

COGNITIVE RIGIDITY AND FLEXIBILITY

A NEUROPSYCHOLOGICAL STUDY

by

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ABSTRACT

This study investigated the effects of imagery on flexibility and the relations among verbal and non-verbal and spontaneous and adaptive flexibility measures. Finally, the effects of brain damage on flexibility and imagery were investigated. Historical and more recent concepts of the cognitive rigidity-flexibility dimension were discussed with special emphasis on the effects of brain damage.

Forty female and fourteen male volunteer students were tested with verbal and non-verbal flexibility tests. Measures of spontaneous flexibility were the Word Fluency Test and the Five Point Test and measures of adaptive flexibility were the Stroop Test and a newly introduced concept identification test, assessing imagery and interference concepts. Furthermore, a questionnaire to assess individual imagery styles was employed as well as the vocabulary and block design subtests of the WAIS.

The results of brain damaged subjects were compared to a matched control group. Furthermore, z-score profiles were prepared to compare the test patterns between the different patient groups.

Four dimensions of cognitive flexibility-rigidity were found in healthy subjects. Furthermore it was found that individual imagery styles had little influence on the performance in flexibility tests. A trend was showing that "habitual verbalizers" had no advantage in solving the tests and had in fact more difficulty with the identification of non-verbal concepts. No significant gender effects were found. Brain damaged patients performed significantly poorer in all flexibility tests than normal subjects.

Several test- and subject variables that effect the performance on flexibility tests were discussed. It was concluded that rigidity-flexibility measures represent different dimensions depending on stimulus mode and type of task. It was further concluded that behavioral rigidity-flexibility is not only the function of test variables, but also of various subject variables namely imagery style, intelligence, age, gender and brain damage. In healthy people, the performance on one test was not found to be predictive for the performance on another flexibility test. On the other hand, in brain damaged subjects rigid behavior seems to extend to a wider range of test performance. Finally, different performance patterns were described for different lesion sites in brain damaged.

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It was by chance that in 1969 I started my first job as a psychologist in a neuropsychology laboratory. At that time, the word "neuropsychology" was rarely heard. After eight years of work in this field, it was no longer chance that I looked for further neuropsychological education.

Many people influenced my interests and had impact on this study. My work at the University Hospital in Zurich in Etienne Perret's Laboratory primarily stimulated my wish to know more about the functions of the human cortex and to look for useful tools to assess patients.

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1. INTRODUCTION

The problem of the behavioral rigidity-flexibility dimension has long been of interest to psychologists. Some of the symptoms in brain damaged patients related to this dimension such as persistence or perseveration, have become important concepts for neuropsychology. Clinicians are able to observe extremely rigid behavior in patients after brain damage; they describe the resulting conflict situations and find connections to certain states of the brain. One of the principal theoretical problems as well as a problem in finding tests to measure this behavioral phenomenon has been whether there is a unique factor underlying such behavior or whether it is necessary to consider several dimensions.

The adjective "rigid" originates from the latin "rigidus", meaning to be stiff. "Flexible" derives from "flectere", meaning to bend. Cognitive rigidity and flexibility should be regarded as poles of the same continuum; if such a continuum exists, then the behavioral manifestations should be observable along a single dimension (Goins, 1962). Rigidity is equivalent to inflexibility. Rigidity is regarded as impairing the successful management of everyday demands. A commonly accepted definition of

rigidity is: "a lack of change of behavior, where a change is necessary for success at a task, and where the subject knows that a change is likely to be demanded" (Chown, 1961).

The focus of this study is on the dimension of rigidity in normals. A second study addresses rigidity as a defect resulting from brain damage. In trying to find out more about the kind of variables that influence flexibility-rigidity behavior, this study investigates the interfering and facilitating effects of habitual imagery styles on flexibility and the relations among flexibility measures. Verbal and non-verbal flexibility and imagery measures allow the observation of performance in normal adult subjects. In addition a group of patients with focal brain lesions will be studied. The frontal lobes have especially been related to rigidity in brain damaged patients. Insofar as this study examines behavioral changes after frontal lobe lesions, it is hoped that the results of this study will contribute to further understanding of frontal lobe functions in man.

In the following review the history of the concept of rigidity will be reviewed first, followed by a review of more recent experimental work and a summary of the effects of brain lesions on rigidity and flexibility. The long history of the topic will only be summarized in so far as it is useful in developing the problem of this study. The

focus will be on the cognitive aspects of behavior. No attempt will be made to review the wide ranging research on personality and rigidity.

In the second chapter the choice of the variables will be developed. In the third chapter the hypotheses are formulated, followed by the methods part in the fourth chapter. Finally, the results of normal subjects and a first exploration of the behavior of a small number of brain damaged subjects are presented and discussed. In the last chapter the conclusions are drawn and some suggestions for further research considered.

1.1 Review of the literature

1.1.1 History

The psychological literature on rigidity was first reviewed by Luchins in 1959. Leach (1967), in a later review, pointed out that over the years research and definitions of rigidity varied with the general trends in psychological thinking. She described three main stages in the development of the concept of rigidity: (1) rigidity as a neurologically determined behavior of individual perception, leading to perseveration and premature closure, (2) rigidity as a defense mechanism, and (3) rigidity as a manifestation of personality variables observable in cognitive behavior. Cattell (1935) was the first to label perseveration on a repetitive motor task as rigidity and to construct tests to elicit this behavior. Together with his co-workers (1949) he found that rigidity arose not only in motor tasks but whenever subjects were required to shift from one task to another. He also noted strong individual differences in degree of repetitive behavior and described extremely perseverative individuals as having a "disposition rigidity".

Rigid behavior was originally labeled "mental inertia" by Spearman (1927). This and Cattell's term both describe a

person with a tendency to respond to an earlier stimulus even though it has been replaced by a new one. The same idea was expanded by Lewin (1935). He regarded personality as being composed of many different "psychical systems", differing in various aspects, with one of them being the degree of rigidity. He carried out a series of experiments on co-satiation with "feeble-minded" and normal children. The results showed that the former were less flexible. In an assigned task, retarded subjects reached satiation quickly and refused to take part in a new task, whereas normal children were willing to continue and were not satiated after the first task. In Lewinian theory, rigidity is linked to the presence of strong boundaries between mental functions; however, this interpretation soon started a controversy.

Kounin (1941) repeated Lewin's work and found contradictory results. His feeble-minded subjects were less likely to exhibit co-satiation than his normal group of children. He believed that the result could be ascribed to the degree of differentiation in these subjects.

Werner (1946) tried to clarify the controversy between Lewin and Kounin. Werner made the distinction between a structural and a functional type of rigidity. The structural interpretation refers to the degree of separation of regions within the personality structure, i.e. the greater the degree of independence, the greater the degree of rigidity.

The functional interpretation, on the other hand, regards rigidity as a perseverative tendency. Werner believed that the differences among investigators stemmed from different definitions of the word rigidity. For Werner, rigidity is a functional rather than a structural concept, and multiform rather than unitary. Influenced by the Gestalt theory, he regarded rigid behavior in unstructured tasks as the result of distracting associations.

1.1.2 Experimental work on rigidity

Many investigators conducted factor analytic studies to determine how personality and perception affect rigid behavior. For example, Schaie (1955) described three dimensions: (1) motor-cognitive rigidity, (2) personality-perceptual rigidity, and (3) psychomotor speed. The first dimension refers to the ability to shift without difficulty from one activity to another. The second denotes the ability to adjust to new surroundings and to change cognitive and environmental patterns. The third, psychomotor speed, is defined as a subject's rate of emission of familiar cognitive responses.

Chown (1959) reviewed earlier investigations and found that there is more than one kind of rigidity. She further states "the experimental work on rigidity has been carried out with the aid of a number of tests, each of which can be

said to measure rigidity in its own right. But the relationships between these tests are not always known; and where they have been investigated, it seems as though more than one type of rigidity is involved" (p.197). She then classified the tests as follows: "Einstellungs-Tests" involve building up a "set", i.e. solving a problem with a different strategy than one would expect to be suitable on the first confrontation with the task. The best known test of this sort is the water-jar test by Luchins (1951). In this test subjects have to discover a method of dividing a given quantity of water among three containers of specified size. The first problems can be solved in one way only and are meant to establish a set. The next problems can be solved in the set way or by a shorter method; the last problems show how well a subject can overcome the set.

Another class of measures are tests of personality or dispositional rigidity, e.g. the Wesley Scale (1953). This inventory consists of 50 items which have been rated for degree of personality rigidity.

The third group of tests mentioned by Chown are tasks assessing concept formation. Such procedures require subjects to discover different but logical ways of categorizing a group of items. Subjects are then requested to group the items differently. Examples in the neuropsychological literature are the Weigl Sorting Test (Goldstein and Scheerer, 1941) and the Wisconsin Card

Sorting Test (Berg 1948, McMurray 1954, Milner 1964). Both tests require sorting; in the Weigl test of tokens, in the WCST of cards according to shape, color or number.

Among other tests of rigidity, the Hidden Objects Test (Cattell, 1946) has been frequently used. The task is to find as many objects as possible hidden in pictures. Cattell used this test to measure "disposition rigidity". Becker (1954) suggested yet a different method to study rigidity. He used aniseikonic lenses, which were originally designed to study distortion in stereoscopic perception. He suggested that a more rigid person would take longer to notice the distortion effects produced by the lenses. His hypothesis still waits to be tested.

Following these early studies, investigations on measurements of rigidity ceased for a decade. In 1968, Breskin published the first results of a non-verbal rigidity test. Most previously used tests characteristically employed the verbal stimulus mode. Breskin's test (BRT) consists of 15 pairs of visual stimuli differing with respect to the laws of Praeganz, a Gestalt law in perception, meaning that figures tend to be perceived toward meaningfulness, completeness, and simplicity. In the BRT, the figure pairs are constructed in such a way that one symbol adheres to the Gestalt, while the other violates the law of Praeganz. Subjects are instructed to choose the item they prefer from the pair. The rigidity score is the number of Praeganz

items selected. The BRT was found to be an instrument which reliably differentiated "more rigid" from "less rigid" subjects. Art students were considered less rigid and accounting majors and secretarial students more rigid. One year later, Gorman and Breskin (1969) investigated the relations of the BRT to tests of semantic redefinition, associational fluency, inductive reasoning, and drawing completion. They found that the performance of rigid subjects was significantly worse than that of flexible subjects on all the measures except for Guilford's associational fluency. Subsequently, Breskin, et al (1970) explored the relationship of the BRT to tests of perseverative rigidity, namely the Test of Behavioral Rigidity (TBR) by Schaie (1955, 1960) and the Stroop Color Word Test (Stroop, 1935). The BRT scores were negatively related to both of these tests; the authors concluded that different aspects of rigidity are measured in the three tests.

Another aspect of rigidity is flexibility in thinking, a subject extensively explored by the Guilford school (Guilford et al, 1957; Frick et al, 1959). Two flexibility factors were found: (1) "spontaneous flexibility", i.e. the freedom from inertia in thinking, and (2) "adaptive flexibility", i.e. the restructuring of interpretations and approaches.

The Torrance Tests of Creative Thinking (1966) are based on factors identified by Guilford such as fluency, flexibility, originality, and elaboration. The set is comprised of 12 tests grouped into verbal, pictorial, and auditory parts. However, a factor analysis gave no support to the interpretation that the four scores (fluency, flexibility, originality, and elaboration) represent independent constructs (Yamamoto and Frengel, 1966). Instead, the factors were found to be task specific.

An analysis of a series of verbal and non-verbal tests by Carlier (1971) showed the existence of a psychological dimension, independent of intelligence yet related to certain personality traits, which she called spontaneous flexibility. Gender differences in the use of mental strategies were also reported. Schultz (1977) focused on the same dimension and conducted a multitrait-multimethod analysis on a variety of tests given to young and old subjects. He found that young subjects performed better on most spontaneous flexibility measures and gender was not significantly related to performance. This suggests that spontaneous flexibility is an individual characteristic which is independent of general intelligence. There is some indication that the dimension is relatively restricted in young and old subjects; however, it appears to extend to a wider range of behaviors among old rather than young people.

1.1.3 Effects of brain lesions on cognitive rigidity

Many investigators have been interested in rigid behavior as a symptom of certain abnormal conditions. Both Lewin (1935) and Kounin (1941) made extensive studies with retarded subjects. They followed a topological approach of personality, i.e. "...the person is said to be structured and differentiated into parts... The psychological environment in which a person behaves is also structured into regions... The concept of rigidity, particularly as applied to a theory of feeble-mindedness, has been tentatively formulated by Lewin. This theory is based upon unpublished studies dealing with the comparative behavior of moron and normal children in experiments concerned with the process of satiation, the resumption of interrupted tasks, and the revealed decided differences between feeble-minded and normal children" (Kounin, 1941, p.251-252). Kounin formulated his theory as follows: "The general theory postulates that rigidity is a positive monotonous function of chronological age. A corollary of this theory is that rigidity is a positive monotonous function of the degree of feeble-mindedness" (p.254).

Werner and Strauss (1942) followed this work by investigating brain damaged children and were able to show that these subjects perseverated far more than normal children. These authors disagreed with the above cited

theory by Kounin that rigidity is a function of chronological age. Perseveration was, therefore, returned to its place as an indicator of rigidity as it was in Spearman's time.

Goldstein (1943) also used a neuropsychological approach to bring about an understanding of the nature of rigidity. He described two types of rigidity resulting from brain damage: "Primary rigidity involves sequelae of an abnormality of the Einstellungs-mechanism, most frequently observed in lesions of the subcortical ganglia. Each performance in action immediately becomes so rigid that responses to extraneous stimuli cease. Secondary rigidity is due to a primary defect of the higher mental processes occurring in cortical damage and cortical malfunctions, such as feeble-mindedness. It occurs only if the individual is confronted with tasks beyond his capabilities" (p.225). Then he offers the following theoretical interpretation: "Rigidity occurs when an organism is unable to come to terms with 'its' environment in an 'adequate' way. It is a means of protection against 'catastrophic conditions' ...Rigidity in feeble-minded children is a consequence of a mental deficiency, especially of the impairment of abstract attitude. Normal individuals may also exhibit rigidity under certain conditions, namely, in performance beyond their capacities". Goldstein made here, for the first time, a clear statement that rigidity can be a manifestation of

certain states of the organism and refers to brain damage as one cause of rigidity. Therefore, rigid behavior can be a symptom of a defective cortex but can also occur in healthy individuals with intact brains. The latter is the case when a task is too difficult and overtaxes the organism's capacity.

Inflexible behavior has been reported as a specific consequence of lesions in the frontal regions in man. Halstead (1947) made major contributions to the neuropsychological understanding of frontal lobe function. He set up a large test battery to study the functions of the frontal lobes, the site, he believed, which accounts for "biological intelligence". But he found that only some tests in his battery discriminated patients with frontal lobe lesions from others. The poorest performance for frontal lobe patients was found on a concept formation task (Category Test); Halstead concluded that frontal lobe patients were most impaired in abstract thinking. Halstead's modified battery has since been used extensively in the neuropsychological assessment of brain damage. Lack of flexibility, as an effect of frontal lesions, has been studied numerous times in tests assessing abstract thinking, problem solving and learning, and memory. There are many reviews which summarize the findings (Spreeen 1977, Hécaen and Albert 1978, Walsh 1978, Damasio 1979, Fuster 1980, and Regard 1980). The reviewers agree that rigidity as a unitary

concept does not apply to the various behavioral dysfunctions. Hegenscheidt and Cohen (1972) also found that the concept of cognitive rigidity is multidimensional. They studied the relationship among three, so-called "pure" measures and found little overlap among them.

Walsh (1978) points out that inflexible behavior is observable after lesions anywhere in the cortex but most pronounced in patients with frontal lesions. Inflexibility has been observed in cognitive, motor and personality functions. The findings will be summarized, but for more details the reader is referred to the reviews mentioned above. It must also be remembered that in reviewing various sources of previous clinical data problems arise because of the diversity of tests used, differences in the specification of lesion types and in the underlying conceptual models. In brief: (1) no gross intellectual deficits are usually associated with frontal lobe damage (Smith and Phillipus 1969, Black 1976). (2) Memory, learning and attentional deficits are common in both left and right frontal damage patients (Prisko 1963, Corkin 1964, Milner 1964 and 1971, Luria 1966, Damasio 1979). (3) Language and verbal deficits are usually found with left frontal damage (Milner 1964 and 1971, Luria 1965, Benton 1968, Ramier and Hécaen 1970, Perret 1974, Benson 1979). (4) Motor deficits and personality problems are related to bifrontal damage (Feuchtwanger 1923, Kleist 1934, Hécaen

1964, Luria 1965, 1966 and 1973, Benson and Blumer 1975, Hécaen and Albert 1978, Damasio 1979, Benson et al 1981). (5) Spatial problems are observed in patients after left and right frontal damage (Heilman and Valenstein 1972, McFie and Thompson 1972, Butters et al 1972, Bruyer and Bontemps 1979). (6) Finally perseverative and inflexible behavior has for a long time been known to be manifest after left sided and bifrontal lesions (Milner 1963, 1964 and 1971, Teuber 1964, Drewe 1974, Perret 1974, Nelson 1976, Robinson et al 1980). Recently, the same behavior was also described for patients with circumscribed right anterior lesions (Jones-Gotman and Milner 1977, Regard 1980). Right sided effects were elicited by employing non-verbal stimuli. The functional asymmetry within the frontal lobes is described in more detail elsewhere (Regard, 1980).

No current theory accounts for the whole range of inflexible behavior. The relationships between inflexibility and brain damage are not yet fully explained. However, there are numerous theoretical conceptions regarding the nature of frontal lobe dysfunctions which will be briefly summarized.

During the last century, Bianchi (1895) already believed that the site of coordination and fusion of the incoming and outgoing products of the several sensory and motor areas of the cortex is in the frontal lobes. He based his conclusion entirely on results derived from animal studies. Brickner (1934) stated that frontal lesions lead to a deficit in the

highest levels of associative processing and to an inability to synthesize. Goldstein (1936 and 1944), as mentioned above, hypothesized that such patients are not able to grasp the entirety of a complex situation or to differentiate one complex situation from another. He further said that this inability produces indifference and unstable emotional behavior as well as regression of the abstract attitude toward the concrete. Perseverations, in his view, help to avoid catastrophes. By this he meant that they are protecting against abnormal distractability and help to cope with the "normal" environment. Milner (1963) focused on interference. From her observations on the Wisconsin Card Sorting Test (WCST), she derived the notion that frontal lobe lesions lead to an impairment of the ability to suppress interference effects of previous actions on a current task.

Teuber (1964, 1972) developed his corollary discharge model on the basis of a series of tests. The model implies that the frontal lobes are controlling behavior. The frontal lobes originate anticipatory discharges to the sensory structures and prepare for the motor activity that is about to occur; they have limited control over reflexive movements and postures and correct for displacements of perception. Nauta (1971) added to this hypothesis that the inability of frontal patients to maintain a normal stability in time is a consequence of a loss of senso-effector organization

involved in mechanisms of perceptual processing and behavior programming. He thought that most of the problems experienced by such patients can be understood by considering the strong fronto-limbic connections, i.e. the neocortical representation of the limbic system in the frontal lobes. Luria (1966 and 1973), based on his intensive case studies, comes to conclusions similar to those of Teuber and Nauta. He described frontal lobe patients as being disturbed in the programming of actions and in active state regulation. Such patients lack control of intentions and cannot correct errors when comparing action and program. In Luria's view the organization of conscious acts, the third unit of his three stage model¹ is responsible for this dysfunction. Although to him a distinction between left and right frontal areas is of minor importance, he believes the left frontal lobe to be more involved in verbal thought, whereas the right frontal lobe is more involved in emotional behavior.

¹ Luria (1973) distinguishes three functional units. They all participate in mental activity. The unit for regulating tone and waking is mainly activated by the reticular formation and its connected subcortical and cortical areas. The unit for receiving, analyzing and storing information is located in the receptive areas of the cortex. The third unit, the system for programming, regulation and verification is located in the anterior regions of the hemispheres.

Finally, inflexible behavior is also a common symptom gerontologists observe in the aged. Recent studies have attempted to answer the question whether this behavior is a general symptom of normal aging, or whether it is strongly associated with certain brain diseases in the elderly (Albert and Kaplan, 1980). A summary of the findings in elderly would go beyond the topic of this study; the reader is referred to reviews by Angleitner (1972), Birren and Schaie (1977), and Botwinick (1978).

1.2 Summary and conclusions

Historically, the rigidity-flexibility dimension has been regarded as a unitary concept. The topological approaches by Lewin and Kounin, the revision of their theories by Werner's comparative-developmental approach and lastly, Goldstein's neuropathological theory have been summarized. More recent investigators came to the conclusion that a multidimensional concept is necessary to capture all the aspects of rigidity. The range and complexity of the manifestation of rigid behavior make clear definitions difficult. For Chown (1961) rigidity simply means a lack of flexibility when a task demands it. There is agreement that rigidity has to be linked to task specific variables as well as to the state of the organism. Varying degrees of inflexibility were found to be manifest in different client groups, such as the mentally retarded and patients with specific brain lesions, but also in normal children and in the elderly.

It was pointed out that the results of various factor analytic studies have suggested several different factors and labels. Only Rubenowitz (1963) found a single general factor. His construct is determined by hereditary, early environmental, cultural, and situational factors with various behavioral manifestations. Chown (1959) summarized different variables which influence flexible behavior such

as different methods of training or the state of the subject (the amount of anxiety, needs and age). She concluded that it might be more appropriate to relabel different test behavior according to the specific difficulty rather than using just one label, "rigidity". For example, she suggests that for learning tasks it might be more useful to talk about "change of expectancy" or "change of set". She continued: "Ideally, both intra- and interindividual reactions to change should be compared. The effect of different tests on different individuals is not known, but if there is a wide variation due to other factors such as intelligence involved in the tests, this may account in part for the inconclusive results so far obtained" (p.216).

Goldstein and later Chown (1961) and Botwinick (1978), refuted the belief that rigidity of behavior is a whole "life style". Instead, they advocated that situational effects, as measured with a set of tests, should receive further attention. Rigidity, therefore, simply would mean the adherence to a task; and its converse, flexibility, would imply the ability to shift from one pattern of activity to another. Also for Goins (1962), who regards behavioral rigidity- flexibility as a continuous dimension, rigid behavior is task specifically defined. His operational definition is "(a) the degree or amount (in time, trials etc.) of change in response (behavior), (b) with respect to the average or normal change for a given situation, (c) where more effective behavior is demanded" (p.49).

Many neuropsychological studies have found that inflexibility is a predominant characteristic after lesions in the frontal lobes. Some theories regarding the nature of frontal lobe dysfunctions have been summarized. It can be concluded that the range of rigid behavior and the mechanisms of difficulty are only partially explained. Manifestations of rigid behavior are observed in conceptual thinking, learning and problem solving as well as in everyday behavior. More studies are needed if there is to be understanding of the variables which influence a person's ability to change. One direction is pointed out by Bradshaw and Nettleton (1981) who wrote that there should be more emphasis on the way stimuli are processed rather than on the type of stimuli in order to allow inferences about normal brain functions from studies with brain damaged individuals. Cognitive rigidity is under study comparing young with old adults (e.g. Kirby et al 1979), but no recent investigations focus on the effects of cerebral lesions on flexibility. Goodglass and Kaplan (1979), in their chapter on the assessment of frontal lobe dysfunction, list four areas involving some aspects of flexibility which should be examined:

1. the ability to initiate and maintain a series of directed associations,

2. the ability to maintain a set in the face of interference,
3. the ability to shift from one conceptual frame to another, and
4. the ability to maintain a series of alternating motor activities.

The current study is designed to investigate the behavior of normal people on a series of tests of rigidity related to different imagery styles. The results are expected to lead to further explorations of the effects of cerebral lesions on rigidity. Of special interest are: (1) the ability to change one's set to meet the requirements of a situation, and (2) the ability to produce a diversity of ideas. Frick et al (1959) distinguished these two dimensions of behavior and their labels, (1) spontaneous flexibility and (2) adaptive flexibility, are used in this study. There is a need to learn how these abilities are related in context to different task demands and subject variables. One particular variable of interest is imagery. As one of the explanations of rigid behavior, it is suggested that a defective mental representation of concepts (imagery ability) might account for their difficulty in conceptual thinking in patients with frontal lesions.

In summary, the central point of the current study is the assessment of degree and type of association between imagery

and flexibility. The performance of normal subjects on several test measures will be the basis for first explorations of the performance of persons with focal brain lesions.

The questions asked are:

1. What is the relationship between verbal and non-verbal measures of spontaneous and adaptive flexibility?
2. How is imagery ability associated with flexibility? Does it have a facilitating or interfering effect on performance on flexibility tests?
3. What are the effects of focal brain damage, especially the differential effects of frontal lesions versus non-frontal lesions, on measures of flexibility and imagery ability?

The variables to be studied will be discussed in the following chapter.

2. SELECTED VARIABLES

In this chapter the choice of the variables and the development of new tests measuring spontaneous and adaptive flexibility, imagery, and intelligence are discussed. The tests will be discussed in detail in the following chapter.

2.1 Spontaneous flexibility

Frick et al (1959) measured a factor labeled spontaneous flexibility by employing tests which measured the diversity of ideas that could be produced in a given period of time. The other factor found was labeled adaptive flexibility, meaning the ability to shift concepts. Examples of the type of tests used to measure spontaneous flexibility were: to think of as many different uses as possible for a common object or to name possible objects belonging to a certain class. Chown (1961) investigated 16 different rigidity tests and found five different factors. She was able to replicate the spontaneous flexibility factor with the same test measures which Frick et al had included in their study. Angleitner (1973) tried to isolate different forms of

rigidity and factor analyzed 13 tests given to a German population. He included only one test to measure spontaneous flexibility which loaded on a factor labeled "Testrigiditaet" (test rigidity). The second factor found by Angleitner was labeled "Fragebogenrigiditaet" (questionnaire rigidity).

For Carlier (1971) spontaneous flexibility is an important source in the process of creative thinking. Like Guilford, she argues that divergent thinking is equivalent to creativity. In her study Carlier looked at verbal as well as non-verbal performance across both sexes. Her non-verbal test was a figure completion task. Her findings indicate different factor structures for males and females. Furthermore, she found the spontaneous flexibility dimension to be independent of test intelligence but related to certain personality traits (as measured with a questionnaire). Schultz (1977) studied spontaneous flexibility in adulthood and old age and also found no significant relation to intelligence, but, in contrast to Carlier, he found no relation to sex either. Schultz found rigidity more related to personality than age, but in older people rigidity was manifest in a wider range of behaviors.

