THE NEUROCOGNITIVE MECHANISMS UNDERLYING PERSEVERATION

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A DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF DOCTOR OF PHILOSOPHY
in the
Department of Psychology

We accept this dissertation as conforming to the required standard.

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UNIVERSITY OF VICTORIA
April 1985

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ABSTRACT

This dissertation was divided into three parts. The first part presented a critical review of the neuropsychological literature regarding perseveration and demonstrated the absence of a systematic theoretical model of the mechanisms underlying this phenomenon, particularly in patients with nonfrontal lesions.

The second part presented such a model, based on both neuropsychological and cognitive data concerned with the voluntary regulation of attention (cerebral activation). Perseveration is viewed as one manifestation of the breakdown of such regulatory processes and the model provides a framework both for the integration of past findings and for future, more systematic investigation of the nature of perseverative phenomena.

The third part presented several such investigations in order to provide both a preliminary empirical validation of the model and to demonstrate its heuristic potential for both neuropsychology and cognitive psychology. Three research questions were investigated using a multiple case study design. Each of eighteen non-frontal (six "deep," six "shallow," six "combined"), seven frontal and eleven normal (non brain-damaged) subjects were tested and the quality and pattern of their results were examined in detail. Both individual performances and trends within and between groups were discussed. A voluntary attention deficit could account for 77.8 percent of the perseverative errors made by the eighteen nonfrontal patients (reflective perseveration) and could not be accounted for by previous explanations of perseverative mechanisms. Furthermore, there was a strong positive association between reflective perseveration and other signs of a voluntary attention deficit. Similar errors, in terms of the quality, pattern and association with other signs of an attentional deficit, were seen in the frontal patients. The majority of patients with deep midline involvement demonstrated signs of an attentional deficit (six combined, four deep), whereas only one shallow patient did so,

providing preliminary support for the model's neuroanatomical proposals. Finally, three classification systems for perseverative errors were investigated, both confirming and extending earlier typologies across a variety of patients and tasks.

The implications of these results for modifications to the model, future investigations and for the potential of such an integrated approach to both neuropsychology and cognitive psychology were discussed.

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ACKNOWLEDGEMENTS

I wish to acknowledge and thank the following hospitals and centres for their cooperation and assistance in this project and for access to their patients, medical records and facilities:

Gorge Rd. Hospital (Victoria, Canada)
After-Care Hospital, Melbourne, Australia.
Alfred Hospital, Melbourne
Austin Hospital, Melbourne
Caulfield Rehabilitation Hospital and Day Care Centre, Melbourne
Hampton Hospital, Melbourne
Kingston Hospital, Melbourne
Manvantara Rehabilitation Hospital, Melbourne
Mount Royal Hospital and Coburg Day Centre, Melbourne
Prince Henry's Hospital, Melbourne
Royal Talbot Rehabilitation Hospital, Melbourne
St. Vincent's Hospital and Bolte Rehabilitation Centre, Melbourne

The Neuro-radiology departments at Prince Henry's, the Alfred, the Austin and St. Vincent's Hospitals and the Dandenong Radiology Centre were of enormous assistance in finding and further interpreting the CT scans and reports. In particular, I wish to thank Dr. Harold Fabrikant and Dr. Alan Lavoire-Pierre who were very generous with their time and patience in discussing the CT scans.

The Photography Departments at the Alfred, Austin, St. Vincent's and, in particular, Prince Henry's Hospitals were also extremely helpful in the reproduction of the CT scans.

My advisor, Professor Lou Costa offered continual encouragement and support from the inception of the ideas forwarded here and played a large part in their development. I wish to thank him for his time, thoughts and humour, all of which were readily available whenever I needed them.

I also wish to thank my committee members for their critical guidance. In particular, I wish thank Professor Michael Masson who ushered me through the corridors of cognitive psychology and with whose encouragement I discovered it to be interesting after all! Thanks are also due to Dr. Kevin Walsh for his support and interest during the "Australian phase" of the project.

Martin Harris drew the diagrams and I wish to thank him for the care he has taken and for giving so generously of his time.

My tireless and ever-cheerful typist, Jane Koetsveld, has worked so hard in the preparation of this document that she deserves a degree of her own and I thank her very much for her efforts.

Special thanks are due to Geoffrey Ewing for his support and to both he and Georgina for their forbearance and for providing perspectives.

Finally, I wish to thank all the participants in this study, who must remain anonymous but without whose cooperation the study could not have proceeded. Each of the patients I interviewed expressed a desire to do anything they could to help others in the future. I admire their selflessness and courage and hope this work goes some way to fulfill those aims.

PART I: INTRODUCTION AND LITERATURE REVIEW

1. INTRODUCTION

This dissertation grew from a longstanding interest in the frontal lobes and the relationship between the frontal and limbic systems - both of which seem to be mostly understood, especially in the clinical setting, more at an intuitive level than from a solid theoretical base. Clinicians are frequently confronted with very subtle and apparently inconsistent test results from patients with frontal lesions despite quite clear devastation in terms of the patient's personal life.

On thinking about these difficulties, perseveration appeared to epitomize, in less subtle form, many of the problems seen with frontal dysfunction. It has been forwarded as a manifestation of personality variables, a defence against overwhelming anxiety, disinhibition of impulse control, distractability, planning difficulties and the failure of voluntary attention. When it becomes a constant and pervasive feature of behaviour, it is considered to be one of the most valuable signs of significant cerebral impairment and with certain qualitative features it is viewed as characteristic of frontal dysfunction.

Perseveration is also found, however, with posterior lesions and with diffuse lesions. There seemed to be no clear understanding of whether these were all manifestations of a unitary disorder, with a single underlying mechanism, or represented different deficits. In fact, a review of the literature regarding perseveration, including the early studies with normal and psychiatric populations, as well as the more recent emphasis as a neuropsychological sign, revealed that there is no good theoretical model to explain the underlying mechanisms involved, or from which testable predictions can be made about perseveration with certain lesions or certain tasks. It is this gap that the present dissertation has attempted to address.

The major thrust of this dissertation is the presentation of a model that has been developed within the framework of the brain as an information processing system. It represents an attempt to integrate both the recent cognitive and neuropsychological literature regarding this system. These two disciplines are both rich sources of information but they seem to have frequently developed in parallel with little cross-fertilization of ideas, even though this appears to offer great potential for both fields.

By integrating them, the proposals to be presented have two aims:

1. to provide a more systematic theoretical model of the mechanisms underlying perseveration and hence of the functional roles of the frontal and fronto-limbic system.

2. to demonstrate how empirical data from neuropsychology can be used for the formulations by cognitive psychologists of how information is normally processed and organized.

The following chapter (Chapter 2) presents a review and summary of the findings that have already been established regarding perseveration, since any model of the underlying mechanisms will have to be able to account for these. Chapter 3 presents an overview of the model in its current, but not final form, together with both the cognitive and neuropsychological evidence used in its development. Chapter 4 examines how well this model does, in fact, account for the perseveration findings and also the extent to which it is able to generate testable hypotheses regarding both the mechanisms underlying perseveration and their possible neuroanatomical substrates. These theoretical considerations are followed by a discussion of the methodological problems encountered in the empirical investigation of such a model - particularly in the initial exploratory phase (Chapter 5). Exploration of three questions raised by the model was conducted as a first step in such investigation. The research design and method used to examine each of these questions are presented in Chapters 5 and 6. The results for each investigation are presented and discussed separately in the subsequent three chapters (Chapter 7, 8, and 9). In each of these chapters the implications of the results for the proposed model are considered. The final chapter presents a summary of the theoretical concepts and empirical findings and suggests directions for future research.

2. THE NATURE OF PERSEVERATION

2.1 Overview

The term "perseveration" was first introduced by Neisser in 1894, who defined it as

> The tendency for a behaviour or thought process to repeat itself, maladaptively and without repetition of the stimulus (cited by Cattell, 1946, p.229).

Since that time there have been a number of different approaches to the study of perseverative behaviour and considerable confusion as to its defining characteristics. Terms used synonymously with perseveration have included: secondary function (Gross, 1902); continuance and hindrance (Stephenson, 1934); mental inertia (Luria, 1973a; Spearman, 1927); sensitivity to set or einstellung (Fisher, 1950; Kaufman, 1963; Stephenson, 1934); inability to shift set (Goldstein & Scheerer, 1941; Milner, 1964,1965); difficulty with creative effort (Cattell, 1946); disposition rigidity (Cattell, 1946; Cattell & Tiner, 1949); stereotyped behaviour (Luria, 1973a, 1973b; Rosvold & Mishkin, 1961); inflexibility (Walsh, 1978) and rigidity (Breskin, 1968; Leach, 1967; Mackie & Beck, 1966; Regard, 1981; Yates, 1967). As noted by Walsh (1978, p.126), however, there is no convincing evidence that these terms refer to a unitary disturbance.

On the other hand, on reviewing the literature, a number of features consistently emerge. These are summarized below and will be discussed more fully in the following section:

1. It is involuntary in nature, although it may occur with insight by the patient as to its inappropriateness.

The early personality theorists (e.g. Cattell, 1946; Stephenson, 1934) interpreted this "persistance of activity after a subject has decided to change that activity" (Cameron & Caunt, 1933) as a failure of "will" or "effort". More recent authors, studying perseveration as a neuropsychological sign, view this lack of voluntary control as part of a more general symptom referred to as a "dissociation between knowing and doing" (Milner, 1964, 1965;

Teuber, 1964; Walsh, 1978).

2. It occurs predominantly in the context of requirements for a rapid series of responses.

3. Under conditions of high anxiety or extreme difficulty and fatigue, low arousal or poor motivation, it may appear as part of normal behaviour.

4. With focal lesions of the posterior cortex, perseveration appears to be largely restricted to activities involving the specific deficits associated with that lesion, whereas with frontal and diffuse lesions, it may be found across a variety of tasks.

The last of these is perhaps the most controversial and least well-documented as the following discussion will demonstrate. Since the major interest here is perseveration as a sign of neuropsychological dysfunction, the following sections review the previous studies of perseveration using brain-damaged subjects.[1]

2.2 Neuropsychological Investigations of Perseveration

Among the earliest and most influential investigators of perseveration in brain-damaged populations was Kurt Goldstein (1944, 1948; Goldstein & Scheerer, 1941). Goldstein was one of the first to demonstrate that, far from being a perceptual peculiarity of certain individuals - as much of the former work had implied - some perseveration in response adaptation was a normal phenomenon (Leach,1967). This has since been confirmed and, as noted above, is particularly evident under conditions of fatigue and anxiety (Walsh, 1978) and poor motivation or low arousal (Cattell, 1946).

Among patients who exhibited it to an extreme degree, Goldstein observed two distinct types of rigid response. The first arose when the subject was faced with a problem that was too difficult for him. An extreme, anxious blocking ("catastrophic reaction") took place; the subject categorically refused to

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[1] For a more extensive review of the history and experimental evidence regarding perseveration in normals, see Monti (1981) and Regard (1981)

acknowledge any change in proffered stimuli and clung rigidly to any previous response. Perseveration was thus seen as a means utilized by the subject to avoid catastrophe. It was also considered to be closely connected with fatigue:

> fatigue is related to distress, that is, tasks produce fatigue because the difficulty or impossibility to fulfill a task produces distress----[and] in a condition of fatigue, perseveration occurs (Goldstein, 1948, p.17-18).

The second type arose when some offered stimulus aroused such strong responses that subjects were unable to break off their reactions when the stimulation changed. He considered this to be most frequently observed in lesions of the subcortical ganglia (Goldstein, 1944).

A review of the more recent literature suggests an implicit assumption has been made by many workers that these two forms of underlying mechanism (overwhelming difficulty vs. inability to shift from strongly aroused responses) distinguish perseveration following posterior cortex and frontal lobe lesions respectively (Milner, 1964; Corkin, 1965). This assumption remains largely untested, however, and has been questioned by several studies of aphasic subjects (Allison & Hurwitz, 1967; Buckingham, Whitaker & Whitaker, 1979). A review of the studies of perseveration where these two groups (frontal and nonfrontal) have been separated will clarify these issues.

2.3 Perseveration Associated with Frontal Lesions

2.3.1 Animal Research

The relationship between lesions of the frontal lobes and perseveration gained increased attention with the findings of a number of animal lesion studies. Perseverative responses were noted to be a major problem underlying failure on such tasks as delayed response and spatial alternation by monkeys with lesions of the frontal lobes (Brutkowski, Konorski & Lawicka 1956; Butter, 1969;

Iversen & Mishkin, 1970; Jacobsen, 1935,1936; Harlow, 1950; Harlow & Settlage, 1948; Mishkin, Vest, Waxler & Rosvold 1969; Pribram, Mishkin, Rosvold & Kaplan 1952). Harlow & Settlage (1948), for example, observed that monkeys with frontal lesions tended to persist in choice responses that had become inappropriate to the resolution of an ongoing problem, maintaining responses that had earlier been adequate to the task. Harlow (1950) distinguished two types of error - perseveration of the stimulus (responses continue to be made to a particular stimulus attribute) and perseveration of response (the same response is made to a different stimulus or attribute). Although these terms were descriptive of the behaviour observed, Mishkin (1964) noted that they were of little help in <u>explaining</u> the results in situations eliciting perseverations. Mishkin proposed the problem to be perseveration of a central mediating process, "one which guided selections among objects according to a relatively stable abstract principle" (p.228). He noted that each experimental situation elicits an initially predominant mode of response in normal and frontal animals alike. This initial preference differs from one situation to another. According to Mishkin, the frontal animals differ from the others only in "greater persistance or perhaps inertia of their initial sets" (p.228).

These studies were followed by a series of experiments in search of the precise locus within the frontal region 'responsible' for perseveration. A number of investigators noted that, although perseveration occurred with both dorso-lateral and orbital lesions, there were significantly more such errors associated with orbital involvement (Mishkin, 1964; Mishkin, et al., 1969; Rosvold & Mishkin, 1961).

Subsequent studies supported the proposal that failures on spatial and reversal alternation produced by gross prefrontal ablation could be attributed to a number of separable deficits which contribute in varying degrees to the emergence of perseverative behaviour. Each of these deficits was considered to be more or less associated with regional distinctions within the frontal lobes and included:

1. a spatial deficit, associated with dorsolateral lesions, particularly the middle third of the sulcus principalis in monkeys (Butters & Pandya, 1969; Butters, Rosen & Stein, 1974; Butters & Rosvold, 1968a, 1968b).

2. a persistence of initial set or of responses that are strongly evoked by a particular stimulus attribute, associated with ventrolateral lesions (Mishkin, 1964; Mishkin, Vest, Waxler & Rosvold, 1969).

3. a heightened distractability and responsiveness to novel stimuli (Gross & Weiskrantz, 1964; Isaac & DeVito, 1958; Harlow, 1952; Orbach & Fischer, 1959; Pribram et al., 1952; Richter & Hines, 1938).

and

4. poor impulse control (Brutkowski et al., 1956; Konorski, 1967; Mishkin, 1964; Stanley & Jaynes, 1949); both 3. and 4. being viewed as disorders of higher levels of cortical inhibition and to be associated with orbital lesions.

2.3.2 Human Research

The study of perseveration in humans with frontal lesions is largely associated with the names of Brenda Milner and Alexander Luria. In 1964 and 1965, Milner reported several tasks in which patients with frontal damage demonstrated an inability "to suppress [their] or to rid [themselves of] perseverative interference from previous sensory events" (1964, p.33). Milner (1964) considered the cortical lesion for this loss to be dorsolateral rather than orbital. Closer inspection of her sample, however, reveals that at least 15 of the 18 patients had as much mesial involvement as dorsolateral and the extent of orbital involvement is not known except for one case (Damasio, 1979). Furthermore, the ventrolateral region appears to have been involved in all but one case, which may be significant in view of the animal findings discussed earlier.

Reemphasizing the nonunitary nature of perseveration, Milner demonstrated frequent dissociations across tasks, depending on lesion location (superior vs. inferior, left vs. right

(Jones-Gotman & Milner, 1977; Milner, 1964,1965). With respect to laterality, a number of other authors have joined Milner in suggesting that, while there is a general inflexibility component associated with the behaviour of all frontal patients, this will be manifested to a greater extent on tasks involving material usually processed by the lesioned hemisphere. Hence, patients with left frontal lesions show greater rigidity on verbal tasks and right frontal patients perform most poorly on non-verbal tasks (Corkin, 1965; Jones-Gotman & Milner, 1977; Perret, 1974; Regard, 1981).

Luria was less concerned with laterality in his studies, his cases consisting mostly of massive frontal tumours likely to result in wide-spread frontal dysfunction. He did, however, propose three major forms of "frontal lobe syndrome" associated with lesions of the dorsolateral, mesial-basomesial and orbital frontal regions. He proposed that:

> lesions in the lateral frontal zones and, in particular in the post-frontal region, as a rule give rise to particularly marked disturbances of the organization of movements and actions, to the disintegration of motor programmes and to disturbance of the comparison of human motor behaviour with its original plan. For this reason, perseverations, the pathological inertia of existing motor programmes and the disturbances of regulation of external behaviour... could be observed particularly clearly with lesions of the lateral zones of the prefrontal, and, in particular, the postfrontal region of the cortex (1973a, p.221).

Patients with lesions of the orbital zones are considered to have disturbances of a different nature due to the "increased disinhibition of their mental processes, which leads to uncontrollable impulsiveness and fragmentation [so that, despite] potentially intact intellectual operations, [they] cannot carry out planned and organized intellectual activity" (1973a, p.223). Disturbances of disinhibited affect and social behaviour are also associated with orbital lesions.

Disruption of the medial zones are associated with a "disturbance of the selectivity of mental processes" leading to confabulations, disorientation and, with deeper lesions, a disturbance of consciousness or "oneiroid states" characteristic of lesions of the limbic system (p.224).

Luria has also provided a detailed analysis of the "motor perseverations" referred to above (Luria, 1965, 1966, 1969, 1973a, 1973b; Luria & Homskaya, 1963; Luria, Pribram & Homskaya, 1964). In 1965 he distinguished between two forms of perseveration which he considered to be associated with two different neuronal systems. The first type (type I)he termed "efferent" perseveration ("perseveration of the motor periphery") and referred to the compulsive repetition of a movement that has been initiated. He emphasized that the overall "programme of action" was preserved in these cases but that its execution was prohibited by the "pathological inertia of individual links in the chain of movements to be performed" (p.3). Luria noted that this form of perseveration may be observed in cases of "massive injury to the frontal lobes extending to the subcortical motor ganglia". He interpreted it as resulting from the loss of the inhibitory role of the premotor-motor ganglia-thalamic system so that a previously automatic discontinuation of a movement now requires the generation of voluntary impulses.

An example of type I perseveration would be a patient who, on being asked to draw a circle, responds continuously thus:  or  , despite no further stimuli being presented. Helmick & Berg (1976) refer to this form as "continuous perseveration". They defined it as follows:

> any response in which all or part of that response was continued beyond the point of completion without interruption by any intervening event such as a significant pause, the insertion of a word or words, or interruption by an examiner (p.146).

The paradigm can be represented more formally as:

Stimulus	Response
A --------------->	A A A A - - - -

Luria's second type of perseveration (type II) refers to the pathological inertia of the programme of action itself. In such cases the initial task is executed and terminated appropriately but the patient, having once performed this task, is incapable of switching to the fulfilment of any other task. When instructed to execute a second task the subject again performs the first task on which she or he is 'stuck' (Luria, 1965). According to Luria (1973a) this symptom occurs characteristically against a background of general asthenia and "adynamia" and occurs most frequently with massive bilateral injuries to the prefrontal cerebral regions not extending to the subcortical motor ganglia.

Type II corresponds more closely with the "perseveration", "inflexibility" and "inability to shift set" described by other authors in patients with prefrontal lesions. It also encompasses perseveration at various levels of complexity; for example, repetition of a particular content such as "square" or a particular mode of activity, such as naming.

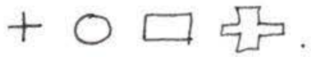
In contrast to the continuous nature of efferent perseveration, this form maybe discontinuous; that is, the perseverate may occur after several other, possibly correct, responses have intervened (Helmick & Berg, 1976). Luria considers this to be consistent with the concept of inert traces, although a milder form than the completely "stuck" or immediate perseveration described above.

These two variations can be represented thus:

Stimulus	Response	Stimulus	Response
A ---------->	A	A - - - - - ->	A
B ---------->	A	B - - - - - ->	B
C ---------->	A	C - - - - - ->	A
(Immediate)		(Discontinuous)	

Goldberg & Tucker (1979), studied a group of patients following the removal of frontal tumour and analyzed the quality of the perseverative errors made when they were asked to draw a series of geometric figures. In addition to a "hyperkinetic-like" perseveration, which corresponded with Luria's efferent type, they found that his second type could be further subdivided into three hierarchically structured forms:

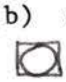
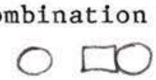
1. Perseveration of activities which seemed to involve confusion between semantic categories, such as pictorial and linguistic representations, or mathematical symbols and geometric figures. These cases were considered to reflect "retrieval of the most appropriate item from an inappropriate memory location." (p.278). For example, when asked to draw a circle after a written (dictation) task the patient might respond with: 

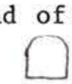
2. Perseveration of features was considered to reflect confusion of generalized spatial characteristics (open vs. closed; concave vs. convex) within a given category (geometric figures). For example, although initially drawing a cross thus,  , the patient draws it as  when asked to draw a cross after completing several other closed figures:  .

