessoinnin sisällön näkökohdan tärkeys yhtenä kognitiivisten toimintojen luonteen ymmärtämistä lisäävänä selitysperustana.

Tutkimuksessa rakennettiin mielekäs prosessointitapojen ja neuropsykologisten seikkojen yhteyksiä kuvaava käsitteellinen malli. Mallin käyttökelpoisuutta voidaan edelleen tutkia monessa eri suunnassa ja jo kerättyyn aineistoon turvautuen. Kognitiivisen prosessointimallin lisäksi olisi tärkeää tietää myös affektiivisesta ja emotionaalisesta prosessoinnista, mikä seikka yleensä on jäänyt prosessointitapojen tutkimuksessa varsin vähälle huomiolle. Lisäksi lingvististen ja persoonallisuustekijöiden yhteydet prosessointiin valaisisivat osaltaan mallin teoreettista pätevyyttä ja luonnetta. Iäkkäiden henkilöiden aineistossa voidaan kuvausjärjestelmää laajentaa aina sosiaalisiin ja elämänkertatietoihin sekä suhteuttaa iäkkäiden prosessointikyky ja neuropsykologinen status laajempiin sosiaalipsykologisiin ja yhteisökehyksiin. Samalla on mahdollista tutkia, miten käsitemalli pystyy ennustamaan fyysistä, psyykkistä ja sosiaalista toimintakykyä. Näin voitaisiin merkittävästi syventää normaaliin vanhenemiseen kohdistuvaa tutkimusta ja saada vankka perusta psyykkisen ja sosiaalisen toimintakyvyn määrittelylle sekä mahdollisesti myös dementian varhaisten riskitekijöiden etsimiselle. Kansainvälisesti katsoen vanhenemisen neuropsykologiaan on paneuduttu merkittävästi vasta 1980-luvulta lähtien; yhtenä tavoitteena on tällöin pidetty iäkkäiden henkilöiden informaation prosessointikyvyn selvittämistä (mm. Feinberg ym. 1980).

Prosessointitapoihin kohdistuvan tutkimuksen merkitys on huomattavin lähinnä teoreettisten näkemysten tarkentamisen, koulutuksen ja oppimisprosessien sekä kuntoutuksen kannalta. Kasvatustieteessä on viime aikoina oltu varsin kiinnostuneita kyky- ja prosessiteorioiden keskinäisen suhteen selvittelystä, sillä kahden erilaisen prosessointitavan on katsottu muodostavan kognitioiden pohjan. Älykkyyden prosessiteoria korostaa oppilaan muuttuvia kognitiivisia taitoja tai strategioita, jotka ilmenevät älykkyys- tai muissa testisuorituksissa, kun taas älykkyyden kykyteoriat ovat vanhastaan korostaneet pikemminkin psyykkisten prosessien muuttumattomuutta. Oppimiseen sovellettuna prosessispesifisen näkemyksen korostaminen tarkoittaisi esim. sitä, että opiskeltava asia ei ole niinkään tärkeä kuin esittämismetodi. Oppimisstrategioitten tutkimus (mm. Pask & Scott 1972; von Wright ym. 1979) viittaisi vahvasti erilaisten prosessointitapojen olemassaoloon ja niiden erilaiseen käyttöön opittavan aineksen hallinnassa. Myös Luria (1979) mainitsee, että mikäli samanaikaisessa synteesissä on häiriö, voidaan kuntoutuksessa käyttää hyväksi peräkkäistä ympäristön vihjeisiin pohjaavaa strategiaa. Samoin voidaan peräkkäisen prosessoinnin vajeita korvata monin tavoin. Aikuisilla tosin kognition riippuvuus ympäristön syötteestä ei ole Lurian mukaan yhtä selvää kuin lapsilla. Kielellisten häiriöiden tiedetään myös olevan viime kädessä palautettavissa samanaikaisuudessa ja peräkkäisyydessä ilmeneviin häiriöihin. Soveltaviin jatkotutkimuksiin on näin ollen tarjolla aiheita.