Measures of spontaneous flexibility always have a measure of productivity in common. The richness of output, for example the number of ideas, can be measured in fluency tests. Since verbal and non-verbal stimuli might trigger

different processing mechanisms, both aspects should be looked at in measures of spontaneous flexibility. As will be seen later, imagery research has paid much attention to the verbal-nonverbal dichotomy. In the neuropsychological literature, this dichotomy has a long history and its interpretation is still controversial. According to the view of several authors (e.g. Kimura, 1961, 1967; Geschwind, 1972; Seamon and Gazzaniga, 1973; Dennis and Whitaker, 1976), the left hemisphere is primarily involved in the processing of semantic information and reflects the operation of language-specific mechanisms. On the other hand, the right hemisphere is specialized in processing complex, non-verbal information. Not all lateralized functions are explained by this dichotomy and additional hypotheses have been proposed such as the sequential-processing hypotheses (e.g. Das, Kirby, & Jarman, 1975; Leong, 1976) and the analytic-holistic hypothesis (for reviews see Moscovitch 1979, and Bradshaw and Nettleton 1981)

Non-verbal aspects of productivity have not been investigated in most of the previously mentioned studies. One exception is Torrance (1966) who used verbal and non-verbal tests in his battery, though his flexibility and fluency scores are not proven to be separate dimensions (Yamamoto and Frengel, 1966).

As for the verbal aspect, the Word Fluency Test introduced by Thurstone as part of the Primary Mental Abilities Test (1948) has often been used with brain damaged subjects. Its diagnostic value in neuropsychological assessment has been established several times (Milner 1964, Benton 1968, Ramier and Hecaen 1970, Perret 1974, Regard 1980). Jones-Gotman and Milner (1977) introduced a non-verbal equivalent, design fluency test. The authors reported the lowest performance for patients with right anterior lesions, compared to patients with lesions elsewhere in the brain. In an exploratory study with a gesture fluency test, Jason (1980) also found a right hemisphere effect. Both of these tests have the disadvantage of being difficult and time consuming to score.

In the present study two fluency tests have been used to assess spontaneous flexibility. They were chosen because they allow the distinction between verbal and non-verbal modes of stimulus and response. The tests also provide an easy way to score productive and repetitive behavior. For verbal fluency Perret's Word Fluency Test (1974) was used; for non-verbal fluency the Five-Point Test introduced by Regard (1980) was used. Pilot data for the latter test exist for patients with circumscribed brain lesions and for normal adults (Regard, 1980) as well as for children (Strauss, Regard, & Knapp, 1981).

2.2 Adaptive flexibility

The commonly accepted definition of adaptive flexibility is the ability to extract the relevant stimulus from varying context and the ability to change a response pattern. Many tests have been devised to assess these components of behavior but results seem to be bound to the type of tests used. Chown (1961) and Angleitner (1973) could not replicate the factor of adaptive flexibility, as previously described by Frick et al (1959). The discrepancy in the results of the two studies may be due to the difference in tests used to measure adaptive flexibility. To illustrate, Frick et al used a test where subjects had to place numbers of crosses on a checkboard so that no two appear in the same row, column, or diagonal, while the other authors used Gottschaldt's Hidden Figure test. In Gottschaldt's test certain outlines are disguised by superimposed figures and the subject is asked to pick out the simple outlines.

Many other examples of the wide spectrum of tests used to assess adaptive flexibility can be found in the literature. One of the dimensions the tests differ in is the verbal and non-verbal aspect. The Wisconsin Card Sorting Test (WCST) is an established task in neuropsychological assessment. Using this test Milner (1963) found that patients with dorsolateral frontal lesions were most impaired. She believed (1964) that it is not a defect in abstract thinking

which leads to the impairment but a general inability to shift behavior when required to do so. Various modifications of this test have been published (Teuber 1951, Drewe 1974, Nelson 1977, Robinson et al 1980). All of the tests mentioned so far make use of the non-verbal stimulus mode. However, in the WCST it is unclear to what extent stimuli can be verbally labeled. For another presumably non-verbal test, the Weigl Form Sorting Test, De Renzi (1961) established an association with verbal ability.

An example of a test using the verbal stimulus mode is the Stroop Test (Stroop, 1935), the classical task where conflicting stimuli interfere with a successful concept shift. Perret (1974) showed that patients with left frontal damage performed poorly on this test as compared to both patients with lesions elsewhere in the brain and to normal individuals. Frontal lobe patients were most disturbed by interference and consequently made the highest number of errors and were slowest in reading the color words. This finding was later replicated by Regard (1980). Perret believes that the difficulty of this test for frontal patients stems from their inability to suppress the "normal habit of using words according to their meaning" and from the inability to switch cognitive sets.

In the current study, tests have been used which assess concept shifting behavior for both verbal and non-verbal

stimuli. The verbal aspect was assessed with the Stroop Test. This test is economical and IQ independent, and it has an established diagnostic validity in neuropsychological assessment (Perret, 1974). In order to test shifting ability for verbal and non-verbal concepts a new concept identification task was introduced. The newly constructed concept identification test uses verbal and non-verbal stimuli and allows also to look at the role of imagery. Previous studies give conflicting information about the role of imagery in concept identification. Ernest (1977) found that imagery is facilitative in concept identification. In this instance imagery has a mediating effect. On the other hand, it could not be demonstrated that people with high imagery ability would do better in such tasks. It is also known that imagery can have an interfering effect. Bryne (1974) for example, showed that visual imagery can produce conflicts in the recall of word lists. Again, maybe the fact that the verbal and non-verbal dimensions were disregarded may have contributed to the conflicting results. The task introduced in this thesis was designed to include sets which require the ability to suppress interference and others which require imagery ability. At some point in the task the associations to cue responses being reinforced were changed or "shifted" without forwarning the subject. Rigidity was defined in terms of failure to shift; the reverse, flexibility, was defined as shifting of response

when a change of concept was required. In particular, the task tested whether or not imagery was an interfering or facilitating variable for concept identification. The test therefore was designed to look at the influence of stimulus mode (verbal or non-verbal) and at type of set (imagery or interference). Imagery ability was also measured independently as discussed below.

2.3 Imagery ability

Imagery research is concerned with the nature and the function of mental images. Richardson (1972) believes that the performance on tests of spontaneous and adaptive flexibility might be related to the quality of imagery ability. No investigation could be found testing this relationship. In the current study it is suggested that there is a relationship between imagery ability and rigidity. It was mentioned earlier that Brickner (1934) believed that frontal lesions lead to a deficit at the highest levels of associative processing. Luria (1966), too, thought that perseverative behavior is caused by the influence of irrelevant associations. In the current study it is suggested that the rigid, perseverative behavior of patients, specifically with frontal lobe damage stems from defective mental representation of associations and defective mental transformation of concepts and images.

Due to a heightened interest in cognitive behavior in the last decade, a large amount of research in this field was published. Reviews on the nature and function of imagery can be found in Paivio (1971), Sheehan (1972), and Cohen (1977). Ernest (1977) reviewed recent findings of imagery linked to learning, memory, perception, and conceptual processes. She listed two studies (Katz and Paivio, 1975, and Durndell and Wetherick, 1976) which showed that imagery is helpful for concept identification. However, another study by Hollenberg (1970) showed that low imagers were better at grasping a conceptual category than were high imagers; they concluded that high imagery ability may be detrimental to abstract thought. Ernest's review suggests that the relationship between imagery ability and flexibility, as measured in fluency tests and concept identification tasks, needs further testing.

Imagery is used in three different ways in neuropsychological studies: one is to look at imagery as a mnemonic aid for brain damaged patients (e.g. Lewinsohn et al, 1977), another is to explain various neuropsychological symptoms as defective mental imagery (e.g. Basso et al, 1980), and a third, the most controversial, is to link imagery with cognitive style associated with hemispheric dominance (e.g. Zenhausern, 1978). Paivio's (1971) observation that brain lesions produce individuals whose abilities correspond roughly to the verbal and non-verbal

imagery types is meaningful, but the association between a person thinking in pictures or in words and hemispheric dominance seems overly simplified.

Investigations of mental rotation have provided some insight into the nature of mental imagery. Also, rotations as a clinical phenomenon have been extensively studied (Royer and Holland, 1975). Tests in which a design has to be rotated require imagery ability. Spontaneous rotations appear almost exclusively after brain damage. A number of constructional tests requiring rotations have been developed. For example, in the Block Rotation Test by Satz (1966 a and b) the subject is asked to copy designs rotated 90 degrees to the right or left. Eighty-two percent of the patients with organic brain disorders and 35 % of the psychiatric and normal subjects were correctly identified by the use of cut-off scores.

Regard (1976) looked at spontaneous rotations produced in the Bender Gestalt Test and in the Rey complex figure in a brain damaged population and found that the performance of patients with focal brain lesions in the right hemisphere, predominantly in the basal temporal area, resulted in the largest number of rotations. She suggested that this might possibly be the result of a right hemisphere disconnection between the cortical and subcortical structures and not the result of low intelligence or of visual input defects as proposed by other investigators. In a later study

(unpublished material), brain damaged patients with localized lesions were required to copy the Rey figure, mentally rotating it by 90 degrees. It was found that patients with left frontal lesions had the most difficulties and displaced the largest number of elements. The study concluded that visual imagery, as measured by required rotation, has an interfering function for patients with left frontal lesions, but not for patients with lesions in the right frontal area. The inflexibility of patients with frontal damage had not previously been associated with defective imagery. However, Rugg (1963) attributed spontaneous flexibility to imagery, and Calvano (1973) studied the predictive value of selected flexibility and imagery tests for paired-associate learning. Information concerning a relationship between these variables is not given.

Ernest (1977) reviewed measures to assess imagery ability. She distinguished three types of measures: subjective ratings, performance tests, and spatial tests. Self ratings are problematic tools because the imagery process remains subjective and uncontrollable to the experimenter. Paivio (1971) and White et al (1977) reviewed these types of tests in detail. Spatial tests and performance measures are more objective but bear the handicap of assessing only certain aspects of imagery ability. Questionnaires and paper and pencil tests are

reported to assess (1) vividness of imagery, (2) habitual use of imagery, (3) imagery control, and (4) spatial imagery.

For the purpose of the current study, a measure for the habitual use of imagery was needed. Paivio (1971) constructed an Individual Differences Questionnaire (IDQ) which assesses the extent to which an individual typically uses imagery and verbal processes in thinking and problem solving. Richardson (1977) shortened the IDQ and related it to an independent criterion, lateral eye movements. The usefulness of the dimension visualizer-verbalizer, as proposed by Paivio and Richardson is still under investigation.

Zenhausern (1978) criticized the verbal-visual dimension because, he argues, "those who think in pictures can be very verbal" and suggests instead a visualizer-nonvisualizer dichotomy. He writes further that coding preference rather than ability is the critical variable to distinguish high and low imagers. No data are yet available for Zenhausern's test, but there are data for the IDQ and more recently also for the short form constructed by Richardson (1977). The Verbalizer-Visualizer Questionnaire (VVQ) was used in this study. It has been found to be a stable measure of an individual's cognitive style. The verbalizer-visualizer dichotomy is historically related to the classical imagery types (Griffitts, 1927) and has in recent years been

thoroughly studied by Paivio (1971). Paivio's initial study involved a factor analysis of the correlations between verbal ability tests. Paivio concluded that imaginal (visual) and verbal processes are different cognitive dimensions. Ernest (1979) provided further evidence for the superiority of high imagers in the perceptual processing of pictures but not for words. More testing is needed to determine whether or not selective disturbances in verbal or non-verbal processing after brain lesions do reflect the two symbolic systems postulated by Paivio. Richardson's (1977) questionnaire to assess the two habitual thinking styles, verbal and visual, uses items extracted from Paivio's (1971) Individual Difference Questionnaire (IDQ). Richardson claimed that with the VVQ a behaviorally and physiologically valid test was found. Habitual verbalizers scored significantly higher than habitual visualizers on the Mill Hill vocabulary scale set A. The test-retest reliability (one week interval) for 17 females was $r = .91$ and for 20 males $r = .92$. Data are available for 5 independent samples of college students (49 females and 286 males, Richardson unpublished). The average score was 8.72 for the 5 samples. In his 1977 paper, Richardson designated those who scored 7 or less as habitual verbalizers and those scoring 12 or more as habitual visualizers. Furthermore, he had a "mixed class" including those who scored between 8 and 11.

2.4 Intelligence

No clear information is available on the relationship between verbal and non-verbal fluency tasks and test intelligence. It is known from studies with elderly subjects (e.g. Chown, 1961) that the relationship between intelligence and flexibility is not linear, i.e. people with low intelligence are not necessarily rigid but low intelligence is often found in rigid people. For the fluency measures used in the present study, no direct correlations with IQ are available. However, Perret (1974), in a study with Word Fluency and the Stroop Test, did have IQ scores for his subjects and found no significant IQ difference between the brain damaged and normal control subjects. This, in context with the significant differences between groups on the other tests, might suggest that there was no significant correlation but provides no direct test of the relationship. The association between intelligence and concept identification is also not thoroughly studied (Bourne, 1966). The performance on such tasks might be dependent on the age of the subject, the complexity of the stimuli or the type of instructions given. Therefore the association between tests of flexibility and imagery on the one hand and intelligence on the other needs to be established in the current study.

Two partial measures of intelligence were chosen to obtain an IQ estimate, the vocabulary subtest as a sample of verbal and the block design subtest as a sample of non-verbal intelligence. Both are part of the Wechsler Adult Intelligence Scale (Wechsler, 1955). The correlation coefficients with the full scale IQ vary from $r = .79$ to $r = .83$ for vocabulary, and from $r = .67$ to $r = .77$ for block design for different age groups (Matarazzo, 1972). Examining the relationship between intellectual loss and inflexibility in brain damaged subjects, Mackie and Eeck (1966) showed that brain damaged patients can suffer intellectual loss without increased inflexibility and that inflexibility can exist in brain damaged subjects without general intellectual loss.

3. HYPOTHESES

The basis for the hypotheses was mainly derived from the literature concerned with neuropsychological defects after frontal lesions. The nature of the defective ability to shift and of the rigid, perseverative behavior after frontal lesions is still only partially understood. As a general hypothesis it is suggested that a fuller explanation could be found if the defective mental representation of images were considered. The current study attempts to define the role of imagery in relation to inflexible behavior. First, hypotheses for the performance of normal subjects are elaborated followed by additional hypotheses for the expected effects in patients with brain lesions.

3.1 Theoretical hypotheses and experimental predictions

Four main variables are investigated: verbal and non-verbal spontaneous flexibility and verbal and non-verbal adaptive flexibility. For these variables, the following theoretical hypotheses, designated (a) and experimental predictions, designated (b), were made:

1. (a) Spontaneous flexibility: a high variability of ideas and hence fewer repetitions are expected in flexible behavior. The verbal and non-verbal mode of stimulus and response are expected to influence behavior differently. The output of ideas should be higher with a verbal stimulus than with a visual stimulus because verbal material is more familiar. The performance on the two fluency tests should be related because both demand sequential processing.

(b) Normal subjects will generate more ideas on the Word Fluency Test than on the Five Point Test. This result is expected to be independent of the fact that verbal output is faster than grapho-motor output. The two tests are expected to correlate significantly.

2. (a) Adaptive flexibility: the ability to suppress interfering stimuli and to adapt to changing task demands with a changed response pattern is an expected part of normal flexible behavior.

(b) In the two adaptive flexibility tests, the Stroop Test and the concept identification task (CIT), the number of correct ideas and the number of repetitions will be proportionally related. Normal subjects are expected to have little difficulty in suppressing interfering stimulus properties in the Stroop Test; average reading times and few errors are expected.

3. (a) With regard to the relationship between the two types of flexibility, it is expected that adaptive and spontaneous flexibility are different cognitive abilities which need not be associated.

(b) A closer relationship is expected between the two fluency tests and between the Stroop Test and CIT than between the two sets of measures of spontaneous and adaptive flexibility.

4. (a) Imagery: differences in imagery ability should be associated with different cognitive and task demands. There should be a normal variation within the verbal and visual type of thinking. High visualizers are expected to perform better on tasks with a non-verbal mode of stimulus while high verbalizers are expected to perform better on verbal tasks. High imagery ability ("visualizing") is predicted to improve the performance in flexibility tasks, in particular in concept shifting.

(b) A high score on the imagery questionnaire is expected to be positively related to the performance on all flexibility tests. Particularly, it is expected that subjects with high scores ("visualizers") will perform better on the Five Point Test and the non-verbal part of the CIT than in the

verbal tests, whereas subjects with low scores ("verbalizers") will perform better on Word Fluency and the verbal part of the CIT than on the non-verbal tests.

5. (a) Intelligence: verbal intelligence is expected to be more related to performance on verbal tasks, and performance intelligence more with non-verbal tasks.

(b) The vocabulary test (WAIS) is expected to be more highly correlated with Word Fluency and the verbal part of the CIT, and the block design test (WAIS) more with the Five Point Test and the non-verbal part of the CIT.

3.2 Effects of brain lesions

The main part of the current study deals with the interrelationship of the measures in normal subjects. However, a first exploration of the behavior of a small number of brain damaged subjects will be attempted. The predictions are based on previous results and the neuropsychological literature concerned with the effects of brain damage on flexibility. The following hypotheses can be stated:

1. For all flexibility measures it is expected that normal subjects will perform better than brain damaged subjects because of an overall decrement of performance in patients and their increased rigidity (Walsh, 1978).
2. Patients with non-frontal lesions should perform better than patients with frontal lesions on all flexibility tests. Furthermore, there will be laterality effects, i.e. left- right differences, depending on stimulus mode and task demands as follows:
 - a) Word Fluency Test: the smallest number of words and the highest number of repetitions will be made by patients with left hemisphere lesions, followed by patients with frontal lesions (Perret, 1974; Regard, 1980).
 - b) Five Point Test: the smallest number of figures will be produced by patients with right hemisphere lesions, followed by patients with frontal lesions. Left frontal lesion patients are expected to make the largest number of repetitions (Regard, 1980).
 - c) Stroop Test: part III (including the most conflicting stimuli) will best discriminate patients with left hemisphere lesions from patients with lesions in other locations as well as from normals (Perret, 1974; Regard, 1980).

- d) CIT: (a) Patients with frontal lesions should perform worse than patients with non-frontal lesions because they should have difficulty in shifting and in dealing with abstract concepts, i.e. they should find the least number of concepts and make the largest number of errors; (b) patients with left frontal lesions should show the greatest impairment on the CIT. This impairment should be more pronounced on the verbal part because verbalization is crucial in the shifting process (Wolff, 1967); (c) as an alternative hypothesis one could postulate that patients with right frontal lesions should perform poorest because they are impaired not only in shifting ability, but in visual-spatial thinking. It is expected that this type of thinking is required to find the correct concept.
- e) Imagery: it is expected that patients with a more verbal style of thinking are represented more in the group with right hemisphere lesions, and more in the group with frontal than non-frontal damage because it was found that patients with frontal lesions show the most rigid behavior (Walsh, 1978) and because it was suggested that rigidity might also be related to low imagery ability. Visualizers, on the other hand, are expected to be

represented more in the group of patients with left hemisphere lesions because compensatory strategies can be expected to become active, i.e. patients with partial loss of visual-spatial skills might more likely use verbal strategies and patients with partial lack of verbal abilities more likely might make use of visual strategies.

- f) Intelligence: patients with lesions in the right hemisphere should score lower on block design and patients with lesions in the left hemisphere lower on the vocabulary test because right hemisphere lesions are known to result in lower performance on visual-spatial tasks (block design) and left hemisphere lesions in lower performance in linguistic abilities (vocabulary). No relation to type of imagery is expected.

3.3 Exploratory predictions for the CIT

Because the concept identification task (CIT) has been newly developed, only exploratory predictions can be made.

1. Because of changing concept complexity, there should be no learning effect throughout the test. Each concept is different with regard to stimulus mode and type of task.

2. Concepts which demand mental transformation (imagery) should be the hardest to identify (Bryne, 1974).
3. Verbal concepts should be easier to identify because less ambiguous labels can be applied and because interfering stimuli of a different mode produce less conflict than those in the same mode (Morton 1969, Schorr 1978).
4. With regard to imagery style, two alternative hypotheses can be postulated: (a) verbal preference in thinking style is expected to be related to better performance in both the verbal and non-verbal part of the test. Kendler and Kendler (1962) found that conceptual thinking is facilitated by intact internal verbalization but not by visual imagery ability; (b) visualizers are faster in perceiving the stimulus attributes and have a better ability to mentally transform information.

4. METHOD

4.1 Subjects

A group of 40 volunteer female students from the University of Southern California, Los Angeles, participated in this study. The average age was 26.7 years (range 20 to 35 years). All were righthanded and had no history of any neurological or psychiatric illness. In addition to this sample, data were also collected from 14 male volunteer students (see Appendix A).

Additional experimental data were collected from brain damaged subjects. Patients with verified localized lesions from the outpatient and inpatient clinics of the Neurosurgery Department of the University of California, Los Angeles (UCLA), patients from the Daniel Freeman Hospital, Inglewood California, and a patient from the Veterans Administration Hospital, Brentwood California, were assessed. Patients were selected according to location of lesion and assigned to four groups: left frontal, right frontal, left non-frontal and right non-frontal to allow descriptive comparisons between left-right and anterior-posterior dimensions. Patients were also selected

according to etiology. Only circumscribed focal lesions verified by surgery report, CT scan, angiography, or EEG were included. Patients with malignant progressive disorders and those having had several operations or multiple lesions were excluded. Lefthanders and patients with language impairment were excluded. The criterion for language impairment was a Token Test score of 14 points or less and a Reporter's Test score below 19 (see Appendix B). A time constraint was set and the patients available until August 1981 were included in the study. Medical charts of 397 patients with focal lesions were read. Only 16 of these qualified and were willing to cooperate.

Table 1 shows the localization and etiology of the lesions. Most patients suffered from cerebrovascular disease; five had hemorrhages, six had localized strokes, four had tumors, and one had a lobectomy for the treatment of epilepsy.

TABLE 1

Localization and etiology of the lesions

Pat.Nr.	Localization	Etiology	Verification of lesion 1)
81	left frontal	stroke	2,4,5
86	left frontal	subd.hematoma	1,2,3,4,5
87	left frontal	intrac.hematoma	1,2,3,4,5
93	left frontal	tumor	1,2,3,4,5
94	left frontal	stroke	2,4,5
84	left parietal	stroke	2,4,5
97	left parietal	stroke	2,3,5
98	left parieto-occ.	tumor	1,2,3,4,5
83	right frontal	hemorrhage	2,4,5
88	right frontal	tumor	1,2,3,4,5
90	right frontal	hemorrhage	1,2,4,5
85	right temp-pariet.	stroke	1,2,4,5
89	right temp-pariet.	tumor	1,2,4,5
91	right parietal	stroke	2,3,5
92	right temporal	lobectomy	1,4,5
95	right parietal	art.ven.malformation	1,2,3,4,5

- 1) 1 operation
 2 CT scan
 3 angiography
 4 EEG
 5 neurology and others

4.2 Method and procedure

The description of the tests to assess spontaneous and adaptive flexibility, imagery, and intelligence will be presented. For detailed test instructions and further test descriptions the reader is referred to Appendix B.

4.2.1 Spontaneous flexibility

Word Fluency: To assess verbal fluency, Milner's (1964) test was modified by having the experimenter record the subject's responses to control for possible motor impairment. The subjects had to produce as many words as possible beginning with the letter "S" within five minutes. The time limit was originally chosen to allow enough time to produce errors. Since verbal output is faster than grapho-motor output (as used in the assessment of non-verbal fluency), the five minutes also allow enough time to compensate for this difference. Cauthen (1978) reviewed investigations with different measurement techniques for verbal fluency and concluded that the tasks remain sensitive to brain dysfunction across variations in testing and time limits.

The following variables were scored: (1) the total number of words and (2) the number of repetitions.

Five Point Test: This test was designed to assess non-verbal fluency (Regard, 1980). The test consists of a sheet, partitioned into rectangles of 4 by 3 cm. Five symmetrically arranged black dots are printed in each rectangle (Appendix C). The subjects were asked to produce as many different figures as possible within five minutes by connecting the dots in each rectangle with straight lines.

The following variables were scored: (1) the total number of figures and (2) the number of repetitions.

4.2.2 Adaptive flexibility

Stroop Test: The procedure as described by Perret (1974) was modified for English speaking subjects. The test consists of three parts which are always presented in the same order. In part I, the color of 24 pseudorandomly arranged dots, placed in 6 rows and 4 columns and printed in blue, green, yellow and red, had to be named as quickly as possible. In part II, the colors in which common words are printed (such as "hard", "over") had to be named, disregarding the verbal content. Again, in part III, subjects were to name the colors in which the color-names "blue", "green", "yellow" and "red" are printed. The actual words had to be disregarded as they did not correspond to the color they were printed in.

The variables scored were: (1) time in seconds to name the color for all 24 stimuli for each of the three parts, and (2) the number of errors for each of the three parts.

Concept Identification Task (CIT): Concept shifting behavior with verbal and non-verbal concepts was tested with a newly developed concept identification task. The task required the subject to discover the relevant attributes

which varied from stimulus to stimulus and to find the reinforced concept. The detailed test and concept descriptions are given in Appendix B. To illustrate the concepts, an example for each can be found in Appendix C. In brief, the concepts for both the verbal and non-verbal part were as follows:

1. concept 1 and 6: original learning without interference (exemplar and non-exemplar contain the same two attributes);
2. concept 2 and 7: with interference (nonexemplar contains dimension conflicting with correct choice);
3. concept 3 and 8: with imagery (mental transformations are necessary to find correct concept which is the combination of elements in exemplar);
4. concept 4 and 9: with imagery (correct choice is a 90 degree rotation of stimulus in exemplar);
5. concept 5 and 10: with both imagery and interference (correct choice is deduced from elements, which require imagery; the interfering cue is the concept reinforced in the previous concept).

The variables scored were: the total of the correctly identified concepts for the verbal part, the non-verbal part, the total of both parts, up to a maximum of 10; the number of incorrect responses for each concept, for the verbal part, for the non-verbal part, and for both parts;

item number of fifth consecutive correctly identified item for each of the ten concepts, for the total of the verbal part, for the of non-verbal part, and for the total for both parts.

4.2.3 Imagery style

Verbalizer-Visualizer Questionnaire (VVQ): Richardson's VVQ was given to all subjects. The subjects were told that the statements in the questionnaire describe some aspects of the way in which people think or what seems to go on in their minds when studying. They were further told that the statements are not designed to assess whether the way they think is good or bad, but that they are attempts to discover characteristics of the way people think in various situations. The instructions were printed on the questionnaire (see Appendix C).

Variable scored: with the aid of a scoring key a score for each subject was computed. Following Richardson's procedure the subject was then assigned to one of three groups: 12 or more points (habitual visualizer), 8 - 11 points (mixed group), and 7 or less points (habitual verbalizer).

4.2.4 Intelligence

The vocabulary and block design subtests of the Wechsler Adult Intelligence Scale (Wechsler, 1955) were given according to standard instructions in order to assess the degree to which the experimental measures are influenced by intelligence.