Goldberg and Tucker further analyzed the errors at this level as a means of inferring dimensions of encoding in normal visual processing.

3. Perseveration of elements, in which all or part of the specific graphical components of the prior response is repeated in a subsequent response resulting in

(a) complete repetition e.g., on being asked to draw a circle and then a square, the patient responds with: 

(b) a combination of both full responses e.g.,  or 

or (c) a blend of fragments from one or both responses e.g., 

In Luria's description of this general type II perseveration, he also gives examples of perseveration across response modality, for example, continuing to write when asked to shift to speech. Although this may be included in the Goldberg & Tucker framework under "perseveration of activities", it was not specifically considered by them - all their examples being within the graphic mode. This then may represent a fourth subdivision.

Goldberg & Tucker also noted that, in all cases with more than one type of perseveration during the early post-operative stages, the process of recovery was invariably the one predicted by the hierarchy. In other words, no matter what the combination of perseverations, higher order perseverations recovered later than lower order ones.

Although these finer distinctions between various types of perseverative errors appear to provide a useful framework for the study of perseveration, this has not yet become generally accepted. Luria's more general distinction between type I (efferent) and type II (program of action) perseverations, however, is now commonly adopted in studies of this phenomenon.

2.3.3 Underlying Mechanisms in Frontal Perseveration

A number of deficits have been proposed to account for the second type of perseverative behaviour, described above, in frontal patients. These are summarized below and can be seen to correspond closely with the deficits derived from the animal research reviewed earlier:

1. A difficulty in the analysis and planning of a program of action (Luria, 1965, 1973a) including a failure to utilize error feedback to modify such programs (Konow & Pribram, 1970; Milner, 1964; Teuber, 1964), associated with dorsolateral lesions;
2. An inability to overcome a previously established response set (Milner, 1964);
3. A heightened distractability and disinhibition of responses to irrelevant stimuli, associated with orbital and orbitomesial lesions (Luria, 1973a) and
4. Poor impulse control (Milner, 1964,1965; Perret, 1964) also associated with orbital lesions.

Luria (1973a) proposed that these various deficits all reflect a more general frontal disorder which was the essential problem in perseveration, at least of his second type. He suggested this was a disorder of voluntary attention, in the context of heightened involuntary attention. This concept has intuitive appeal, but his analysis failed to account systematically for nonfrontal perseveration (reviewed in the following section) nor for the varying subtypes of perseverative errors in his second form as described by Goldberg & Tucker, (1979).

2.4 Perseveration Associated with Posterior Lesions

While it is generally accepted that marked perseveration as a focal neuropsychological sign suggests frontal lobe pathology (Goodglass & Kaplan, 1979; Hecaen & Albert, 1978, p.357; Lezak, 1976, p.434, 1983, p.519; Walsh, 1978, p.127), the occurrence of perseveration in patients with focal posterior lesions is usually dismissed with a passing acknowledgement and little further discussion. This is not due however, to an absence or rarity of perseveration in these patients. Rather, it appears to reflect the paucity of studies which have specifically investigated this phenomenon. Most studies of perseveration primarily focus on the behaviour of frontal patients. When posterior patients have been included, they have largely served as a control group, with the major comparisons of interest being between frontal and combined posterior groups, despite the observation of heightened perseveration in particular subgroups of posterior patients. Even when regional distinctions have been made within the posterior group and used in the comparisons, the usual explanation of high rates of perseveration in one or more of these subgroups is that of difficulty, that is, variations of Goldstein's (1944) "catastrophic reaction hypothesis" (e.g., Corkin, 1965; Jones-Gotman & Milner, 1977; Milner, 1964, 1965). Difficulty is assumed because the perseverating subgroup typically demonstrates obvious deficits when dealing with similar material; for example, right temporal patients both perseverate and make spatial errors on a task of drawing nonsense designs (Jones-Gotman & Milner, 1977). Although some qualitative differences between frontal and posterior perseverative errors have occasionally been noted (e.g., "rule-breaking" in frontals) (Milner, 1964; Teuber, 1964), no further test of this assumption of different underlying mechanisms has been conducted.

Perhaps the major reason for this neglect of posterior perseveration has been the further assumption that it occurs much less frequently than with frontal lesions. Although a number of studies appear to support this contention (Corkin, 1965; Jones-Gotman & Milner, 1977; Milner, 1964, 1965), there have also been some studies showing the opposite trend (Regard, 1981; Teuber, 1951, cited in Milner,1964). Both findings may be confounded by a number of factors, in particular:

1. the tendency, discussed above, to combine posterior patients irrespective of lesion location;
2. variations in the nature of the task (e.g., Milner, 1964 and Teuber, 1951, used two different forms of the Wisconsin Card Sorting Test);
3. selection bias, e.g., in Milner's studies patients with lesions of the left temporoparietal speech area were not included due to surgical policy.

The presence of a marked tendency to perseverate (in the absence of general dementia) can certainly not be taken to be diagnostic of frontal involvement in the individual case. Regard (1981), for example, using a small series of 16 patients (5 left frontal; 3 right frontal; 3 left nonfrontal; 5 right nonfrontal) found that:

1. patients with left hemisphere disease, <u>especially nonfrontal</u> lesions, made the largest number of perseverations on Word Fluency, and
2. patients with <u>right nonfrontal</u> lesions made the largest number of repetitions on a nonverbal fluency test (5-point Test).

Similarly, Allison & Hurwitz (1967) concluded from a study of 24 aphasic patients that:

> perseveration is not an occasional accompaniment to aphasia but that it occurs in the majority of cases (p.446).

Yamadori (1981) found perseveration in 86.8 per cent of the aphasics he studied. Pick (1931/1973) even concluded that perseveration:

> appears mainly with disorders resulting from lesions of the temporal lobe (usually on the left side) (p.63).

The small number of studies directly addressing perseveration associated with posterior lesions becomes even more surprising when one considers that perseveration in aphasics was described by Hughlings-Jackson as early as 1879. Similarly, Pick (1892, cited in Hudson 1968) reported a posterior case which he described as "pseudo-apraxia" due to the perseverational characteristics. Liepmann (1905) also described perseveration in apraxic patients and considered that it occurred particularly with lesions of the posterior third of the brain. Schiller (1947) also emphasized the importance of perseveration in World War II patients with lesions of the parietal and parietorolandic regions (Hecaen, 1967).

More recently, Critchley (1966) reported tactile and visual perseverations (the latter being termed palinopsia) with parietal lesions. He described these as the continuation or "reappearance of perceptions after the removal of the object that was at the base of the original perception" (cited in Hecaen & Albert, 1978, p.147). He also used the term palinopsia to refer to the illusory extension of visual perception to a greater area than usually provoked. Bender, Feldman & Sobin (1968) asserted that palinopsia was always associated with other optical illusions and that it was related to visual after-images of the normal subject. They found visual perseveration to occur mainly in cases with mild field defects and to disappear when the field defect became severe or improved. Kinsbourne & Warrington (1963) also concluded that visual perseveration represented an enhancement of the normal process of visual after-image formation, perhaps as a result of the release of cortical visual systems from their normal inhibitory influences. Swash (1979) argued against the normal after-image association and made a distinction between palinopsia, being a recurrence and perseveration being a continuation of a visual image. This is similar to the distinction between the type II and type I perseveration, respectively, described earlier for motor responses.

Despite this similarity however, neuropsychological studies have failed to clarify whether these perceptual phenomena refer to the same underlying disturbance(s) found in the more common motor perseveration. Earlier work with normal subjects often included a similar concept of sensory perseveration using such measures as duration of visual after-image (Notcutt, 1943; Rethlingshafer, 1942; Rim, 1955). There was little success, however, among studies attempting to demonstrate a unifying underlying factor either within these tests themselves or across these and other tests involving a motor response (see Monti, 1981, for more detailed review). The rarity of perceptual perseveration in clinical populations probably accounts for the paucity of knowledge in this area.

2.4.1 Underlying Mechanisms in Posterior Perseveration

As noted earlier, the most common explanation of motor perseveration with posterior lesions is that it merely reflects the "normal" breakdown of behaviour in the face of difficulty - related to fatigue and/or distress (Goldstein's catastrophic reaction hypothesis) or at least to perceptual confusion. Frontal perseveration is then seen to represent an "abnormal" disruption of behaviour or "perseveration proper".

The few investigators who have conducted detailed studies of posterior perseveration, while not disputing that difficulty and fatigue promote such perseveration, argue that they are neither necessary nor sufficient to account for all the perseverative errors they encountered (Allison & Hurwitz, 1967; Buckingham, Whitaker & Whitaker, 1979; Leicester, Sidman, Stoddard & Mohr, 1971).

Allison & Hurwitz, for example, concluded that:

> the presence of emotional tension and anxiety facilitated perseveration but it could be demonstrated also in patients whose mood was equable and in some who were affectively disturbed, it did not occur.
>
> As to the role of fatigue, brain damage may increase fatiguability, but when perseveration was pronounced in our patients it occurred especially at the commencement of an examination. Too rapid presentation of stimuli could also favour its occurrences but it could be elicited even when intervals of one to five minutes were allowed to elapse between stimuli (p.445).

Perceptual confusion was also unlikely in this study as patients would often perseverate "on trying to reach the same goal by one means but not by another" (p.446).

Yamadori (1981) found that the severity of aphasia was not related to the incidence of perseveration. Similarly, Buckingham, Whitaker & Whitaker (1979) commented that:

> The degree of difficulty of various tasks has been shown to be related to perseveration in some cases; this is, of course, related to Goldsteins's "catastrophic response". There is a problem, however, with the theories relating stimulus complexity to perseverating behaviour. It is often the case that when a patient "locks in" on a perseverate it will be produced for difficult as well as for simple stimulus items (p.350).

Unfortunately, this is not such a "problem" for Goldstein's hypothesis as Buckingham and his colleagues suggest. Goldstein, in fact, included this "difficult-to-easy" phenomenon in his proposals, stating that:

> We consider perseveration as a means utilized by the organism to avoid catastrophe...As a matter of fact, it becomes apparent if a task is <u>particularly</u> difficult or the patient was exposed directly before to such tasks. In the latter case, he may perseverate even in "easy" tasks. The preceding difficult task made it impossible for the equalization process to "take place in an adequate way". Therefore, the new task touches the organism in an abnormal condition, and thus it may be unable to solve even "easy" tasks (1948, p.18).

More problematic for the catastrophic reaction hypothesis would be perseverative errors on an easy task followed immediately by success on a more complex task of the same nature. Although this was not specifically described by Buckingham, Whitaker & Whitaker (1979) there were other examples in their data which would be difficult to account for in terms of Goldstein's model. For instance, there seems to be no reason to infer "avoidance of catastrophe" in the following (p.339):

STIMULUS		RESPONSE
knife	---------	knife
hammer	---------	hammer knife

where the patient perseverates after giving the correct response.

Buckingham et al. (1979) also noted that, although perseveration did occur after long pauses when the patient was "apparently attempting to retrieve nouns... and which may represent a catastrophic response" (p.348), perseverates were also uttered when the patient was <u>not</u> effortfully searching for words. In these cases there was never any pause before the production of the perseverate and all the sentences had normal intonation and stress patterns.

Based on such observations of the linguistic perseverations of two posterior aphasics, Buckingham Whitaker & Whitaker (1979) concluded that their data "are best characterized as representing difficulties in going from one program of action (some task or response requiring a set of movements) to another" (p.350). They considered this form of perseveration to be examples of what both Liepmann (1905) and Hudson (1968) termed "intentional perseveration" (i.e., when a performance is intended but not realized). It is also clearly similar to Luria's type II perseveration. Indeed, Hudson (1968) considered the two to be equivalent although Buckingham and his colleagues were more reluctant to do so because of the lesion location differences.

Yamadori (1981) also referred to the verbal perseverations he found in aphasics (of varying types) as "intentional" perseveration. He distinguished three types of this form of perseveration according to the temporal relationship of a response to the original stimulus:

1. Stuck type - in which an incorrect response was repeated when the same stimulus was presented again. Following the earlier schematic representations for the frontal subtypes, this type can be restated as:

Stimulus		Response
A	-------------------	X
A	-------------------	X

2. Immediate type in which task A would be responded to by a correct response, but for the next task B, response B(A) would be produced in which a portion of the previous stimulus/response A would be coupled with the current stimulus/target response B:

Stimulus		Response
A	-------------------	A
B	-------------------	B(A)

3. Delayed type in which stimulus A would be correctly repeated, as would stimulus B but perseveration would appear for the third task C with response C(A):

Stimulus		Response
A	-------------------	A
B	-------------------	B
C	-------------------	C(A)

Yamadori pointed out that any hypothesis regarding the nature of perseveration must be able to account for these various subtypes. For example, an hypothesis proposing inertia of the motor apparatus (Luria, 1971) cannot explain delayed perseveration since "if it is due to inertia, it must cease when the next step is correctly performed" (Yamadori, 1981, p.593). Similarly, Wepman (1972) proposed that perseveration in aphasia was a manifestation of impaired attention. Because of an occasional closing of an attention "shutter" to the outside world, a response produced when the shutter was open would be perseverated. Yamadori (1981) criticized this hypothesis, pointing out that it did not explain why the perseverative response is elicited (rather than, for example, confabulatory responses) and that the failure to respond correctly to a stimulus could not be taken as a failure to perceive that stimulus adequately.

From his study of apraxic patients with parietal lesions, Liepmann (1905) concluded that:

> Intentional perseveration [is] an ideational disorder in which there is an impasse in the area of sensory pre-preparation of movement with the result that new stimuli excite a previous idea and the movement caused thereby (cited in Hudson, 1968, p.572).

Similarly, Buckingham et al. (1979) concluded that:

> given the stimulus-response parameters used, intentional perseveration results from a sensory-motor ideation disorder in which new stimuli do not necessarily evoke repeated responses, but rather induce recall processing, the result of which is perseverated behaviour (p.350).

Following a single case analysis of a patient with marked intentional perseveration, Hudson (1968) proposed a more detailed explanation of the underlying mechanisms, applicable to both frontal and posterior patients. He suggested that:

> intentional perseveration is due to impairment of an inhibitory system influencing memory which results in an augmentation of facilitatory activity. [This facilitatory activity is related to the establishment of new memory] such that ideas which have been recently acquired are recalled during attempts to develop new ideas. [This occurs because] the augmented activity relative to recently established memory is protracted and attempts at further ideation during this period produce sufficient excitation to induce recall. As the degree of augmented activity diminishes excitation is less apt to induce recall and the establishment of new memory becomes possible (p.581).

In view of the gross memory loss observed in his patient he further suggested that:

> permanent registration of memory may not occur despite enhancement of facilitatory activity... This may be due to extensive injury to systems influencing memory and activity that was initially excessive in the establishment of new memory may not be sustained after excitation fails to induce involuntary recall (p581).

In terms of the neuroanatomical correlates of this model he concluded that disruptions of connections of the frontal lobes with the limbic system may be an important factor in perseveration. Furthermore he suggested that disruption of connections to the limbic system with regions of the cerebrum other than the frontal lobes might produce perseveration in specific functions. Allison and Hurwitz (1967) had come to the same conclusion, although without speculating about the actual mechanisms involved.

Hudson's proposal is an interesting one and represents a much needed attempt to provide a model of the processes and systems involved in perseveration. However, his post hoc explanation regarding the failure of permanent registration despite increased facilitatory activity seems awkward at best. Also, his model fails to account for the commonly observed appearance of a perseverate in a discontinuous manner so that a number of correct (or non-perseverative) responses may occur between the perseverated items. According to his model perseveration should be greatest immediately after the establishment of a new trace and decrease, in continuous fashion, thereafter. As discussed earlier this is not always the case (see Buckingham et al., 1979, for examples). Yamadori (1981), adopting Hudson's proposal, deals with this problem of delayed perseveration by suggesting that the three different subtypes of perseveration described in his study reflect three different degrees of inhibitory dysfunction:

> If disinhibition is strong, stuck type would predominate. Delayed type can be a reflection of the least degree of disinhibition, immediate type being in between (p.594).

This remains unsatisfactory, however, since the least disinhibition would also mean the least augmentation of facilitatory activity so that a response is unlikely to be still active when the delayed perseveration is to take place. It also does not explain why that particular response would be given in favour of the intervening, more recent (i.e. more active)responses. The problem of the memory disorder in Hudson's patient also remains with this explanation.

The notion of limbic disconnection, on the other hand, has been raised by several authors and seems worthwhile pursuing. Buckingham, Whitaker & Whitaker (1979), for example, commented that, while the frontal lobes did not appear to be involved in their patients, the lesions of the temporal and parietal lobes "could have very well extended deeper into these lobes, possibly cutting some of the thalamic projection fibers" (p.351). This concept of subcortical disconnection is examined further in Section 2.5 below where studies reporting perseveration associated with lesions of limbic or other deep structures are reviewed.

Finally, Leicester, Sidman, Stoddard & Mohr (1971) have de-emphasized the role of abnormal physiological function as a cause for posterior perseveration. Using a single case experimental design with aphasic patients, they concluded their study with the following remarks:

> Previous workers have believed that perseveration was caused by abnormal physiology - abnormally facilitated and persistent after-effects of ideation, memory or motor performance. We have described perseveration due to repeating previously correct and reinforced responses and perseveration with established principles of behaviour and neither requires any abnormal physiology. There are probably a number of different processes by which perseveration is produced (p.154).

Leicester and his colleagues fail to explain, however, why some patients are more vulnerable, to an abnormal degree, to such behavioural control parameters. They admit that certain instances of perseverative errors in their patients remained totally unexplained. On the other hand, their study did emphasize the importance of considering the stimulus-response characteristics involved in any analysis of perseverative errors and these issues will be considered further in Section 2.6

2.5 Perseveration Associated With Lesions Of Deep Midline Structures

There has been a recent increase of interest in the functional roles of subcortical structures, in particular the thalamus and the basal ganglia. Research in this area has generally focussed on language deficits following lesions or electrical stimulation of these structures in the left hemisphere. Such studies have largely been of a single case report or multiple case report form and there has been considerable variability both within and between studies in the degrees and types of reported language disturbances. However, one of the most consistent findings has been the presence of perseveration (e.g. Allan, Turner & Gadea-Ciria 1966; Brunner, Kornhuber, Seemuller & Wallesch, 1982; Ciemins, 1970; Glosser, Kaplan & Loverme, 1982; Luria, 1977; Mohr, Watters & Duncan, 1975; Ojemann, 1975b; Papagno & Guidotti, 1983; Reynolds, Turner, Harris, Ojemann & Davis 1979; Riklan & Levita, 1969, 1970; Van Buren, 1975; Wallesch, Kornhuber, Kunz & Brunner, 1983;).

Precise clinico-anatomical correlations amongst subcortical structures in these studies is problematic however (Glosser et al., 1982). Although CT scan or other measures were used to delineate the site of the lesions (usually thalamic), there was also likely to be involvement of other subcortical and cortical areas resulting from several secondary neural processes, especially in the acute phase, such as mass effects with haemorrhages and tumours and oedema with infarction and surgery. The close proximity of the various subcortical structures makes this particularly relevant. The rapid improvement of perseverative features within the first six weeks post-surgery in the "thalamic" case reported by Luria (1977) and the disappearance of the previously marked perseveration at an examination three months post-thalamic-haemorrhage in the case reported by Glosser et al. (1982) certainly raise such questions regarding precise anatomical correlates. Despite this, perseveration is currently considered to be a typical feature of at least one form of "thalamic speech" (Reynolds et al., 1982)

Brunner, Kornhuber, Seemuller & Wallesch (1982) studied 40 patients with well-demarcated vascular lesions of the left hemisphere defined by CT scans. The patients were divided into seven groups based on localization of the cortical lesion (prerolandic, postrolandic, absent) and the presence/absence of a basal ganglia lesion(lenticular and/or caudate nuclei). There was a minimum of five months between onset and testing so that acute secondary effects were minimized. Despite this precaution, the authors noted that precise clinico-anatomical correlation remained difficult since surrounding structures, mostly white matter (and in at least one subject the thalamus) were damaged as well as basal ganglia. However, the presence or absence of a basal ganglia lesion represented a common feature of group membership.

They examined the occurrence of "repetitive verbal behaviour" defined as follows:

<u>Perseveration:</u> Repetition of an utterance (or part of it) which initially was at least partly correct. Exceptions

were repetitions which occur in normal speech (for emphasis etc.)

Perseveration was divided into phonemic perseveration and lexical perseveration.

Stereotypy: Semantically and syntactically correct phrases with no or little informational content, which were used repeatedly.

Automatism: Repetition of invariable utterances with no semantic or syntactic context, mostly short neologisms but sometimes lexical items or even short phrases.