Prosessointitapojen tutkimukselle voidaan osoittaa laajempiakin yhteyksiä. Kouluelämässä on viime aikoina korostettu voimakkaasti sitä, että eri oppiaineita ja sisältöjä olisi integroitava turhan pilkkomisen sijasta. On muistettava, että tämä integraatio tapahtuu viime kädessä oppijan päässä, joskin tätä integroitumista voidaan tietysti jossain määrin helpottaa. Tutkimus viittasi myös siihen, että tämä yhdentymisprosessi ei alkeellisella tasollakaan ilmetessään ole sattumanvarainen, vaan mielekkäästi sidoksissa muuhun kognitiiviseen rakenteeseen.

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APPENDIX 1

TABLE A. Means and standard deviations (in parentheses) on simultaneous and successive processing in the left (N =33), right (N =39) hemisphere and control group (N =32).

Dysfunction	Sim. n-v.		Sim. v.		Succ.	
Left hemisphere	506	(96)	469	(97)	472	(130)
Right hemisphere	485	(101)	511	(83)	516	(85)
Control	506	(105)	514	(117)	509	(80)
	ns.		ns.		ns.	

TABLE B. Means and standard deviations (in parentheses) on simultaneous and successive processing in the anterior (N =29), posterior (N =40) and control group (N =32).

Dysfunction	Sim. n-v.		Sim. v.		Succ.	
Anterior	518	(94)	485	(90)	485	(111)
Posterior	482	(103)	488	(86)	495	(109)
Control	506	(105)	514	(117)	509	(80)
	ns.		ns.		ns.	

APPENDIX 2

TABLE A.

Means and standard deviations among different samples on the tasks of simultaneous and successive processing.

TEST	Neurological patients (N=121)[x]	Control group (N=32)	The brain damaged group LA (N=12)	LP (N=17)	RA (N=17)	RP (N=21)	Elderly (N=58)
WAIS: Inform.	8,97 (2,97)	10,47 (3,54)	8,5 (2,95)	9,23 (3,75)	9,65 (2,47)	10,65 (2,87)	9,53 (2,85)
WAIS: Simil.	10,17 (1,94)	11,86 (3,01)	10,00 (2,56)	9,15 (1,41)	12,0 (3,37)	11,72 (2,19)	9,103 (2,65)
WAIS: Digit Symbol	6,60 (3,43)	7,83 (3,13)	9,75 (2,96)	6,75 (3,82)	7,69 (3,05)	7,65 (3,30)	3,45 (2,64)
WAIS: Block Design	7,67 (3,54)	9,63 (3,34)	11,22 (3,93)	8,0 (3,31)	9,06 (2,08)	7,55 (3,41)	3,83 (3,06)
BVRT	5,89 (1,79)	6,22 (2,26)	6,67 (2,71)	6,5 (1,83)	5,86 (2,28)	5,8 (1,70)	4,64 (1,99)
WMS IV	8,75 (4,11)	9,8 (3,74)	7,22 (4,76)	8,2 (4,23)	10,27 (3,77)	11,48 (3,74)	9,36 (3,96)
WMS V	9,05 (1,73)	10,0 (1,63)	9,25 (1,91)	8,65 (1,41)	10,12 (1,76)	9,29 (1,35)	8,69 (1,73)
WMS VI	8,36 (3,44)	9,87 (3,56)	9,44 (4,19)	9,6 (3,60)	9,57 (3,48)	9,62 (3,72)	4,97 (2,85)
WMS VII easy	15,07 (3,64)	16,55 (2,08)	15,67 (2,35)	13,38 (5,42)	15,5 (2,77)	15,95 (1,39)	6,95 (2,11)[xx]
WMS VII hard	6,10 (3,25)	6,45 (3,08)	5,44 (4,22)	4,85 (3,62)	6,0 (3,57)	7,05 (2,58)	4,71 (2,87)

x) Missing data on variables is substituted by the group mean. This group consists of 15 non-neurological patients.
xx) The raw score is devided by two before calculating means and standard deviations.