Scored variables were: (1) vocabulary scaled score and (2) block design scaled score.

The tests were administered in individual sessions in the following order: the verbal and non-verbal parts of the WAIS, the two fluency tests, and the two parts of the CIT. The verbal and non-verbal parts were counterbalanced both to avoid order effects and to avoid discouraging patients with unilateral defects which selectively affected performance. Two orders were chosen to control the influence of the verbal and non-verbal mode of stimulus on performance. The order was alternated. Fifty percent of the subjects were tested in order 1 and fifty percent in order 2.

order 1	vocabulary	order 2	block design
	block design		vocabulary
	Word Fluency		Five Point Test
	Stroop Test		Stroop Test
	Five Point Test		Word Fluency
	CIT verbal part		CIT non-verbal part

CIT non-verbal part

CIT verbal part

VVQ

VVQ

The time to test each subject was approximately 1 1/2 hours.

4.2 Analysis

For an overview the variables are summarized first:

Test:

Variable:

Word Fluency	total number of words number of repetitions
Five Point Test	total number of figures number of repetitions
Stroop Test	reading time in seconds number of errors
CIT	correctly identified concepts total, verbal, non-verbal incorrect responses total, verbal, non-verbal item at criterion total, verbal, non-verbal total time in minutes
VVQ	key score
WAIS	vocabulary scaled score block design scaled score

4.3.1 Analysis

To test the experimental predictions formulated in section 3.1, the following analyses were computed:

1. Test of difference between Word Fluency (total number of words) and Five Point Test (total number of figures: t-test, critical level of significance $p < .05$).
2. Inspection of degree and direction of the relationship between Word Fluency and Five Point Test, total number of words, figures and repetitions: correlation matrix.
3. Relationship between Word Fluency and Five Point Test as well as between Stroop Test and CIT: (1) correlation matrix, (2) factor analysis.
4. Relationship between imagery and flexibility: (1) one-way analysis of variance for each test with three levels of imagery (visualizers, mixed group, verbalizers) with follow-up single mean comparisons and (2) correlation matrix.
5. Relationships between vocabulary, Word Fluency and the verbal part of the CIT, as well as between block design, Five Point Test and the non-verbal part of the CIT: correlation matrix.

4.3.2 Effects of brain lesions

Statistical analyses were only computed for the comparison between patients and normal control subjects. From the pool of the control subjects a sample matched for

age and education with the patient group was selected for the statistical comparisons.

A multivariate analysis of variance between the two groups for the flexibility measures as well as the VVQ was computed. A first exploration of the results of the small number of brain damaged patients was attempted by comparing patients with left hemisphere lesions and patients with right hemisphere lesions, as well as patients with frontal and non-frontal lesions, using the chi-square test for each variable. Additionally, z-score profiles were prepared to compare test patterns between groups. Furthermore, a correlation matrix was computed for all patients to test the difference in association pattern among the tests compared to normals.

4.3.3 Exploration of the CIT

The exploratory predictions (section 3.3) were tested as follows:

1. Comparison of the number of trials (item number when subject reached criterion) for each concept to test for order effects: within anova repeated measures design, subjects (S1-n) by concept (C1-10).
2. Comparison of imagery concepts with interference concepts: t-tests with grouped data.

3. Comparison of the total number of verbal concepts correctly identified to the total of non-verbal concepts correctly identified: t-test.
4. Relationship of imagery style to CIT performance: one-way analysis of variance between the three levels of imagery style and the number of correctly identified verbal and non-verbal concepts.

4.3.4 Analysis of order of tests effect

Order 1 and order 2 were compared by a multivariate analysis of variance including all alternated tests.

4.3.5 Post-hoc analysis of intelligence

To explore the degree of relationship between general intelligence and the new tests, correlations were computed between the estimated IQ (sum of vocabulary and block design scaled scores) and the CIT (total of correctly identified concepts), and between IQ and VVQ score. Additionally, since modifications were made in some tests, the correlations between the estimated IQ and the two fluency tests and the Stroop Test were also computed.

5. RESULTS

The results are reported in the order of the hypotheses as stated in chapter 3.

5.1 Results for normal control subjects

Table 2 shows the average performance and standard deviations for all variables for 40 female control subjects. Multivariate analyses of variance between this group and the group of 14 males were computed and no gender differences were found (Appendix A). All further calculations were made for the females and repeated for the combined sample. The results are reported for the female sample only.

5.1.1 Spontaneous flexibility

The hypothesis that more ideas would be generated with verbal stimuli than with non-verbal stimuli could not be confirmed ($t = 1.25$, $p < .217$). The means for both the Word Fluency Test (51.9) and the Five Point Test (55.5) were unexpectedly high compared to previous data collected with a Swiss speaking population (48.8, and 38.3 respectively) (Regard, 1980).

The expected positive correlation between the verbal and non-verbal output was low ($r = .35$, $p < .014$). Between repetitions in both tests, no significant correlation was found (Table 3).

TABLE 2

Means and standard deviations for all measures (40 normals)

Variable	M	SD
IQ estimate	28.13	3.82
Vocabulary	15.27	2.05
Block design	12.90	2.67
Word Fluency: number of words	51.90	11.67
repetitions	.33	.94
Five Point Test: number of figures	55.48	18.41
repetitions	2.88	4.51
Stroop Test: reading time part I	10.10	2.01
reading time part II	12.00	2.49
reading time part III	19.25	5.18
errors part I	.03	.16
errors part II	.03	.16
errors part III	.23	.53
CIT: correct concepts total	9.40	.84
correct concepts verbal part	4.83	.38
correct concepts non-verbal part	4.58	.71
errors total	13.95	7.09
errors verbal part	4.65	2.82
errors non-verbal part	9.30	5.97
errors concept 1	.03	.16
concept 2	2.45	2.53
concept 3	.55	.96
concept 4	.25	.44
concept 5	1.45	1.13
concept 6	.28	.91
concept 7	2.80	2.45
concept 8	2.25	1.85
concept 9	1.38	2.03
concept 10	2.63	3.30
item at criterion total	73.60	12.57
item at criterion verbal part	33.18	5.44
item at criterion non-verbal part	40.43	9.75
items concept 1	5.10	.63
concept 2	9.45	4.09
concept 3	6.20	2.17
concept 4	5.33	.73
concept 5	7.10	2.70
concept 6	5.55	2.05
concept 7	10.33	4.25
concept 8	8.50	3.25
concept 9	8.08	4.10
concept 10	8.15	3.70
time total	11.83	5.12
VVQ	8.88	2.15

TABLE 3

Correlations between the flexibility measures (40 normals)

Variables with:	1	2	3	4	5	6	7	8	9
1 Word Fluency									
2 repetitions	.294 .033								
3 Five Point	-.349 .014	-.122 .226							
4 repetitions	-.023 .445	-.046 .389	.322 .021						
5 Stroop time	-.255 .056	-.033 .420	-.203 .104	-.384 .007					
6 Stroop errors	.116 .239	.004 .491	.086 .299	-.020 .451	-.030 .426				
7 CIT verbal	-.181 .132	.161 .161	.099 .272	-.087 .297	-.093 .283	-.305 .028			
8 CIT non-verb.	.223 .083	.020 .451	.389 .007	.159 .164	-.061 .355	.056 .366	.096 .278		
9 CIT err.tot.	-.232 .075	-.231 .076	-.382 .008	-.052 .374	-.018 .457	.235 .072	-.473 .001	-.705 .000	
10 CIT time	-.131 .211	-.152 .174	-.358 .012	-.172 .144	-.142 .191	.374 .009	-.146 .184	-.464 .001	.455 .002

first number = r; second number = p

5.1.2 Adaptive flexibility

No serious problems were expected for normal subjects in suppressing interfering stimuli in the Stroop Test. The previously observed results (Perret, 1974, and Regard, 1980) that there is an increasing difficulty in the test from plate I to III could be confirmed by increased reading times (I= 10.1 sec, II= 12.0 sec, III= 19.3 sec) and increased number of errors (I=0.03, II=0.03, III= 0.23).

In the CIT, normal subjects found an average of 9.4 concepts out of the maximum 10. A mean total of 14 errors was found, i.e. approximately one and one half per concept. The correct answer after the five consecutive correct responses was found on average after approximately 7.5 items (item number total: 73.6). These results suggest that normal subjects learn the task and shift to a new response after the first or second error. A more detailed analysis of this test is presented below.

Table 3 shows the correlation matrix for ten variables derived from the Stroop, the Five Point and the Concept Identification Test. A significant correlation between Stroop Test (number of errors, plate III) and CIT (number of verbal concepts) was found ($r = .305$, $p < .028$). A significant correlation was also found between the Stroop Test and CIT concept 2 ($r = .40$, $p < .005$). Furthermore, reading time in the Stroop Test significantly overlapped

with the number of repetitions in the Five Point Test ($r = -.38, p < .007$).

5.1.3 Spontaneous versus adaptive flexibility

Moderate correlations exist between the verbal fluency test (Word Fluency) and the non-verbal fluency test (Five Point Test) ($r = -.35, p < .014$) as well as between the Stroop Test and the verbal part of the CIT ($r = -.305, p < .028$). On the other hand, significant correlations were also found between Word Fluency and part I and II of the Stroop Test ($r = .45, p < .002$). To assess the complex relationships between the different flexibility measures more fully and to gain information on whether there are dimensions for stimulus mode (verbal/non-verbal), type of task (spontaneous/adaptive flexibility) or both, a factor analysis with a subset of 10 variables was computed (BMD, P-series, 1979). The unrotated factors were principal components and the number of factors was limited to those with eigenvalues greater than 1.00. Four significant factors were found. Rotations were performed with a maximum number of 50 iterations. The factor patterns were highly similar for the unrotated solution, for the Varimax (orthogonal), and for the direct Quartimin (oblique) rotations. Table 4 shows the sorted Quartimin factor loadings (pattern) for four factors on the basis of 10 variables.

TABLE 4

Sorted Rotated Factor Loadings

Variables	Factors			
	1	2	3	4
CIT non-verbal concepts	.85	0	0	0
Five Point Test figures	.72	0	0	-.28
Word Fluency repetitions	0	.88	0	0
words	0	.63	-.39	0
CIT verbal concepts	0	0	.84	0
Stroop errors part III	0	0	-.69	0
time part III	0	0	0	.88
Five Point Test repetitions	.26	0	0	-.68
Block design	.46	.42	.39	0
Vocabulary	.43	.44	0	.35
VP	1.76	1.63	1.51	1.49

Loadings less than .25 have been replaced by zero

Factor score covariance (computed from factor structure and factor score coefficients)

	Factor			
	1	2	3	4
Factor 1	1.00			
Factor 2	.26	1.00		
Factor 3	.02	.04	1.00	
Factor 4	-.11	-.01	.06	1.00

In this solution, four dimensions of common variance were found. Factor I showed the highest loadings for the non-verbal part of the CIT, the Five Point Test and the Block Design Test and can be viewed as a non-verbal stimulus mode factor. The second factor to be extracted had the highest loadings for the Word Fluency Test and vocabulary and can be labeled as a verbal spontaneous flexibility factor. The third factor was a verbal adaptive flexibility factor with loadings for the verbal part of the CIT and the Stroop Test (number of errors). The last extracted factor showed loadings for the Stroop Test (time) and the Five Point Test (errors) and could be labeled as a rigidity factor across the verbal and non-verbal stimulus mode.

In summary, the factor analysis showed that the mode of stimulus used in the tasks was a stronger dimension than the type of task. Tests with a verbal stimulus mode can be regarded as having two dimensions, one for spontaneous flexibility tests, and another one for adaptive flexibility tests. For the non-verbal stimulus mode a similar split into two dimensions was not found.

5.1.4 Imagery

The prediction that a high score in the VVQ would be positively related to flexibility measures could not be confirmed. The VVQ was found to correlate significantly with

only one variable out of twenty-six. The overlap was with concept 4 of the CIT ($r = -.510$, $p < .001$). This concept was designed to measure imagery ability. The relationship between VVQ and CIT (non-verbal concepts) was modest and not significant ($r = .232$, $p < .075$) (see Table 5 including only the major variables of the flexibility tests).

TABLE 5

Correlations between VVQ and flexibility tests

Variables	VVQ correlations with:	
	r	p
Word Fluency total words	.06	.36
repetitions	-.26	.06
Five Point total figures	.15	.19
repetitions	-.08	.32
Stroop reading time part III	-.01	.50
errors part III	.07	.33
CIT concepts verbal part	-.03	.43
concepts non-verbal part	.23	.08

The VVQ scores were normally distributed with a mean of 8.88 (SD 2.15, range 4 to 13). Using Richardson's cutoff scores ten subjects had scores of 7 and below and were assigned to the "verbalizer" group, 26 subjects had scores between 8 and 12 (mixed group) and 4 subjects had a score of 12 and more (visualizers). Analyses of variance with three levels of imagery scores did not show a significant effect of imagery style on the performance in flexibility measures.

Instead of Richardson's group partitions, a new analysis was computed on the basis of the distribution of this sample. Subjects scoring one standard deviation below the mean (<6) were assigned to the verbalizer group, subjects scoring one standard deviation above the mean (>11) were assigned to the visualizer group, and the rest to the mixed group. A one-way analysis of variance with three levels (imagery types) showed a significant main effect for the non-verbal part of the CIT ($F = 3.953, p < .028$). Single mean comparisons showed a significant difference between verbalizers and the other two groups, indicating that the verbalizers typically had the lowest result in the non-verbal part of the CIT. (Table 6).

TABLE 6

F-tests of significance for three levels of imagery style

Variable	F	p
Word Fluency total words	.429	.655
repetitions	1.636	.209
Five Point Test total figures	1.225	.306
repetitions	1.026	.369
Stroop reading time part III	.895	.417
errors part III	.433	.652
CIT total concepts	1.403	.259
verbal concepts	.974	.387
non-verbal concepts	3.953	.028*
total errors	.999	.378
verbal errors	.782	.465
non-verbal errors	2.541	.093

* multiple range test (Scheffé):
 verbalizers M = 3.80 SD = .84 (p<.05)
 visualizers M = 4.56 SD = 1.01
 mixed M = 4.72 SD = .46

5.1.5 Intelligence

The vocabulary and the block design scores were correlated with thirteen test variables (Table 7). Vocabulary was significantly related to the number of repetitions in the Word Fluency Test ($r = .40$, $p < .005$), to the Five Point Test ($r = .27$, $p < .047$), to the non-verbal part of the CIT ($r = .28$, $p < .043$), and to the total number of errors on the CIT ($r = -.42$, $p < .004$). Block design was significantly related to the Five Point Test ($r = .52$, $p < .001$), to the the total number of concepts on the CIT ($r = .37$, $p < .009$), to the total number of errors ($r = -.48$, $p < .001$) and to the time on the CIT ($r = -.47$, $p < .001$). Furthermore it was found that block design also correlated with the verbal part of the CIT ($r = .33$, $p < .018$) and with the number of repetitions in Word Fluency ($r = .39$, $p < .018$). In summary, vocabulary correlated with four out of 10 variables and block design correlated with five out of the ten employing both verbal and non-verbal modes of stimuli.

TABLE 7

Correlation between vocabulary, block design and flexibility measures

Variables with:	Vocabulary		Block design	
	r	p	r	p
Word Fluency total words	.173	.143	.172	.134
repetitions	.403	.005	.389	.006
Five Point total figures	.268	.047	.517	.000
repetitions	.021	.450	.020	.451
Stroop time part III	.126	.219	-.050	.379
Stroop errors part III	-.058	.360	-.092	.285
CIT verbal part	-.035	.415	.332	.018
CIT non-verbal part	.275	.043	.261	.052
CIT total concepts	.217	.089	.372	.009
CIT total errors	-.415	.004	-.476	.001

5.2 Effects of brain lesions

As described above, the sixteen patients with verified brain lesions were individually matched for age, gender and education with the same number of normal control subjects. Table 8 gives an overview of the variables. Mean comparisons between age, education and time after surgery showed no significant differences between the normal and the brain damaged and within the brain damaged groups.

Table 9 shows the means and standard deviations for the patient and the control groups on all test measures.

TABLE 8

Variables for patients and matched control group

Groups	n	Age		Education (years)		time after surgery (months)	
		M	SD	M	SD	M	SD
normal controls	16	44.3	19.6	14.2	1.9		
brain damaged	16	45.9	19.3	12.8	2.0	18.8	45.6
F		0.055		3.610			
P		.817		.067			
left hemisphere	8	50.9	21.6	13.4	.9	7.4	12.0
right hemisphere	8	41.0	17.6	12.3	2.1	30.3	63.2
F		1.400		1.280		0.867	
P		.670		.277		.368	
frontal	8	43.6	18.5	12.1	2.0	12.1	20.9
non-frontal	8	48.3	21.9	13.5	1.9	15.4	33.9
F		1.510		2.002		0.053	
P		.600		.179		.821	

TABLE 9

Means and standard deviations: patients and matched controls

Variable	normal controls		patients	
	M	SD	M	SD
IQ estimate	26.44	3.39	20.25	2.82
Vocabulary	15.25	1.98	11.75	1.98
Block design	11.19	2.69	8.50	1.55
Word Fluency: tot. words	46.38	13.27	25.38	16.71
repetitions	.19	.54	1.25	1.84
Five Point: tot. figures	43.94	15.94	28.38	17.12
repetitions	1.63	1.93	5.19	6.29
Stroop Test: time, part I	12.50	2.88	16.56	5.59
time, part II	14.31	3.14	22.81	9.09
time, part III	24.06	7.74	39.06	18.14
errors, part I	.13	.34	.38	.50
errors, part II	0	0	.56	.89
errors, part III	.56	1.26	3.06	3.32
CIT: correct concepts total	9.13	1.15	6.94	1.81
verbal	4.69	.60	3.69	1.01
non-verbal	4.44	.81	3.25	1.29
errors total	17.75	12.94	40.94	16.93
verbal	6.50	5.66	16.94	9.64
non-verbal	11.25	8.16	24.00	10.44
concept 1	.38	.89	1.13	2.22
concept 2	3.19	3.06	5.38	3.42
concept 3	.69	1.08	2.69	2.98
concept 4	.25	.45	2.81	3.45
concept 5	2.00	3.06	4.94	3.51
concept 6	.56	1.15	2.19	2.11
concept 7	2.75	3.09	6.25	3.62
concept 8	3.00	2.28	2.44	2.45
concept 9	1.44	2.16	3.31	3.65
concept 10	3.56	4.16	9.69	4.77
item at criterion total	78.06	17.20	108.06	23.67
verbal	35.69	7.12	49.63	11.97
non-verbal	42.38	11.62	58.19	14.45
concept 1	5.69	1.58	6.31	2.65
concept 2	10.69	4.41	13.9	4.86
concept 3	6.69	2.92	9.13	4.52
concept 4	5.25	.45	9.50	4.95
concept 5	7.31	3.01	12.75	5.13
concept 6	6.31	2.80	9.56	3.76
concept 7	9.13	4.18	14.00	4.41
concept 8	9.69	3.72	9.88	4.37
concept 9	7.81	3.66	9.81	4.58
concept 10	9.43	4.80	14.94	3.94
time total	13.63	5.08	25.19	13.12
VVQ	8.25	2.49	7.38	2.71

A multivariate analysis of variance between the two groups for the flexibility measures as well as the VVQ was significant ($F = 3.031$, $p < .023$) (Table 10). Significant univariate differences were found for all variables except the VVQ (a). A separate multivariate analysis of variance for the error variables (b) was computed for the two groups. The multivariate comparison was significant ($F = 4.576$, $p < .004$). All univariate comparisons were significant.

TABLE 10

Multivariate and univariate comparisons: patients and controls

Multivariate tests (Wilk's Lambda criterion)		Univariate tests		
F	p	F	p	
a. 3.031	.023*	Word Fluency total	15.497	.000***
		Five Point total	7.083	.012*
		Stroop time part III	9.253	.005**
		CIT concepts verbal	11.497	.002**
		CIT concepts non-verbal	9.687	.004**
		VVQ	.906	.349
b. 4.576	.004**	Word Fluency repetitions	4.887	.035*
		Five Point repetitions	4.699	.038*
		Stroop errors part III	7.942	.008**
		CIT errors verbal	13.960	.001***
		CIT errors non-verbal	14.818	.001***

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

Table 11 shows the results of the patients separated into left and right hemisphere lesion groups and Table 12 for the patients separated into frontal and non-frontal lesion groups. For each variable chi-square tests were computed between the groups with left and right hemisphere lesions, and between frontal and non-frontal groups. No significant differences could be found for either of the comparisons. Because of the large variability of baseline results no mean differences could be found and further statistical analyses were not indicated. Z-score profiles were made for visual inspection of trends and further description (see Figures 1 and 2). It should be kept in mind that the trends described below failed to find statistical significance and hence are only of speculative interest. Table 13 shows the correlation matrix for the brain damaged group including ten variables. The results will be included in the descriptions below.

TABLE 11

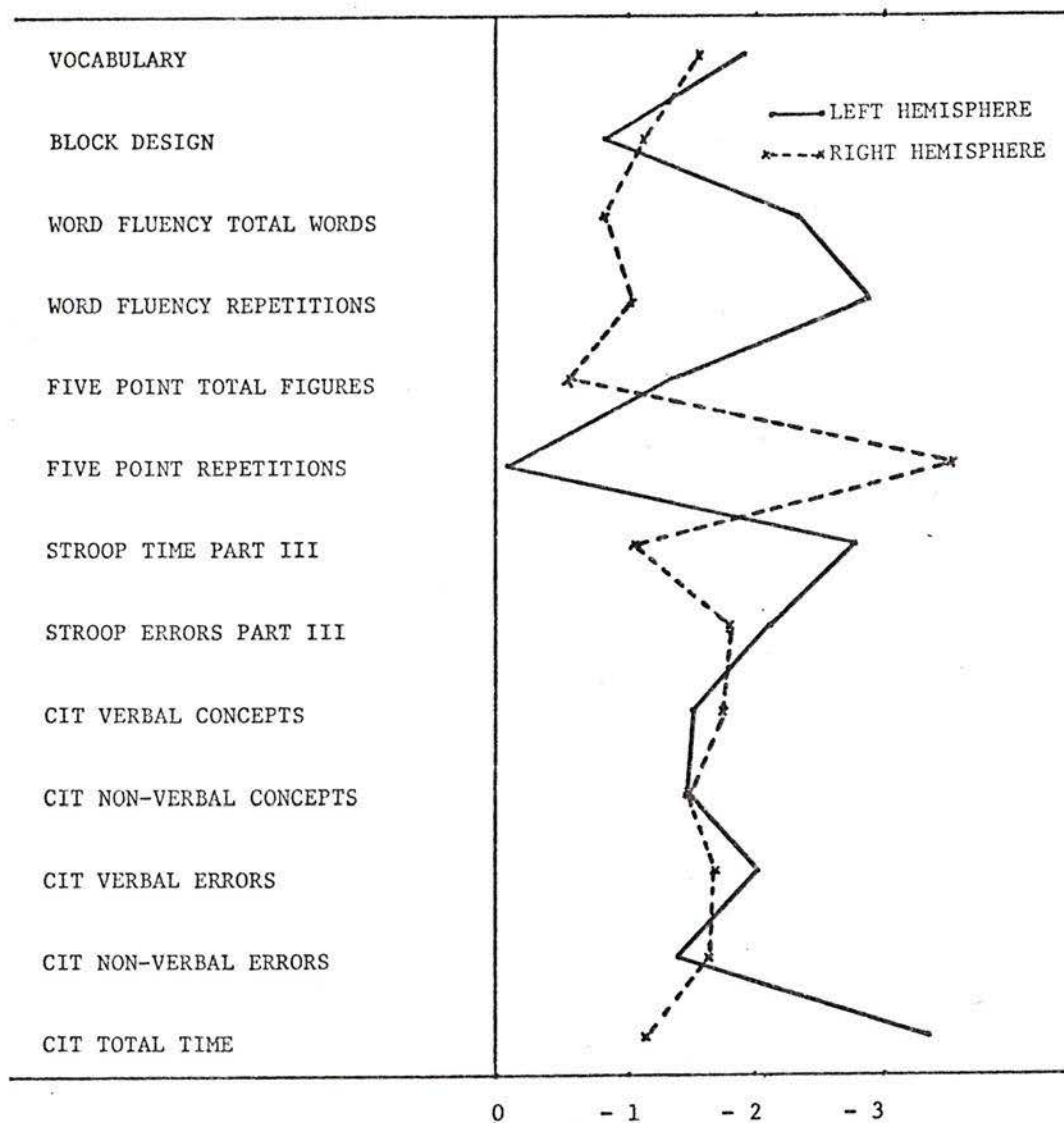
Means and standard deviations: left and right hemisphere

Variable	left hemisphere		right hemisphere	
	M	SD	M	SD
IQ estimate	20.25	2.82	20.25	2.82
Vocabulary	11.38	2.00	12.13	2.03
Block design	8.88	1.25	8.13	1.81
Word Fluency total words	15.75	9.19	35.00	17.39
repetitions	1.75	2.49	.75	.71
Five Point total figures	21.25	8.68	35.50	20.90
repetitions	1.88	2.64	8.50	7.25
Stroop time part I	18.00	6.68	15.13	4.19
part II	26.25	9.45	19.38	7.80
part III	45.63	21.49	32.50	12.05
errors part I	.38	.52	.38	.52
part II	.88	1.13	.25	.46
part III	3.25	1.83	2.88	4.49
CIT concepts total	7.00	1.31	6.88	2.30
verbal	3.75	1.04	3.63	1.06
non-verbal	3.25	1.39	3.25	1.28
errors total	41.00	15.30	40.88	19.49
verbal	17.88	11.51	16.00	8.04
non-verbal	23.13	8.95	24.88	12.31
concept 1	2.00	2.93	.25	.46
concept 2	5.50	3.12	5.25	3.92
concept 3	3.50	3.38	1.88	2.48
concept 4	2.50	3.51	3.13	3.61
concept 5	4.38	3.29	5.50	3.85
concept 6	2.00	1.69	1.38	2.56
concept 7	7.75	2.96	4.75	3.77
concept 8	1.75	1.49	3.13	3.09
concept 9	2.75	3.41	3.88	4.02
concept 10	8.88	3.94	10.50	5.63
item at criterion total	108.63	21.69	107.50	27.02
verbal	50.13	12.19	49.13	12.56
non-verbal	58.00	13.88	58.38	15.96
concept 1	7.38	3.50	5.25	.46
concept 2	14.13	4.52	12.25	5.31
concept 3	10.00	4.21	8.25	4.92
concept 4	9.13	5.06	9.88	5.17
concept 5	12.00	5.63	13.50	4.84
concept 6	9.63	4.07	9.50	3.70
concept 7	15.63	3.89	12.38	4.53
concept 8	8.50	3.12	11.25	5.18
concept 9	9.13	3.98	10.50	5.29
concept 10	15.13	3.83	14.75	4.30
total time	30.75	12.54	19.63	11.86
VVQ	7.13	3.31	7.63	2.13