Recurring Utterances: Almost incessantly and fluently repeated automatism.

Echolalia: Immediate repetition of examiner's utterance. It could be varied by changing personal pronoun and flexion form or by completion.

These authors concluded that:

1. Subcortical infarcts of the dominant hemisphere involving basal ganglia led to aphasia.

2. The aphasic symptoms could not be accounted for by general intellectual deterioration or other such factors.

3. The aphasic syndrome resulting from cortical infarction was more severe when the lesion extended into the basal ganglia, although the size and localization of the cortical infarction were comparable.

4. Automatisms and recurring utterances only occurred if there was a combined cortical and basal ganglia lesion. However, they commented that the isolated basal ganglia lesions may have been too small for these features to appear.

Although they did not draw conclusions regarding the occurrence of perseveration, examination of their case report data indicated that perseveration occurred in all groups but was most prevalent in subjects with:

(a)lesions extending across the Rolandic fissure i.e. combined frontal and posterior lesions (with and without basal ganglia involvement but especially with basal ganglia involvement) and (b) posterior lesions with involvement of basal ganglia.

2.5.1 Underlying Mechanisms in Deep Structure Perseveration

A number of different mechanisms have been proposed to account for the aphasic or "quasi-aphasic" (Luria, 1977) syndromes seen with subcortical lesions, perseveration generally being considered a typical feature of such syndromes. Brunner et al. (1982) interpret their results in terms of a model of multiple representation of function within the cerebral hemispheres as proposed by Kornhuber (1980). In other words, they consider that long lasting symptoms show that the anatomical and functional deficit cannot be compensated whereas transient symptoms only indicate that the damaged structure is part of a functional system which serves the impaired ability. If a lesion not only destroys one part of a functional system but also its possible compensators, the impairment of function is more extensive and stable. They consider the nature and severity of the symptoms seen in their patients with both cortical and basal ganglia involvement fit this model of multiple representation of function.

A variety of other mechanisms underlying the reported language deficits seen with thalamic lesions have been proposed. Mohr, Watters & Duncan (1975), Ojemann (1975b) and Riklan & Cooper (1975) all related the thalamic role in language to various aspects of arousal, alerting, activation and/or attention, though each in a somewhat different way. Fedio and Van Buren (1975) and some of Ojemann's data suggested that the thalamic role also involves an interaction with memory mechanisms. Shaltenbrand (1975) suggested timing mechanisms were involved. Similarities between these concepts and the mechanisms postulated for frontal and posterior perseveration discussed earlier are clear.

Luria (1977) subscribed to the alerting/attention/ activation school, suggesting that his patient demonstrated a defect of vigilance which was material-specific in nature. He proposed that the surgical destruction of parts of the left thalamus and its connections with the verbal zones of the left temporal cortex resulted in:

> a specific kind of derangement, where the specificity of the speech process was lost, the blocking of already evoked or extraneous associations became impossible and the selectivity of speech had broken down (p.458).

This disturbance was seen to be associated with "important changes in gating and blocking processes". Thus the occurrence of perseverative errors and extraneous, often unpredictable, associations (also considered typical) were seen as manifestations of the same underlying defect of regulatory control.

It should be noted that the perseveration described by Luria in this patient, and in other studies cited here, was similar to that described earlier as frontal type II or "plan of action" perseveration and not the efferent (type I) perseveration formerly associated by Luria with deep lesions involving the basal ganglia (Luria, 1965). Most authors appear to agree that efferent perseveration is caused by a deficit in a more peripheral or "lower level" system and not by disruption of the more abstract "plan of action". Luria's localization of this efferent form to the premotor-motor ganglia system may have been too restricted however, since both forms have been reported with basal ganglia lesions and also with thalamic and supplementary motor area stimulation (Ojemann, 1977; Penfield and Roberts, 1959) and in speech and writing with posterior lesions (Helmick and Berg, 1976; Lebrun, 1976).

2.6 Stimulus-response Characteristics

2.6.1 Stimulus Characteristics

In addition to the influence of irrelevant stimulus parameters noted by Leicester, Sidman, Stoddard & Mohr (1971) and discussed earlier, a number of stimulus features have been regularly noted in the perseveration literature. The type of stimulus parameters which promote perseveration[2] appear to be similar for both frontal and posterior patients, as well as for normals (e.g. Allison and Hurwitz, 1967; Luria 1973a, 1973b; Milner, 1964; Notcutt, 1943). These include:

1. Rapid alternations - two or more similar tasks performed independently and in alternation;

2. Fluency tasks - generation of a nonstereotyped series of responses;

3. Conflict - where a previously reinforced or well-established response is no longer appropriate.

Leicester, Sidman, Stoddard & Mohr (1971) distinguished between identity and nonidentity tasks and noted that perseveration is more likely to occur with nonidentity tasks:

> Identity tasks are those in which simultaneous matching within the stimulated modality can occur, with no requirements for prior experience with the stimulus e.g., immediate repetition and copying designs. Nonidentity tasks require learned mediating responses e.g., reading, tactile naming and writing to dictation.

Halpern (1965) found that, for a group of dysphasic subjects:

1. through the visual modality, words of high and medium abstraction level produced significantly more perseveration than low, while through the auditory and visual-auditory modalities no significant differences were found;

2. regardless of modality no significiant differences existed among nouns, verbs and adjectives;

3. regardless of modality, long words produced significantly more perseveration than short;

4. regardless of modality, no significant differences existed between words of frequent and infrequent occurrence in the language;

5. regardless of abstraction level, part of speech, word length and

---

[2] Perseveration refers to Luria's type II or intentional perseveration in the remainder of this dissertation. Efferent perseveration will be designated as such whenever it is being considered.

frequency of occurrence, the visual modality produced significantly more perseveration than the auditory and visual-auditory modalities, except in the case of words of high abstraction level where the auditory mode produced significantly more perseverations.

2.6.2 Response Characteristics

Although there is some suggestion of hierarchical error types in the examples given by Allison and Hurwitz (1967) and Buckingham, Whitaker & Whitaker (1979) in their studies of linguistic perseveration, no attempt to organize the errors of posterior patients in this manner has been made. Indeed, other than the geometric figure drawings studied by Goldberg and Tucker (1979), this form of analysis has not been applied to perseverative errors of any class with either frontal or posterior patients. Buckingham, Whitaker & Whitaker (1979) noted both combinations and hybrid blendings in their study, similar to those found by Goldberg and Tucker. Allison and Hurwitz also commented on this tendency for characteristics of both the perseverative and the target response to occur together. Perseveration across response modality (e.g., oral-motor) as described by Luria (1973a; 1973b) in frontal patients has not been described in posterior or deep midline patients.

Although the definition of perseveration has often included the criterion of the repetition of "an initially correct, or partly correct, response" (e.g, Ojemann, 1975b; Brunner et al., 1982), there has been no rationale given for the exclusion of repetitive errors where the initial response was incorrect. Repetitions of incorrect responses are occasionally reported separately (e.g., Ojemann, 1975b) - and tend to occur together with correct response repetition - but they are often not reported at all. Buckingham, Whitaker & Whitaker (1979) noted that the perseverate did not have to occur initially as a correct response but that a response related to a given stimulus may emerge for the first time on a later (now incorrect) item. Yamadori (1981) also commented on this phenomenon (described in a study by Rochford, 1974) and concluded that "in theory an original motor response need not necessarily be realized.

The initial stimulus is processed but might remain silent" (p.594).

Buckingham et. al. (1979) reported that the probable target and the perseverate often had the same initial segment and that syllabic or syntactic stress of an item may be associated with its later perseveration by aphasic (i.e. left hemisphere lesioned) patients. Goldberg & Tucker (1979), among others, have also found initial segment similarity to be important.

No detailed study of the perseverative errors made by posterior patients with right hemisphere lesions has been published.

2.7 Summary

This chapter has presented the current "state of the art" regarding perseveration. While traditionally considered a frontal sign, perseveration has been reported in both frontal and nonfrontal patients.

Although not emphasized in this review, the previous studies have clear methodological problems - both statistical and design flaws being evident. As noted, the "frontal" investigations have failed to control adequately for the possible confounding effects of selection bias; for task-specific parameters (single tasks have generally been used to demonstrate anterior-posterior dissociation), and for the averaging of results across subgroups of posterior patients. Inappropriate use of parametric techniques is frequently seen in the statistical analyses of results in these studies, leading to the unjustified inference that significant differences between the mean tendency to perseverate of frontal and posterior groups reflect qualitatively dissociable mechanisms underlying this phenomenon. Where reported, considerable overlap in the range of perseverative errors found in the two groups can be seen but remains unexplained in any systematic manner.

The "posterior" studies have been largely of a qualitative rather than a quantitative nature and generally follow a "descriptive case study" methodology (Yin, 1981). Where explanatory concepts have been invoked, these have been post hoc in nature and the data presented fail to fulfill the requirements needed for such inferences from case material (see Monti, 1982; Shallice, 1979a). The suggestion of deficit-specificity in posterior perseveration (Allison and Hurwitz, 1967), for example, has not been systematically investigated. The possibility that these patients perseverate on tasks in which they show no other more basic deficit can not be ruled out.

Three major models have been implicitly or explicitly (post hoc) proposed to explain the occurrence of perseveration in anterior and posterior groups. These can be paraphrased as follows:

Model I — Avoidance of catastrophe - all perseveration (frontal and posterior alike) reflects a defence against overwhelming difficulty and/or a "catastrophic reaction" and subsequent fatigue (Goldstein).

Model II — (a) Avoidance of catastrophe underlies perseveration in posterior patients who perseverate only on tasks in which their deficits produce perceptual confusion and/or overwhelming difficulty, but

(b) frontal patients perseverate because of a deficit in voluntary attention and/or other regulatory processes (planning and executing a sequential program of action) especially in the face of strong incorrect impulses (Luria, Milner).

Model III — In addition to catastrophic avoidance, which may occur more readily in posterior patients than normals or frontals, another more specific mechanism underlies both frontal and posterior perseveration. This mechanism has been described as a disruption of the mechanisms involved in "recall processing" (Buckingham, Whitaker & Whitaker) and elaborated in terms of facilitatory and inhibitory mechanisms (Hudson, Yamadori).

A number of authors have commented on the possible significance of limbic disconnection in the production of noncatastrophic perseveration. A review of studies of thalamic and of basal ganglia lesions added weight to the concept of the importance of deep midline structures for this symptom, although the term "limbic" may be too narrow (basal ganglia involvement can not be ruled out at this stage). These studies also forwarded a number of mechanisms to explain perseveration and associated features seen with subcortical lesions. These mechanisms bear a striking resemblance to the noncatastrophic proposals of Model II above (i.e. attention-regulatory dysfunction) and/or Model III (i.e. recall processing dysfunction) but have not before been considered in this wider context of anterior - posterior comparisons of perseverative behaviour.

None of the studies have attempted to derive testable hypotheses, a priori, on the basis of these concepts, although some can be easily inferred. To an extent, this has reflected the exploratory state of knowledge in this area, especially with posterior patients.

There is some descriptive-anecdotal evidence suggesting that catastrophic avoidance is neither necessary nor sufficient to account for perseveration in any group but there has been no systematic investigation of this proposal. Furthermore, none of the explanations have been elaborated in sufficient detail to account for the stimulus-response characteristics or subtypes of perseverative errors noted in various studies. These can be summarized under three different classificatory systems:

1. <u>The Temporal Relationship Between the Perseverate and its Original Stimulus or Original Execution.</u>

Both frontal and posterior studies have referred to two major types in terms of this temporal relationship, with the second type, often referred to as intentional perseveration, being further divided into a number of sub-types:

(i) <u>Type I: Efferent, continuous</u> or <u>hyperkinesia-like</u>

represented as:

STIMULUS	RESPONSE
A --------->	A, A, A, A,

(ii) Type IIa: Stuck

represented as:

STIMULUS		RESPONSE
A	--------->	X
A	--------->	X

(iii) Type IIb: Immediate

represented as:

STIMULUS		RESPONSE
A	---------->	A
B	---------->	A

(iv) Type IIc: Discontinuous or delayed

represented as:

STIMULUS		RESPONSE
A	---------->	A
B	---------->	B
C	---------->	A

2. The Relationship Between the Perseverate and the Stimulus or Target Response which Elicited it.

Both frontal and posterior patients have been noted to perseverate

(i) when the stimulus or task involves rapid alternation, fluency (generation of a series of nonstereotyped responses) or conflict with a previously reinforced or well-established response

(ii) when the task involves a nonidentity response;

(iii) when the target and perseverate have the same initial segment.

3. The Nature of the Perseverate Itself

Goldberg and Tucker (1979) described three major subtypes of error seen at least in frontal intentional perseveration on a graphic task:

(i) Perseveration of elements - where the specific components of a response are repeated.

(ii) Perseveration of features - where a higher level feature of a response is repeated.

(iii) Perseveration of activities - where the form of the response is repeated.

A model which can integrate these various considerations is lacking. An attempt to provide such a detailed model, as a tentative framework for the further investigation of the mechanisms underlying perseveration, is the purpose of the remainder of this dissertation.

PART II: THEORETICAL PROPOSALS

3. AN INTEGRATED NEUROCOGNITIVE MODEL OF PERSEVERATION

3.1 The Concept of a Neurocognitive Model

A number of equally valid conceptualizations or models could be forwarded to account for perseveration. As mentioned in Chapater 1, the aim of the present dissertation is to investigate the heuristic utility of a model which has been developed within the framework of the brain as an information-processing system, that is, a model which attempts to integrate the knowledge derived from both neuropsychology and cognitive psychology.

As noted in the foregoing literature review, previous explanations of the underlying mechanisms in perseveration have failed to provide a thoroughgoing account of this phenomenon. They did suggest, however, (particularly in the work of Luria) that a more detailed investigation of voluntary and involuntary attention might be worthwhile. Furthermore, there has been a recent upsurge of interest by cognitive psychologists in attentional mechanisms and a number of intriguing parallels across the two disciplines can be drawn.

The following section reviews some of the recent developments in the conceptualizations of attention made by workers in cognitive psychology. These ideas are then incorporated into an information-processing model which can represent the systems and processes which might be involved in perseveration; that is, a model of "normal" behaviour, the breakdown of which might result in perseverative errors. Possible neuroanatomical correlates of these systems and processes are then explored and a tentative neurocognitive model derived as a framework for understanding and further investigating perseveration.

Before presenting these ideas, however, a number of cautions and explanations are necessary. It must be emphasized that the diagrams represent a conceptual model only. Being an information processing model there are the inevitable flow-chart boxes. Although there are suggestions as to neuroanatomical regions that might be predominantly involved in the functional activity represented by each box, the boxes and arrows should be taken to represent neither the regions themselves nor their interconnections. Similarly, there is no attempt to indicate all the brain regions which would be involved in this process. Despite the appearance of a sort of "cortical phrenology" with this type of approach, it is to be constantly borne in mind that complex functional systems are involved and that this does not represent an attempt to go back to the idea of discrete centres for certain processes, functioning in isolation from the rest of the brain.

The cost of the reductionism of a simple model like the one proposed here, leading to conceptualizations several times removed from reality, must be weighed against the heuristic value of such a model i.e., its predictive and explanatory power and its ability to generate hypotheses which will eventually lead to its replacement. It is with this aim in mind that the following ideas are put forward.

3.2 Voluntary (Controlled) and Involuntary (Automatic) Attention

Consider the typical situation in which perseveration occurs. This is usually in the context of a goal-oriented activity (Buckingham,Whitaker & Whitaker 1979) in which an examiner presents the subject with a stimulus of some type (instructions, objects etc.) and the subject gives a response based, in whole or part, on a previously activated but now inappropriate response. In order to understand such breakdown of intentional behaviour, we must first consider the processes which would normally be required for a correct response.

Given that the subject would be bombarded by a huge variety of both relevant and irrelevant stimuli at the same time the task is presented, some selection is obviously required. The first process to consider, then, is that of selective attention.

In recent years cognitive psychology has been shifting away from the "filter" models of Broadbent, (1958, 1971) and Treisman

(1960,1969) to "capacity" models of selective attention (Kahneman, 1973; Underwood, 1976). Capacity models assume that there is a general limit on one's capacity to "exert effort" and that this limited capacity or attentional supply can be allocated, according to certain rules, amongst selected subsets of concurrent mental activities.

The major distinction between capacity and filter approaches is that the earlier filter models viewed selective attention as resulting from the blocking or attenuation of irrelevant material, whereas capacity theorists view selection as occurring due to the accentuation of certain material rather than any active blocking of information. In the latter theories the attenuation or "inhibition" of previously unattended material is due to decay during the time taken to shift attention across items rather than an active inhibitory mechanism (Kahneman, 1973; LaBerge, 1975; Moray, 1969; Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977).

Using these capacity concepts, selection of, and response to, certain stimuli parameters is assumed to be the result of the allocation of attention/effort/resources from a limited supply. The stage at which this selection takes place has been the topic of considerable controversy (see Kahneman, 1973 and Underwood, 1976 for reviews). Recent evidence seems to largely support the "late selection" theorists (Deutsch & Deutsch, 1963; LaBerge, 1975; Larochelle, Rodriguez & McLelland, 1980; Norman, 1968, 1979; Schneider & Shiffrin, 1977). These theorists assume that there is an automatic encoding, based on learning, of all input stimuli - from the time they are received to the production of perceptual features and activation of associated, higher level information which may be both intramodal and intermodal. The depth to which this automatic processing proceeds will depend on prior experience with the stimulus (Schneider & Shiffrin, 1977). A relatively novel but not unknown word, for example, may be processed phonetically (and hence can be repeated) but may not proceed automatically to the activation of associated semantic network i.e., "meaning". It is most likely to partially activate a number of different networks with similar components but which have no automatically integrated meaning at a higher order level. On the other hand, a highly over-learned word may be "understood" automatically via the automatic spread of activation throughout a well-established "deeper" network (with minimal requirement for attention). Since these concepts will be important in the later consideration of system breakdown and perseverative errors, they will be considered in more detail below.

First, the networks referred to above are assumed to represent the hypothetical structure of semantic long term memory[1] or knowledge. This knowledge is viewed as a collection of units sometimes referred to as logogens [2] (Morton, 1964, 1969; Schneider & Shiffrin, 1977); nodes (Collins & Loftus, 1975; Quillian, 1969) or frame terminals (Friedman, 1979; Minsky, 1975), each of which may consist of a complex set of informational elements. These units/logogens become complexly and increasingly interconnected through learning, forming networks of associated units. Within each network, the units are viewed as being organized at various levels, possibly hierarchically. This can be related to the Goldberg & Tucker (1979) study where perseverative errors were used to infer the nature of these levels in visual encoding (e.g. open/closed, concave/convex).

Most of these units are normally passive and inactive and it is this state that is termed long term store (LTS). When a stimulus possesses certain critical features, it activates one or more of these units, the set of currently activated units being termed short term store (STS) (Schneider & Shiffrin, 1977).

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[1] The distinction is made between semantic and episodic memory after Tulving (1972). Only semantic memory will be referred to by the terms long term memory or store, in the remainder of the dissertation.

[2] Logogens were originally introduced by Morton (1964) to refer only to linguistic knowledge or "word-recognizers" (logo=word, genus=birth). I have taken the liberty here to extend this term to a more generic notion referring to the basic units involved in both verbal and nonverbal processing.

The learned interrelationships between nodes may result in a sequence of information processing (node/logogen activation) that nearly always becomes active in response to a particular input configuration (spreading activation). Inputs may be internally or externally generated and include the general situational context. Such a sequence is activated without the necessity for active control or attention by the subject. That is, once activated the sequence or spread of activation is executed with few or no demands on the limited capacity supply. These sequences are referred to as "automatic" and differ from a single logogen in that they are not necessarily unitized; that is, the same logogens may appear in different automatic sequences depending on the contextual input.

The allocation of attention to a selected subset of these activated logogens in STS will result in further "controlled" processing, such as rote rehearsal, serial search, decisions, operations and strategies. Controlled processes are generally viewed as slow-acting and hence available to conscious awareness (Posner & Snyder, 1975). However, Schneider & Shiffrin (1977) distinguish between 2 classes of controlled processes:

1. accessible processes which can be initiated and modified by verbal instruction; they are slow-acting and perceived by the subject.

2. veiled processes which are difficult to modify through verbal instruction, fast-acting and not easily perceived through introspection.

Both require the allocation of resources for their operation. The limited capacity in these models determines the extent to which further analysis of this controlled form may proceed.

The specification and elaboration of the various components or sub-systems - and their organization - in such models have been the subject of a large volume of research in both cognitive psychology and, more recently, neuropsychology. Although this research does not always involve a consideration of the role of voluntary attention, it is aimed at depicting the separable stages through which the stimulus-response sequence progresses (with or without voluntary control). This endeavour, known as "fractionation"

(Shallice, 1979a, 1979b), has been characterized by considerable controversy. The two areas in which the most detailed specification of component stages has taken place appear to be those of memory and linguistic functioning (especially reading) (for example, Baddeley, 1976; Coltheart, Patterson & Marshall, 1980; Neisser, 1969; Neisser & Becklen, 1975).