TABLE 12

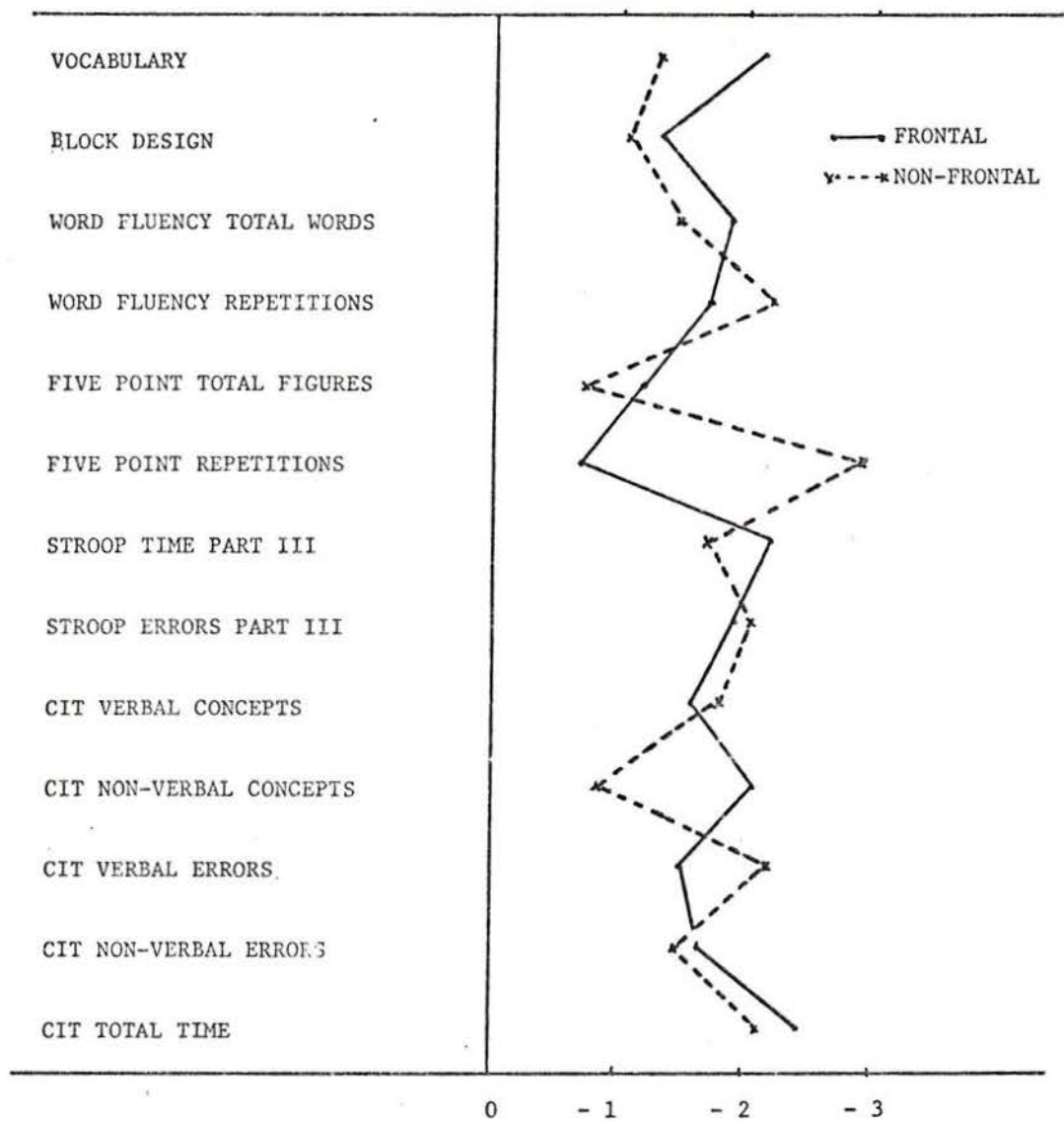
Means and standard deviations: frontal and non-frontal

Variable	frontal		non-frontal	
	M	SD	M	SD
IQ estimate	19.25	2.38	21.25	2.82
Vocabulary	11.00	1.93	12.50	1.85
Block design	8.25	1.28	8.75	1.83
Word Fluency				
total words	21.13	10.54	29.63	21.13
repetitions	1.13	1.25	1.38	2.39
Five Point				
total figures	24.88	13.02	31.88	20.75
repetitions	3.00	3.67	7.38	7.76
Stroop time				
part I	16.63	6.00	16.50	5.56
part II	21.50	7.67	24.13	10.70
part III	40.88	20.37	37.25	16.82
errors				
part I	.13	.35	.63	.52
part II	.50	1.07	.63	.74
part III	3.00	2.27	3.13	4.29
CIT concepts				
total	6.50	1.41	7.38	2.13
verbal	3.75	.89	3.63	1.19
non-verbal	2.75	1.17	3.75	1.28
errors				
total	39.63	14.04	42.25	20.32
verbal	15.00	7.80	18.88	11.38
non-verbal	24.63	9.75	23.38	11.72
concept 1	.88	1.73	1.38	2.72
concept 2	5.75	3.66	5.00	3.38
concept 3	1.63	1.85	3.75	3.62
concept 4	2.25	2.92	3.38	4.03
concept 5	4.50	2.73	5.38	4.31
concept 6	1.50	1.60	2.88	2.42
concept 7	6.38	4.00	6.13	3.48
concept 8	2.50	2.67	2.38	2.39
concept 9	3.75	3.85	2.88	3.64
concept 10	10.50	4.41	8.88	5.28
items at criterion total	109.13	19.96	107.00	28.28
verbal	50.00	9.89	49.25	14.46
non-verbal	58.88	13.92	57.50	15.89
concept 1	6.25	2.78	6.38	2.72
concept 2	14.63	4.60	11.75	4.98
concept 3	8.63	4.31	9.63	4.96
concept 4	8.50	4.66	10.50	5.35
concept 5	13.25	4.92	12.25	5.63
concept 6	8.63	4.17	10.50	3.30
concept 7	14.00	4.38	14.00	4.75
concept 8	10.25	5.09	9.50	3.82
concept 9	10.38	4.87	9.25	4.53
concept 10	15.63	3.89	14.25	4.13
total time	26.00	13.70	24.38	13.39
VVQ	7.38	3.02	7.38	2.56



(zero z-scores are based on the matched control group)

Figure 1: Z-score profiles for the left and right hemisphere patient groups



(zero z-scores are based on the matched control group)

Figure 2: Z-score profiles for the frontal and non-frontal patient groups

TABLE 13

Correlations between flexibility tests: patients

Variables with:	1	2	3	4	5	6	7	8	9
1 Word Fluency									
2 repetitions	-.077 .389								
3 Five Point	.748 .000	-.043 .437							
4 repetitions	.430 .048	-.068 .402	.640 .004						
5 Stroop time	-.476 .031	.169 .266	-.360 .086	.074 .393					
6 Stroop error	-.440 .044	-.003 .496	-.167 .268	.483 .029	.483 .029				
7 CIT verbal	.519 .020	.152 .288	.318 .115	-.199 .230	-.473 .032	-.450 .040			
8 CIT non-verb.	.369 .080	.084 .379	.360 .085	-.162 .274	-.431 .048	-.689 .002	.216 .210		
9 CIT err.tot.	-.527 .018	.043 .437	-.459 .037	.168 .267	.506 .023	.617 .005	-.786 .000	-.524 .019	
10 CIT time	-.592 .008	.114 .337	-.464 .035	-.044 .436	.941 .000	.561 .012	-.456 .038	-.464 .035	.546 .014

first number = r; second number = p

In the Word Fluency Test patients with lesions in the left hemisphere produced the least number of words (\bar{M} =15.75) and also made the largest number of errors (\bar{M} =1.75). The best performance was made by patients with right non-frontal lesions.

On the Five Point Test, patients with left hemisphere lesions produced the smallest number of figures followed by patients with frontal lesions. The highest number of repetitions were made by patients with lesions in the right hemisphere, and mostly by patients with frontal lesions. The earlier finding that patients with right frontal lesions would have the most difficulties on this test could not be confirmed in this descriptive evaluation.

The correlation (Table 13) between the two fluency tests was much higher for patients than it was for normal controls (see Table 3), (r =-.748, p <.001); Guilford's (1950) z-test of the difference between r-coefficients was significant (t =1.86, p <.01).

On the Stroop Test patients with left hemisphere lesions took the longest time to read the stimuli (\bar{M} =45.6). They also made the largest number of reading errors (\bar{M} =3.25), especially the group with left frontal lesions (\bar{M} =3.40). Unlike the control group, the Stroop Test (plate III) correlated significantly with Word Fluency (r =-.44, p <.044) and with the number of correctly identified concepts in the CIT (r =.574, p <.01).

On the CIT patients with frontal lesions solved the least number of concepts correctly (6.5 out of ten). Patients with right frontal lesions did worse (5.67) than patients with left frontal lesions (7.6). The latter solved the concepts as well as patients with right non-frontal lesions. The number of errors made was on average the same for all groups; the within group variability was large. The verbal part of the test showed small differences between the groups. On the other hand, on the non-verbal part of the test, as predicted, patients with frontal lesions found the least number of concepts (2.75), compared to patients with non-frontal lesions (3.75). Patients with left sided lesions took longer to solve the CIT compared to patients with right sided lesions (30.8 min. and 19.6 min. respectively).

The correlations among the flexibility measures (Table 13) in general were higher and more frequently significant than in healthy subjects.

The distribution of the scores on the VVQ was quite similar for all patient groups. It was predicted that patients with lesions in the left hemisphere would more likely have a "visualizer" score and patients with lesions in the right hemisphere a "verbalizer" score. By inspection, no such trend is found. On the contrary, the inspection of the group means showed the lowest score for patients with left non-frontal lesions (5.67), followed by the group with

right frontal lesions (6.33). The highest score was found for patients with right non-frontal lesions (8.40). In a correlation matrix with twenty-six variables, the VVQ correlated significantly with seven measures: with the number of verbal concepts in the CIT ($r = .49$, $p < .037$) and with concepts numbers 4, 5, 6, and 10. Furthermore, the VVQ was related to the Stroop Test ($r = -.645$, $p < .003$) and to the total time to solve the CIT ($r = -.624$, $p < .005$).

For all patients, the block design score was lower by inspection than the vocabulary score. For both tests, no noticeable differences were found between the patient groups. The VVQ was not significantly correlated with the two WAIS subtests. Vocabulary correlated only with concept 7 of the CIT, and the block design was significantly related to the Five Point Test ($r = .412$, $p < .049$), to the total number of concepts in the CIT ($r = .56$, $p < .012$) and to several single concepts, most strongly with concept 9, i.e. non-verbal rotation ($r = .822$, $p < .001$).

5.3 Exploratory results of the CIT

First the results of the normal control group will be reported and then those of the patients.

5.3.1 Results of normal subjects

It was predicted that there will be no learning effect throughout the test because each tested concept in itself is like a different task. A repeated measures multivariate analysis of variance between order 1 and order 2 for the number of trials needed for each concept demonstrated no significant difference. This suggests that the order of presentation of the two parts of the test did not influence the performance. Since the concepts are so different in task demand, it is very likely that there was no learning effect. Figure 3 shows the mean scores for each separate concept. The highest number of items for a correct solution was needed on concepts 7, 2 and 8, and the largest number of errors were made on concepts 7, 2 and 10. In concepts 7 and 2 the effects of interference were tested, and in concepts 8 and 10, imagery ability. The verbal concepts were significantly better identified than the non-verbal ones ($t = 2.04, p < .048$).

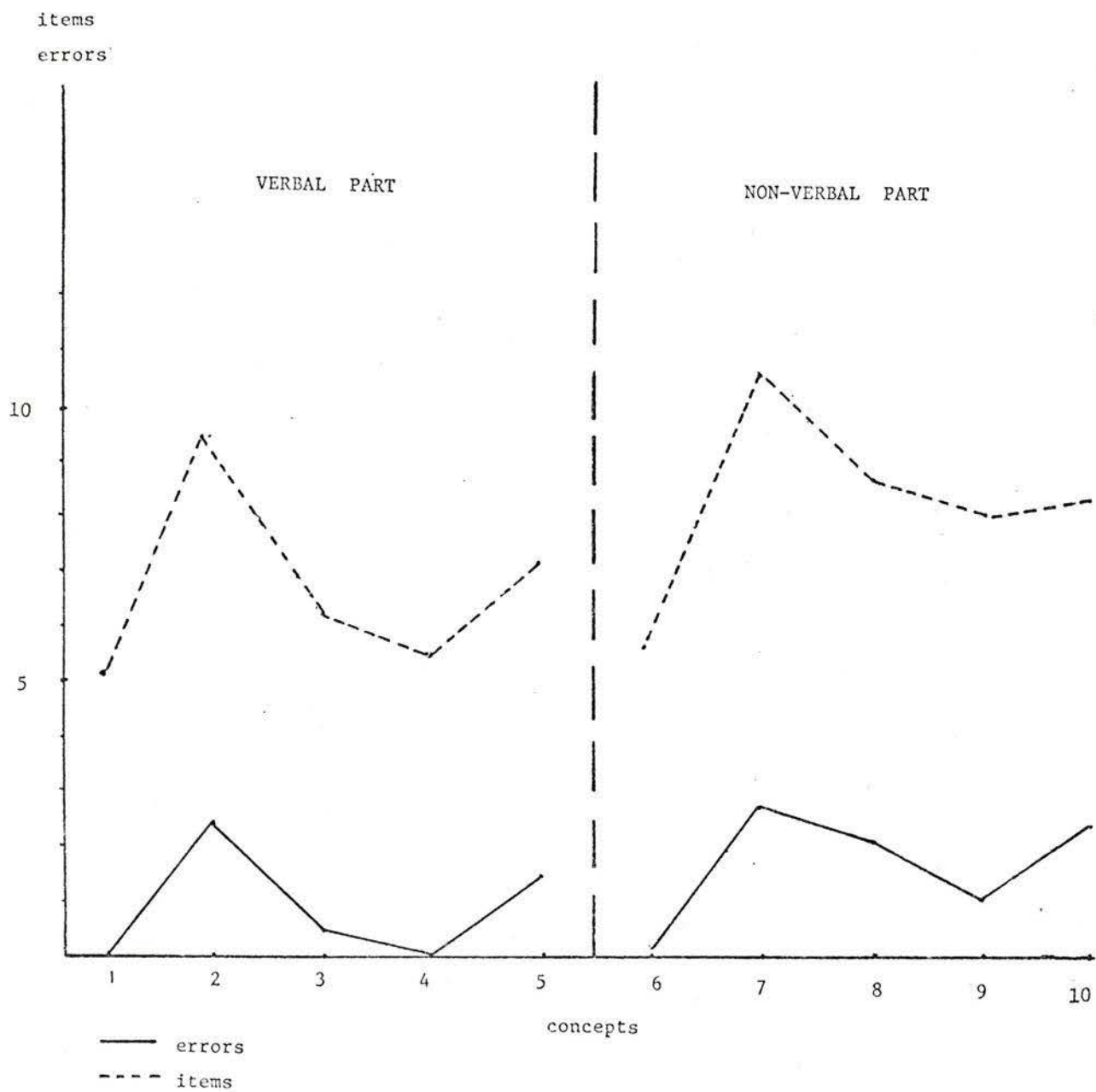


Figure 3: Mean scores for CIT concepts: normal subjects

In order to test whether stimulus mode (verbal or non-verbal) or whether the type of concept tested (imagery or interference) influenced the performance more strongly, the number of items needed to solve these different concepts were summed as follows: (1) concepts testing imagery in verbal mode (3 and 4), (2) imagery in non-verbal mode (8 and 9), (3) interference in verbal mode (2 and 5), and (4) interference in non-verbal mode (7 and 10). Comparing the means (1) and (2) to (3) and (4), it was found that concepts with a verbal mode were significantly easier to solve than concepts using a non-verbal mode ($t = 4.60$, $p < .001$) and concepts with imagery were significantly easier than those with interference ($t = 4.84$, $p < .001$).

An analysis of variance between the three levels of imagery style and the CIT was significant as shown in Table 5 ($F = 3.953$, $p < .028$) indicating that verbalizers solved the least number of non-verbal concepts. Additionally, the correlations between VVQ and concepts 3, 4, and 10 were significant. In other words, a higher score on the VVQ was found to be related to better performance on these concepts.

5.3.2 Results of brain damaged patients

It should be kept in mind that the main part of this study deals with the performance of normal subjects and that the testing of a small group of patients is only a first

exploration of the performance on the CIT. Figure 4 illustrates the CIT performance of the four lesion types of patients and the matched control group. By inspection, patients solved the verbal part of the test in a pattern similar to healthy subjects. However, in the non-verbal part, the patterns are different. In addition to the difficulties in concept 7 and 10, concepts 4 and 9 also elicited more errors in patients than in normals. Statistical differences between the matched control group and the four patient groups together were found for the number of errors made in concepts number 3 ($t = -.252$, $p < .017$), number 4 ($t = -2.95$, $p < .006$), number 5 ($t = -2.52$, $p < .017$), number 6 ($t = -2.71$, $p < .011$), number 7 ($t = -2.94$, $p < .006$), and number 10 ($t = -3.87$, $p < .001$). In Table 14 the results are summarized in "cookbook" style. On the right side of the table are the concepts which were best solved and on the left side those which were least frequently solved.

items
errors

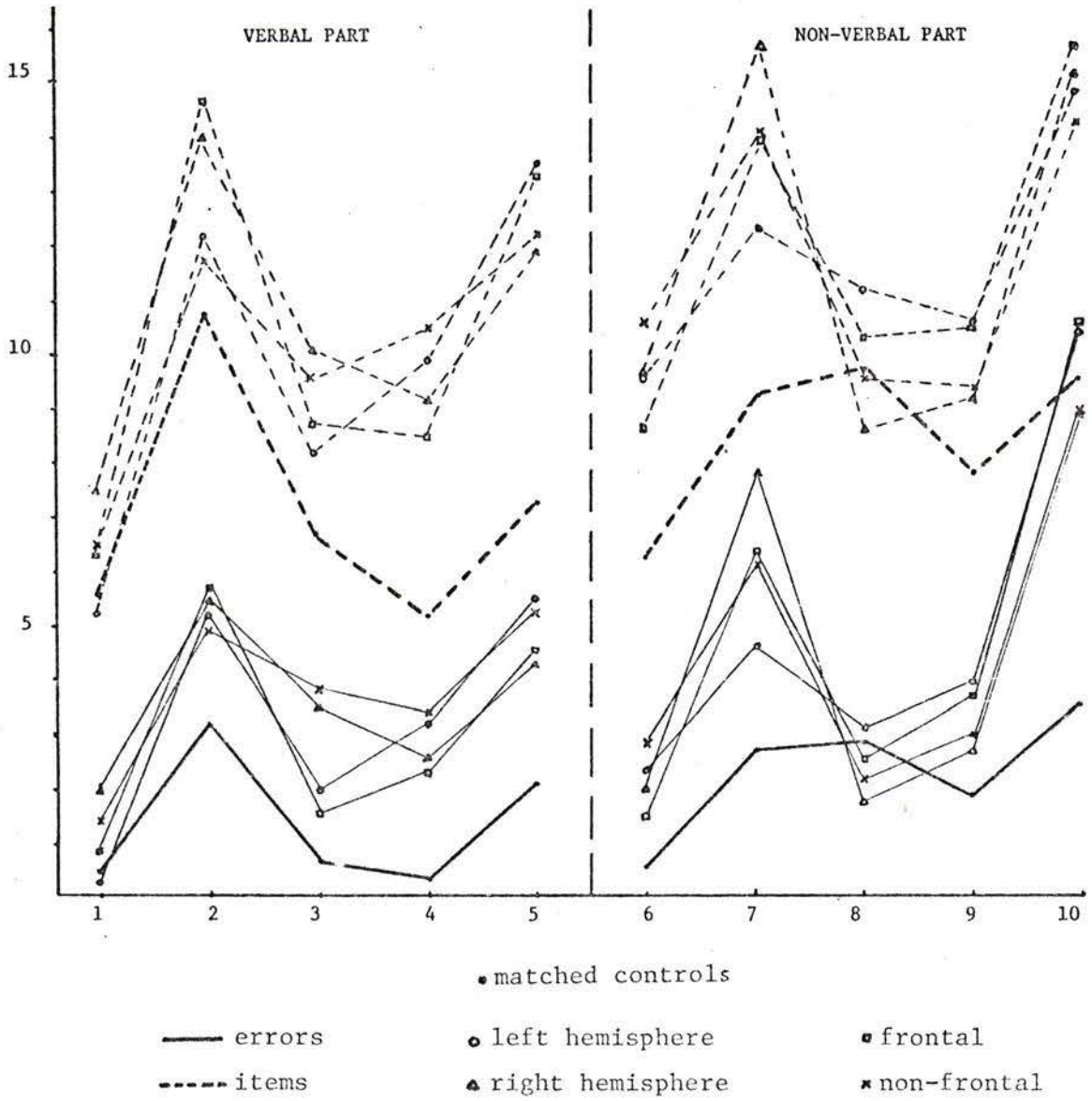


Figure 4: Mean scores CIT concepts: patient groups and matched controls

TABLE 14

Rank order of best and worst solved CIT concepts

Groups	Concepts				
	1	worst 2	3	9	best 10
normal controls	10	2	7	6	1
	2	8	10	4	1
left hemisphere	10	7	2	6/1	8
	7	10	2	8	1
right hemisphere	10	5	2	3	1
	10	5	7	3	1
frontal	10	7	2	6	1
	10	2	7	4	1
non-frontal	10	7	5	6	1
	10	2	5	9	1
left frontal	10	7	2	1	4
	10/7	2	5	3	1/4
right frontal	10	2	5	6	1
	10/2	5	8	6	1

first line = concept order for error variable
second line = concept order for item number variable

The exception to the rule that concepts 10, 2 and 7 were the hardest to solve, was that patients with lesions in the right hemisphere had difficulties also with concepts 5 and 8. Concept 8 (spatial rotation) was best solved by patients with left hemisphere, mainly frontal, lesions. As expected, the two introductory learning concepts (1 and 6) were solved best by all groups.

5.4 Order of tests

No significant test order effect was found between order 1 and order 2 for the alternated tests (multivariate test of significance: $F = 1.58$, $p < .184$).

5.5 Intelligence

The IQ estimated on the basis of the two subtests, vocabulary and block design, correlated significantly with six out of eleven variables in brain damaged patients. Significant correlations were found with the number of concepts in the CIT ($r = .385$, $p < .006$) and with the non-verbal part of the CIT ($r = .352$, $p < .014$) as well as with other variables of the CIT: the total number of errors ($r = -.576$, $p < .001$) and the total time ($r = -.468$, $p < .001$). No significant relationship was found between the estimated IQ and the VVQ. Finally, the estimated IQ

correlated with the Five Point Test ($r = .52$, $p < .001$) and the number of repetitions in Word Fluency ($r = .49$, $p < .001$). No significant correlations were found with the Stroop Test and the total number of words produced in Word Fluency.

6. DISCUSSION

The results of this study will be discussed in terms of the predictions made. First, the results of the healthy subjects and then the results of the patient groups will be commented upon. A more general discussion will then follow in an attempt to describe more clearly some of the test variables and subject variables that influence cognitive rigidity-flexibility.

6.1 Performance of the healthy subjects

There was no significant difference between the two fluency tests assessing spontaneous flexibility. The correlation between the two tests was low. Both tests were assumed to measure one function, i.e. fluency. However the two tests varied in stimulus mode and required different, complex cognitive operations. The prediction made on the basis of previous data that verbal output would be higher than non-verbal output could not be confirmed. Cultural and language differences might account for the generally higher performance of the American population compared to the Swiss population, since both were comparable in age, education and IQ estimate (Regard, 1980). Furthermore, the introduction

of two standard examples in the Five Point Test with the American sample might account for some of the differences. Also, most of the Swiss students were fluent in more than one language and it is likely that this created some output interference in Word Fluency.

The correlation between the total output as well as the number of repetitions in both fluency tests was significant but small. The number of errors made in the tests were not significantly related.

With regard to the tests used to assess adaptive flexibility the following findings can be reported. In the Stroop Test the expected performance pattern was found. The difficulty increased from plate I to plate III. Most errors occurred and the slowest reading times were found on plate III which was designed to provide the strongest interference. For the purpose of this study, Perret's (1974) version of the test was translated into English. A comparison of the new data with previous investigations (Perret, 1974; Regard, 1980), shows again, though less pronounced, that the English speaking population reads the color names faster than the Swiss population.

Between the Stroop Test (reading time, part III) and the second measure used to assess adaptive flexibility, the total number of concepts in the CIT, no significant relationship was found. However, the number of errors in

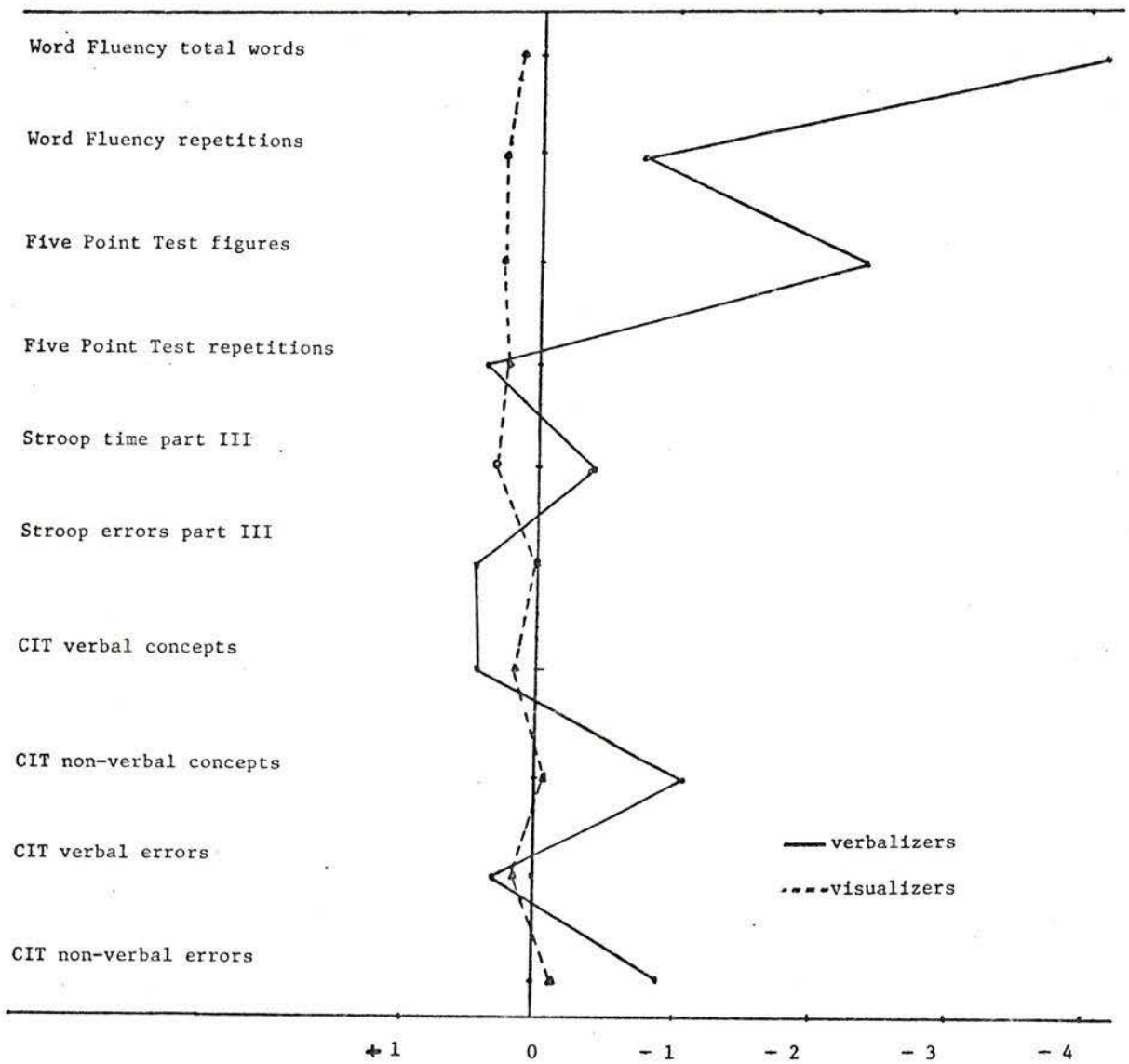
the Stroop Test was significantly related to the verbal part of the CIT as well as to the overall time for the CIT.

In the analysis of tests assessing spontaneous and adaptive flexibility significant correlations were found between the Stroop Test and the number of errors on the Five Point Test. A factor analysis, which was computed to assess whether dimensions for type of task (spontaneous and adaptive flexibility) or for type of stimulus used in the tasks (verbal and non-verbal) could be found showed that the first factor extracted represented a non-verbal dimension. The verbal stimulus mode was found to be represented in two separate dimensions, one for verbal spontaneous flexibility and one for verbal adaptive flexibility. Frick et al (1959) were able to extract two separate factors for the type of flexibility but they did not test the influence of stimulus mode. As this study shows, stimulus mode affects the performance on the two types of task. This element was not compared in previous investigations. Breskin's studies with a non-verbal flexibility test showed no relation to a Stroop task nor to verbal fluency. A distinction between different types of flexibility tests, as Frick et al (1959) proposed seems to be dependent on the actual type of tests chosen and the statistical decisions made by the researcher. These authors, for example, accepted test loadings as low as .30 in the description of their factors.

The factor analysis in this study did not show a unitary "rigidity" dimension. The error variables of all tests used did not load on one single factor. This finding supports Chown's (1959) and Goins' (1962) notion that rigid performance on one task is not necessarily predictive for the performance on another flexibility task. In the current study, error measures loaded on different dimensions: for tests applying a verbal stimulus mode, two separate dimensions were found, and for tests applying non-verbal stimuli one dimension was found. This finding questions the conceptualization of cognitive rigidity-flexibility as a unitary dimension. As Chown (1959) proposed, it is more meaningful to find task specific names instead labeling tests, which assess only one aspect of rigidity, as flexibility tests. The factor "verbal spontaneous flexibility" could then remain "Word Fluency". Also, since the non-verbal fluency test had as little in common with Word Fluency as the Stroop Test, it is more meaningful to talk about non-verbal flexibility in connection with visual-spatial abilities.

It was predicted that imagery style might influence the performance on flexibility tasks but the results lend only partial support to that prediction; specifically it was found that (1) a higher imagery ability is correlated with more flexible behavior, i.e. reduced rigidity, and (2) that

different styles of imagery overlap with different task performances. Since the VVQ scores were normally distributed from high to low scores, not many subjects had an extreme "verbalizer" or an extreme "visualizer" score. Therefore, the hypothesis that imagery style is related to certain kinds of performances can not be rejected. If we consider only the extreme cases, the results could be interpreted to mean that in fact "verbalizers" performed different than "visualizers". As Figure 5 shows "verbalizers" scored lower on both fluency tests and significantly lower on the non-verbal part of the CIT. The "visualizers" on the other hand performed similarly to and in some tests even higher than the whole sample. Test intelligence seems not to account for this finding (IQ estimate for the verbalizers, \bar{M} =28.0, for the visualizers, \bar{M} =28.2).



(zero z-scores are based on the three groups of imagery style)

Figure 5: Z-score profiles for verbalizers and visualizers:
normal controls

The VVQ was significantly related to concept 4 of the CIT: the higher the VVQ score the less items were needed to find the correct answer. This finding suggests that higher VVQ scores facilitated the solution of the CIT concepts which require imagery ability. These results support the findings by Katz and Paivio (1975) and Durndell and Wetherick (1976) who showed that high imagery ability does in fact facilitate concept identification. However, such a conclusion based on the current findings would assume that the sets which required imagery ability were all of comparable difficulty. Whether or not this was indeed the case cannot be answered since a difficulty rating was not part of this study; one could conclude, however, that next to the two learning concepts, concepts requiring imagery ability were the easiest to solve. Katz and Paivio (1975) also failed to prove that pictures facilitated conceptualization better than words. The non-verbal stimuli used in the CIT were difficult to label and imagery could only be applied successfully after some kind of translation. The current study includes no evidence that there is superiority of high imagers for the perceptual processing of abstract figures. Ernest (1979) found superiority of recognition only after non-verbal priming of her subjects.

One could argue that the non-verbal part of the CIT was obviously harder because the figures were difficult to label. If that were the case, one would expect that

"verbalizers" find this part of the test easier since it is their preferred cognitive style, but such a trend was not found. Furthermore, if the non-verbal part were the more difficult one, one would expect to find different mean performances for the two parts in the "mixed group". However, the twenty-five subjects in this group found an equal number of concepts in the verbal and non-verbal part of the CIT ($\bar{M} = 4.76$; $\bar{M} = 4.72$).

Paivio's dual coding theory assumes that abstract material is represented in the verbal system. No studies were available which tested this theory in the context of non-verbal abstract stimuli. All the studies mentioned used pictures or simple figures i.e. easy to label material. The current investigation cannot support Paivio's theory because the results lean more in the opposite direction, i.e. habitual verbalizers have more difficulty with abstract stimuli and have no advantage over visualizers with verbal stimuli as previously suggested (e.g. Stewart, 1965).

Another conclusion from the current study can be drawn: imagery style seems not to be a constant characteristic of a person's thinking style, but fluctuates over time. Healthy subjects seem to change their cognitive style depending on the task demands. Styles then vary inter- and intra-individually, and it looks as if imagery style is a "flexible" style in higher order processing. Richardson's (1981) comments point to the possibility that a preferred

style can develop: "Cognitive style dimension of verbalizer-visualizer develops throughout childhood and adolescence, partly on the basis of self discovery. Thus one may come to realize that on the whole spatial tasks or tests are easier than verbal tasks or tests, or vice versa. As a result, one may develop an habitual preference for processing information in one way rather than another. From this it may sometimes happen that a significant correlation emerges when scores on the VVQ are related to scores on a spatial or verbal test". He further says: "However, no logical necessity requires this because an individual may be equally skillful in handling both types of cognitive tasks or tests. Only where an individual is considerably better on one or the other of the verbal or spatial ability tests would a correlation with the VVQ be likely". This last statement is in agreement with the findings of the current study.

Subtests of the WAIS served as control variables for the verbal and non-verbal aspects of the tests used in this study. It was found that block design was more strongly related to tests using non-verbal stimuli, than was the vocabulary subtest with verbal tests. This finding might be interpreted to mean that functions required in the CIT and the Five Point Test share something that is also required in the block design test. The unexpected relationship between

this test and the verbal part of the CIT might indicate that in fact this part requires more visual-spatial processing than the verbal part, even though the stimuli of the verbal part were letters. Another possible explanation for this finding could be that the variable "speed" is shared between these tests.

The CIT was explored separately because it was a new test developed for the purpose of the current study. It was predicted that concepts requiring mental transformation would be hardest to identify. This prediction could not be supported. On the contrary, it seems that concepts that require the suppression of interfering stimulus attributes were the most difficult. This finding appears to be independent of stimulus mode. Interference by a different mode than the stimulus which the subject has to respond to, as used in the verbal part of the CIT, was found not to reduce the quality of the performance as has been suggested by Morton (1969), Allen et al (1978), and Schorr (1978). An explanation for this discrepancy might be that the verbal stimuli in the CIT were meaningless and therefore not eliciting more interference than the nonsense figures used as stimuli in the non-verbal part of this test. Also, it can not be determined what kind of conflict was more active, a perceptual, a conceptual or a response conflict.

The significant relationships between VVQ and some concepts of the CIT, together with the fact that imagery concepts seemed easier, support the notion that imagery ability is facilitating for concept identification (Katz and Paivio, 1975; Durndell and Wetherick, 1976). Kendler and Kendler (1962) found that verbalization does facilitate concept identification. The Kendler study was investigating the behavior of children; it is possible that adults use different strategies when dealing with such tasks (Wolff, 1967), i.e. that verbal ability and imagery ability are not to be regarded as opposites in adults. It is more likely that a combination of both is used in concept identification. Furthermore it was predicted that verbal concepts would be easier to identify because less ambiguous labels can be applied. This was confirmed by the results. Significantly more concepts could be identified in the verbal part of the CIT than in the non-verbal part. The unexpected correlations between vocabulary and the non-verbal part of the test and between block design and the verbal part lead to the speculation that when verbal abilities are applied in solving the verbal part of the CIT, interference occurs. On the other hand, attempts to verbalize the stimuli in the non-verbal part of the test facilitate the task. It can be presumed that the habitual use (meaning) of the letters in the verbal part has to be suppressed. Since "verbalizers" found fewer non-verbal

concepts than "visualizers" and since a higher vocabulary score was related to more correct non-verbal concepts, one can conclude that high verbal ability is not necessarily identical to verbal preference in thinking style.

6.2 Performance of brain damaged subjects

Since the analysis of the performance of brain damaged patients was based on a very small number of subjects, interpretations have to be made with caution. The main object of this section is to point out differences and communalities between the performance of patients and normal control subjects. Whenever possible and available, the differences between patients with left and right, and frontal and non-frontal lesions will be included. It should be kept in mind that the exploration of the differences between patient groups with different localized lesions remains exploratory at this time because of the small number of patients available.

As predicted, patients significantly differed from their matched controls in all tests except for the VVQ.

In Word Fluency patients had on average of only about 54 percent of the normal output. The established finding that patients with lesions in the left hemisphere produce less words than patients with lesions in the right hemisphere and patients with frontal lesions less than patients with non-frontal lesions is, at least as a trend supported.

Patients with lesions in the left hemisphere made also the highest number of errors. The modification of this test does not seem to change the established findings in the literature. Cauthen (1978) reviewed various types of verbal fluency tests, which differ in output mean and time and concluded that the instrument remains the same despite the variability in measurement techniques.

As for the Five Point Test, the previous result that patients with right hemisphere lesions produce the fewest number of figures could not be confirmed (Regard, 1980). Patients with right hemisphere lesions did make the largest number of repetitions but the group variance was large.

The fluency tests were more highly correlated in patients than in the control group. The flow of associations seems more quickly exhausted in brain damaged patients than in normals; this lack of flow produces blanks or repetitions. Repetition errors in associational fluency seem to occur similarly in all brain damaged patients independent of stimulus type.

The inspection of the Stroop Test results supports previous findings presented by Perret (1974) and Regard (1980). Patients with left hemisphere lesions had the longest reading times and made the largest number of errors followed by patients with frontal lesions, i.e. these patients had the most difficulty in suppressing verbal interference.

For the CIT the hypothesis that patients with frontal lesions would find the least number of concepts could statistically not be confirmed but inspection of the data showed the weakest performance for this group. The neuropsychological literature agrees that such patients, compared to patients with other cortical lesions, have more difficulties in shifting and in dealing with abstract concepts. Patients with right frontal lesions performed worse than patients with left frontal lesions. This result tends to favour the second hypothesis which predicted that patients with right frontal lesions will perform poorest on this test because they are not only impaired in shifting ability but also in their visual-spatial abilities. It is possible that such patients cannot make the necessary interconnection between imagery and verbal symbol. Patients with lesions in the left hemisphere did not have the lowest performance on this test. This, together with the findings in healthy subjects (as discussed above), is again not supportive of the notion that verbal abilities are crucial for successful concept identification.

A detailed analysis of the CIT performances showed that in the verbal part of the CIT patients showed a similar pattern as the controls, i.e. they had difficulties with the same concepts whereas in the non-verbal part, groups differed. In the non-verbal part, the more complex part of the test, patients with right hemisphere lesions and

patients with frontal lesions had additional problems with the non-verbal concept requiring rotation. This trend is congruent with Regard's (1976) earlier report that rotations elicit different problems for patients with frontal lesions as compared to patients with lesions in the right hemisphere.

The predictions made for the VVQ in brain damaged patients could not be supported on the basis of the small groups of patients with focal lesions. No imagery style was consistently found in a particular patient group. Patients with left hemisphere lesions tended towards lower scores compared to patients with right hemisphere lesions. Patients with right frontal lesions had the lowest scores (verbalizers). The general hypothesis of this study that patients with frontal lesions might lack the ability to mentally transfer information due to poor imagery ability cannot be rejected. As suggested by Zenhausern (1978) the two extremes of the VVQ scale might better be labeled visual and non-visual. In brain damaged patients rigidity appears to be a more unitary behavioral manifestation than it is in normal subjects. The correlations between flexibility tests were generally higher and more frequent for the patient group. In patients, it also seems that type of task (spontaneous or adaptive) and stimulus mode are of less importance for performance than in normals. However, further investigations are needed to confirm this finding. It needs

also to be clarified how stimuli which are hard to label and which do not allow for verbal control are affected by unilateral lesions.

6.3 Some variables influencing cognitive rigidity-flexibility

In this section an attempt is made to single out the variables which are of importance for the performance on flexibility tests. The order in which they are discussed does not represent a rank order.

6.3.1 Test variable: stimulus mode

The literature on imagery suggests a verbal and non-verbal dimension in imagery style. Furthermore, for the fluency tests, previous data in the verbal and non-verbal stimulus mode were available. In the neuropsychological literature it is still controversial whether this dichotomy is one of the parameters distinguishing hemisphere functions. Many research findings and clinical evidence indicate that the left hemisphere is involved in the more analytical, sequential or categorical processing, i.e. the kind of processing involved when language is produced or received. The salient feature of left hemisphere function is not the ability to generate speech but the ability to

make the context logical. On the other hand, since the right hemisphere is more involved in wholistic, simultaneous or parallel processing, it is better prepared to deal with visual-spatial tasks. It follows then that dealing with verbal or non-verbal stimuli in a test is not identical to verbal or visual-spatial processing.

The factor analysis revealed different dimensions for stimulus mode. Other investigations have shown that verbal and non-verbal abilities are factorially independent (e.g. Paivio, 1971; Guilford, 1967). The results of this study confirm that tests with different stimulus modes do load on different dimensions. However, this finding does not imply that these dimensions correspond to verbal and non-verbal processing. The tasks used in this study, especially the CIT, required not only the recognition of stimuli, but also the performance of some kind of higher cognitive manipulation. In the non-verbal stimulus mode, the type of task did not seem to influence the result as much as it did for tasks employing a verbal stimulus mode. For the verbal mode two dimensions could be distinguished, one for verbal successive processing and one for verbal simultaneous processing (Das et al, 1975). The exploratory study with brain damaged patients might help also to answer whether different cognitive styles are linked with brain organization. This will be discussed in a separate section.

In both the Word Fluency Test and the verbal part of the CIT, the meaning of "verbal" is not identical to language or communication. In fact, in both tests subjects had to suppress the habitual use of language symbols. This in itself is interference. It was suggested by Cauthen (1978) that in verbal fluency subjects first make use of associations and search categories; when the string of associations runs out, the task changes into a shifting task, a skill which seems to be independent from stimulus mode is then required. Inspecting the results of the subjects with a preferred habitual verbal thinking style, there is no evidence that these subjects have an advantage in solving the verbal fluency task. Also, higher vocabulary scores, as an index of verbal skills in general, did not correlate with this test. Vocabulary correlated only with one other verbal variable, the number of repetitions in Word Fluency. This might indicate that the flow of associations is under better control in subjects with higher verbal skills. The correlation between the block design test and the verbal part of the CIT, on the other hand, allows the conclusion that processes other than language were active. Paivio (1978) showed that serial and global processing can interact with verbal and imagery processes, i.e. a typical verbal task can be processed globally and a typical imagery (visual) task can be processed serially.

In summary, the results suggest that stimulus mode does influence performance on flexibility tests. Tests with non-verbal stimuli form a separate dimension from tests with verbal stimuli. In the Word Fluency Test and the verbal part of the CIT subjects made fewer errors than in their non-verbal counterparts. Verbal and non-verbal stimuli do elicit different processing styles; processing styles are different, not parallel. Further studies are needed to determine exactly in what way they are different.

6.3.2 Test variable: type of task

Two types of tasks were distinguished in this study: spontaneous flexibility tasks or fluency tests and adaptive flexibility tasks. These two categories were chosen according to factor analytic studies by Frick et al (1959). The current study was partially able to replicate these two dimensions. It was found that the type of stimulus mode is one of the variables to be distinguished. As mentioned earlier, tests with a non-verbal stimulus loaded on the first factor and tests with a verbal stimulus loaded on two dimensions, one for spontaneous and one for adaptive flexibility. No previous studies were available to support this finding. Previous investigators either studied just one flexibility dimension or did not distinguish between tests with different stimulus modes.

The correlations found among the various tests, and the results of the factor analysis suggest that it is not meaningful to stick to two flexibility dimensions, unless the labels are used in a more circumscribed, limited sense. Instead, it would be more appropriate to inspect the four different tests and clarify the processes and abilities needed to solve them successfully. Just as Chown (1959) and Goins (1962) suggested, in healthy subjects a rigid performance on one test is not predictive for the performance on another flexibility test.

As discussed already, it seems likely that in the fluency tests the task demands change within the test (Cauthen, 1978), i.e. the tests designed to assess spontaneous flexibility might turn into an adaptive flexibility test. It would have to be determined how and under what circumstances such a change takes place.

All four tests used in this study to assess the two flexibility dimensions involve different cognitive abilities, ranging from sensory to complex mental functions. For the Stroop Test, Stirling (1979) was able to demonstrate two loci of effects: stimulus effects occurring during conceptual coding, and response effects occurring during response selection.

The question is not what type of task measures cognitive flexibility- rigidity more appropriately than another, the question is what different aspects of flexibility are

assessed with a task. Inspecting the errors made in the four tests, the repetitions in the fluency tests did not correlate with the errors made in the tests to assess adaptive flexibility. The number of errors made in the Stroop Test were related to the verbal part of the CIT. All four tests then seem to probe different aspects of function and consequently provoke different types of error. Several decades ago, Notcutt (1943) already disproved Spearman's "law of inertia" by showing that different perseveration measures need not correlate. He distinguished four types, (a) the "creative effort type", (b) the "alternative type", (c) the "associative type", and (d) the "sensory type" of perseveration. The factor analysis in the current study also suggests different error types. Following Notcutt's categories there would be a d-type (errors made within the verbal and non-verbal stimulus mode), and a combined a-b-c-type (errors made within the verbal stimulus mode). Similarly, Forster et al (1955) explored the performance of subjects in different shifting tasks. They could not find a common rigidity-flexibility factor and there was little correlation among the tasks.

What can be concluded about the influence of type of task on cognitive flexibility? Since the study did not find two distinct factors for type of task it is more appropriate to describe cognitive rigidity-flexibility in terms of specific tasks. Also, the tasks can be described in terms of error

type they evoke: errors due to a difficulty in suppressing a previous answer or due to lack of new associations or due to strong interference. The type of tasks used in this study could also be distinguished according to whether the response choice is small or large: spontaneous flexibility tests were tasks with a large choice and adaptive flexibility tests were tasks with a small choice (a fifty percent chance of being correct).

6.3.3 Subject variable: imagery style

From the results with healthy subjects it appeared that people with a more verbal style perform more poorly in flexibility tests than people with a visual style. It was discussed earlier that imagery style should be understood as a "flexible" behavior characteristic. In patients, no significant differences were found between imagery style and locus of lesion. The questionnaire did, however, significantly correlate with time measures in the Stroop Test and the CIT, indicating that visualizers solve such problems faster than verbalizers. In healthy subjects such relationships were not found.

The generally weak relationships between imagery style and performance in the flexibility tests have already been discussed. It was reasoned that the basis for the predictions in this study was derived from investigations

that dealt with the extreme ends on the imagery style dimension. However, in a random sample of young people the scores were normally distributed and no dichotomy in style was found. Also, in patients a higher percentage (38) of the subjects were verbalizers and most frequently represented in the groups with left hemisphere and right frontal lesions, an observation which can either reflect a lesion effect or the premorbid, individual imagery style.

It is important to caution that imagery style should not be confounded with imagery ability. Zenhausern's reasoning for a reflection of cerebral dominance in imagery style was based on mixed evidence, partially from studies dealing with imagery style and partially from others dealing with imagery ability. Even if in fact imagery style can be found to correlate with tests measuring imagery ability (which could not be found in this study), it is not necessarily logical to conclude that they are the same thing.

This study suggests that imagery style is a variable characteristic of the individual and does not function like an "ability" that develops to a certain level. An attempt was made by Richardson (1977) to clarify the test-retest reliability of his questionnaire, but more research is needed with other populations to demonstrate if such a style dimension has any and what kind of predictive validity. Even before further correlational studies get under way, better measurements need to be developed (Strosahl, 1981).

6.3.4 Subject variable: intelligence

Historically, flexibility has always been regarded as part of the qualities that make a person behave intelligently (e.g. Spearman, 1927; Guilford, 1967). Later, many other investigators showed that intelligence and cognitive rigidity and flexibility need not be closely related. Since the concept of intelligence is not clearly defined in the first place, it is not clear from what part of the concept of intelligence flexibility should be distinguished. However, some authors who studied cognitive flexibility also provided information regarding the relationship to intelligence. Both, Carlier (1971) and Schultz (1977) found no significant relationship between spontaneous flexibility tests and test intelligence, and Forster et al (1955) found no relationship between adaptive flexibility tests and intelligence. The neuropsychological literature agrees that patients with frontal lobe lesions are more rigid than patients with lesions elsewhere in the brain (Walsh, 1978), but there is no evidence that frontal damage affects commonly used IQ measures (Rylander, 1939; Mackie and Beck, 1966; Stuss et al, 1981).

In the current study, the sum of the vocabulary and block design scaled scores correlated with most of the tests. The relationship was stronger with tests in the non-verbal stimulus mode than with tests in the verbal stimulus mode.

This might either express that non-verbal tests are more difficult per se, or that visual-spatial skills facilitate the performance on these tests. Since the estimated IQ correlated with the overall time needed to solve the CIT, it might have been a "speed" factor that led to the relationship between IQ and the non-verbal tasks. The speed factor was not explored in detail in this study, but its significance upon rigidity and intelligence is well known (e.g. Rokeach, 1955; Fourneaux, 1960; Payne, 1960).

As the early studies showed, only certain cognitive abilities decrease with low IQ and are consequently related to more rigid behavior. Lack of intelligence therefore is not directly related to rigidity (Mackie and Beck, 1966).

6.3.5 Subject variable: age

The design of this study did not include age as a variable. Nevertheless, some a posteriori comparisons were made and will be commented upon. It is a long-held belief that older age is closely related to increased rigidity, but Chown (1961) and Botwinick (1978) reviewed the literature and concluded that rigidity is not necessarily part of the life style in the elderly. From among the recent flow of investigations, only a small number can be included here, but the reader is referred to a study on cognitive rigidity and flexibility in young and old adults (Ermini, 1981). The

age range in the normal group in the current study was small (15 years). Significant correlations with age for this sample were found for the Stroop Test, reading time part III ($r = .28$, $p < .042$), and the total number of errors made in the CIT ($r = -.28$, $p < .040$). The correlation matrix for the brain damaged subjects, whose ages ranged from 20 to 76 years, revealed many significant correlations. Only a moderate correlation was found with verbal fluency ($r = .44$, $p < .044$). This finding supports the results of Cauthen (1978) and Ermini (1981), who both found no age effect for verbal fluency comparing two age groups with healthy educated subjects. Verhoff (1980) on the other hand, demonstrated an age effect in males on this variable. Benton et al (1981) found a minimal decline in verbal fluency in a mixed gender sample of healthy old people below 80 years of age and only an eleven percent decline in subjects older than 80. Strauss et al (1981) found an increase in performance up to age 10 in a study with children ranging in age from 6 to 12 years.

As for non-verbal fluency, no age relationship with the Five Point Test was found in the current study. Strauss et al (1981) again found a performance increase with age in children. Ermini (1981) found a significant decrease with age for older women, but the mean was still comparable to the performance of the 12 year old children in Strauss' study.

In summary, fluency performance seems to increase in childhood and young age independent of sex, and then to decline more rapidly for males than females in old age.

The reading time in the Stroop Test was also age related in young and old healthy subjects (Ermini, 1981) as well as in brain damaged patients. In the current study age correlated negatively in brain damaged subjects with the number of correctly identified concepts in the CIT, and positively with the total number of errors and the total time. Ermini (1981) reported a significant decline for her group of older women for the verbal part of the test only. Wetherick (1965) also found a failure to change verbal concepts in old males.

Imagery style was not related to age in the normal group. Additional data was collected with the VVQ from 20 healthy older women (mean age: 66.8, range 15 years). The mean score was 6.3, SD 2.15 and, compared to the 40 women in this study, was significantly lower ($t = 4.41$, $p < .001$). This would indicate a tendency in older subjects toward the "verbalizer" style. But Kosslyn (1980, p.420) cautions against such an inference and says that there is no guarantee that imagery questionnaires test the same function at different age levels.

To sum up, the current investigation and Ermini's study did not find age differences for the error measures in the fluency tests and the Stroop Test. Only in the verbal part

of the CIT, more errors occurred with age. This result supports the views of Chown (1961), Angleitner (1973), and Botwinick (1978) that cognitive rigidity is not increasing with age in general. The changes are test specific and might, as the above mentioned results show, depend on stimulus mode as well as other variables. They might not even represent age effects at all. All investigations mentioned were cross-sectional studies and Schaie (in Birren and Schaie, 1977) went so far as to say that declines in cognitive flexibility are due to cohort differences and not age changes.