An example of the controversy surrounding this model-building or fractionation approach in the linguistic domain can be seen in the proposals regarding the nature of the information contained in a given unit or logogen. Some models propose that the same system which recognizes a letter string as a familiar word contains semantic and phonological information about that word (e.g. Coltheart, 1978; Forster, 1976; Morton, 1964). In contrast, Morton's (1969,1979) revised model proposes that the "input logogen" acts as a word recognizer (feature detector) but contains no information regarding semantic or response codes. It is linked to (or capable of accessing) separate semantic and phonological systems where the related information is activated. Recent findings, both from studies using normal subjects (e.g., Morton, 1969; Winnick & Daniel, 1970) and neurological case studies (e.g. Marshall & Newcombe, 1973, 1980; Schwartz, Saffran & Marin, 1980; Warrington, 1975), provide strong support for the second model, i.e. a model specifying separate recognition, semantic and response systems (Morton & Patterson, 1980; Patterson, 1981).

The performance of a particular response is viewed, in most models, as depending on the level of activation of the units in various systems - though clearly there are differences as to the nature and number of these systems. In the model described above, proposed by Morton (1969, 1979; Morton & Patterson, 1980), a response will be determined by the activation of the input logogen system and/or the semantic system; information from either or both of these systems being converted to a phonological (i.e. response) code when it passes to the next stage, the "response buffer". This transfer has been described in the following manner:

> The presentation of a stimulus display gives rise to activations in a set of detectors or logogens, as does the presence of a context. The effects of context and stimulus input add together to determine the central tendency of the activation of each individual logogen. Activation of logogens reach a peak shortly after stimulus presentation and then decay back to the base level as time goes on, although contextual inputs are assumed to have a much slower decay rate than perceptual inputs. Each logogen has a threshold and when the threshold is....... exceeded, the presented item can then be transferred, via a limited capacity channel, into a response buffer for recirculation and/or overt response (Larochelle, McLelland & Rodriquez, 1980, p.686).

The reference here to a "limited capacity channel" resembles the old filter models discussed earlier and has recently been criticized by Larochelle, McLelland & Rodriquez(1980). They modify Morton's notion so that the item to be reported is <u>selected</u> from a set of activated logogens. These authors suggest that it is in this process of selection of to-be-reported items that the limited capacity processing resources are engaged. They describe the process as follows:

> In choosing a response the subject attempts to select the most strongly activated logogen from the set of activated units. When one logogen's activation is much stronger than the activation of all of the others, this selection task is easy, but when there are several weakly activated logogens so that activation of no single logogen stands out above the others, the selection task is more difficult (p.687).

They further suggest two possible views of this selection process. The first posits an "all-or-nothing" mechanism whereby only one item at a time can be selected and selection simply takes more time when it is difficult. As time goes by, the activation of other logogens begins to decay so that identification processes that must be delayed will simply be less accurate than those invoked earlier.

The second possibility which also accounted for their data was a model in which the selection mechanism is a sharable resource whose performance is reduced when it must be divided among different tasks. This model assumes that the item to be reported first receives the bulk of resources whereas the items to be reported late only receive what remains, until selection is finished for the item reported first.

Irrespective of which of these two versions is adopted, Larochelle's model is satisfactory only for the limited situation where the most strongly activated logogen is likely to be the correct item, that is, the item the subject wishes to select. In this case the subject may rely on automatic activation by the stimulus and follow a selection policy of "strongest wins" with confidence.

It does not account, however, for situations where this policy will be inefficient; for example, should the subject be required to report the opposite of the perceived item, or its superordinate category or a recently learned association to the item. In this case selection must be based on a searching strategy which seeks to activate the required association and selection of the logogen which is most strongly activated by direct stimulation will result in failure. Morton (1979, Morton & Patterson, 1980) views such a task as necessarily involving and relying upon activation of the semantic ("cognitive") system, rather than direct input-output transfer, but does not discuss the process by which the correct choice becomes the most strongly activated (above threshold) unit within this system. The model to be proposed here presents a more comprehensive approach to this problem and might be viewed as a combination of the threshold model of Morton and the active selection model of Larochelle, resulting in a dual process system similar to that proposed by Schneider & Shiffrin (1977) (but with some differences and elaboration as discussed below).

3.3 The Proposed Model

3.3.1 Cognitive Considerations

This model adopts Schneider & Shiffrin's (1977) concept of short term store (STS) as described in the previous section; that is, a store which is unlimited in terms of number but time-limited in terms of continuous decay. This might be compared with Morton's response buffer - although the concepts are not synonymous.

The units activated in STS will be the "feature detector" units required for recognition and/or repetition but might also include associated semantic units (through spread of activation across networks). In view of the discussion above, these two types of units are considered to constitute separable (associated) subsystems and do not necessarily occur together in the same manner each time. The model proposed here is a general one, however, with a focus on the mechanisms regulating voluntary attention to various stages in the stimulus-response sequence. Consequently, detailed breakdown of the components or subsystems comprising these stages is not necessary for the purposes of the current proposals and is not considered further.

In order for these units to be further processed and/or given as an overt response, the allocation of attention/resources to them is required. The reception of such attention may be conceived as corresponding to entering (and being processed in) "working memory" (a term taken from Baddeley (1976) and Baddeley & Hitch (1974), referring here to a similar but not synonymous concept).

The time limitation is imposed by the decay that occurs between activation beyond STS threshold and reception of attention. More recently activated units will have greater likelihood of entry into working memory (i.e. receiving attention) than earlier items unless these earlier items were subject to controlled processing (either due to a plan to attend to them or to their "automatic-attention-calling features" [Schneider & Shiffrin, 1977]).

Units in working memory will also be subject to decay but this is assumed to occur at a slower rate than those units which have received automatic activation only. They will also be available to conscious awareness if they have received accessible processing. Conscious awareness may not be possible for some units entering working memory on the basis of veiled processing (see Section 3.2).

Logogens required for appropriate response but not sufficiently activated to pass STS threshold can be actively "selected" by the allocation of resources/attention to these units. This will involve search - of STS and/or LTS - and voluntary activation. Since these units are only activated beyond threshold by virtue of such controlled processes, they will be part of working memory (i.e., subject to slower decay and conscious awareness).

Responses will be based on the most strongly activated units in working memory. For the most part, these will be the most recently attended logogens (given the principle of continuous decay). If, however, the strongest logogen (or logogen network) is not the intended response, additional voluntary activation will be required before the response is emitted to ensure priority of the correct network (response competition). If there are insufficient resources available (from the limited supply) for this to occur in the allotted time, then the subject may:

1. recognize that the correct item has not been found (or not sufficiently activated, e.g., tip of the tongue phenomenon) and prevent the emission of other responses. This is assumed to be the result of a gating mechanism which is continually active, to a greater or lesser extent, between working memory and the conversion of its units (or their response elements) to motor impulses. The gate may vary across response modes(e.g. oral vs. manual) and may be lifted voluntarily following a decision to respond. Very strongly activated logogens may, however, break through the gate. To increase the level of the gate voluntarily is assumed to be resource-consuming. This includes restoration of previous gating after it has been lifted if this occurs prior to the emission of a response. Automatic restoration will proceed upon sensory feedback that a response has been completed.

2. If there is insufficient time or the subject fails to institute

the above evaluative and gating procedures, he/she may give an incorrect response on the basis of the most strongly activated units at that time (e.g., a perceived word rather than its opposite).

In summary, then, response selection in the present model can be actively manipulated in two ways:

1. by the allocation of attention to required logogens, with the amount of resources required being inversely proportional to the amount of initial activation,

and

2. by manipulating the time at which the response is given (gating).

In addition, a third possibility is available via:

3. Perceptual and/or response readiness, or set.

"Readiness" refers to the priming of certain units so that a lesser degree of activation will be required for them to pass the STS threshold (perceptual readiness) or to be the strongest in working memory, that is, receive priority in motor conversion (response readiness). This priming may be either volitional (and therefore resource consuming), as with instructions to expect a particular item or intentions to respond a certain way, or automatic, as a result of the spread of prior activation through a closely connected network.

On leaving working memory the logogens pass to a high level motor zone for conversion to motor impulses. Following conversion, these motor impulses are transferred to a motor organization zone where they are integrated into a smooth sequence. Resource/attention/effort may again be required at this stage depending on the extent of integration required (new or complex activities vs. well-established skills).

Finally, although most activities require at least some attention, there are, of course, some stimulus-response sequences which are completed relatively automatically. Some authors view behaviour as forming a continuum in this regard - from totally automatic activities through to those completed with maximum demands on capacity (Hasher & Zacks, 1979). Totally automatic behaviours are mostly innate (Hasher & Zacks, 1979) and in the current model would proceed from STS directly to motor conversion. Relatively automatic activities (those requiring minimal attention) would be well-established, over-learned habits which receive strong automatic activation from a particular stimulus situation and constitute a closely connected network of mutually activating units. Reception of even minimal controlled processing, by definition, infers passage through working memory, albeit rapid and hence less available to conscious awareness (veiled processes). These ideas can be summarized and elaborated by the use of flow charts of the proposed system, as described below:

Figure 1 represents the initial stage of sensory reception. Input is received at modality-specific centres which activate higher, integrated, perceptual and possibly semantic logogen networks, at both intramodal and intermodal levels (with interaction between these two levels to facilitate cross-modal activation spread).

Attention will then be allocated to various subsets of these activated logogens (possibly following some form of search). Those activated beyond threshold will be transferred to working memory, where further controlled processing may be conducted (Figure 2). Note that working memory is not conceived as a separate structure or system in this model but represents the <u>process</u> of receiving controlled operations.

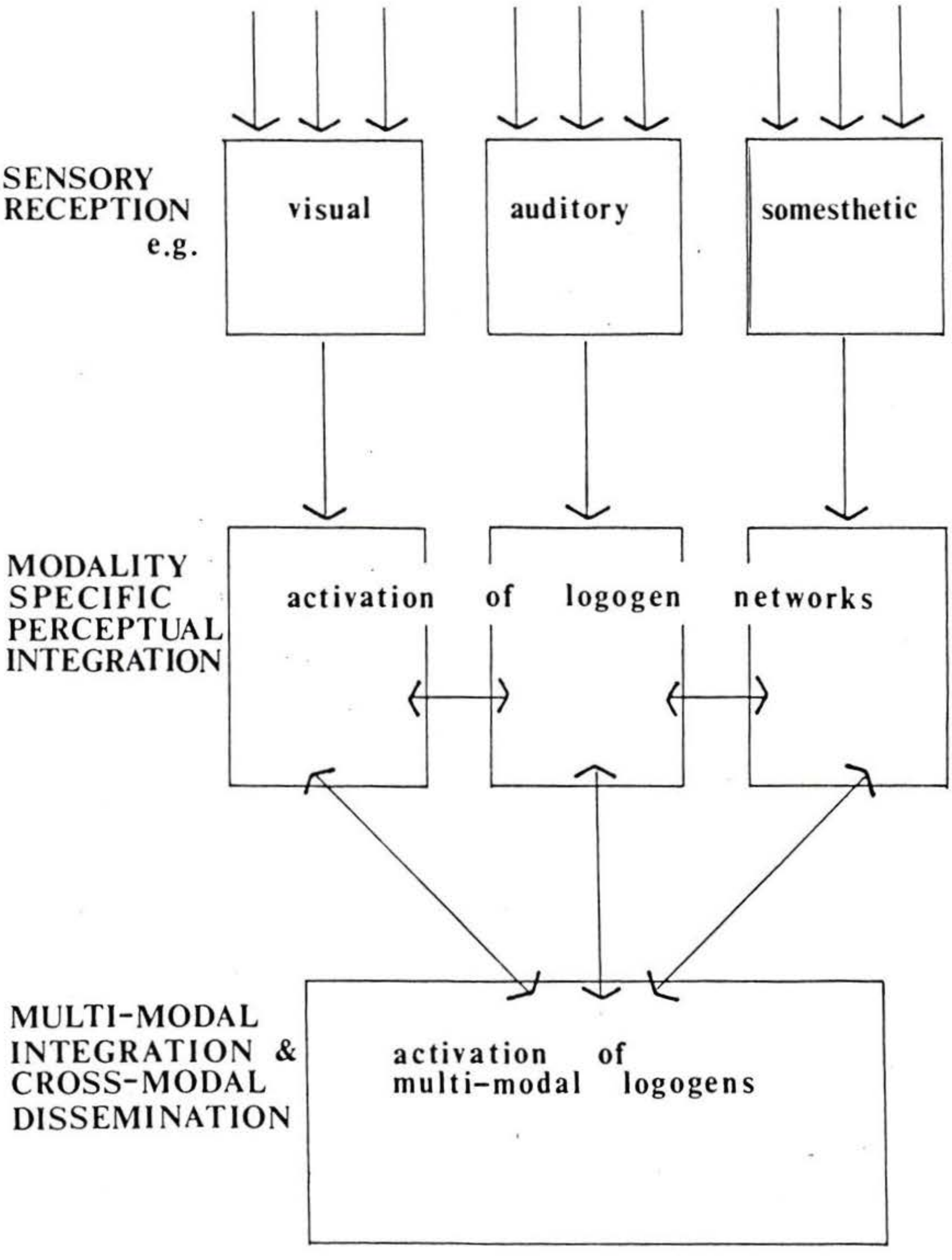

FIGURE 1. Initial Stages of Sensory Reception and Network Activation

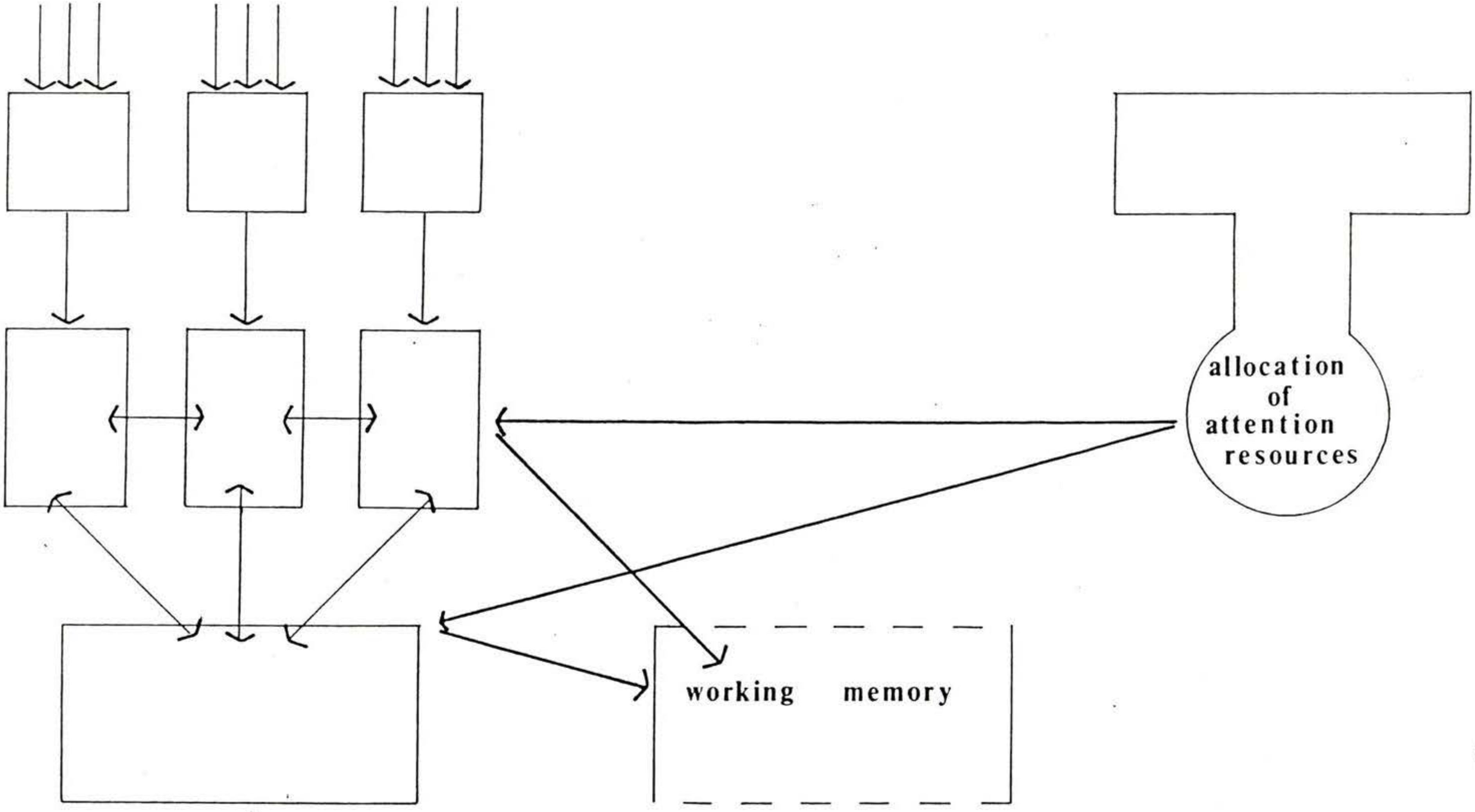

FIGURE 2. Allocation of Attention

The allocation policy will be determined by three factors (shown in Figure 3):

1. Momentary intentions or the goals and strategies of voluntary attention. For example, instructions to look for a certain stimulus or perform certain operations might lead to a plan for strategic scanning and search or the allocation of certain resources (e.g. STS resources) directed to items in working memory.

2. Enduring dispositions[3] or "automatic-attention-calling features" (Schneider & Shiffrin, 1977) which reflect the rules of involuntary attention - both innate and learned. These rules determine orienting responses such as directing attention to novel, sudden or unexpected stimuli, ones own name, etc. If sufficiently strong, enduring dispositions can override momentary intentions and temporarily redirect the allocation of attention.

3. The effects of arousal - arousal and capacity are assumed to be closely related and to vary together within moderate ranges (Kahneman, 1973). Extremely high or low levels, however, are considered to result in systematic changes in allocation policy. A state of over-arousal tends to lead to a narrowing of attention such that allocation is concentrated on the dominant and most salient aspects of the situation with increased lability of the allocation policy (Kahneman, 1973). That is, with optimal arousal momentary intentions usually control selective attention unless there is a strong orienting pull, whereas, with over-arousal, there is a potentiation of the influence of enduring dispositions over momentary intentions. A state of under-arousal, on the other hand, may result in a failure to adopt a task set (inadequate formulation of momentary intentions) and a failure in the evaluation of one's performance resulting in an insufficient adjustment of capacity investment to meet the demands of the task.

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[3] These terms (momentary intentions, enduring dispositions) are taken from Kahneman's (1973) model and refer to similar concepts although the remainder of the model is not the same as that proposed by Kahneman.

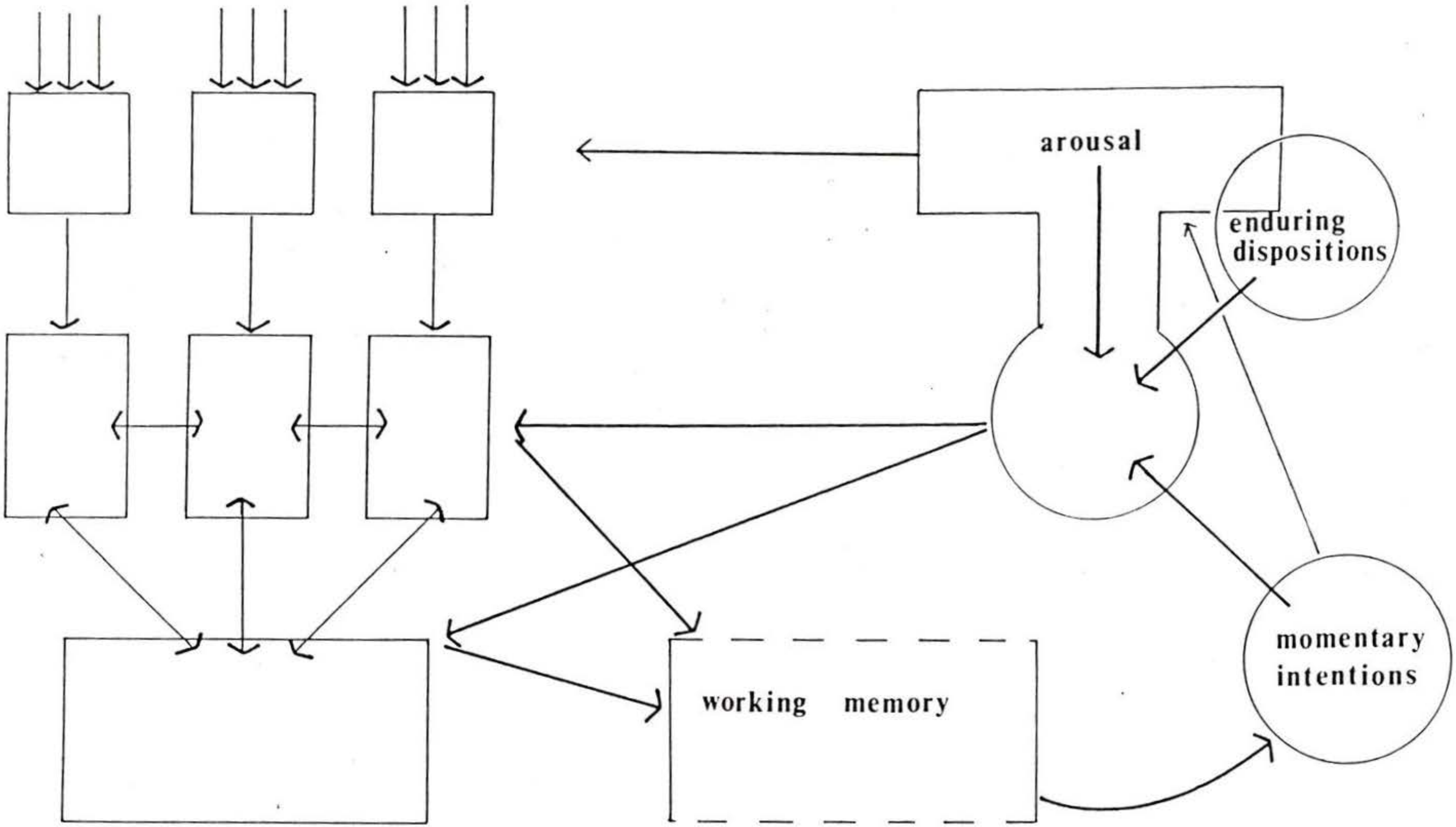

FIGURE 3. Factors Determining the Allocation Policy

The effect of arousal on the reception and processing of incoming stimuli is shown by an arrow in Figure 3. The arrow from working memory to momentary intentions in Figure 3 indicates that an evaluation of demands and possible responses and a subsequent decision regarding response will be made. The response may be either covert (continued allocation or re-allocation of attention or "thinking") or overt (action).