6.3.6 Subject variable: gender

This study provided no evidence for sex differences (see Appendix A). However, a closer inspection of the performance of males and females revealed some results which showed a trend for females to deal better with verbal than visual material. Even though this study cannot support any findings which show sex differences in cognitive flexibility tests, a very brief excursion into the literature is indicated.

For verbal fluency, no sex differences have been reported in other investigations (Maccoby and Jacklin, 1974, p.82). For the Five Point Test, Strauss et al (1981) found also no difference between boys and girls and Torrance (1966) found

no sex differences in his figural fluency test. Only Carrier (1971) found sex related differences in a non-verbal flexibility test. Stroop (Maccoby and Jacklin, 1974, p.99) found no differences although Alpaugh and Kaufmann (1972) and Golden (1974) reported that males made more errors than females in this test. As for the CIT, no studies are available for comparison. Hoyer et al (1979) investigated sex differences unsuccessfully on a problem solving task with varying irrelevant stimuli. For the VVQ, no sex differences have been published. Ernest (1979) found a significant interaction between imagery and sex, but in this study imagery was defined on the basis of spatial manipulation tests.

The sparse and sometimes controversial evidence for gender differences in tests assessing cognitive rigidity and flexibility leads to the conclusion that gender appears to be a variable of little importance for this behavioral dimension.

6.3.7 Subject variable: brain damage

The results of the brain damaged subjects have already been discussed in detail. The question which remains to be addressed is whether there is evidence to determine the influence of brain damage on cognitive flexibility. One source of evidence is the finding that the correlations

between the test measures were more frequently significant and higher in brain damaged than in normal control subjects. This can also be interpreted as evidence that a low or high performance on one test is in general more predictive for the performance on another test within the brain damaged population. Rigidity seems to be a more general symptom in brain damaged than in normal subjects.

In this study some tentative evidence was found that site of lesion affects cognitive rigidity-flexibility. Such evidence has to be regarded in the context with other variables discussed. The following error analysis (Table 15) was calculated to exemplify the influence of site of lesion on rigidity in fluency and concept identification. The percent error is to be understood as the inverse of the percent of flexibility. This analysis reveals that patients with left hemisphere lesions, especially with non-frontal lesions, make the largest number of errors in Word Fluency. In the Five Point Test, patients with right hemisphere lesions, frontal and non-frontal, produced the largest number of repetitions. In the CIT patients with right frontal lesions produced the largest number of consecutive errors, i.e. almost sixty percent of the total errors made.

This discussion suggests that the term "brain damage", used as a title of this section may not appropriately describe the actual findings because site of lesion emerges as an important factor. The statistical analysis failed to

TABLE 15

Error analysis: patient and matched control groups

groups	n	Word Fluency ¹⁾	Five Point Test ¹⁾	CIT ²⁾
matched controls	16	.4	3.7	30.4
left hemisphere	8	11.1	8.9	47.7
right hemisphere	8	2.1	23.9	55.0
frontal	8	5.4	12.1	53.0
non-frontal	8	4.7	23.1	49.7
left frontal	5	7.1	7.7	46.6
left non-frontal	3	24.9	11.3	48.8
right frontal	3	2.8	18.3	59.4
right non-frontal	5	1.9	26.2	50.5

1) percent of total output

2) repetition errors (more than two consecutive errors in percent of the total errors made in all ten concepts)

reach significance because of the small number of subjects.

However, case studies or studies with small numbers of subjects may be of importance for a fuller exploration of complex relationships, as Shallice (1979) has pointed out.

Hopefully, new studies will allow to discuss the effect of brain damage according to site of lesion.

Neuropsychologists are aware of the symptom of rigidity and assign the defect mostly to frontal lobe dysfunctions

(Walsh, 1978). A pronounced and general defect of patients with frontal lobe lesions in cognitive flexibility tests

could not be demonstrated in this study. It is important to remember that tests of the general area of cognitive rigidity-flexibility elicit errors which depend on stimulus mode and type of task. Furthermore, as another recent study in this field shows (King and Snow, 1981), tests have to be carefully analyzed with respect to task demands, i.e. the probable processes involved in successfully solving a task, before a behavior can be labeled as a specific defect.

7. CONCLUSIONS

The primary goals of this study were to investigate the relationships among several different flexibility tests and to learn more about the effects of various test variables and subject characteristics. In normal people it was found that it is perhaps more appropriate to talk about flexibilities in a plural rather than a single dimension. The results of this study support to some degree the view that cognitive rigidity-flexibility involves several dimensions.

In this study qualitative and quantitative aspects of rigidity-flexibility were distinguished. It can be concluded that an operational definition of rigidity-flexibility has to include the function of test variables (stimulus mode and type of task) and varies dependent on subject variables (brain damage, imagery style and age). Still, the definition remains incomplete since there is variance which is not explored in the experimental situation, i.e. how does assessed rigidity behavior correspond to real life situations (Thompson, 1966). As long as there is understanding that the construct stands for a variety of different behaviors which are again influenced by various

variables the term does not need to be abandoned. An analogy would be the term "forgetting". Questions like forgetting what, under what kind of circumstances, etc. follow immediately. Applied to rigidity the question would be rigid in what, because of what etc. These are the type of questions to be addressed. Some answers were found and discussed.

Some of the more specific suggestions concern the individual tests used in this study. In addition to the mentioned suggestions in the discussion part, in future studies with fluency tests it should be investigated whether subjects follow more one part of the instructions than another. Do subjects pay more attention to the word "different" in the instruction (draw/say as many different figures/words, see Appendix B), which might elicit more "flexibility", or is more attention paid to the word "many", which could elicit more "fluency"? As for the CIT, further validity studies would be important, and more tests of this kind applying non-verbal material (i.e. not figures) are needed.

Cognitive rigidity-flexibility seems to hold better as a unitary concept for a brain damaged population than for healthy people. Historically, the concept was introduced mainly from neuropathological studies. Yet, in this first application of a series of flexibility tests, no general rigidity dimension could be found and the inspection of the

performance of the brain damaged patients revealed different error patterns dependent on site of lesion.

One of the most interesting results found in this study is that the "habitual verbalizing" tendency as expressed in a questionnaire did not result in better performances in any of the flexibility tests. Nor was an advantage on either test seen for patients with left hemisphere lesions, who tended to have lower scores on the verbalizer-visualizer dimension of imagery style. Left hemisphere patients have only a partial loss of verbal functions and it seems that as long some verbal functions are available they are used for processing complex cognitive tasks. As Landis, Cummings and Benton (1980) could show in patients with aphasia, only when verbal strategies are no longer available, can patients' linguistic capacities improve. These authors believe that the functions of the right hemisphere can become fully effective only when access to the verbal processing systems is no longer possible. The assessment of imagery style in patients with lateralized brain lesions remains of interest to explore how efficient the verbal or visual system is; efficient in the sense as to how well can verbalization or visualization of perception and response serve as a corrective and guiding function in performing higher cognitive tasks. Research emphasis should be directed on the effectiveness and degree of participation of different imagery styles and different processing mechanisms.

In this study, rigidity was viewed as a negative behavior. But there are also positive sides to rigidity. People who manifest rigid behavior can perhaps better prevent stimulus overflow, can suppress inappropriate answers, or rigidity may simply strengthen endurance.

The old problem of whether lesion studies are the appropriate model to infer brain mechanisms in healthy people remains. Two major types of studies have traditionally been used: alter brain functions and observe behavior, or alter a behavior and study brain functions. However, recovery studies provide additional information and recently tend to replace lesion studies. In practice, one would have to study carefully the kind of errors made by subjects in flexibility tests; then suitable learning strategies could be taught according to the findings. Recovery studies offer not only a good research approach, but also allow a real-world application of the work.

Finally, the role of several other functions related to the concept of rigidity would be of interest. Specifically, the relation of memory (see Fuster, 1980), attention and language with cognitive rigidity-flexibility need further clarification. Two recent studies investigated the performance of aphasic patients in relation to conceptual thinking with contradictory results. Lubinski et al (1980) found aphasics not impaired in concept formation, though slower, whereas Semenza et al (1980) found selective

impairments according to aphasia type in the understanding of class (two objects or events share the same identifiable superordinate) and thematic relationships of non-verbal concepts (objects or events occur thematically together) relationships of non-verbal concepts.

As is true for all constructs, their existence is only justified if it provokes the researcher to study it in its components. This study tried to disentangle the concept of behavioral rigidity-flexibility. We hope that it contributed toward a clarification of some of the issues.

REFERENCES

- Albert, M.S., & Kaplan, E. Organic implications of neuropsychological deficits in the elderly. In L.W. Poon, J.L. Fozard, L.S. Cermak, D. Arenberg, & L.W. Thompson (Eds.), New direction in memory and aging. New York: Erlbaum, 1980.
- Allen, T.W., Marcell, M.M., & Anderson, P. Modality-specific interference with verbal and nonverbal stimulus information. Memory & Cognition, 1978, 6, 184-188.
- Alpaugh, A., & Kaufmann, L. Color perception, interference of word frequency, recency of exposure, and familiarity with color names. Unpublished manuscript, 1972.
- Angleitner, A. (Factor analysis of the concept of rigidity). Archiv fuer Psychologie, 1973, 125, 73-104.
- Basso, A., Bisiach, E., & Luzzatti, C. Loss of mental imagery: a case study. Neuropsychologia, 1980, 18, 435-442.
- Becker, W.C. Perceptual rigidity as measured by aniseikonic lenses. Journal of Abnormal and Social Psychology, 1954, 49, 419-422.
- Benson, D.F. Aphasia, alexia and agraphia. New York: Churchill Livingstone, 1979.
- Benson, D.F., & Blumer, D. (Eds.). Psychiatric aspects of neurologic disease. New York: Grune & Stratton, 1975.
- Benson, D.F., Stuss, D.T., Naeser, M.A., Weir, W.S., Kaplan, E.F., & Levine, H.L. The long-term effects of prefrontal leucotomy. Archives of Neurology, 1981, 38, 165-169.
- Benton, A.L. Differential behavioral effects in frontal lobe disease. Neuropsychologia. 1968, 6, 53-60.
- Benton, A.L., Eslinger, P.J., & Damasio, A.R. Normative observations on neuropsychological test performance in old age. Journal of Clinical Neuropsychology, 1981, 3, 33-42.
- Berg, E.H. A simple objective technique for measuring flexibility in thinking Journal of General Psychology, 1948, 39, 15-22.

- Bianchi, L. The functions of the frontal lobes. Brain, 1895, 18, 497-530.
- Birren, J.E., & Schaie, K.W. (Eds.). Handbook of the psychology of aging. New York: Van Nostrand Reinhold, 1977.
- Black, F.H. Cognitive deficits in patients with unilateral war-related frontal lobe lesions. Journal of Clinical Psychology, 1976, 32, 366-372.
- BMD Manual. Biomedical computer programs. Health Science Computing Facility. Los Angeles: University of California, Los Angeles, 1979.
- Botwinick, J. Aging and behavior: A comprehensive integration of research findings. New York: Springer, 1978.
- Bourne, L.B. Human conceptual behavior. Boston: Allyn and Bacon, 1966.
- Bradshaw, J.L., & Nettleton, N.C. The nature of hemispheric specialization in man. The Behavioral & Brain Sciences, 1981, 4, 51-63.
- Breskin, S. Measurement of rigidity, a non verbal test. Perceptual and Motor Skills, 1968, 27, 1203-1206.
- Breskin, S., Gorman, B.S., & Hochman, H.S. Non verbal rigidity and perseveration. Journal of Psychology, 1970, 75, 239-242.
- Brickner, R. An interpretation of frontal lobe function based upon the study of a case of partial bilateral frontal lobectomy. Research Publications, Association for Research in Nervous and Mental Disease, 1934, 13, 259-351.
- Bruyer, R., & Bontemps, N. Lésion du cortex cérébral et percéption de la durée: approche neuropsychologique de la "chronognosie". Journal de Psychologie, 1979, 3, 279-297.
- Bryden, M.P., & Allard, F. Visual hemifield differences depend on typeface. Brain and Language, 1976, 3, 191-200.
- Bryne, B. Item concreteness versus spatial organization as predictors of visual imagery. Memory & Cognition, 1974, 2, 53-59.

- Butters, N. Soeldner, C., & Pedio, P. Comparison of parietal and frontal lobe spatial deficits in man: extrapersonal versus personal space. Perceptual and Motor Skills, 1972, 34, 27-34.
- Calvano, M.A. The prediction of imaginably mediated paired-associate learning from selected cognitive factors. (Doctoral dissertation, University Southern Illinois, 1973). Dissertation abstracts, 1973, 5706-A.
- Carlier, M. (Differential study of a dimension of creativity). Sciences de l'art, 1971, 8, 29-38.
- Cattell, R.B. On the measurement of perseveration. The British Journal of Educational Psychology, 1935, 5, 76-92.
- Cattell, R.B. The riddle of perseveration: creative effort and disposition rigidity. Solution in terms of personality structure. Journal of Personality 1946, 14, 229-238, 329-367.
- Cattell, R.B., & Tiner, L.G. The varieties of structural rigidity. Journal of Personality, 1949, 17, 321-341.
- Cauthen, N.R. Verbal fluency: normative data. Journal of Clinical Psychology, 1978, 34, 126-129.
- Chown, S. Rigidity - a flexible concept. Psychological Bulletin, 1959, 56, 195-223.
- Chown, S. Age and the rigidities. Journal of Gerontology, 1961, 16, 353-362.
- Cohen, G. The psychology of cognition. New York: Academic Press, 1977.
- Corkin, S. Somesthetic function after focal cerebral damage in man. Unpublished doctoral thesis. McGill University, 1964.
- Damasio, A. The frontal lobes. In K.M. Heilman, & E. Valenstein (Eds.), Clinical neuropsychology. New York: Oxford University Press, 1979.
- Das, J.P., Kirby, J., & Jarman, R.F. Simultaneous and successive synthesis: an alternative model for cognitive abilities. Psychological Bulletin, 1975, 82, 87-103.
- Dennis, M.D., & Whitaker, H.A. Language acquisition following hemidecortication: linguistic superiority of the left over the right hemisphere. Brain and Language, 1976, 3, 404-433.

- De Renzi, E., Faglioni, P., Savoiardo, M., & Vignolo, L.A. The influence of aphasia and of the hemisphere side of the cerebral lesion on abstract thinking. Cortex, 1966, 2, 399-420.
- De Renzi, E., & Ferrari, C. The Reporter's Test: a sensitive test to detect expressive disturbances in aphasics. Cortex, 1978, 14, 279-293.
- Drewe, E.A. The effect of type and area of brain lesion on Wisconsin Card Sorting Test performance. Cortex, 1974, 10, 159-170.
- Durndell, A.J., & Wetherick, N.E. The relation of reported imagery to cognitive performance. British Journal of Psychology, 1976, 67, 501-506.
- Ermini, D. Cognitive rigidity and flexibility in young and old adults. Unpublished master's thesis, Los Angeles: University of Southern California, 1981.
- Ernest, C.H. Imagery ability and cognition: a critical review. Journal of Mental Imagery, 1977, 2, 181-216.
- Ernest, C.H. Visual imagery ability and the recognition of verbal and nonverbal stimuli. Acta Psychologica, 1979, 43, 253-269.
- Ernest, C.H. Visual imagery ability and the recognition of verbal and nonverbal stimuli. Acta Psychologica, 1979, 43, 253-269.
- Feuchtwanger, E. Die Funktion des Stirnhirns, ihre Pathologie und Psychologie. In O. Foerster, & K. Willmanns, (Eds.), Monographien aus dem Gesamtgebiete der Neurologie und Psychiatrie, 1923, 38, 4-194.
- Forster, N.C., Vinacke, W.E., & Digman, J.M. Flexibility and rigidity in a variety of problem solving situations. Journal of Abnormal and Social Psychology, 1955, 50, 211-216.
- Fourneaux, W.D. Intellectual abilities and problem-solving behavior. In H.J. Eysenck, Handbook of abnormal psychology. London: Pitman Medical Publishing, 1960.
- Frick, J.W., Guilford, J.P., Christensen, P.R., & Merrifield, P.R. A factor analytic study of flexibility in thinking. Education & Psychology Measurements, 1959, 19, 469-496.
- Fuster, J.M. The prefrontal cortex. New York: Raven Press, 1980.

- Geschwind, N. Language and the brain. Scientific American, 1972, 226, 340-348.
- Goins, A.E. Rigidity - flexibility: toward clarification. Merrill-Palmer Quarterly, 1962, 8, 41-61.
- Golden, C.J. Sex differences on the Stroop color and word test. Perceptual and Motor Skills, 1974, 39, 1067.
- Goldstein, K. The significance of the frontal lobes for mental performances. Journal of Neurology and Psychiatry, 1936, 17, 27-56.
- Goldstein, K. Concerning rigidity. Character and Personality, 1943, 11, 209-226.
- Goldstein, K. The mental changes due to frontal lobe damage. Journal of Psychology, 1944, 17, 187-208.
- Goldstein, K., & Scheerer, M. Abstract and concrete behavior. An experimental study with special tests. Psychology Monographs, 1941, 2, No. 239.
- Goodglass, H., & Kaplan, E., Assessment of cognitive deficit in the brain-injured patient. In M.S. Gazzaniga (Ed.), Handbook of behavioral neurobiology (Vol.2, Neuropsychology). New York: Plenum Press, 1979.
- Gorman, B.S., & Breskin, S. Non-verbal rigidity, creativity and problem solving. Perceptual and Motor Skills, 1969, 29, 715-718.
- Griffitts, C.H. Individual differences in imagery. Psychology Monographs, 1927, 37, No. 127.
- Guilford, J.P. Fundamental statistics in psychology and education. New York: McGraw Hill, 1950.
- Guilford, J.P. The nature of human intelligence. New York: McGraw Hill, 1967.
- Guilford, J.P., Frick, J.W. Christensen, P.R., & Merrifield, P.R. A factor analytic study of flexibility in thinking. University of Southern California, Reports from the Psychology Laboratory, 18, 1957.
- Halstead, W.C. Brain and intelligence. Chicago: University Press, 1947.
- Hécaen, H. Mental symptoms associated with tumors of the frontal lobe. In J.M. Warren, & K. Akert (Eds.), The frontal granular cortex and behavior. New York: McGraw Hill, 1964.

- Hécaen, H., & Albert, M.L. Human neuropsychology. New York: Wiley, 1978.
- Hegenscheidt, M., & Cohen, R. (Determination of cognitive flexibility in brain-damaged persons). Zeitschrift fuer klinische Psychologie, 1972, 1, 1-20.
- Heilman, K.M., & Valenstein, E. Frontal lobe neglect in man. Neurology, 1972, 22, 660-664.
- Hollenberg, C.K. Functions of visual imagery in the learning and concept formation of children. Child development, 1970, 41, 1003-1015.
- Hoyer, W.J., Rebok, G.W., & Sved, S.M. Effects of varying irrelevant information on adult age differences in problem solving. Journal of Gerontology, 1979, 34, 553-560.
- Jason, G.W. The nature of hemispheric asymmetries in motor function. Paper presented at the International Neuropsychology Society Conference, Italy, 1980.
- Jones-Gotman, M., & Milner, B. Design fluency: the invention of non-sense drawings after focal cortical lesions. Neuropsychologia, 1977 15, 653-674.
- Katz, A.N., & Paivio, A. Imagery variables in concept identification. Journal of Verbal Learning and Verbal Behavior, 1975, 14, 284-293.
- Kendler, H.H., & Kendler, T.S. Vertical and horizontal processes in problem solving. Psychological Review, 1962, 69, 1-6.
- Kimura, D. Cerebral dominance and the perception of verbal stimuli. Canadian Journal of Psychology, 1961, 15, 166-171.
- Kimura, D. Functional asymmetry of the brain in dichotic listening. Cortex, 1967, 3, 163-178.
- King, M.C., & Snow, W.G. Problem-solving task performance in brain-damaged subjects. Journal of Clinical Psychology, 1981, 37, 400-404.
- Kirby, N.H., Nettlebeck, T., & Goodenough, S. Cognitive rigidity in the aged and the mentally retarded. International Journal of Aging and Human Development, 1978-79, 9, 263-272.
- Kleist, K. Gehirnpathologie. Leipzig: Barth, 1936.

- Kosslyn, S.M. Image and mind. Cambridge: Harvard University Press, 1980.
- Kounin, J.S. Experimental studies of rigidity. I. The measurement of rigidity in normal and feeble-minded persons. II. The explanatory power of the concept of rigidity as applied to feeble-mindedness. Character and Personality, 1941, 9, 251-272, 273-282.
- Landis, T., Cummings, J.L., & Benson, D.F. Le passage de la dominance du langage a l'hémisphère droit: une interprétation de la récupération tardive lors d'aphasie globales. Revue Medicale Suisse Romande, 1980, 100, 171-177.
- Leach, P.J. A critical study of the literature concerning rigidity. British Journal of Social and Clinical Psychology, 1967, 6, 11-22.
- Leong, C.K. Lateralization in severely disabled readers in relation to functional cerebral development and synthesis of information. In R.M. Knights, & D.J. Bakker (Eds.), The neuropsychology of learning disorders. Baltimore: University Park Press, 1976.
- Lewin, K. A dynamic theory of personality. New York: McGraw Hill, 1935.
- Lewinsohn, P., Danaker, B., & Kikel, S. Visual imagery as a mnemonic aid for brain-injured persons. Journal of Consulting and Clinical Psychology, 1977, 45, 717-723.
- Lubinski, R., Chapey, R., & Tedesco, L.A. Concept formation by aphasic adults using Kendler's rehearsal and nonrehearsal paradigm. British Journal of Disorders of Communication, 1981, 15, 175-182.
- Luchins, A.S. The Einstellung Test of rigidity; its relation to concreteness of thinking. Journal of Consulting and Clinical Psychology, 1951, 15, 303-310.
- Luchins, A.S. Rigidity of behavior. Eugene: University of Oregon Books, 1959.
- Luria, A.R. Two kinds of motor perseveration in massive injury of the frontal lobes. Brain, 1965, 88, 1-10.
- Luria, A.R. The higher cortical functions in man. London: Travistock, 1966.
- Luria, A.R. The working brain. An introduction to neuropsychology. New York: Basic Books, 1973.

- Maccoby, E.E., & Jacklin, C.N. The psychology of sex differences. Stanford: Stanford University Press, 1974.
- Mackie, J.B., & Beck, E.C. Relations among rigidity, intelligence, and perception in brain damaged and normal individuals. Journal of Nervous and Mental Disease, 1966, 142, 310-317.
- Matarazzo, J.D. Wechsler's measurement and appraisal of adult intelligence. (5th ed.). Baltimore: Williams & Wilkins, 1972.
- McFie, J., & Thompson, J.A. Picture arrangement: a measure of frontal lobe function? British Journal of Psychiatry, 1972, 121, 547-552.
- McMurray, J.G. Rigidity in conceptual thinking in exogeneous and endogeneous mentally retarded children. Journal of Consulting Psychology, 1954, 18, 366-370.
- Milner, B. Effects of different brain lesions on card sorting. Archives of Neurology, 1963, 9, 90-100.
- Milner, B. Some effects of frontal lobectomy in man. In J.M. Warren, & K. Akert (Eds.), The frontal granular cortex and behavior. New York: McGraw Hill, 1964.
- Milner, B. Interhemispheric differences in the localisation of psychological processes in man. British Medical Bulletin, 1971, 27, 272-277.
- Morton, J. Categories of interference: verbal mediation and conflict in card sorting. British Journal of Psychology, 1969, 60, 329-346.
- Moscovitch, M. Information processing and the cerebral hemispheres. In M.S. Gazzaniga (Ed.), Handbook of behavioral neurobiology (Vol. 2, Neuropsychology). New York: Plenum Press, 1979.
- Nauta, W.J.H. The problem of the frontal lobe: a reinterpretation. Journal of Psychiatry Research, 1971, 8, 167-187.
- Nelson, H.E. A modified card sorting test sensitive to frontal lobe defects. Cortex, 1976, 12, 313-324.
- Notcutt, B. Perseveration and fluency. British Journal of Psychology, 1943, 38, 200-208.
- Paivio, A. Imagery and verbal processes. New York: Holt, Rinehart & Winston, 1971.

- Paivio, A. The relationship between verbal and perceptual codes. In Handbook of perception (Vol. VIII). New York: Academic Press, 1978, p.375-397.
- Payne, R.W. Cognitive abnormalities. In H.J. Eysenck, Handbook of abnormal psychology. London: Pitman Medical Publishing, 1960.
- Perret, E. The left frontal lobe of man and the suppression of habitual responses in verbal categorical behaviour. Neuropsychologia, 1974, 12, 323-330.
- Prisko, L. Short term memory in focal cerebral damage. Unpublished doctoral thesis, Montreal: McGill University, 1963.
- Ramier, A.M., & Hécaen, H. Rôle respectif des atteintes frontales de la latéralisation lésionnelle dans les déficits de la "fluence verbale". Revue Neurologique, 1970, 123, 17-22.
- Regard, M. (Rotation in the copy and recall of visual stimuli in brain damaged patients). Paper presented at the Tagung experimentell arbeitender Psychologen, Bochum, 1976.
- Regard, M. A contribution to the neuropsychological assessment of frontal lobe deficits in man with special attention to the right non-dominant side. Individual study, University of Victoria, 1980.
- Richardson, A. Verbalizer-visualizer: a cognitive style dimension. Journal of Mental Imagery, 1977, 1, 109-126.
- Richardson, A. Subject, task, and tester variables associated with initial eye movement responses. Journal of Mental Imagery, 1978, 2, 85-100.
- Richardson, A. Personal communication, March, 12, 1981.
- Robinson, A.L., Heaton, R.K., Lehman, R., & Stilson, D.W. The utility of the WSCT in detecting and localizing frontal lobe lesions. Journal of Consulting and Clinical Psychology, 1980, 48, 605-614.
- Rokeach, M. The effect of perception time upon rigidity and concreteness of thinking. Journal of Experimental Psychology, 1950, 40, 206-216.
- Royer, F.L., & Holland, T.R. Rotational transformation of visual figures as a clinical phenomenon. Psychological Bulletin, 1975, 82, 843-868.

- Rubenowitz, S. Emotional rigidity-flexibility as a comprehensive dimension of mind. An empirical study of a construct and its psychological and social implications. Stockholm: Akuquist & Wiksall, 1963.
- Rugg, H.O. Imagination. New York: Harper and Row, 1963.
- Rylander, G. Personality changes after operations on the frontal lobes. A clinical study of 32 cases. Copenhagen: Munksgaard, 1939.
- Satz, P. A block rotation task: the application of multivariate and decision theory analysis for the prediction of organic brain disorder. Psychology Monographs, 1966 (a), 80, No. 629.
- Satz, P. Specific and nonspecific effects of brain lesions in man. Journal of Abnormal Psychology, 1966 (b), 71, 65-70.
- Schaie, K.W. A test of behavioral rigidity. Journal of Abnormal and Social Psychology, 1955, 51, 604-610.
- Schaie, K.W. Examiner manual for the test of behavioral rigidity. Palo Alto: Consulting Psychology Press, 1960.
- Schorr, D., Balzano, G., & Smith, E.E. Selective interference between imagery and perception: is it modality specific or relation specific? Bulletin of the Psychonomic Society, 1978, 12, 419-422.
- Schultz, N.R. Spontaneous flexibility and rigidity in adulthood and old age: a multitrait-multimethod analysis. Dissertation Abstracts, 1977, 38, 2349.
- Seamon, J.G., & Gazzaniga, M.S. Coding strategies and cerebral laterality effects. Cognitive Psychology, 1973, 5, 249-256.
- Semenza, C., Denes, G., Lucchese, D., & Bisiacchi, P. Selective deficit of conceptual structures in aphasia. Class versus thematic relations. Brain and Language, 1980, 10, 243-248.
- Shallice, T. Case study approach in neuropsychological research. Journal of Clinical Neuropsychology, 1979, 1, 183-211. Shallice, T. Case study approach in neuropsychological research. Journal of Clinical Neuropsychology, 1979, 1, 183-211.
- Sheehan, P.W. (Ed.). The function and nature of imagery. New York: Academic Press, 1972.

- Smith, W.L., & Phillipus, M.J. (Eds.). Neuropsychological testing in organic brain dysfunction. Springfield: C.C. Thomas, 1969.
- Spearman, C. The abilities of man, their nature and measurement. London: McMillan, 1927.
- Spellacy, F., & Spreen, O. A short form of the Token Test. Cortex, 1969, 5, 390-397.
- Stewart, J.C. An experimental investigation of imagery. Unpublished doctoral dissertation, University of Toronto, 1965.
- Stirling, N. Stroop interference: an input and an output phenomenon. Quarterly Journal of Experimental Psychology, 1979, 31, 121-132.
- Spreen, O. Neuropsychologische Stoerungen. In J.L. Pongratz (Ed.) Klinische Psychologie. 1. Hb.bd., Bd.8., Handbuch der Psychologie in 12 Baenden, Goettingen: Hogrefe, 1977.
- Strauss, E., Regard, M., & Knapp, P. Children's production on verbal and non-verbal fluency tasks, submitted.
- Stroop, J.R. Studies of interference in serial verbal reactions. Journal of Experimental Psychology, 1935, 18, 643-662.
- Strosahl, K.D., & Ascough, J.C. Clinical uses of mental imagery: experimental foundations, theoretical misconceptions, and research issues. Psychological Bulletin, 1981, 89, 422-438.
- Stuss, D.T., Kaplan, E., Benson, D.F., Weir, N.S., Naeser, M.A., & Levine, H.L. Long-term effects of frontal leucotomy. An overview of neuropsychological residuals. Journal of Clinical Neuropsychology, 1981, 3, 13-32.
- Teuber, H.L. The riddle of frontal lobe function in man. In J.M. Warren, & K. Akert (Eds.), The frontal granular cortex and behavior. New York: McGraw Hill, 1964.
- Teuber, H.L. Unity and diversity of frontal lobe functions. Acta Neurobiologiae Experimentalis, 1972, 32, 615-656.
- Teuber, H.L., Battersby, W.S., & Bender, M.B. Performance of complex visual tasks after cerebral lesions. Journal of Nervous and Mental Disease, 1951, 114, 413-429.
- Thompson, W.R. Early experiential and genetic influences on flexibility. In O.J. Harvey, Experience, structure and adaptability. New York: Springer, 1966.

- Thurstone, L.L., & Thurstone, T.M. SRA Primary Mental Abilities. Chicago: Science Research Association, 1948.
- Torrance, E.P. Torrance Tests of Creative Thinking. Princeton: Personnel Press, 1966.
- Walsh, K.W. Neuropsychology. A clinical approach. Edinburgh: Churchill Livingstone, 1978.
- Wechsler, D. Manual for the Wechsler Adult Intelligence Scale. New York: Psychological Corporation, 1955.
- Werner, H. The concept of rigidity: a critical evaluation. Psychological Review, 1946, 53, 43-52.
- Werner, H., & Strauss, A.A. Experimental analysis of the clinical symptom 'perseveration' in mentally retarded children. American Journal of Mental Deficiency, 1942, 47, 185-188.
- Wetherick, N.E. Changing an established concept: a comparison of the ability of young, middle-aged and old subjects. Gerontologia, 1965, 11, 82-95.
- Wesley, E. Perseverative behavior in a concept formation task as a function of manifest anxiety and rigidity. Journal of Abnormal and Social Psychology, 1953, 48, 129-134.
- White, K., Sheehan, P.W., & Ashton, R. Imagery assessment: a survey of self-report measures. Journal of Mental Imagery, 1977, 1, 145-170.
- White, L. Interference proneness and the ability to shift attention in old age. Dissertation Abstracts, 1978, 39, (5-B), 2549.
- Wolff, J.L. Concept-shift and discrimination-reversal learning in humans. Psychological Bulletin, 1967, 68, 369-408.
- Yamamoto, K., & Frengel, B.A. An exploratory component analysis of the Minnesota tests of creative thinking. California Journal of Education Research, 1966, 17, 220-229.
- Zenhausern, R. Imagery, cerebral dominance and style of thinking: a unified field model. Bulletin of the Psychonomic Society, 1978, 12, 381-384.

Appendix A

POST-HOC ANALYSIS OF GENDER DIFFERENCES

In this study no predictions were made postulating gender differences. Previous evidence is quite conflicting and often based on small differences. In the course of the study additional data were collected on 14 male volunteer students (mean age 28.2, range 20 to 35 years) and compared to the female sample. The comparison tested the common notion that females are better in processing verbal information and males better in processing visual-spatial material (e.g. Maccoby & Jacklin, 1974).

Table 16 includes the mean performance and standard deviation for the test measures of female and male subjects. Multivariate analyses of variance were computed for (a) the flexibility tests and the VVQ, and (b) for the error measures. Using Wilk's Lambda criterion, both analyses showed no significant multivariate differences (a: F . 0.883, p . 0.558, and b: F . 0.148, p . 0.218). The univariate comparisons were also not significant.

TABLE 16

Means and standard deviations: females and males

Variable	Females (n=40)		Males (n=14)	
	M	SD	M	SD
IQ estimate	28.13	3.82	28.79	3.19
Vocabulary	15.28	2.05	15.64	2.13
Block design	12.90	2.67	13.14	2.28
Word Fluency words	51.90	11.67	55.64	15.85
repetitions	0.33	0.94	0.71	0.91
Five Point figures	55.48	18.41	50.29	14.71
repetitions	2.89	4.51	1.71	2.37
Stroop time, III	19.25	5.18	19.21	4.02
errors, III	0.23	0.53	0.29	0.61
CIT verbal part	4.83	0.38	4.71	0.47
non-verbal part	4.58	0.71	4.21	0.47
errors verbal	4.65	2.82	6.29	4.83
errors non-verb	9.30	5.97	11.57	6.64
VVQ	8.88	2.15	8.43	2.44

Appendix B

TEST INSTRUCTIONS AND ADDITIONAL TEST DESCRIPTIONS

1. Word Fluency

Instructions: "In this test I would like you to give me as many words as you know beginning with the letter 'S' until I stop you". E. writes the letter 'S' at the top of a page in view of the subject. Ss. are allowed to look at the page throughout the test. They are further instructed: "You should not use proper names such as Seattle or Susan. It is important that you do not repeat any words". If words are repeated or words beginning with other letters are given, E. corrects only the first infraction, repeats the instruction and helps by saying: "try to give me another word beginning with 'S'". Timing is interrupted during corrections.

2. Five Point Test

Instructions: "In this test I want you to draw as many different figures as you can until I stop you. Connect the black dots with straight lines in each of the rectangles. You don't have to use all the dots, for example you can do this". E. draws two standard examples. "Be careful not to repeat figures and not to draw lines which do not connect

dots". If S. does not follow the rules, E. corrects only the first time and repeats the instructions. Timing is interrupted during the corrections.

3. Stroop Test

Instructions: "Here you see many rows of colored dots. (Only part I is shown). You should name their color as fast as you can without error. Start here". E. names color of first dot and points from left to right, row by row. If errors occur, they are corrected immediately and S. is told to go on as rapidly as possible. During corrections, timing is stopped. For part II and III, E. says: "Here again, try to name the colors of these words as fast as you can, avoiding errors. Start here". Again, E. names the color of first word and interrupts timing for necessary corrections. It is important that E. says 'name' the colors and not 'read' to avoid the reading of the words.

4. CIT

Additional test description: A nonreversal shift selection paradigm was chosen (Bourne, 1966). Interference was produced in two ways: (a) by showing stimuli with misleading attributes, and (b) by using a previously reinforced concept in a new concept identification set. Imagery was included in two ways: (a) as a mediating process or strategy to recognize the stimuli, and (b) in the

concepts where mental transformations of stimuli were required.

The stimulus factors were (a) verbal nonsense trigrams and (b) non-verbal geometric patterns. The response mode was non-verbal, i.e. the subjects were asked to point to the correct choice. The experimenter gave immediate corrective feedback by reinforcing the correct choice with up and down head movements accompanied by the word "correct".

The test material consisted of a total of 320 cards. There were 16 stimulus cards (orange) and 16 response cards (green) for 10 concept sets, 5 verbal and 5 non-verbal. The cards measured 3 by 5 inches and were presented vertically. The stimulus cards contained the exemplar, i.e. the stimulus which exemplified the concept and the nonexemplar with the relevant or irrelevant (conflicting) cues. The response card for the answer selection consisted of two stimuli, one with correct and one with incorrect attributes. The verbal stimuli were letters printed in Folio Medium 36 typeface. Bryden and Allard (1976) found that familiar typefaces were more correctly identified in the right visual field than in the left visual field, thus assumed to be processed primarily by the left hemisphere. The position of the stimulus containing the correct attributes was pseudorandomly alternated and appeared 50 percent of the time on the upper half and 50 percent on the lower half of the card. The subject was presented simultaneously with a

stimulus and a response card to reduce the memory load. The cards were collated in binders and always presented in the same order. After 20 seconds the page was turned to the next item.

After five consecutive correct choices, the concept was shifted without forewarning the subject. There were a maximum of 16 trials per concept. When the criterion of five correct answers in a row was not reached by the sixteenth item a score of 17 was assigned.

The concepts for the verbal and non-verbal part were constructed as follows:

a. Verbal (letter trigrams)

(underlined attribute = correct answer)

1. concept: original learning without interference
 - a1 vertical
 - a2 horizontal
 - b1 big letters
 - b2 small letters
2. concept: with interference, i.e. nonexemplar contains conflicting dimensions from first concept
 - a1 same writing of letters (big or small)
 - a2 mixed writing of letters
 - b1 vertical (interference)
 - b2 horizontal
3. concept: with imagery, i.e. correct concept is the combination of letters to a word
 - a1 letters apart
 - a2 letters together
 - b1 same writing
 - b2 different writing
 - c1 correct combination (word)
 - c2 incorrect combination (word)
4. concept: with imagery, i.e. correct choice is a 90 degree rotation of letters in exemplar
 - a1 two letters

a2 three letters
 b1 same set of letters
 b2 different set of letters
 c1 rotation (at random to left and right)
 c2 nonrotated, same position

5. concept: with imagery and interference, i.e. deduction is letter of standard, and interference from previous concept
 a1 standard
 a2 different set of letters
 b1 rotation (interference)
 b2 nonrotation
 c1 deduction (one letter from standard missing)
 c2 same as a1 or a2

b. Non-verbal (geometric patterns)

(The same concepts as in the verbal part were tested)

1. concept: original learning without interference
 a1 overlap of two elements
 a2 no overlap
 b1 same form
 b2 different form
2. concept: with interference
 a1 same form
 a2 different form
 b1 overlap (interference)
 b2 no overlap
3. concept: with imagery
 a1 shapes apart
 a2 shapes together
 b1 same form
 b2 different form
 c1 correct combination
 c2 incorrect combination
4. concept: with imagery
 a1 one element
 a2 more than one element
 b1 same form
 b2 different form
 c1 rotation
 c2 nonrotated, same position
5. concept: with imagery and interference
 a1 same form
 a2 different form
 b1 rotation (interference)

b2 nonrotated
c1 deduction
c2 same as a1 or a2

Instructions: "I will show you cards with meaningless letters/figures. E. shows the samples. Here you see two figures/sets of letters I would like you first to inspect them carefully (stimulus card). Then, try to find a pattern down here (response card) which has something in common with the first card. You should try to get as many correct answers in a row as possible, but you can't avoid mistakes. They are necessary to figure out the correct answer. I will help you by saying "correct" or "wrong" after each answer. Listen carefully to what I say after each answer. Now then let's start". After 15 sec. exposure time E. indicates that time is up and asks for a guess. After 20 sec. the next card is shown. If no answer is given, the item is scored as a failure. Overall time to solve the verbal and non-verbal parts is measured.

Any query during the task as to whether there has been a change in the important attribute is answered by saying: "just keep on pointing to the correct answer".

5. VVQ

For instructions and scoring key see Appendix C.

6. Token Test

As a short screening device for possible impairment of receptive speech in patients, the short form of the Token Test was given (Spellacy and Spreen, 1969). Items of each subtest from the original form are included. Each subtest represents a different level of linguistic difficulty. Large and small circles and squares, made of plastic, in the colors red, yellow, blue, white and green are presented in a standard arrangement in front of the subject, who is asked to point to the tokens as requested. Before the test starts, E. makes sure that form and color are recognized and the words "circle" and "square" are understood.

Instructions: "In this test you don't need to talk. Listen carefully to the instructions I will give you. It starts with very easy questions, for example (E. reads first item in a clear voice without any special prosodic emphasis).

Scoring: total correct items, max. 16, cut-off point is 14 points or less (pass/fail score).

7. Reporter's Test

The Reporter's Test (De Renzi and Ferrari, 1978) was given as a short screening device for potential expressive speech impairments in patients. The task for the S. is to describe the experimenter's manipulations. The tokens from the Token Test serve as test material. The test has five

parts. The performance carried out by E. corresponds in part to the commands of the Token Test and requires the S. to construct a sentence with a simple syntactic structure, verb and object.

Instructions: The 20 tokens are laid down on the table in a standard arrangement and the subject is told: "Now, I'm going to do some things with these tokens. Imagine that a person is sitting beside you, but can't see what I'm doing (E. shields the tokens with a cardboard held vertically). Your task is to describe what I am doing as carefully as possible, so that this person would be able to repeat exactly what I do on another set of tokens. As you see, there are circles, squares, some are large and some small, some are yellow, red, blue, green and white. If only the large tokens are present (the small tokens are covered up) and I touch this one (E. points to the red circle), you must say 'touch the red circle', but if I touch it when all tokens are present you have to say 'touch the large red circle', otherwise it would not be clear which of the two red circles has been pointed to". Each item of the test is repeated once, if the S. first reproduction is faulty.

Scoring: the total number of correct items is scored, max. 26 (pass/fail score), the cut-off score is 19 points and below. A description is given 1 point if it is correct on the first presentation of the item, 0.5 point if it is correct on the second presentation only. The scores are

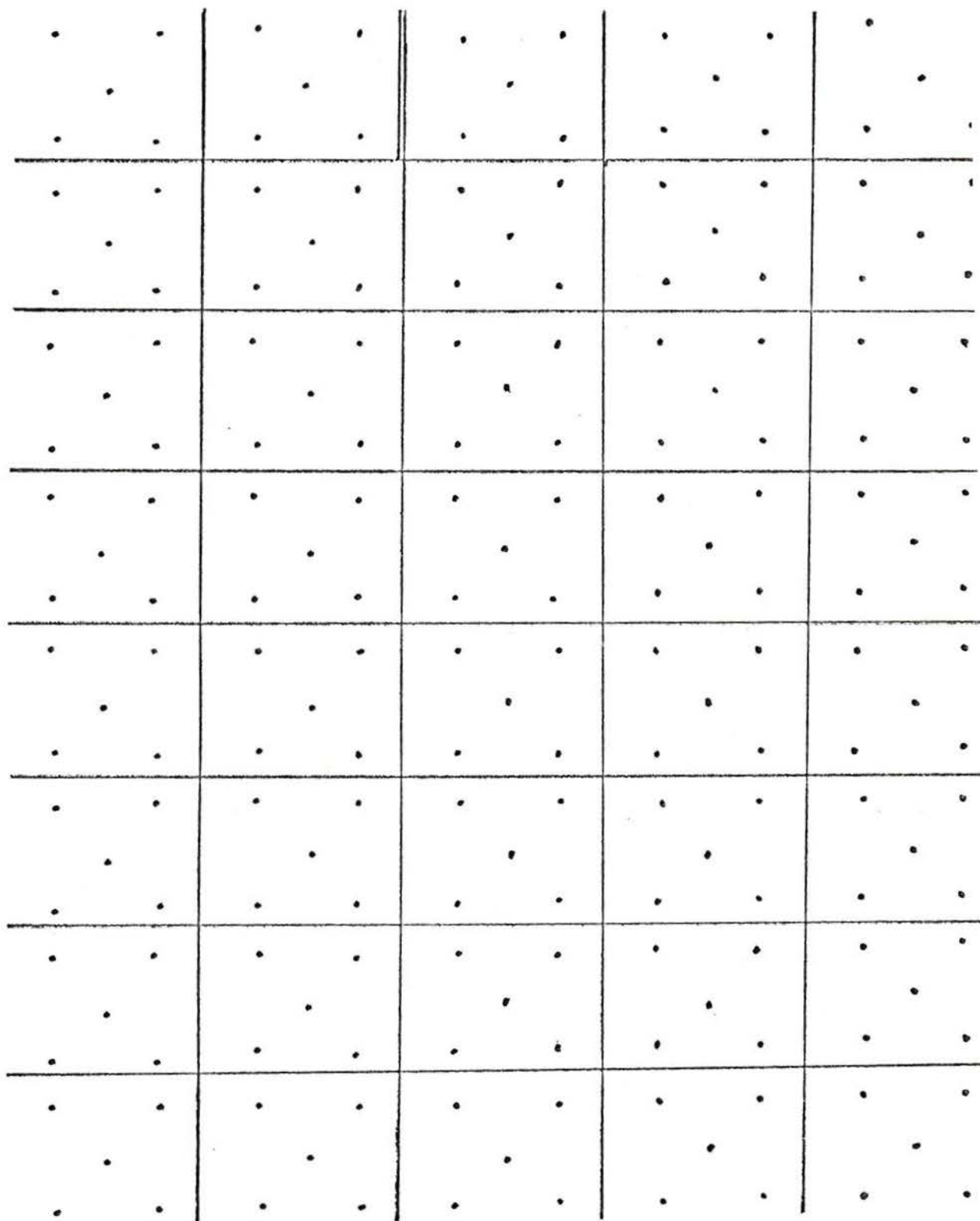
corrected for the number of years of schooling according to De Renzi and Ferrari (1978). Mild dysarthric or phonemic errors, which leave comprehension of speech unimpaired, do not affect the scoring.

Appendix C

TEST FORMS

1. Five Point Test
2. CIT scoring sheet and concept examples
3. VVQ
4. Token Test
5. Reporter's Test

For Word Fluency and the Stroop Test no special forms were needed.

FIVE POINT TEST

date:

Nr.:

tot.fig.

name:

Dg.:

tot.repe.

age: sex:

loc.:

name:	age:	sex:	(dg:		loc:	date:				
			a 1st	a 2nd						
v			C.I.T.							
1.1.	T B	2.1.	T B	3.1.	T B	4.1.	T B	5.1.	T B	
2.	T B	2.	T B	2.	T B	2.	T B	2.	T B	
3.	T B	3.	T B	3.	T B	3.	T B	3.	T B	
4.	T B	4.	T B	4.	T B	4.	T B	4.	T B	
5.	T B	5.	T B	5.	T B	5.	T B	5.	T B	
6.	T B	6.	T B	6.	T B	6.	T B	6.	T B	
7.	T B	7.	T B	7.	T B	7.	T B	7.	T B	
8.	T B	8.	T B	8.	T B	8.	T B	8.	T B	
9.	T B	9.	T B	9.	T B	9.	T B	9.	T B	
10.	T B	10.	T B	10.	T B	10.	T B	10.	T B	
11.	T B	11.	T B	11.	T B	11.	T B	11.	T B	
12.	T B	12.	T B	12.	T B	12.	T B	12.	T B	
13.	T B	13.	T B	13.	T B	13.	T B	13.	T B	
14.	T B	14.	T B	14.	T B	14.	T B	14.	T B	
15.	T B	15.	T B	15.	T B	15.	T B	15.	T B	
16.	T B	16.	T B	16.	T B	16.	T B	16.	T B	corr.conc. __/5
corr. item	___	___	___	___	___	___	___	___	___	tot.corr. ___
err.	___	___	___	___	___	___	___	___	___	tot. err. ___
nv										
1.1.	T B	2.1.	T B	3.1.	T B	4.1.	T B	5.1.	T B	
2.	T B	2.	T B	2.	T B	2.	T B	2.	T B	
3.	T B	3.	T B	3.	T B	3.	T B	3.	T B	
4.	T B	4.	T B	4.	T B	4.	T B	4.	T B	
5.	T B	5.	T B	5.	T B	5.	T B	5.	T B	
6.	T B	6.	T B	6.	T B	6.	T B	6.	T B	
7.	T B	7.	T B	7.	T B	7.	T B	7.	T B	
8.	T B	8.	T B	8.	T B	8.	T B	8.	T B	
9.	T B	9.	T B	9.	T B	9.	T B	9.	T B	
10.	T B	10.	T B	10.	T B	10.	T B	10.	T B	
11.	T B	11.	T B	11.	T B	11.	T B	11.	T B	
12.	T B	12.	T B	12.	T B	12.	T B	12.	T B	
13.	T B	13.	T B	13.	T B	13.	T B	13.	T B	
14.	T B	14.	T B	14.	T B	14.	T B	14.	T B	
15.	T B	15.	T B	15.	T B	15.	T B	15.	T B	
16.	T B	16.	T B	16.	T B	16.	T B	16.	T B	corr.conc. __/5
corr.item	___	___	___	___	___	___	___	___	___	tot.corr. ___
err.	___	___	___	___	___	___	___	___	___	tot.err. ___
						a+bcorr.	___			a+b corr.conc. __/5
						a+b err.	___			

G
L
O

verbal: example

n
s
t

stimulus card

M
I
Y

R
J
H

response card

W
T
E

verbal: concept 1

o
t
e

stimulus card

n
s
i

GRL

response card

T
L
A

verbal: concept 2

tuk

stimulus card

n
L
W

ORZ

response card

O P T

verbal: concept 3

R I f

stimulus card

S L Y

T O P

response card

M
V

verbal: concept 4

KI

stimulus card

M >

KE

response card

p q m

verbal: concept 5

d g n

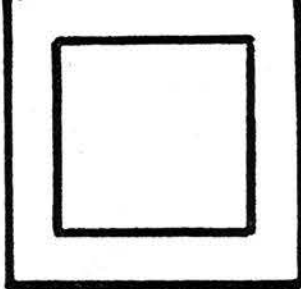
stimulus card

q m

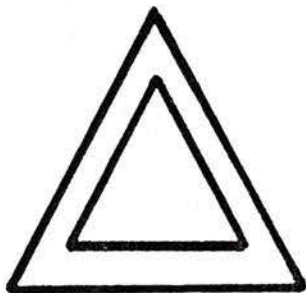
p q m

response card

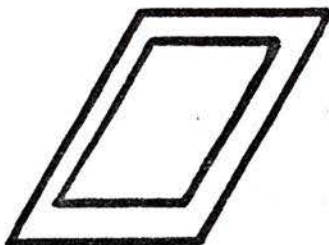
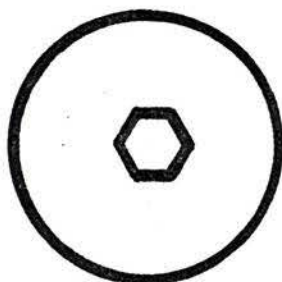
non-verbal: example