A decision for overt response will lead to transfer of the most strongly activated logogens to the high level motor region for conversion to motor impulses and thence to the motor organization zone where they are integrated into a smooth motor sequence. In order for this transfer to occur the decision must be communicated to the gating mechanism, discussed earlier, so that the appropriate response mode can be activated (selective lifting of the gate).

A decision for continued covert processing may require the restoration or increase of gating which will consume resources (i.e., require attention allocation). The organization of smooth motor behaviour may also require varying amounts of effort/attention.

These processes are indicated in Figure 4.

According to Teuber (1964) the decision for overt response will also be accompanied by simultaneous feedback to the earlier levels of the logogen networks preparing these units for the perceptual consequences of such movement (corollary discharge). This may be seen as one level of perceptual set. This priming of logogens prior to stimulus input (readiness) was discussed earlier and can be represented by the same diagram in the absence of stimulus input and response arrows. Automatic activities, passing through this entire process with minimal or no requirements for attention, are presented in Figure 4 by the arrows on the far left.

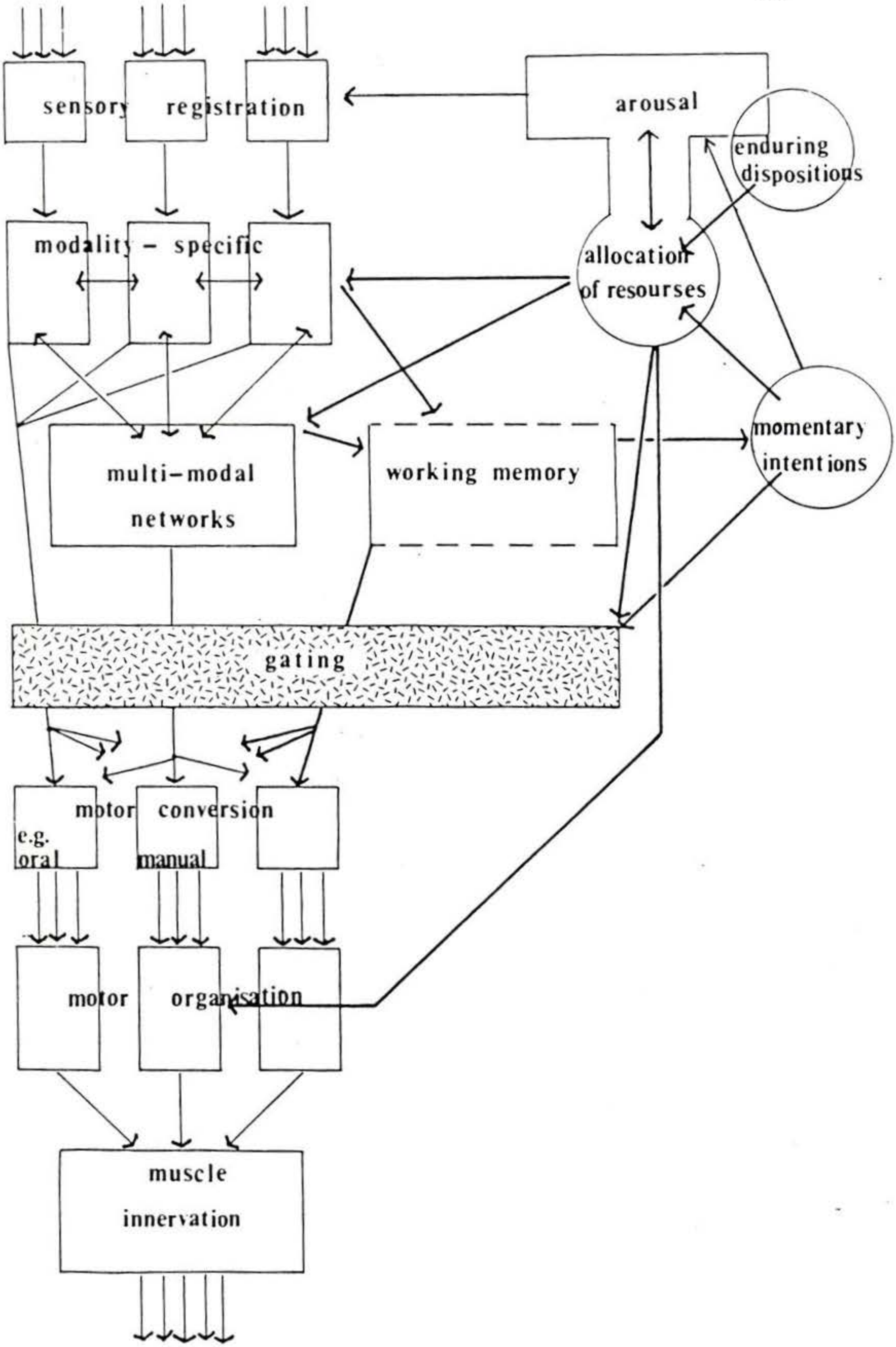

FIGURE 4. The Gating Mechanism and Motor Conversion

3.3.2 Neuroanatomical considerations

Since this model is a conceptual representation of brain processes (albeit simplistic), it is now appropriate to turn to a consideration of the neuropsychological literature in order to provide tentative neuroanatomical correlates of the components of this system. Again, the reader is cautioned regarding the heuristic and conceptual purpose of this model and against the view that the complexity of brain function can be reduced to such simple isomorphisms (see Feeney, Pittman & Wagner 1974). On the other hand, there exists an extensive neuropsychological literature relevant to the processes addressed by this model. An integration of this knowledge with theoretical conceptions derived from cognitive psychology is a much neglected but potentially very fruitful endeavour. An attempt at such an integration is presented here.

Consider each of the components of the somewhat complicated diagram in Figure 4 which has been redrawn in Figure 5 with the following neuroanatomical considerations included to clarify the discussion:

1. The initial stage of sensory registration is easily identified as a representation of the activity of the "primary reception zones" of the posterior cortex as described by Luria, 1973a.

2. The "secondary-association" cortical regions (Luria, 1973a; Walsh, 1978) can be compared with the LTS and the STS (activated) networks of the modality-specific logogen stage. The semantic system is part of this network although these semantic units may be located separately from the feature analysis units, that is, in different parts of the secondary association zones.

3. Integration of information from the various modalities into a multi-modal, unitary perceptual interpretation, together with the dissemination of information from one modality to another (activation of associated networks in a non-stimulated modality) is considered to be largely conducted by the "tertiary zones" of the

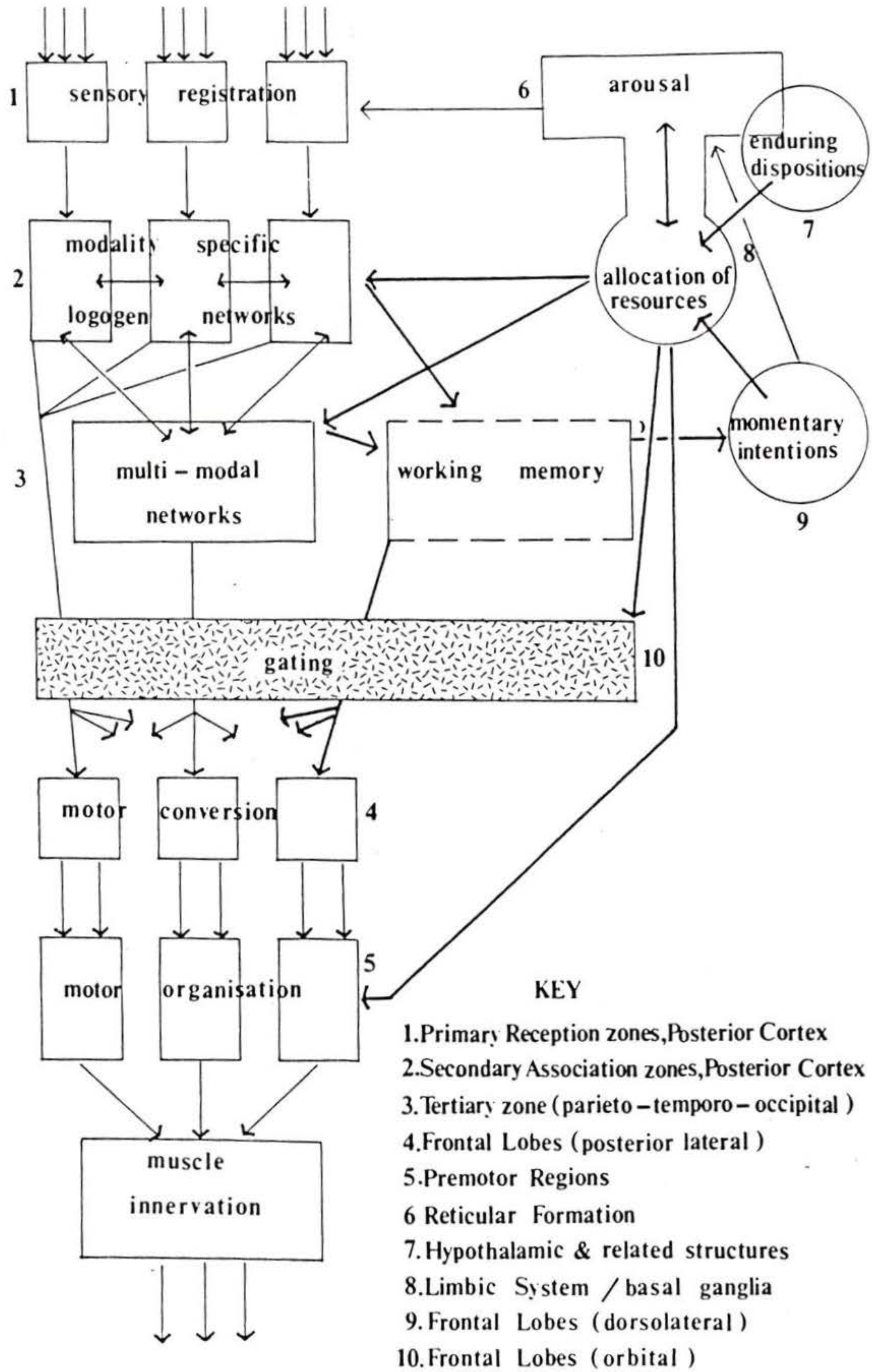

FIGURE 5. The Proposed Model: Showing the Operation of Selective Attention in a Stimulus-Response Sequence, & the Proposed Neuroanatomical Correlates.

posterior cortex i.e., the parieto-temporo-occipital junction at the angular gyrus (Benson, 1979; Luria, 1973a). This region may also correspond to the "comparator" of Allport's (1977) model for the perception of printed words. Some authors also consider this region to play a facilitatory role in arousal (e.g., Heilman 1979). Heilman proposes that the left angular gyrus activates/arouses the left hemisphere in response to information presented to the contralateral (right) hemispatial field and in expectancy of verbal input. The right angular gyrus responds to both hemispatial fields and has the capability of bilateral activation. These concepts have not been firmly established, however, and are not included in the diagram at this stage.

4. The higher order conversion of logogens to motor impulses might be considered to correspond to the posterior lateral zones of the prefrontal lobes, thought to function as the tertiary zones for the motor system (Luria, 1973a).

5. The organization of these motor impulses into smooth "kinetic melodies" has been proposed as the major role of the premotor regions (Luria, 1973a). The premotor, motor and motor basal ganglia systems are viewed as the major components of the muscle innervation (and denervation upon completion) for the actual performance of these sequences.

6. Arousal has been clearly associated with the reticular formation (Luria, 1973a; Moruzzi & Magoun, 1949; Pribram & McGuiness, 1975). A path from the sensory input to arousal might also be included in the diagram to reflect the nonspecific arousal reaction to incoming stimuli. The regulatory role of the hippocampal and frontal regions on the reticular formation will be considered below.

7. The influence of enduring dispositions may be mediated by different structures for innate and learned stimuli. Hypothalamic and related subcortical structures appear to be important in this regard, at least for innate orienting reactions (N. Goldberg, personal communication, 1981; Pribram & McGuiness, 1975).

8. A number of findings regarding the neuropsychology of attention suggest a close correspondence between the allocation mechanism (the

distribution and implementation of attention/resources) in this model and the activity of deep midline structures, that is, the limbic system, particularly the hippocampal and thalamic structures (Luria, 1973a; Monti, 1981; Pribram & McGuiness, 1975), and the basal ganglia (Ojemann, 1975b, 1977). It is intriguing to consider, at this point, the recently proposed concept of multiple resources (Norman & Bobrow, 1975) (e.g., short term memory resources; motor resources; modality specific perceptual resources) and the possible correspondence of different subcortical structures with the distribution and implementation of each of these resources. For example, left and right hippocampal structures might be predominantly involved with the allocation of verbal and nonverbal STM resources respectively. For the purposes of this dissertation, however, a general correspondence between deep midline structures (the limbic system and basal ganglia) as a whole and the allocation mechanism (for all resource types) will be assumed, leaving further specification of sub-structure roles to future modifications of the model. The path from these structures back to the arousal region would indicate the inhibitory role of the limbic system (Pribram & McGuiness, 1975).

9. There is now a considerable amount of evidence to suggest that the formulation of momentary intentions, or plans, forms at least a major part of the functional role of the frontal lobes, particularly the dorsolateral prefrontal regions. Given the central importance of momentary intentions in this model of voluntary and involuntary behaviour, and of frontal lesions in previous discussions of perseveration (see earlier review), this evidence is considered in more detail:

Abnormalities of attention have long been described as a prominent symptom of frontal dysfunction. In a recent review of the prefrontal system, Fuster (1980) described these abnormalities as adopting two interrelated forms:

> One is distractability. Perception and behaviour become exceedingly vulnerable to distraction by irrelevant sensory stimuli. The patient is unable to resist interference to stimuli that would normally be suppressed or ignored. The other form of attention disorder, perhaps more characteristic of prefrontal dysfunction, is a deficit of concentration... [which] critically affects higher cognitive processes. The patient has an unusually severe difficulty in focusing and sustaining attention on internal representations and trends of thought. He seems to lack the active and purposive attention required to execute mental operations of any complexity or duration (p.113).

Similarly, Luria (1966, 1971, 1973a, 1973b) has been a strong advocate of the role of the frontal lobes, particularly the dorsolateral regions, in the control of "higher" voluntary attention. He considers the frontal regions represent a "functional unit" for the "programming, regulation and verification of activity" and describes lesions of these regions as leading not only to disturbances of the higher forms of voluntary attention but also to the enhancement of "elementary forms of the orienting reflex (or involuntary attention) evoked by the direct effect of irrelevant stimuli." (1973a, p.197)

These descriptions correspond closely with the behaviour that would be expected to result from disruption of the momentary intentions of the present model. Such disruption would leave the allocation policy to the vagaries of enduring dispositions, including those which would normally be of insufficient strength to interrupt ongoing processing. In the absence of such orienting stimuli (distractability), automatic sequences would dominate behaviour (since control of sequences requiring active attention would be absent or unstable). This is consistent with frontal patients' tendency for noncreative, stereotyped behaviour (Luria, 1973a; Walsh, 1978).

Furthermore, there would be a failure to evaluate responses both before and after they are emitted, assumed to be conducted at the stage of momentary intentions - or at least used in the formulation of momentary intentions - resulting in a failure to correct errors, even when such errors are recognized. This is consistent with the frequent description of frontal patients as prone to "rule-breaking" and as demonstrating a "dissociation between knowing and doing" (Milner, 1964, 1965; Teuber, 1964; Walsh, 1978).

Also, disruption of momentary intentions would be expected, in the present model, to result in a disturbance of corollary discharge and readiness, since these are viewed as following a similar momentary intentions->allocation->activation pathway. This is again consistent with clinical neuropsychological findings with frontal patients (Luria, 1973a; Teuber, 1964).

The frontal regions are also known to be involved in the regulation of the non-specific arousal component of voluntary attention - via the fronto-amygdala-reticular circuitry - with the dorsolateral regions being largely facilitatory and the orbital regions having an inhibitory influence (Luria, 1973a; Luria & Homskaya, 1966; Pribram & McGuiness, 1975).

10. The orbital regions of the frontal lobes are also considered to be involved in motor inhibition (particularly the ventrolateral regions) (Brutkowski, 1964; Mishkin, 1964; Rosvold & Szwarcbart, 1964). This suggests a correspondence between these regions and the gating mechanism of the current model. The description of patients with orbital lesions as showing heightened impulsivity and distractability in the context of potentially intact intellectual operations (Luria, 1965, 1973a) is consistent with the expected behaviour resulting from disruption of this gating mechanism with the remainder of the system intact.

11. Perceptual and response readiness correspond to earlier concepts of "alertness" (Pribram & McGuiness, 1975); "activation" (Posner & Boies, 1971) and "intention" (K. Heilman, personal communication, 1981). They are associated with the notion of contingent negative variation (CNV) or expectancy waves (Grey-Walter, Cooper, Aldridge, McCallum & Winter 1964; Luria,

1973a; Posner & Boies, 1971) or, more specifically, transcortical variations (multiple local potential shifts) (Pribram & McGuiness, 1975). Consistent with the current model, Pribram and McGuiness consider the circuitry involved in this system to be regulated by the basal ganglia of the forebrain and dorsal thalamus, although the current model also includes the frontal influence described by Luria (1973a; 1973b) in his discussion of expectancy waves. This may also be consistent with the earlier discussion regarding multiplicity of resources and specificity of subcortical structures in their allocation (see (8) above). It may be, for example, that dorsal thalamus and basal ganglia are primarily involved in the allocation of the "search and activate" resources for below threshold logogens (in either states of expectancy or for subsequent non-identity responses) while other subcortical structures are involved in the controlled operations associated with working memory.

A final consideration is that of laterality. Differences between left and right hemisphere functioning were briefly mentioned in this discussion of the various components of the neuro-cognitive model. No firm predictions regarding the generality of this model for both hemispheres, however, can be made from the evidence reviewed here. Differences in the <u>nature</u> of the processing (and hence of the material processed) at various levels in the model would certainly be expected; for example, sequential analytic processing of familiar material on the left and simultaneous, "hypothesis-testing" processing of novel material on the right (Bradshaw & Nettleton 1980; Goldberg & Costa, 1981). Furthermore, the organization of the logogen networks may differ in order to facilitate this processing; for example, closely-connected, well-established, hierarchical networks on the left and diffuse, loosely-connected, heterarchical networks on the right (Goldberg & Costa, 1981; Semmes, 1965). This would have implications for the type of task and the nature of the errors involved in system breakdown with lesions of the different hemispheres but would not necessitate differences in the overall structure of the model presented here. It is assumed, then, that the model can be used interchangeably (allowing for differences in the <u>content</u> of the processes and subsystems) as a framework for the investigation of perseveration following lesions of either hemisphere. Each hemisphere is assumed to constitute a separate system, that is, they are assumed to be independent, albeit interacting, systems each with its own resource supplies. This is consistent with a recent conceptualization by Friedman & Polson (1981, Friedman, Polson, Dafoe & Gaskill, 1982), although the current model considers multiple resources within each system to be likely, whereas the Friedman & Polson model views each hemisphere as a single undifferentiated resource system.

3.4 Summary

The preceding sections have outlined the background and development of the current model. The model is based on a number of recent theoretical proposals and empirical findings by cognitive psychologists studying selective attention. It focusses on the operation of selective attention (allocation of resources) in a stimulus - response sequence. The influcence of factors which are voluntary (momentary intentions) and involuntary (enduring dispositions) is considered, as is the operation of a gating mechanism. The model has then been elaborated by the tentative assignment of corresponding neuroanatomical regions. The resultant neurocognitive model is summarized diagrammatically in Figure 5 (page 55) with each component discussed more fully in the text.

The following chapter considers how well this model accounts for previously established findings regarding perseveration and whether it leads to testable hypotheses. The remainder of the dissertation represents an initial exploration of its empirical utility.

4. PERSEVERATION REVISITED - THE ROLE OF VOLUNTARY ATTENTION

4.1 Underlying Mechanisms

Perseveration may be viewed as one sign of system failure. If we accept the foregoing model as a first approximation of the system, perseveration implies that some previously activated (and therefore, to a greater or lesser degree, primed) but no longer appropriate logogen network was the most strongly activated network in working memory at the time of response emission. Hence, it also implies that the correct response network was of insufficient strength to compete successfully with this primed network. The extent to which the emitted response is a combination or hybrid of the two networks will reflect the degree to which this competition was partially successful - or sections of the response in which there was no overlap and hence no competition.

A previously activated response may be the most strongly activated network in working memory when:

(a) there has been insufficient time for significant decay of this network and, by the same token, insufficient time to build up the required strength of activation, conduct the search and/or perform the required operations, for the required response. This implies that the automatic activations resulting from the new stimulus were insufficient for automatic emission of correct response, and/or

(b) the perseverated network was reactivated, in part or whole, by the presentation of the new stimulus or the activation of the required response. Reactivation might be due to a direct association with the stimulus (an old well-established habit or recently reinforced link) or it may be due to overlap or similarity between newly activated networks and the previously activated network (spread of activation). This increased activation would require a strongly activated new response for successful competition. If sufficient time is available, failure to gain priority must be due to either:

(c) the absence of the required response in the behavioural repertoire or

(d) insufficient allocation of resources to make this response the strongest.

Insufficient allocation of resources might also result from two different causes; namely:

(i) an inefficient (misdirected) allocation policy or

(ii) resource overload.

Resource overload might itself result from too difficult a search (due to a large number of partially activated logogens) or from particularly weak activation of the required logogen.

That an incorrect response is emitted also implies breakdown of self-monitoring-gating mechanism. This may occur when:

1. the demand for rapid response is such that there is insufficient time for monitoring prior to responding;
2. there is a failure to evaluate responses and/or formulate an allocation policy for modifications; or
3. there is a failure to implement the delay in response (gating) and reallocation required.

Hence, according to this model, there are a number of separable underlying mechanisms which might result in a perseverative response. This is consistent with the perseveration literature, reviewed earlier, in which it has been frequently suggested that multiple deficits are involved.

It is also clear that the nature of the task is important. In summary, tasks of overwhelming difficulty (capacity overload), such as those involving (a) rapid responses, (b) similar stimuli or response networks, (c) shift from strongly associated responses and/or (d) unavailable or very weakly activated logogens, will make a perseverative response more likely, even when the system is intact. This is also consistent with the task-dependent findings of the perseveration literature for both normal and brain-damaged populations.

Perseveration would also be expected under conditions of high arousal and of under-arousal since both these conditions were noted earlier to result in reduced efficiency in the strategic allocation of attention. Since over-arousal would be expected under conditions of stress, including overwhelming task difficulty, and under-arousal would be seen in states of fatigue, these task and state predispositions to perseveration are consistent with Goldstein's hypothesis regarding the underlying mechanisms of perseveration as a defence against or response to difficulty-induced catastrophic reactions and subsequent fatigue. In both the current model and Goldstein's explanation, this "catastrophic perseveration" would be expected in both normal and brain-damaged subjects if the task characteristics are sufficiently difficult and, hence, will have no localizing significance. However, in addition to these task conditions, in which structural breakdown of the system is not necessary, the current model suggests that perseveration may also result from dysfunction at specific sites within the system and that the characteristics of the resultant syndromes will have localizing significance. Clearly this requires perseveration on tasks which do not usually evoke such responses when the system is intact and this will be a necessary condition in the following discussion of these "localizing syndromes" predicted by the model.

4.2 Perseverative Syndromes as Localizing Signs of Dysfunction

Consider a task in which perseveration is rarely seen because the required responses are very easy for an intact system. In this case the automatic activation of the response by the new stimulus is so strong that no or minimal attentional activation is required for it to be the strongest above-threshold logogen in working memory. In such a situation, there is no (or little) requirement for resource allocation for success on the task. In normal subjects this would occur on tasks considered to be relatively automatic. These include tasks involving well-established stimulus-response sequences, such as the naming of familiar objects; listing of words included in a strongly connected network (e.g. animals); reciting an over-learned series (e.g., days of the week) and so on. It would also occur on identity tasks (Leicester, Sidman, Stoddard & Mohr 1977); for example, matching, copying and immediate repetition, where the response can again be implemented directly from automatic activations in short term memory without the need for controlled processing. Hence, these tasks would also cause no difficulties when the system is disrupted in the formulation and/or implementation (allocation) of momentary intentions for search or for controlled processing of working memory units, since these processes are not required. In terms of the current neurocognitive model, this suggests that patients with dorsolateral frontal lesions should perform adequately on such automatic tasks (when there are no strong distracting stimuli to compete with the required response and consecutive responses are not rapid). This is consistent with the findings regarding perseveration in frontal patients (Luria, 1969; Milner, 1964; Walsh, 1978). It also suggests that patients with limbic or cortico-limbic disconnection (disconnection of the allocation mechanism) will perform well on such tasks. Some studies provide tentative support for this (Luria, 1969; Luria, Homskaya, Blinkov & Critchley 1967).

On the other hand, perseveration would be expected when there has been disruption of LTM networks so that previously automatic activations now require voluntary attention to reach threshold or when the required logogens are no longer available at all (capacity overload). According to the current model this would be expected with lesions of the posterior cortex. With circumscribed lesions this would be expected to be deficit-specific perseveration, consistent with the findings of Allison & Hurwitz (1967). It would also be expected to be particularly evident under requirements for rapid response (or even when some response is demanded) so that the gating mechanism is set for non-monitored response emission. With additional time the patient will be able to delay response until the required (or at least different) response has received sufficient activation or a "don't know" evaluation is made. This also suggests that tasks requiring controlled processing in working memory should provide no difficulty for patients with such cortical lesions, provided access to working memory of the required logogens is assured, (sufficient activation to pass "threshold"). This form of deficit-induced perseveration can be considered as a special case of normal catastrophic perseveration in which the crucial difficulty level has been lowered for specific tasks.

Consider now a task in which strategic allocation of attention to logogens in working memory is required for the correct response. In this case reliance on automatic activation is insufficient; for example, reversing a series, rapid alternation; and shifting from a strong set.

Assume that capacity overload is not in question. That is,
(i) activation of the required logogens beyond threshold consumes minimal resources and
(ii) the operations to be performed in working memory are within capacity limits so that perseveration on these tasks is uncommon - although they may be found to be more or less difficult - when the system is intact.

From the previous discussion (Section 4.1) perseveration might be expected on these tasks when there is

(a) an inefficient (misdirected) allocation policy

and (b) a failure to formulate or implement the gating-evaluation-reallocation mechanism prior to response emission.

In the current model disruption of momentary intentions, that is, <u>dorsolateral frontal lesions,</u> would lead to both these conditions.

A failure to formulate strategic allocation plans in accordance with task demands would leave the system to the vagaries of enduring dispositions and responses would be given on the basis of the strength of automatic activations of logogens in short term memory. Hence, responses are likely to include echolalia and mirroring (treating a nonidentity task as an identity task) or the intrusion of stereotyped habitual responses when the stimulus evokes a strong automatic stimulus - response sequence. Perseveration can be expected whenever a prior response is strongly activated or reactivated for whatever reason - rapidity of responses, network similarity and so on. Since the formulation of plans for timing the responses, self evaluation and reallocation would also be impaired, responses are likely to be impulsive and rapid, even when the task does not specifically demand speed, making perseveration even more likely.

On the other hand, <u>intact programming</u> in the context of such impulsive, premature responses would be expected by disruption to the gating mechanism itself (here assumed to be the orbital frontal regions, especially the more lateral aspects). In this case irrelevant but rapidly completed automatic sequences triggered by the stimulus would be emitted despite the expected arrival of a controlled decision. Hence, these patients can be described as demonstrating a "dissociation between knowing and doing". Note however that this is different from the dorsolateral patient who may be able to repeat instructions or recognize an error but is unable to utilize this information in the formulation of plans. Here the orbital patient can indeed formulate the correct strategies but fails because of difficulty in impulse control. Perseveration would be expected to be reduced if external structuring of response emission is provided for these patients. These predictions are consistent with the descriptions of dorsolateral and orbital frontal patients reviewed earlier.

Another situation in which perseveration might be expected is when, although momentary intentions (frontal) structures are intact, their implementation is disrupted. This would occur with deep mesial lesions, disconnecting cortico-subcortical fibres and/or disrupting the limbic/basal ganglia system itself. This is consistent with the occurrence of perseveration and extraneous associations previously reported with lesions of deep midline structures.

For the gating mechanism to operate there must be recognition that this is a previous response which means it must have received controlled processing in working memory. Since regulation of such controlled processing is now disrupted, this may not have occurred so that pre-response evaluation and rejection will be less likely.

In contrast to catastrophic perseveration, the perseveration described above will not be associated with specific deficits in the processing of the task material (destruction or weakening of logogens or their interconnections). Patients with noncatastrophic perseveration should have no difficulty on automatic tasks. It is only with controlled processing in working memory (or in strategic search required for entry to working memory) that perseverations will be demonstrated. Perseverations may be associated with certain material, however, reflecting lateralization of the dysfunction, and/or specific disconnections of deep mesial structures, but only on reflective (attention-demanding) tasks.

Such reflective perseveration should decrease when external structuring of attention is provided; for example, manipulation of figure-ground contrast so that the correct stimulus-response sequence becomes that with the strongest automatic activation and/or the most likely to receive controlled attention. However, such improvement will disappear when the subject is required to shift this structuring to internal regulation.

As noted earlier, a number of authors have suggested that limbic disconnection may be important in posterior perseveration (Allison & Hurwitz, 1967; Buckingham, Whitaker & Whitaker 1979; Hudson, 1968;), although the underlying mechanisms were unclear. In these studies, however, the patients had both posterior cortical lesions and possible cortico-limbic disconnections. Such patients are likely to demonstrate the characteristics of both catastrophic and reflective perseveration described above. According to the current model patients with posterior lesions which extend to subcortical structures would be expected to show perseveration which is both more pervasive and occurs on easier items than seen with either cortical or subcortical lesions alone. These patients would be expected to perseverate on previously automatic tasks which now require voluntary attention, as with purely cortical lesions. However, they would be expected to do so at an earlier point than the latter patients, since even logogens within capacity limits may not receive the attention they require. Inability to regulate controlled processing of certain responses in working memory will also mean the gating mechanisms will be less likely to prevent an incorrect perseverative response (i.e. this response will not be "tagged" as a previously activated logogen).

A final consideration is the occurrence of perseveration in which the content of the response is not in error but the response modality is perseverated; for example, when a patient continues to write when asked to respond orally. This would appear to be the result of a deficit in the formulation of a basic plan of action and response set and hence would be expected in conjunction with reflective perseveration but not with catastrophic perseveration. In the current model this would occur with frontal or subcortical lesions but not pure posterior cortical lesions.

An interesting corollary of this conceptualization of the mechanisms underlying perseveration is that the lesions presumed to lead to reflective perseveration, that is to the failure to regulate voluntary attention strategically, would also be likely to lead to a reduction in spontaneously initiated activities since these also require self-directed activation. Responses would be more likely to rely on external stimulation in these cases. This is consistent with the adynamia reported with frontal lesions (Luria, 1969) and might also account for the finding by Allison & Hurwitz (1967) of an association between increased perseveration and the absence of spontaneous speech.

The model proposed here might also account for the hierarchical nature of perseverative errors described by Goldberg & Tucker (1979). It will be recalled that the model adopts the view of long term semantic memory put forward by Quillian (1969), Schneider & Shiffrin (1977), Collins & Loftus (1975) and others. This view is that LTM consists of complexly interconnected units which form associated networks. Within each network the units are viewed as being organized at various levels, possibly hierarchically. Should two similar, or associated, stimuli be presented in succession, it is likely that certain overlapping units in their networks will be strongly activated which may result in either full or partial perseveration of the first response when the second stimulus is presented. The nature of the error will reflect the level at which the network overlap took place and hence can be expected to reflect the (hierarchical) organization of the units retrieved.

4.3 Summary and Conclusions

To summarize, the current model postulates that intentional perseveration results from the breakdown of the system regulating voluntary attention in both frontal and nonfrontal patients. This may be the result of reversible or irreversible factors:

1. Reversible factors refer to temporary system failure due to such transient factors as distress or fatigue. Such factors occur in circumstances of capacity overload (tasks of overwhelming dificulty or requirements for very rapid responses) and result in states of over or under-arousal, leading to temporary disruptions of the system. Perseveration under these conditions does not imply an acquired deficit in voluntary attention; the integrity of the voluntary attention system can be demonstrated when the temporary failure has passed (for example, planned sequencing is intact on other tasks). This form is referred to as catastrophic perseveration (after Goldstein) and may be seen in all subjects, including normals. It is likely to be most frequently seen in patients with lesions of the posterior cortex on tasks involving their deficit. Such patients are likely to become fatigued and/or distressed more readily when confronted with a deficit-related task.
2. Irreversible factors refer to damage to a component of the voluntary attention system, resulting in pervasive system failure. Perseveration in such cases will be seen on tasks requiring planned self-regulation of resources/attention allocation, even when these tasks do not involve capacity overload (overwhelming difficulty) or requirements for very rapid responses. An acquired deficit in voluntary attention can be further demonstrated by other signs of the system's failure (for example, nonperseverative errors indicative of the disruption of planned sequencing of responses). This form is referred to as reflective perseveration and can be seen not only in frontal patients (consistent with established findings of an attentional deficit with frontal lesions) but also in certain nonfrontal patients, that is, those with lesions involving deep midline structures (limbic system and/or basal ganglia) or lesions which disconnect these structures from frontal or posterior cortex.

Hence the model currently divides perseverating patients into four broad neuroanatomical lesion groups (subject to further fractionation in the future) each with different predictions regarding the factors underlying the perseveration seen in that group. These are summarized below:

1. Frontal Lobes: reflective perseveration associated with an acquired deficit in the voluntary attention system. At least three perseverative pattern subtypes may be associated with dorsolateral, medial and orbital lesions.

2. Deep Midline Structures (limbic system and/or basal ganglia) or disconnection of such structures: reflective perseveration associated with an acquired deficit in the voluntary attention system. A number of subtypes may be associated with damage to specific structures.

3A. Posterior Cortex (shallow lesions only): catastrophic perseveration associated with temporary changes in arousal in response to confrontation with deficit-related tasks.

3B. Posterior Cortex extending to Deep Midline Structures (or extensively disconnecting such structures): both catastrophic and reflective perseveration, the latter being associated with an acquired deficit in the voluntary attention system.

It is now possible to compare this account with the three models, described in Section 2.7, which were derived from previous explanations of perseveration in frontal and posterior patients:

By the inclusion of reflective perseveration in Group 3B, it is clear that the current model rejects the proposition, advocated by Goldstein (1944, 1948), (Model I), and also by the proponents of Model II (Luria 1973; Milner 1964, 1965), that catastrophic perseveration is sufficient to account for all posterior perseveration.

In contrast, the present account corresponds closely with Model III, forwarded by Hudson (1968) and supported, to a greater or lesser extent, by Allison & Hurwitz (1967) Buckingham, Whitaker & Whitaker (1979) and Yamadori (1981). In both Model III and the current model catastrophic perseveration accounts for some perseveration in posterior patients but another mechanism accounts for the pervasive perseveration seen in both frontal and posterior patients. The present model differs from Model III in its description of this mechanism, replacing the vague notion of "disturbed recall processing" with the more detailed consideration of a disturbance of the implementation of voluntary attention. Both Model III and the current model implicate concomitant damage to or disconnection of deep midline structures in the production of this syndrome in posterior patients.

Part III: EMPIRICAL VALIDATION

5. RESEARCH QUESTIONS AND DESIGN

5.1 Research Questions.

On the basis of the foregoing review of the perseveration literature and the neurocognitive model proposed to account for the findings, a number of areas requiring further investigation become evident. Although the model appears to account satisfactorily for the previous findings, it also provides a number of predictions. Such predictions must be tested to confirm the validity of its proposals. This fulfills the heuristic requirements of a scientifically useful model in addition to its explanatory power.

Three related investigations were conducted as part of the preliminary phase of the empirical application of the model. As such, they were directed to an assessment of the basic features of the model. The more specific predictions which can be derived from the model rest on the viability of these basic features. Furthermore, given the paucity and inadequacy of much of the previous research, it was decided that any such preliminary investigations must aim to produce as much data as possible which can be used to refine the model before more specific investigations are conducted. Hence the current investigations were largely exploratory in nature.

The first and most basic postulate of the model is that at least some perseveration seen in nonfrontal patients cannot be accounted for by temporary (catastrophic) factors but is related to a deficit in voluntary attention, similar to that seen in frontal patients. Before testing the predictions regarding which nonfrontal patients demonstrate such a deficit, it is necessary to assess the validity of such a postulate. Hence, the question addressed by the first investigtion was:

Question 1: Can perseveration in nonfrontal patients be shown to be related to a deficit in voluntary attention?

If it can be shown that some perseveration in nonfrontal patients is related to a deficit in voluntary attention, the neuroanatomical features of the model can be investigated. However, although the model provides for relatively specific clinico-anatomical predictions, certain general propositions need to be established before such detailed analyses can proceed. It is necessary, for instance, to establish the involvement of deep midline structures in general before the role of particular bodies among these structures be investigated. This is further determined by such clinical limitations as (a) the difficulty of precise neuroanatomical specification in the absence of post-mortem examination and (b) the difficulty of finding patients with "pure" lesions circumscribed to particular structures. Therefore, rather than investigate narrowly defined neuroanatomical correlates, the question addressed by the second investigation attempted to establish a broad base for further, more refined, investigations in the future:

<u>Question 2:</u> Can the deficit in voluntary attention in nonfrontal patients be shown to be related to involvement of deep midline structures?

Finally, it was noted earlier that previous studies have described a number of different types of perseverative errors. However, such studies have been extremely limited in number, sample and tasks used. Goldberg & Tucker (1979) used only frontal patients and only one task (drawing geometric designs) whereas Yamadori (1981) used only aphasic patients and, again, only one task (repetition of verbal stimuli). It is clear that any model of perseveration must be able to explain the occurrence of all error types. However, at this stage, it is also necessary to document the number and nature of such types across a variety of patients and a variety of tasks. The model must be able to accommodate any subtypes which are demonstrated in this broader context. The question addressed by the third investigation was:

Question 3: What types of perseverative errors can be demonstrated when a variety of patients and of tasks are examined?

5.2 Research Design

In choosing the most appropriate research design in which to conduct each of these investigations, a number of considerations had to be taken into account. Foremost among these considerations, the design must ensure that the information gathered is relevant to the question being asked. Each question investigated here required different data (or at least different aspects of a data base) and raised different design problems regarding the validity and reliability of the inferences to be made. These are considered below for each investigation.

Question 1: Can perseveration in patients with nonfrontal lesions be shown to be related to a deficit in voluntary attention?

This question is essentially concerned with perseverative mechanisms. A multiple case study approach was considered the most suitable design to conduct such an investigation. A case study design refers to a research strategy in which individual subjects, or a small number of subjects thought to exhibit the same characteristics, are studied intensively (Chassan, 1979; Shallice, 1979a; Yin, 1981). This design was selected after consideration of the following issues:

1. Previous investigations regarding the underlying mechanisms of perseveration have largely relied on case studies (Buckingham, Whitaker & Whitaker, 1979; Hudson, 1968; Luria, 1965).

2. Mechanisms are generally inferred, either directly (as in the current study) or indirectly (as in most previous research in this area), from an information processing model. Shallice (1979a) concluded, after reviewing the problems associated with the case study approach, that it remains the most promising neuropsychological technique for providing data to test such information-processing models. A number of other authors have

pointed to the scientific utility of case study or "individual-centred" research in psychology (Barlow & Hersen, 1973; Hersen & Barlow, 1976; Kazdin, 1976, 1981; Kinsbourne, 1971; Kratochwill, 1978; Shapiro, 1966; Yule & Hemsley, 1977) and particularly in neuropsychology (Luria, 1979; Marin, Saffran & Schwartz, 1976; Patterson, 1981; Shallice, 1979a, 1979b;).