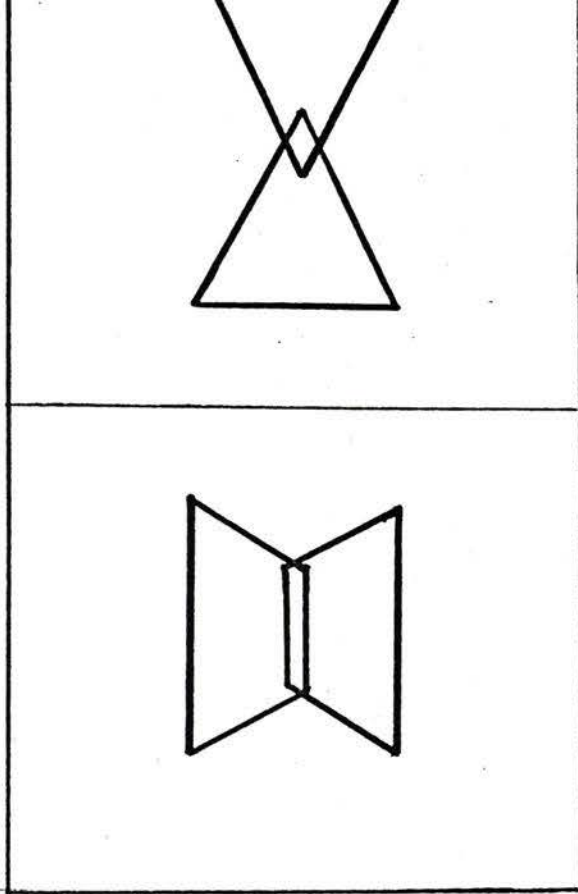
stimulus card



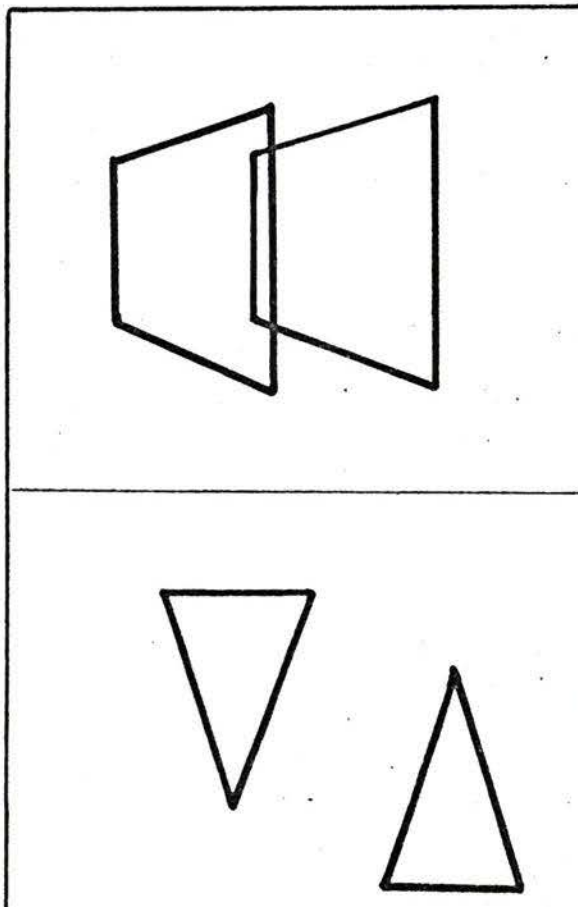
response card



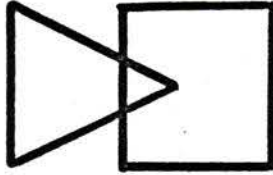
non-verbal: concept 1



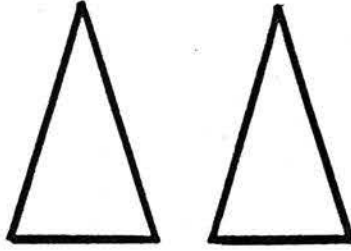
stimulus card



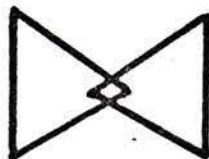
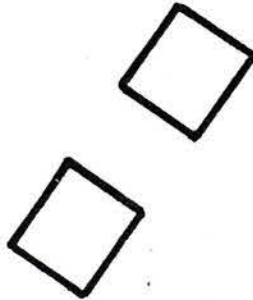
response card



non-verbal: concept 2

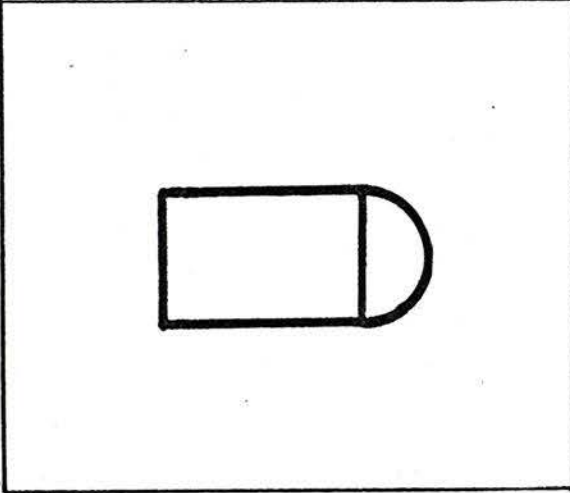
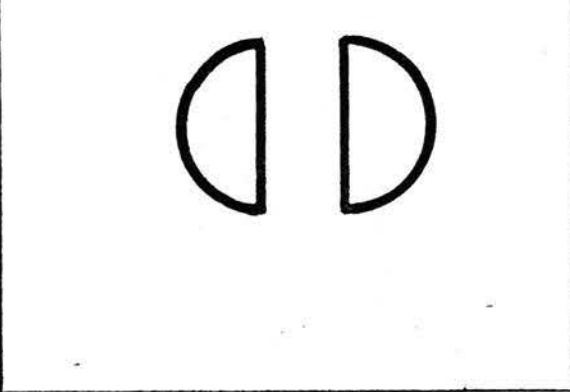


stimulus card

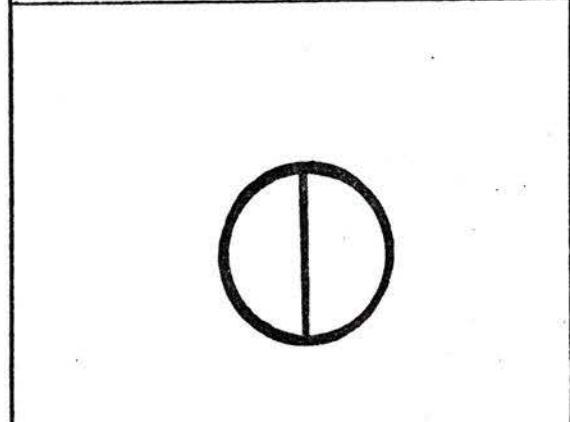
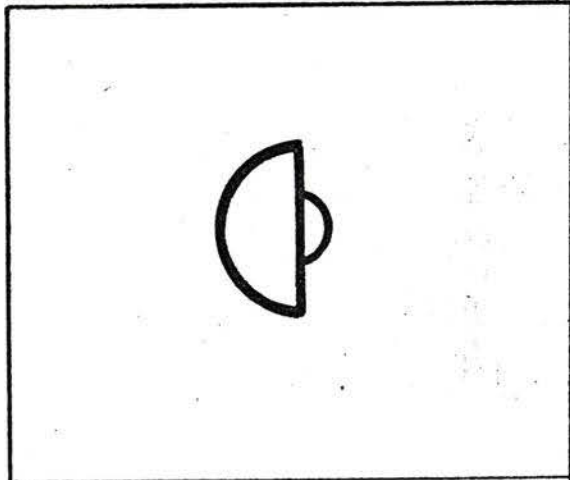


response card

non-verbal: concept 3

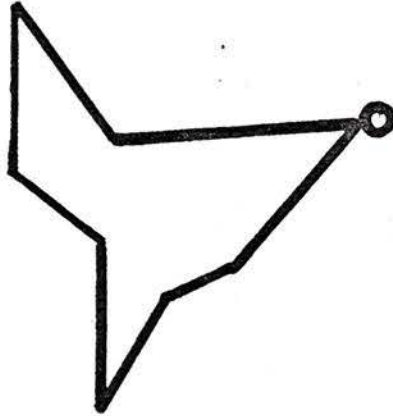
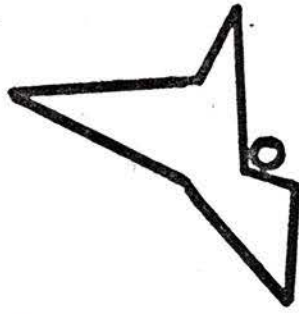


stimulus card

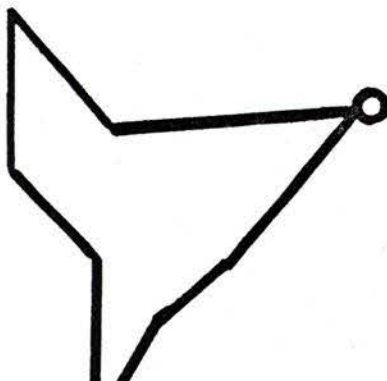
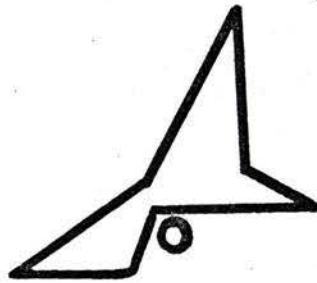


response card

non-verbal: concept 4

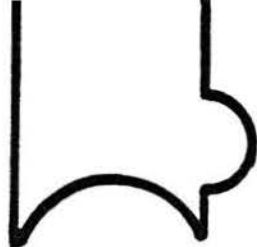


response card

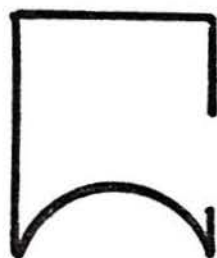


response card

non-verbal: concept 5



stimulus card



response card

- | | | |
|--|-------------|--------------|
| 14. I read rather slowly. | <u>TRUE</u> | FALSE |
| 15. I cannot generate a mental picture of a friend's face when I close my eyes. | TRUE | <u>FALSE</u> |
| 16. My mind seldom wanders when I am reading. | TRUE | FALSE |
| 17. Some of the thoughts that pop into my head seem to have nothing to do with anything that I have previously experienced. | TRUE | FALSE |
| 18. I don't believe that anyone can think in terms of mental pictures. | TRUE | <u>FALSE</u> |
| 19. I prefer to read instructions about how to do something rather than have someone show me. | TRUE | <u>FALSE</u> |
| 20. My dreams are extremely vivid. | <u>TRUE</u> | FALSE |
| 21. If I want to imagine a series of movements - like the steps of a dance - I tend to get stuck at some stage in the sequence of imagined movements and can't visualize the rest of them. | TRUE | FALSE |
| 22. I have better than average fluency in using words. | TRUE | <u>FALSE</u> |
| 23. Sometimes my thoughts keep coming back to the same things over and over again, no matter how much I try to think of something else. | TRUE | FALSE |
| 24. My daydreams are rather indistinct and hazy. | TRUE | <u>FALSE</u> |
| 25. I spend very little time attempting to increase my vocabulary. | <u>TRUE</u> | FALSE |
| 26. My thinking often consists of mental pictures or images. | <u>TRUE</u> | FALSE |
| 27. No matter how hard I try to concentrate, thoughts unrelated to my work tend to creep in. | TRUE | FALSE |
| 28. I find it very difficult to remember peoples' faces. | TRUE | FALSE |
| 29. After hearing a tune a few times, I can usually remember it. | TRUE | FALSE |
| 30. My sense of direction is not very good. | TRUE | FALSE |

(underlined answer = visualizer; range 0-15)

SHORT FORM OF THE TOKEN TEST

Name _____ Date _____

Examiner _____ Score _____

PRESENT ALL TOKENS AS IN PRESCRIBED FORM

1. Show me a GREEN one.	1:
-------------------------	----

PRESENT LARGE TOKENS ONLY. (COVER SMALL TOKENS WITH A SHEET OF PAPER)

2. Show me the GREEN CIRCLE.	2:
------------------------------	----

PRESENT ALL TOKENS.

3. Show me the SMALL, WHITE CIRCLE.	3:
-------------------------------------	----

PRESENT LARGE TOKENS ONLY.

4. Take the RED CIRCLE and the GREEN SQUARE.	4:
5. Take the YELLOW SQUARE and the BLUE SQUARE.	5:
6. Take the WHITE CIRCLE and the RED CIRCLE.	6:

PRESENT ALL TOKENS.

7. Take the LARGE, WHITE CIRCLE and the SMALL, GREEN SQUARE.	7:
8. Take the SMALL, BLUE CIRCLE and the LARGE, YELLOW SQUARE.	8:
9. Take the LARGE, GREEN SQUARE and the LARGE, RED SQUARE.	9:
10. Take the LARGE, WHITE SQUARE and the SMALL, GREEN CIRCLE.	10:

PRESENT THE LARGE TOKENS ONLY.

11. PUT the RED CIRCLE ON the GREEN SQUARE.	11:
12. TOUCH the BLUE CIRCLE WITH the RED SQUARE.	12:
13. TOUCH the BLUE CIRCLE AND the RED SQUARE.	13:
14. MOVE the GREEN SQUARE AWAY FROM the YELLOW SQUARE.	14:
15. PUT the GREEN SQUARE BESIDE the RED CIRCLE.	15:
16. PUT the RED CIRCLE BETWEEN the YELLOW SQUARE and the GREEN SQUARE.	16:

(with permission of F. Spellacy and O. Spreen, Neuropsychology Laboratory,
University of Victoria)

Appendix A
LISTING OF RAW DATA

Code list:

(each subject has three data cards)

<u>Column position</u>	<u>Variable</u>
1	Groups: 1=normal, female 2=normal, male 3=left frontal 4=left non-frontal 5=right frontal 6=right non-frontal 7 and *=normals used as matched controls
2- 3	Subject id
5	Test order 1 or 2
6-10	Age
11-15	IQ estimate
16-20	Vocabulary
21-25	Block design
26-30	Word Fluency, number of words
31-35	Word Fluency, repetitions
36-40	Five Point Test, number of figures
41-45	Five Point Test, repetitions

46-50	Stroop Test, plate I reading time
51-55	Stroop Test, plate II reading time
56-60	Stroop Test, plate III reading time
61-65	Stroop Test, plate I errors
66-70	Stroop Test, plate II errors
71-75	Stroop Test, plate III errors
76-80	VVQ
6-10	CIT verbal concepts
11-15	CIT non-verbal concepts
16-20	CIT total concepts
21-25	CIT errors concept 1
26-30	concept 2
31-35	concept 3
36-40	concept 4
41-45	concept 5
46-50	concept 6
51-55	concept 7
56-60	concept 8
61-65	concept 9
66-70	concept 10
71-75	errors verbal concepts
76-80	errors non-verbal concepts
6-10	errors total
11-15	item (after 5 consecutive correct answers), concept 1
16-20	concept 2
21-25	concept 3

26-30	concept 4
31-35	concept 5
36-40	concept 6
41-45	concept 7
46-50	concept 8
51-55	concept 9
56-60	concept 10
61-65	items verbal concepts
66-70	items non-verbal concepts
71-75	items total
76-80	total time

Data listing

Columns:

	12	5	6	11	16	21	26	31	36	41	46	51	56	61	66	71	76
11612	25	29	16	13	51	0	64	5	9	13	16	0	0	0	0	7	
1162	5	5	10	0	0	1	1	2	1	0	0	0	0	1	4	2	
1163	6	5	5	7	6	7	6	5	5	5	6	30	27	57	9		
1 111*	33	29	14	15	37	0	38	1	11	12	19	0	0	0	9		
1 12	5	5	10	0	2	0	0	1	1	0	2	0	1	3	4		
1 13	7	5	8	5	5	6	6	5	8	5	6	29	30	59	13		
1 311*	29	26	18	8	46	0	27	2	12	13	34	0	0	0	10		
1 32	4	4	8	0	4	3	0	2	0	3	5	0	1	9	9		
1 33	18	5	17	14	5	7	5	11	17	5	6	48	44	92	18		

12311*	23	22	14	8	44	0	27	0	13	14	18	0	0	0	6
1232	5	3	8	0	0	2	1	2	0	2	9	4	1	5	16
1233	21	5	5	8	6	11	5	11	17	17	6	35	56	91	16
12511	30	30	18	12	49	0	63	0	10	11	15	0	0	0	8
1252	5	5	10	0	0	1	0	1	0	0	2	1	1	2	4
1253	6	5	5	10	5	6	5	5	7	7	6	31	30	61	7
12711	24	34	19	15	68	0	74	3	9	13	21	0	0	0	7
1272	5	5	10	0	0	0	0	1	0	2	0	1	1	1	4
1273	5	5	5	5	5	6	5	11	5	7	6	26	34	60	7
12911	20	28	14	14	46	1	74	27	7	8	9	0	0	0	8
1292	5	5	10	0	4	0	1	1	4	1	0	0	1	6	6
1293	12	5	11	5	6	6	12	6	5	5	6	33	34	67	8
13111	27	35	18	17	66	3	67	2	9	11	26	0	0	0	8
1312	5	5	10	0	0	1	0	1	0	1	1	0	0	2	2
1313	4	5	5	8	5	6	5	6	7	5	5	29	28	57	8
13311	21	27	15	12	24	0	48	3	12	14	19	0	0	0	13
1332	5	5	10	0	5	0	0	2	4	3	2	0	1	7	10
1333	17	5	5	5	5	11	16	11	10	5	6	31	48	79	9
13511	28	31	16	15	69	0	105	9	9	12	15	0	0	0	8
1352	4	5	9	0	6	0	0	1	0	3	1	0	1	7	5
1353	12	5	17	5	5	6	5	12	6	5	6	38	34	72	7
13711	24	25	16	9	47	0	52	7	10	11	14	0	0	0	8
1372	4	4	8	0	0	0	0	6	0	3	6	5	10	6	24
1373	30	5	5	5	5	17	5	10	14	14	17	37	60	97	12
13911	23	26	13	13	68	0	82	0	7	10	13	0	1	1	9
1392	5	5	10	0	3	1	0	1	0	4	1	4	1	5	10
1393	15	5	9	8	5	6	5	11	6	12	6	33	40	73	16

12311*	23	22	14	8	44	0	27	0	13	14	18	0	0	0
1232	5	3	8	0	0	2	1	2	0	2	9	4	1	5
1233	21	5	5	8	6	11	5	11	17	17	6	35	56	91
12511	30	30	18	12	49	0	63	0	10	11	15	0	0	0
1252	5	5	10	0	0	1	0	1	0	0	2	1	1	2
1253	6	5	5	10	5	6	5	5	7	7	6	31	30	61
12711	24	34	19	15	68	0	74	3	9	13	21	0	0	0
1272	5	5	10	0	0	0	0	1	0	2	0	1	1	1
1273	5	5	5	5	5	6	5	11	5	7	6	26	34	60
12911	20	28	14	14	46	1	74	27	7	8	9	0	0	0
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1293	12	5	11	5	6	6	12	6	5	5	6	33	34	67
13111	27	35	18	17	66	3	67	2	9	11	26	0	0	0
1312	5	5	10	0	0	1	0	1	0	1	1	0	0	2
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13311	21	27	15	12	24	0	48	3	12	14	19	0	0	0
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1353	12	5	17	5	5	6	5	12	6	5	6	38	34	72
13711	24	25	16	9	47	0	52	7	10	11	14	0	0	0
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1373	30	5	5	5	5	17	5	10	14	14	17	37	60	97
13911	23	26	13	13	68	0	82	0	7	10	13	0	1	1
1392	5	5	10	0	3	1	0	1	0	4	1	4	1	5
1393	15	5	9	8	5	6	5	11	6	12	6	33	40	73

1 212	25	28	14	14	52	0	46	1	12	13	22	0	0	0	7
1 22	5	4	9	0	2	0	0	0	0	3	4	2	10	2	19
1 23	21	5	10	5	5	5	5	11	12	11	17	30	56	86	18
1 412	32	26	14	12	59	0	51	2	10	11	21	0	0	1	8
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1 43	22	5	17	8	5	10	5	12	8	17	8	45	50	95	23
1 612	23	27	17	12	56	0	34	2	8	9	13	0	0	1	11
1 62	4	4	8	0	6	0	0	4	0	0	2	1	12	10	15
1 63	25	5	14	5	5	17	5	5	7	7	17	46	41	87	13
1 812*	33	31	17	14	41	0	46	0	13	16	28	0	0	0	10
1 82	5	5	10	0	1	0	0	1	0	0	3	3	1	2	6
1 83	8	5	8	5	5	6	5	5	10	9	8	29	37	66	8
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1103	13	5	10	10	5	6	5	10	5	5	8	36	33	69	11
11212	27	32	15	17	76	0	62	3	10	10	15	0	0	0	12
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1223	15	5	14	5	5	6	5	17	7	5	6	35	40	75	11
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13012	24	36	19	17	67	5	59	0	9	10	16	0	0	0	5
1302	5	4	9	0	1	0	1	1	0	4	1	1	4	3	10
1303	13	5	8	5	6	6	5	17	7	7	9	30	43	73	9
13212*	22	26	13	13	55	0	57	0	10	11	15	0	0	0	11
1322	5	5	10	0	3	0	0	0	0	5	3	0	1	3	9
1323	12	5	12	5	5	5	5	11	11	5	6	32	38	70	9
13412	27	32	18	14	66	1	62	6	8	13	20	0	0	0	10
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1343	4	5	5	5	6	5	5	7	6	5	6	26	29	55	5
13612	25	23	12	11	47	0	41	1	9	10	21	0	0	0	10
1362	5	5	10	1	2	0	0	1	0	6	2	2	3	4	13
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1402	5	4	9	0	4	0	1	2	1	4	2	8	1	7	16
1403	23	5	13	5	9	7	7	16	8	17	9	39	57	96	15
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2532	4	4	8	2	6	2	0	1	0	6	3	4	2	11	15
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2553	13	5	11	14	6	6	5	6	8	5	5	42	29	71	10
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2572	4	4	8	0	9	0	1	0	0	1	3	8	7	10	19
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2523	8	5	14	7	5	6	5	5	6	5	7	37	28	65	11

25412	29	30	16	14	65	1	31	0	9	11	24	0	0	2	12
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2543	20	5	5	5	5	6	5	17	17	7	6	26	52	78	8
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2563	9	5	5	5	5	5	5	5	8	9	9	25	36	61	9
25812	32	31	18	13	60	0	69	0	10	12	19	0	0	0	7
2582	5	4	9	0	1	1	2	1	0	4	4	7	5	5	20
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26012	25	23	14	9	29	1	37	7	13	12	19	0	0	0	3
2602	4	3	7	0	9	4	2	1	1	3	8	0	5	16	17
2603	33	5	17	13	9	6	7	10	17	5	17	50	56	106	14
26212	21	26	13	13	47	0	48	0	10	12	22	0	0	1	7
2622	4	5	9	3	7	0	0	2	1	3	4	2	0	12	10
2623	22	12	17	5	5	7	7	10	9	7	5	46	38	84	10
26412*	35	30	14	16	61	0	58	5	14	13	18	1	0	0	8
2642	5	5	10	1	0	0	0	1	0	0	2	0	1	2	3
2643	5	7	5	5	5	6	5	5	8	5	6	28	29	57	6
3811	73	21	12	9	23	4	27	8	12	25	85	0	1	5	3
3812	3	3	6	1	8	3	4	8	1	9	0	2	13	24	25
3813	49	6	17	8	14	17	7	17	5	7	17	52	53	107	50
3861	36	20	12	8	35	1	22	1	9	16	30	0	0	2	6
3862	5	3	8	0	0	0	0	5	2	9	1	2	11	5	25
3863	30	5	5	5	5	17	12	17	9	11	17	37	66	103	23
3871	22	24	14	10	16	0	38	0	19	20	25	0	0	0	10
3872	4	5	9	0	6	1	0	1	0	1	1	0	1	8	3
3873	11	5	17	6	5	6	5	6	6	5	6	39	28	67	16

3931	28	17	9	8	12	1	21	0	15	17	35	0	0	5	10
3932	5	2	7	0	2	3	0	1	1	11	3	11	9	6	35
3933	41	5	10	15	5	6	6	17	9	17	17	41	66	107	28
3941	58	17	8	9	12	1	9	0	27	38	46	1	3	5	11
3942	4	1	5	5	9	1	0	3	5	8	2	1	9	18	25
3943	43	13	17	10	5	11	17	17	14	6	17	56	71	127	28
4841	76	24	13	11	11	0	14	2	28	42	72	0	1	2	2
4842	3	3	6	1	8	3	4	8	1	9	0	2	13	24	25
4843	49	6	17	8	14	17	7	17	5	7	17	52	53	107	50
4971	72	21	12	9	11	7	21	2	16	24	33	1	0	3	8
4972	4	4	8	1	5	10	2	1	4	8	3	2	6	19	23
4973	42	6	13	17	8	5	11	17	9	8	14	49	59	108	23
4981	42	18	11	7	6	0	18	2	18	28	39	1	2	4	7
4982	2	5	7	8	6	7	10	8	2	7	4	2	9	39	24
4983	63	13	17	11	17	17	12	17	11	12	16	75	68	143	28
5831	47	18	11	7	22	1	14	4	21	18	30	0	0	0	9
5832	3	3	6	0	3	5	4	8	2	9	0	7	14	20	32
5833	52	5	17	15	9	17	10	17	5	13	17	63	62	125	10
5881	59	18	12	6	11	1	19	2	19	24	52	0	0	5	6
5882	3	2	5	1	10	0	8	5	1	2	6	6	15	24	30
5883	54	6	17	5	17	15	7	11	17	17	17	60	69	129	40
5901	26	19	10	9	38	0	49	9	11	14	24	0	0	2	4
5902	3	3	6	0	8	0	2	5	0	2	7	1	12	15	22
5903	37	5	17	5	8	17	5	10	17	7	17	52	56	108	13
6851	31	19	11	8	53	2	49	8	12	15	25	1	0	0	10
6852	4	4	8	0	3	3	0	10	8	4	3	5	13	16	33
6853	49	5	9	8	5	17	15	14	12	14	17	44	72	116	15

6891	72	21	15	6	15	0	26	20	20	37	51	1	1	13	6
6892	2	1	3	1	1	6	9	11	2	7	7	11	17	28	43
6893	71	6	6	17	17	17	12	17	17	17	17	63	80	143	37
6911	41	24	13	11	56	1	75	19	11	15	30	1	1	3	8
6912	5	4	9	0	0	0	2	1	3	2	0	0	8	3	16
6913	19	5	5	5	13	6	9	7	8	5	17	34	46	80	12
6921	20	18	10	8	36	0	18	2	14	17	26	0	0	0	10
6922	4	4	8	0	9	1	0	3	3	11	1	1	4	13	20
6923	33	5	17	6	5	13	13	17	6	6	10	46	52	98	17
6951	32	25	15	10	49	1	34	4	13	15	22	0	0	0	8
6952	5	5	10	0	8	0	0	1	0	1	1	0	1	9	3
6953	12	5	10	5	5	6	5	6	8	5	6	31	30	61	13
7711	58	29	18	11	55	0	55	1	10	12	18	0	0	0	8
7712	5	5	10	0	3	0	0	1	0	0	0	0	0	4	0
7713	4	5	11	5	5	6	5	5	5	5	5	32	25	57	12
7721	59	30	16	14	65	0	41	1	11	13	22	0	0	1	6
7722	5	5	10	3	2	0	1	0	0	1	1	1	5	6	8
7723	14	10	8	5	6	5	5	9	6	7	12	34	39	73	17
7731	69	26	16	10	39	0	43	4	14	19	29	0	0	1	5
7732	4	5	9	0	5	0	0	3	0	4	5	1	2	8	12
7733	20	5	17	5	5	8	5	12	13	6	7	41	43	84	15
7741	72	27	17	10	43	2	36	3	14	21	31	0	0	0	8
7742	4	3	7	0	10	0	0	2	2	10	4	0	9	12	25
7743	37	5	17	5	5	8	13	17	11	5	17	40	63	103	23
7751	73	19	12	7	21	0	23	0	21	18	39	1	0	5	11
7752	3	4	7	2	10	0	0	13	4	6	2	3	14	25	29
7753	54	9	17	5	5	17	13	13	9	11	17	53	63	116	20

7761	76	25	16	9	28	0	30	0	14	16	35	0	0	1	6
7762	5	5	10	0	3	2	1	0	2	1	3	8	2	6	16
7763	22	5	9	10	6	5	9	6	8	14	9	35	46	81	14

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Perret, E., Regard, M., & Schmidli K. (The Token Test: quantitative assessment of aphasia). Schweizerisches Archiv fuer Neurologie, Neurochirurgie und Psychiatrie, 1974,114, 298.

- Regard, M., & Perret, E. (Neuropsychological diagnosis and localization of brain damage: correspondence with other neurological methods). *Fortschritte der Neurologie und Psychiatrie*, 1977, 45, 517-528.
- Regard, M. (Introduction to clinical neuropsychology). Zurich: Institute of Applied Psychology, 1977.
- Landis, T., Regard, M., & Serrat, A. Iconic reading in a case of alexia without agraphia caused by a brain tumor: a tachistoscopic study. *Brain and Language*, 1980, 11, 45-53.
- Strauss, E., Regard, M., & Knapp, P. Children's production on verbal and non-verbal fluency tasks (submitted).
- Regard, M., & Perret, E. Hemispheric specialization in the human frontal lobes: a neuropsychological study (in preparation).

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