3. Problems of internal and external validity could be accommodated within a multiple case study design. These problems and the means adopted to deal with them are considered in more detail below:

(a) Internal Validity

In an elegant discussion of the use of the single case method in neuropsychology Shallice (1979) pointed out that to test any specific hypothesis both positive and negative evidence is needed. The negative type of investigation attempts to demonstrate that other systems in the overall functional system can not account for the observed deficits. It is, therefore, essential that adequate documentation of the patient's other abilities and deficits be conducted - not only those used to select the case (Kinsbourne, 1971; Parsons & Prigatano, 1978; Patterson, 1981; Shallice, 1979a, 1979b). In the current study each patient received both a general examination of higher neuropsychological status and a "perseveration battery". Thus, the possible confounding contribution of factors such as perceptual deficits, dementia and aphasia could be assessed in each case. In addition, the alternative explanation of perseveration as a response to overwhelming difficulty or fatigue (Goldstein, 1944) was investigated in each case.

In the positive type of investigation the hypotheses generated by the model are tested directly (Shallice, 1979a). In the current study, positive evidence was required of a breakdown of voluntary attention in nonfrontal perseverating patients. This was sought both by an analysis of the qualitative features of the perseverative errors and by the demonstration of concomitant behaviour which was indicative of such an attentional breakdown (referred to as associated errors in the remainder of the dissertation).

More specifically, the following parameters were incorporated into the test battery in an attempt to provide useful positive and negative evidence:

(i) Variation of item order in sequential tasks.

Items within the subjects' repertoire (i.e., completed successfully) when presented separately or in a certain order were presented sequentially or in a different order. Failure on the latter presentations could not be attributed to difficulty of the items *per se* (negative evidence) but, rather, to a difficulty in shifting selective attention from strongly activated to less activated responses (positive evidence). This could take the form of a perseverative error (reflective perseveration) or some other strongly activated response; for example, the intrusion of a strong but irrelevant item from the environment (associated error).

Problems of fatigue and failure to "equalize" (see p.18) were also ruled out by examination of the entire protocol (negative evidence).

(ii) Variation of a task along a single parameter which involves controlled/planned attention to internal representations.

A previously successful task was not altered in any other respect but the requirement for strategic allocation of attention. Hence, the difficulty of the task could not account for any emerging perseverative or other errors (negative evidence). Since the only change was the requirement for voluntary regulation of responses, support for a deficit in such attentional allocation was garnered (positive evidence). The concomitant occurrence of other errors known to be associated with the breakdown of voluntary attention added further support to the notion that such a breakdown underlies the perseverative errors.

(iii) Conflict between intention and enduring disposition.

This involved tasks where the intended response was demonstrated to be within the subjects' repertoire (negative evidence). The breakdown of voluntary attention is assumed (by the current model) to result in the dominance of strong, well-established or automatic responses. Intrusion of such responses on tasks where they were triggered (but were inappropriate) and where the correct response was available to the subject (but not selected) provided positive evidence of a deficit in voluntary attentional processes.

Shallice (1979a) and Weiskrantz (1968a) also pointed to the necessity for a spectrum of tasks and parameters in a methodologically sound case study. Shallice (1979a) refers to this principle as the necessity for "converging operations", after a similar approach advocated by Garner, Hake & Eriksen (1956) in experimental psychology. This principle ensures that any critical inference is checked by different means. This is particularly important in neuropsychological studies where tasks are inevitably multideterminant and the risk of using a single test to measure a specific process is highlighted (Kinsbourne, 1971; Shallice, 1979b; Teuber, 1955; Weiskrantz, 1968b). In the current study a "perseveration battery" was developed in order to incorporate the three test parameters, described above, across a wide variety of tasks.

Shallice (1979a) also pointed out that a corollary of this prediction-testing method in case studies is that new tests may be devised - or used in a novel manner - so that normative information is not available. He noted that, in some cases, it may be necessary to demonstrate whether the patient is at or below the normal range. In the current study several new tests were developed and others were modified. In order to demonstrate the level of difficulty on these tests and as a general guide for the classification of perseverative errors, a group of normals (i.e., non brain-damaged subjects) were given the same test battery. These results were not intended as normative data in the more general sense. The tests used in this investigation were devised to specifically elucidate the proposed hypotheses. An attempt was made for normal subjects to cover the range of age, education and premorbid intellectual ability seen in the various case studies. However, the normal group did not represent a random nor representative sample suitable for reference in general clinical practice. The new tests were exploratory only.

It would be appropriate to collect systematic normative data in the future only if they were demonstrated to be of likely clinical or heuristic value in this study.

Finally, the literature, reviewed earlier, established that frontal patients characteristically show deficits in the regulation of voluntary attention. This was incorporated into the current model. A series of frontal patients was included, therefore, for comparison with the nonfrontal cases. Similar errors were expected (both in terms of qualitative features and the tasks on which they occur) providing positive evidence for a common underlying deficit in attentional regulation.

(b) External Validity

The use of clinical material to make inferences about normal cognitive functioning has been frequently criticized (Gregory, 1961; Postman, 1975). The supporters of a clinical-to-normal approach generally acknowledge the problems associated with it. However, they argue that it remains an important source of evidence for psychological models of normal cognitive processes because:

(i) any such model must be able to account for the observed dissociations between impaired and preserved abilities in neuropsychological patients (Marin, Saffran & Shwartz, 1976; Shallice& Warrington, 1970).

(ii) such patients provide opportunities to observe the properties of separable systems in relative isolation (Patterson, 1981; Saffran & Marin, 1975; Shallice & Warrington, 1970, 1975; Wickelgren, 1968).

These arguments have been particularly advocated by workers in the fields of reading (Patterson, 1981), language (Marin, Saffran & Schwartz, 1976) and memory (Shallice, 1979b) where the case study approach has been applied most frequently.

The other major threats to external validity rest on the extent to which the findings can be corroborated or replicated.The present design involved multiple case studies rather than a single case in order to address this issue. Shallice (1979a) considers the role of replication in fractionation studies (such as the present investigation) to be important but limited. The demonstration of even one case with the postulated separation of subsystems argues strongly for their separate existance. However, replication or corroboration in other cases can only serve to strengthen the inferences made by minimizing the possibilities of sampling bias, atypical neuronal development, fluctuations in the state of the patient and reorganization of function (Patterson, 1981; Shallice, 1979a). As discussed in the following section, more than one case is essential when making neuroanatomical inferences. Furthermore, the present investigation was exploratory, making a series of cases necessary to provide an opportunity for the predicted deficits to be demonstrated. Sidman (1960) recommended replication under different conditions to provide strong support for a particular inference. This recommendation, together with the clinical difficulty of finding identical lesions in patients matched on other variables, led to the inclusion of a wide variety of subjects with respect to age, education, premorbid intellectual ability and locus of lesion (apart from being nonfrontal). The demonstration of a voluntary attention deficit associated with perseveration in each additional nonfrontal patient was taken as corroborative evidence. Furthermore, a positive correlation between the incidence of perseveration and the incidence of associated errors would be expected if the present model which predicts a common attentional deficit, is correct (internal validity). Such a correlation could only be calculated if a series of patients was included.

Question 2: Can the deficit in voluntary attention in nonfrontal patients be shown to be related to involvement of deep midline structures?

Previous studies investigating the neuroanatomical correlates of perseveration have generally invoked the traditional group comparisons, using multivariate statistics (Corkin, 1965; Drewe, 1974, 1975; Milner, 1964). However, this approach to clinical neuropsychological material has come under increasing criticism recently. There are a number of reasons for this which can be summarized as follows (see Monti, 1982; Shallice 1979a, 1979b for full discussion).

1. Heterogeneity of the characteristics of any group of neuropsychological patients is inevitable. This has two ramifications:

(i) Since lesions cannot be assigned randomly to representative groups from the population, self-selection into groups - defined on whatever basis (e.g., lesions locus; presence/absence of a particular symptom) - will result in an enormous range of variation in all other attributes such as age, premorbid intelligence, lesion size, severity of symptom, presence and severity of other symptoms, etiology and so on. Although some authors have recommended the use of analysis of covariance to minimize these problems (e.g. Douglas & Peters, 1977; Shallice, 1979a) this reflects a misunderstanding of the appropriate use of this technique (Anderson, 1963; Evans & Anastasio, 1968). Indeed, no statistical procedure can be used to adjust for attributes that are inextricably related to the variable of interest (Lord, 1967, 1969).

(ii) In addition to the uncontrollable effects of such extraneous variables, heterogeneity of the properties of the symptoms under investigation means that potentially important features may be submerged by the averaging of group results (Hersen & Barlow, 1976; Kinsbourne 1971; Parsons & Prigatano, 1978; Shapiro, 1966; Sidman, 1960). This is particularly relevant to the study of perseveration. The previous discussion makes it clear that marked individual differences would be expected with respect to the tasks which elicit perseveration in each case. Among other factors this will depend on the particular locus of the lesion (even though it lies within a broad category) and the consequent interruption of associated functional systems. No two cases are likely to be identical in this respect so that detailed investigation of each case is necessary to provide a clear understanding of the nature of the perseverative syndrome.

2. There is little likelihood of finding sufficient numbers of patients with theoretically revealing symptoms of the same kind (Hersen & Barlow, 1976; Levy & Olson, 1979; Shallice, 1979a). Even

if one could define precisely the nature of the group of interest, that is, there was sufficient homogeneity to enable averaging of results, the liklihood of finding a sufficiently large group of subjects for multivariate analysis is very low.

3. Group classifications are static in nature. This refers to the problem that the traditional group approach can only, at best, investigate the properties of the group as a whole and does not allow for further breakdown of such a group into subcategories in a progressive manner. Given the current level of knowledge and research with respect to the neuroanatomical correlates of perseveration this is a particularly disadvantageous aspect of the multivariate group approach.

On the other hand, the case study approach also presents difficulties when neuroanatomical inferences are to be made. It is possible, for example, that the observed deficit does not reflect disruption of the lesioned area but, rather, represents a statistical artifact due to selection from the extreme end of the normal distribution (Shallice, 1979a). Similarly, the possibility of atypical neuronal development and the liklihood that the lesion involves more than one structure make neuroanatomical inferences from a single case extremely tentative. Replication (or a series of cases in which a common structure is involved) becomes essential for such inferences, preferably with post-mortem confirmation of the sites. When only broad neuroanatomical correlates are known or predicted (as in the present study), a process must begin whereby there is an aggregation of cases defined by specific patterns of dysfunction. Their neuropathological findings are then correlated in an attempt to progressively define the minimal lesion responsible for the particular syndrome (see Mair, Warrington & Weiskrantz, 1979, for an example of this process).

Some recent studies investigating the neuroanatomical correlations of perseverative and/or associated symptoms appear to have recognized these difficulties. They have incorporated a case study approach within a group (lesion locus) comparison design. This takes the form of multiple case studies which can be broadly classified according to lesion locus but can be discussed separately according to variations of locus and/or other factors within their broad groups. The study by Brunner, Kornhuber, Seemuller & Wallesch (1982) exemplifies this approach. The results for each case were reported separately but general trends within and across groups were identified and discussed. This approach maintains the rich information regarding clinical variations and hence provides a basis for further studies with more refined neuroanatomical classification.

A similar approach was adopted for the investigation of the second question. Nonfrontal subjects with lesions in each of the following broad neuroanatomical groups were included in the series of case studies described for Question 1.

(i) Deep (D): Deep midline structures with no cortical involvement.

(ii) Combined (C): Posterior cortex with extension to deep midline involvement.

(iii) Shallow (S): Posterior cortex with no deep midline involvement.

Variation within each group was anticipated and could be explored by reference to individual case data. On the other hand, evidence of a voluntary attention deficit was expected in at least some of the subjects with deep midline involvement (deep (D) and combined (C) subjects). Shallow patients were expected to show no evidence of such a deficit. Indeed, the demonstration of a voluntary attention deficit in even one shallow (S) patient was sufficient to reject the model's neuroanatomical proposals.

Inclusion of patients with unilateral lesions of both left and right hemispheres allowed some preliminary investigation of laterality effects.

Question 3: What types of perseverative errors can be demonstrated when a variety of patients and of tasks are examined?

Previous studies investigating perseverative error classification have generally used a purely qualitative analysis with a single patient group (Allison & Hurwitz, 1967; Goldberg &

Tucker, 1979; Leicester, Sidman, Stoddard & Mohr, 1971; Yamadori, 1981). In Section 2.7 it was noted that the three classificatory systems emerging from these studies have been based on either

(i) the temporal relationship between the perseverate and its original stimulus or original execution;

(ii) the relationship between the perseverate and the stimulus or target response which elicited it;

or (iii) the nature of the perseverate itself (the Goldberg-Tucker typology).

The data collected in the investigation of the previous two questions allowed for the examination of the errors made on a wide variety of tasks by each nonfrontal patient, as well as those made by frontal and normal subjects. Each error was classified according to the three systems above and compared with previously described subtypes.

6. METHOD

6.1 Subjects.

All patients were considered for inclusion on the basis of

(a) referral from a staff member

or (b) a search of medical histories, at the following hospitals:

Alfred Hospital
Caulfield Rehabilitation Hospital & Day Centre
Hampton Rehabilitation Hospital
Kingston Rehabilitation Hospital
Mount Royal Rehabilitation Hospital and the
Coburg Day Centre
Prince Henry's Hospital
Royal Talbot Rehabilitation Hospital
St. Vincent's Hospital (Bolte Rehabilitation Centre)

(all hospitals are within the Melbourne Metropolitan area).

6.1.1 Neurological Characteristics.

A. Nonfrontal Patients

Subjects were included if they fulfilled the following criteria:

(i) Nonfrontal focal brain lesion confirmed by CT scan (one isotope scan), neurological examination and, where possible, angiography and neurosurgical report. Where the CT scan report failed to clearly specify the extent of the lesion (e.g., involvement of deep structures or extension to frontal regions) the scan was examined by a neuroradiologist and discussed with the author.

(ii) Nonacute, exclusion of effects, such as oedema and diaschisis, which might contribute indirectly to frontal and/or deep midline dysfunction (even though such structures were not included in the lesion location descriptions from (i)). A minimum of six weeks between onset or surgery and testing was set.

(iii) Testable, able to comprehend test instructions (discussed with speech pathologist when in doubt) and willing to participate after explanation of the study and participation requirements (all participation was voluntary and the subject had the right to terminate at any time).

Patients were excluded if they did not fulfill the above criteria or demonstrated significant cerebral atrophy (inappropriate to age), dementia or psychosis. Cases where the diagnosis was uncertain and multiple or diffuse lesions could not be ruled out were also excluded.

Eighteen nonfrontal patients were included. They were divided into three groups according to lesion locus:

[1] SHALLOW (S) (N=6): Posterior cortical lesion without involvement of deep midline structures. Lesions restricted to the cortex (i.e., with no white matter involvement) were rare, so the lesion was classified as "shallow" if deep midline structures (limbic system or basal ganglia) were not involved.

[2] DEEP (D) (N=6): Lesion of deep midline structures (limbic nuclei and/or basal ganglia) not extending to the cortex.

[3] COMBINED (C) (N=6): Posterior cortical lesion extending to include one or more deep midline structures.

Etiology and laterality are summarized for each group in Table 1. Neurological details of each subject, together with the relevant CT scan image and report and other relevant information, are presented in Appendices 1-3.

Table 1. Etiology And Laterality For Each Subgroup of Nonfrontal Patients

	Shallow (S) N=6	Deep (D) N=6	Combined (C) N=6
ETIOLOGY:			
Infarct	3	3	4
Haemorrhagic Infarct	0	1	1
Haematoma (Intracerebral)	2	2	0
Meningioma	1	0	1
LATERALITY:			
Left	3	3*	5
Right	3	3	1

* Patient VI had a recent left-sided deep lesion, with left hemisphere neurological signs but the CT scan also showed old shallow lesions in the right hemisphere. This patient was classified as Deep/left but the right-sided lesions were taken into account in the interpretation of her performances.

B. Frontal Subjects.

Subjects were included if they fulfilled the following criteria:

(i) Frontal, or predominantly frontal, focal lesion confirmed by CT scan, neurological examination and, where possible, angiography and neurosurgical report.

(ii) Testable - able to comprehend test instructions and willing to participate after explanation of the study and participation requirements.

Patients were excluded if they did not fulfill the above criteria or demonstrated significant cerebral atrophy, dementia or psychosis. Two subjects were tested while mass effects may have contributed to their performances; one was within six weeks of the onset of a large haematoma (subsequently evacuated), the other had a malignant tumour in situ (steroids had resolved signs of increased intracranial pressure). Both patients were orientated to person, place and time, fully conscious and able to remember the examiner each day. In both patients their symptoms and signs (both neurological and neuropsychological) were referrable to frontal lobe dysfunction. All other subjects were tested at least 6 weeks post onset.

Seven frontal subjects were included. Etiology and laterality are summarized in Table 2. Neurological details of each subject, together with the relevant CT scan image and report and other relevant information are presented in Appendix 4.

Table 2. Etiology and Laterality for Frontal Patients (N=7)

Etiology	
Haematoma (subdural)	1
Haematoma (intracerebral)	3*
Infarct	2
Tumour	1
Laterality	
Left	3*
Right	4

* Patient UV had a recent left frontal haematoma but a history of previous right frontal and anterior parietal infarcts some two years earlier. He was classified on the basis of the most recent lesion (i.e. haematoma/left) but the bilateral involvement was considered in the interpretation of his results.

C. Normals

Normal subjects were included if they fulfilled the following criteria:

(i) No history of brain damage, psychosis or learning difficulties.

(ii) No evidence of dementia - all subjects were living independently. Subjects were excluded if there was a discrepancy of more than 20 points between estimated I.Q. (see Section 6.1.3) and Wechsler Memory Scale Memory Quotient.

(iii) Range of age and education to correspond to the experimental subjects.

Eleven normal subjects were included. Table 3 provides the details of each subject.

Table 3. Description Of Each Normal Subject (N=11)

Case	Detail: Age, Sex, Education, Occupation, Other.
XY	82; Male, Intermediate (Gr. 10); Plumber until retirement.
TY	77; Female, 6th Grade & Business studies; Typist until marriage.
NT	62; Female, Gr. 12 & 1 yr Commercial Stud.; Secretary-Medical Receptionist till marriage
OK	62; Female, Matric (Gr. 12); Journalist until married
XN	58; Female, Leaving (Gr. 11); Priv. secretary (retired) artist
EO	54; Male, L.L.B.; Solicitor
QZ	44; Female, T.S.T.C. & Grad. Dip. Spec. Ed.; Teacher
TX	43; Female; 7-8th Grade, Bookkeeper; Leg amputation following M.C.A. no head injuries.
TV	33; Male; L.L.B., Solicitor.
NS	33; Male, 4yrs law, Dip. Ed;3yrs Dip Land Arch.(cont.); Student
TQ	21; Male, Gr. 11 & 4yrs trade school, Sheet metal worker

6.1.2 Demographic Characteristics

The demographic characteristics (Age, Sex, Education) of each group are summarized in Tables 4 - 6

Table 4. Distribution Of Age In Each Group

GROUP	20-29	30-39	40-49	50-59	60-69	70-79	80-89	X	S.D.
NORMAL N=11	1	2	2	2	2	1	1	51.7	18.1
FRONTAL N=7	0	0	2	2	3	0	0	56.9	8.6
SHALLOW N=6	0	1	1	3	0	0	1	54.6	14.8
DEEP N=6	0	0	0	2	2	2	0	65.1	8.2
COMBINED N=6	0	0	0	2	2	1	1	65.0	10.0

Table 5. Sex Distribution In Each Group

GROUP	MALE	FEMALE
NORMAL N=11	5	6
FRONTAL N=7	4	3
SHALLOW N=6	5	1
DEEP N=6	4	2
COMBINED N=6	4	2

Table 6. Education Distribution In Each Group

GROUP	NO. OF YEARS OF EDUCATION 6-8	9-10	11-12	TER.	X	S.D.
NORMAL	2	1	4	4	12.2	3.6
FRONTAL	3	4	0	0	8.2	2.8
SHALLOW	3	2	0	1	9.2	2.2
DEEP	1	1	1	3	12.5	3.3
COMBINED	3	0	2	1	10	3.2

6.1.3 Cognitive Characteristics

A number of tests were administered in order to

(a) estimate premorbid I.Q. range

(b) document the general neuropsychological status of each patient, and

(c) demonstrate absence of generalized dementia.

The following tests were administered to all subjects.

Block Design } from the Wechsler Adult Intelligence
Vocabulary } Scale (W.A.I.S.) (Wechsler, 1955)

Nelson Adult Reading Test (N.A.R.T.) (Nelson, 1982)

Raven Coloured Progressive Matrices (R.C.P.M.) (Raven, 1956)

Benton Visual Retention Test (B.V.R.T.) (Benton, 1974)

Wechsler Memory Scale (W.M.S.)[1] (Wechsler & Stone, 1945)

Goldstein-Scheerer Stick Test (Goldstein & Scheerer, 1941)

(Items 1,2,6,5,9,10,14,13,17,18,21,22,26,25)2

Purdue Pegboard (Purdue Research Foundation, 1948)

Rey Auditory-Verbal Learning Test (R.A.V.L.T.) (Rey, 1964).

Spontaneous speech was also monitored in a brief semi-structured

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[1] Where time or other factors limited administration, Logical Memory subtest was administered and remaining tests given as possible.

[2] Items selected following Helmick & Berg (1976)

interview. The interview covered such topics as the patients' occupational and educational history; their medical history; the conditions, staff and rehabilitation programme of the hospital they were attending; problems they had encountered since the onset of their illness and any questions they had regarding the research project or the examiner.

Individual results on each of these tests can be found in Appendices 5 - 9 and were taken into account in the interpretation of performances on the perseveration battery tests, as described in the results. Standard administration and scoring was followed for all tests except the W.M.S. where the Logical Memory subtest was administered separately from the remainder of the test. W.M.S. Memory Quotient was calculated in the standard manner.

Premorbid IQ Estimate.

An I.Q. score range was set for scores on each of four tests; Block Design, Vocabulary, N.A.R.T. and R.C.P.M., as shown in Table 7. The highest estimate from any one (or more) of these tests was taken as the estimated premorbid I.Q. score range, unless educational and occupational status indicated a marked under-estimate would be made in this manner, in which case these latter factors were included in the estimation.

Table 7. Estimated Premorbid I.Q. Score Ranges Based On Scores on 4 Tests

I.Q. Estimates	Block Design	Vocab	N.A.R.T	R.C.P.M.
D-Av: Dull-Normal/Average	≤10	≤10	80-105	<70
Av-B: High Average/Bright-Normal	12-15	12-15	106-119	70>90
S-Vs: Superior/Very Superior	16+	16+	120+	90+

Distribution of premorbid IQ estimates in each group are shown in Table 8.

Table 8. Number Of Subjects In Each Group Within Each Estimated Premorbid IQ Range

Group	D-Av		Av-B		S-Vs	
	N	%	N	%	N	%
NORMAL (N=11)	0	0	5	45.5	6	54.5
FRONTAL (F) (N=7)	4	57	3	42.9	0	0
SHALLOW (S) (N=6)	2	33.3	2	33.3	2	33.3
DEEP (D) (N=6)	0	0	4	66.7	2	33.3
COMBINED (C) (N=6)	2	33.3	3	50	1	16.7

The premorbid I.Q. score range of two frontal (F) patients, classified as dull-normal/average, may have been underestimated on the basis of their test scores. One (Pt. XH) had an extensive right hemisphere lesion (lowering nonverbal scores) but may have been disadvantaged on verbal tasks since Dutch was her native language, even though her English was adequate for general testing. She had left school early due to family circumstances so educational and occupational status were not helpful. The other (Pt. UV) had bilateral involvement which may have lowered performance on both verbal and nonverbal tasks. One combined (C) patient (Pt. PD) had a very similar history to the first frontal patient described above, that is, a right hemisphere lesion and Dutch native language, together with early school removal. She may also have been underclassified as dull-normal/average. In the absence of objective data to the contrary these classifications were left as dull-normal/average. A second combined (C) patient (Pt. US) was considered to have a marked under-estimate on the basis of his test scores. He had a Bachelor of Arts degree and worked as a meteorologist prior to his stroke, including expeditions to the Antarctic where an ice shelf had been named after him. On this basis he was classified in the superior/very superior range. All others were classified on the basis of best test scores and are considered as reasonable approximations, erring on the conservative side if incorrect.

6.2 Perseveration Tests And Criteria For Measurement.

6.2.1 Test Development And Selection

In Section 5.2 three test parameters to be incorporated in the perseveration battery were described. These parameters were included as part of the design in order to elicit positive and/or negative evidence for a voluntary attention deficit. In summary, they consisted of:

(i) variation of order on sequential tasks

(ii) variation requiring allocation of attention

(iii) conflict with an enduring disposition.

The required battery of tests, then, had to include a wide variety of tasks, each of which incorporated at least one of these test parameters.

A preliminary investigation was conducted in order to select the most efficient battery of tests which fulfilled these requirements. An optimal number of testing sessions was also established. This preliminary investigation did not provide normative data nor investigate the reliability and validity of the tests in any systematic manner. The case studies presented here represent a series of experiments with individual patients. As such, the test battery was used as a research tool rather than a psychometric measure. The tests were considered valid if they satisfied one of the parameters described above. Reliability was only relevant within subjects and the testing procedure included testing over several sessions, each on a different day. Inferences were drawn on the basis of the entire test protocol rather than individual tests and retesting was possible whenever reliability of single tests was seriously questioned (e.g., patient fatigue).

The preliminary investigation was initiated in Canada and continued in Australia, where the main study was to be conducted. Subjects were selected from the following hospitals:

Gorge Road Hospital, Victoria, Canada
Caulfield Rehabilitation Hospital, Melbourne, Aust.
Mount Royal Hospital, Melbourne, Aust.

Patients were referred to the study by treating staff members at the relevant hospital. Referrals were made of patients known to perseverate, in any area of functioning, who were willing to participate in the study. Thirteen patients were included. These patients represented a broad range of demographic and neurological characteristics. Tests were rejected if they were too cumbersome to administer, too difficult to score or they failed to give rise to perseveration in any subject. They were also excluded if other similar tests were selected, in order to shorten the battery and reduce redundancy. Rejected tests included the following:

1. Object Sorting Test (Goldstein & Sheerer, 1941) - with modifications using the same objects (naming, drawing, reading, writing, recall),
2. Months of the year - repetition forwards and backwards,
3. Male names by alphabet
4. Female names by alphabet
5. Design Fluency (Jones-Gotman, 1977)
6. Sequential hand movements (Christensen, 1975)

The selected tests formed the perseveration battery and could be divided into three groups, corresponding to the three parameters they incorporated:

(i) Sequential tests - in which the order was varied (four tests)

(ii) Regulation tests - in which the degree of required attentional regulation was varied (four tests)

(iii) Conflict tests - in which a response was required which conflicted with a previously well-established and recently executed response (two tests).

These tests are described in detail in the following section.

6.2.2 Perseveration Test Battery

(i) Sequential Tasks (Naming, Writing, Reading, Drawing)

These tasks were devised by the author. A series of 9 cards (4" X 6") was used for the sequential tasks. On each card there was a coloured outline drawing of a familiar object, as shown in Figure 6, which also shows the manner in which the cards were presented to the subject.

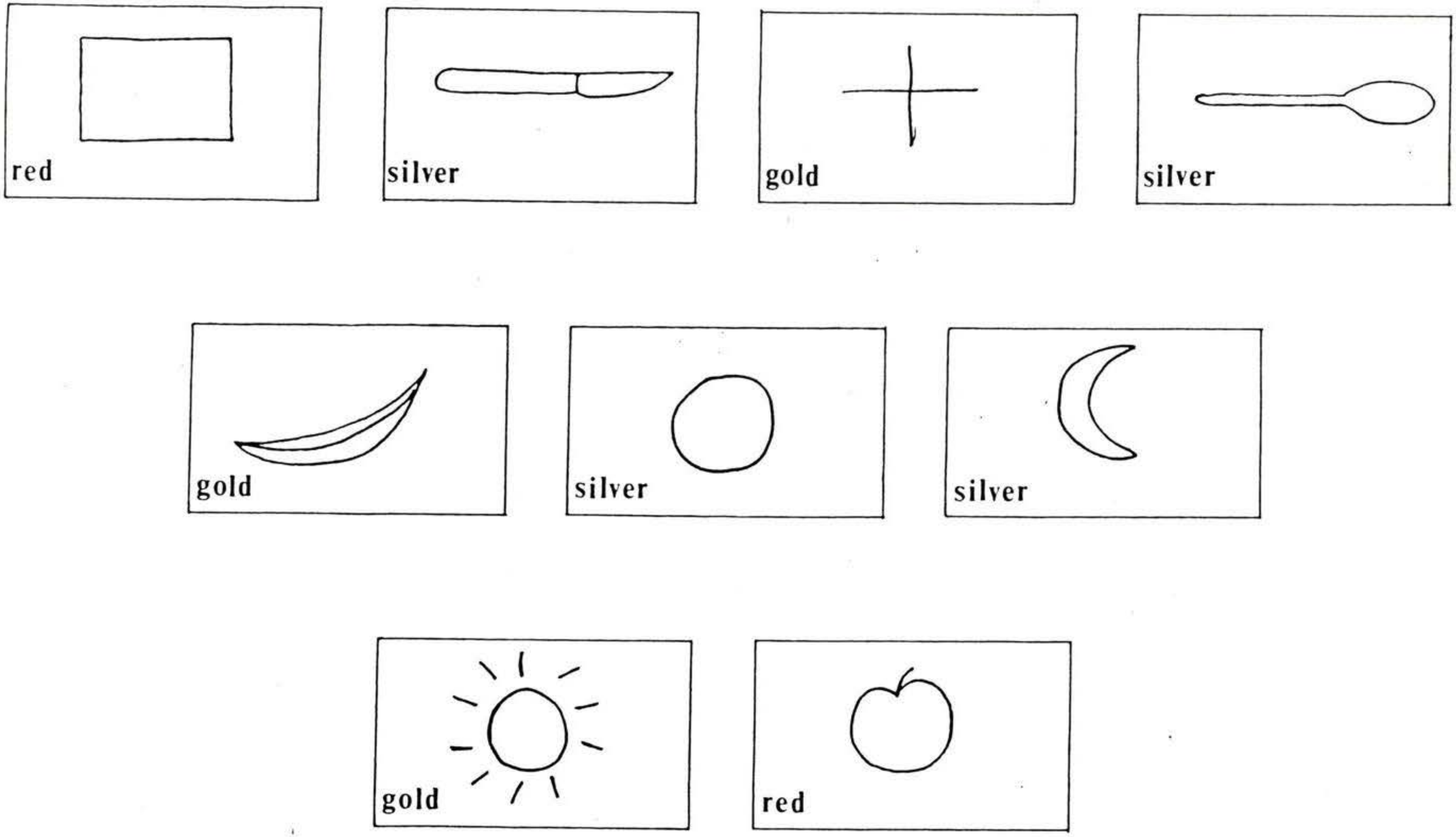


FIGURE 6. Presentation of Items for Sequential and Sorting Tasks

There were four sequential tasks related to these cards - in each task the 9 items were presented twice; in one order on the first trial and in a different order on the second trial. The order was the same for all subjects and across all four tasks and is given in Table 9. The four tasks involved naming, writing, reading and drawing of the items by the subject, respectively, and are described in more detail below:

Table 9. Order Of Presentation Of Items On The Sequential Tasks

Trial 1		Trial 2	
1	SQUARE	10	BANANA
2	CIRCLE	11	CROSS
3	CROSS	12	SQUARE
4	KNIFE	13	SPOON
5	SPOON	14	SUN
6	MOON	15	APPLE
7	BANANA	16	CIRCLE
8	APPLE	17	KNIFE
9	SUN	18	MOON

[1] NAMING

The cards were displayed as in Figure 6. The subject was instructed to name each item as the examiner pointed to it. Items were pointed out in the order specified in Table 9 for both trials which were given successively. If the subject failed to name an item correctly she/he was told the correct name and asked to repeat it.

[2] WRITING

The procedure was the same as for the naming task but the subject was asked to write the name of the item rather than say it. Spelling errors were not corrected. The name of the item was supplied if complete blocking occurred.

[3] READING

Subjects were asked to read a list of words (large capital lettering written in a vertical column). The list consisted of the names of the 9 items, each written twice (i.e., 18 words in total), in the order of presentation of the other tasks as shown in Table 9.

[4] DRAWING

The cards were removed from sight and the subject was asked to draw each one (as it had been previously presented) when the examiner gave its name. The examiner dictated the name of each of the 9 items, twice, in the prescribed order.

SCORING: For each sequential task, the presence/absence of perseverative and/or associated errors was noted. All errors were classified as severe, moderate or mild and as catastrophic or reflective (see Section 6.2.3 for definitions of these terms).

(ii) Regulation Tasks (Alternations, Verbal Fluency, 5 Dot Fluency, Trails)

[1] ALTERNATIONS

Four series (devised by the author) were administered. In each case the examiner began the series ("model") and then instructed the subject to continue the sequence across the page. A minimum of 5 alternations was set.

The models were as follows:

1) □ ▫ □ ▫ .....

2) A B C D a b c d .....

3) m m m m.......

   w w w w.......

   m w m w.......

4) ↑↑→ ....

SCORING: The presence/absence of perseverative and/or associated signs on any of the series was noted. Errors were classified according to severity and as either catastrophic or reflective.

[2] VERBAL FLUENCY

There were three "automatic network" subtests, in which the subject was asked to list as many words as possible in a category which is a well-established (closely associated) grouping for most people. These tests served to establish the subjects' ability to perform a fluency task and their repertoire within each category.

There were six "regulation" subtests in which the subject was again asked to list as many words as possible in a given category but

(a) the words were now to be ordered according to a given rule

and (b) the category was not usually a closely associated network, that is, it involved active search.

More specifically, the subtests were as follows:

[i] ANIMALS (Automatic network)

The subject was instructed as follows:

"Tell me as many different animals as you can, in any order, and keep going until I say stop".

The subject was given 60 seconds before the task was terminated.

[ii] ANIMALS BY SIZE (Regulation)

The subject was instructed as follows:

"I want you again to tell me as many different animals as you can but this time I want you to put them in order of their size; that is, I want you to tell me the smallest animal you can think of first, then one just a little bit bigger, then a little bigger again and so on, making sure that each one is bigger than the one before it. Don't get too big too quickly or you'll run out. Keep going until I say stop".

The subject was given 60 seconds to complete the task.

[iii] ANIMALS BY ALPHABET (Regulation)

Prior to the administration of this task it was established that the subject could recite the alphabet.

The subject was then instructed as follows:

"Again I want you to tell me as many different animals as you can but this time I want you to order them according to the alphabet; that is, the first one is to begin with A, the next with B, then C and so on. Only one animal for each letter and keep going until I say stop".

The subject was allowed 60 seconds to complete the task.

[iv] MALES (Automatic network)

The following instructions were given:

"I want you to tell me as many different male names as you can, in any order, and to keep going until I tell you to stop".

The subject was given 60 seconds.

[v] FEMALES (Automatic network)

The same instructions were given as for MALES but the subject was now asked to supply female names (60 seconds).

(vi) MALE-FEMALE (Regulation)

The subject was instructed to give one male then one female then one male and to keep on alternating male-female names until the examiner said 'stop'. The subject was told to be careful not to give two male names or two female names together (60 seconds).

The verbal fluency tests described above [(i) to (vi) inclusive] were devised by the author.

(vii to ix) F.A.S. (Regulation)

The F.A.S. verbal fluency tasks, or "Controlled Word Association" tasks were taken from standard neuropsychological tests (e.g., Neurosensory Centre Comprehensive Examination for Aphasia (Spreen & Benton, 1969)) and have been used in previous studies of perseveration (Milner, 1964; Perret, 1974; Regard, 1981).

The subject was instructed as follows:

"I will give you a letter of the alphabet and I want you to tell me as many different words as you can that begin with that letter. <u>But,</u>

there are some rules; this time you are <u>not</u> allowed to have people's names or the names of towns or countries, that is, you are not allowed to have any words that begin with a capital letter - <u>and</u> - you are <u>not</u> allowed to have the same word with a different ending, that is, eat, eating, eaten, eats - that would be cheating. So, as many <u>different</u> words as you can, no capital letters, starting with the letter:

[vii] F (60 seconds)

[viii] A (60 seconds)

[ix] S (60 seconds)

The instructions were repeated before the start of each letter and the examiner ensured that the subject understood the task and could remember the rules before proceeding each time.

SCORING: For each verbal fluency task, the number of responses was noted and classified regarding fluency (see Section 6.2.3). The presence/absence of perseverative and/or associated errors was also noted and all errors were classified regarding severity and as either catastrophic or reflective.

[3] 5 DOT FLUENCY

This test was taken from Regard (1980, 1981) (Five Point Test) although the instructions were slightly modified.

The subject was instructed as follows:

"In this test I want you to draw as many <u>different</u> designs as you can by joining the dots in each square. You can join as many dots as you like in each square; for example, you may just join 2 dots, like this (examiner demonstrates in square 1) or more than 2 dots, like this (examiner adds to first model). You must alway join dot to dot, that is, you can not go between the dots like this (examiner demonstrates error) - that would be an error. I will give you five minutes and I want to see how many <u>different</u> designs you can think of. Be careful not to repeat the same design. Keep going until I say stop".

The task was terminated after five minutes. The form for this test is presented in Appendix 10.

SCORING: The percentage repetition was classified as severe, moderate or mild perseveration (see Section 6.2.3). Catastrophic factors were noted where present.

[4] TRAILS (A AND B)

These tests were originally introduced in the Army Individual Test Battery (1944) and have since become a standard part of neuropsychological testing. They were administered in the standard manner.

These tests require the subject to join a group of numbered circles (1 to 25) in ascending order (Trails A) and to join a similar group of numbered or lettered circles in ascending and alternating order (i.e. 1 -> A -> 2 -> B -> 3) (Trails B).

The test forms are presented in Appendices 11 and 12. The subject was instructed to complete the series as quickly as possible and the task was timed.

SCORING: The time taken was not scored since irrelevant factors (e.g. paresis, non-preferred hand use) were often involved in slow performances. The presence/absence of associated signs was noted.

(iii) Conflict Tests. (Series Reversal, Sorting)

[1]SERIES REVERSAL

There were three tasks devised by the author. In each task the "enduring disposition" was initially triggered (and executed) and the intended responses were demonstrated to be within the subject's repertoire. The subject was then asked to produce a series in conflict with the habitual or "enduring" form.

(i) Days Of the Week

The subject was asked to recite the days of the week

(a) Forwards

(b) Backwards

(ii) Counting 1-20

The subject was asked to count aloud

(a) from 1-20

(b) from 20-1

(iii) Reversed S

The subject was asked to draw a series of S. (SSSSSSSSS)
The subject was then asked to draw a "back to front S" (i.e. Ƨ).

If this could not be done spontaneously, a model was drawn for the subject and she/he was asked to copy it and then draw it again. If the subject was able to reverse the S she/he was then instructed to draw a series of them (i.e. ƧƧƧƧƧƧ...)

(iv) Reversed 7

As for S, the subject was asked first to draw a series of seven's (i.e. 7777777) and then to draw a "back to front seven" (i.e. Γ). A model was demonstrated if necessary. If the subject was able to draw a reversed 7, she/he was instructed to draw a series of them (i.e. ΓΓΓΓΓ)

SCORING: The presence/absence of perseveration and/or associated errors on any series reversal task was noted. Errors were classified according to severity and as either catastrophic or reflective (as defined in Section 6.2.3).

[2] SORTING

Again, this test was devised by the author. The 9 cards used in the sequential tasks described earlier were displayed as shown in Figure 6. The subject was asked "to sort the cards into groups that belong together." On completion of sorting the subjects were asked to explain the groups they had constructed.

The cards were then replaced (as in Figure 6) and the subject was instructed to "again sort them into groups that belong together but this time in a different way, that is, a different reason for sorting them into groups that go together." When completed the subject was again asked to explain the sorting.

If the cards had not been sorted according to colour in either trial, the subject was again asked to sort in a different way ("Is there any other way you can see to sort them?"). If colour was still not used, the examiner placed the yellow cards together and asked the subject if they could see why they might be sorted that way. If colour was recognized the subject was asked to complete the remaining cards by the same principle. If the subject could not recognize colour, the remainder were sorted by the examiner into colour groupings and the subject was again asked why they might belong that way. If the colour principle was still not recognized the examiner would point to one group and say "what is the same

about these?" If colour was still not recognized, the examiner asked the subject to identify the colours of the items in each group.
SCORING: Perseveration of a sorting principle was noted. Failure to recognize the colour principle in the absence of catastrophic factors was noted. Perseveration was classified according to severity.

6.2.3 Classification of Errors

I Definitions

(a) Perseverative Errors

For the purposes of the current study, and on the basis of previous studies of perseveration discussed in Chapter 2, a perseverative error was defined as:

An incorrect response which is referable, in whole or part, to a prior stimulus-response event.

(b) Associated Signs (Associated Errors and Reduced Fluency)

For the purposes of the current study associated signs are defined as signs, other than perseverative errors, which indicate a loss of voluntary regulation of behaviour i.e. a dissociation between "knowing" (momentary intentions) and "doing" (response). These include the following (characteristically described for frontal patients, as discussed in Section 2.3 and generally accepted as indicative of the breakdown of voluntary attention):

A. Associated Errors

(i) tangential responses or looseness of association, after beginning correctly, i.e., where the original intention fails to guide the responses and they become irrelevant;

(ii) rule-breaking, despite understanding and recall of instructions, especially when the error is repeated;

(iii) failure to inhibit responses known to be incorrect (impulsivity);

(iv) discrepancy between verbalization of intended action and the action itself;

(v) intrusion of automatic responses, echolalia, mirroring.

B. Reduced Fluency

Consistent with features such as adynamia and reduced spontaneous speech noted in frontals and perseverating aphasics (Allison & Hurwitz, 1965; Luria, 1973;), severely reduced output on the verbal fluency tasks, despite adequate repertoire, was taken as a sign of impaired voluntary regulation of behaviour (selective activation of responses in the absence of external stimulation).

II Catastrophic vs. Reflective Errors

All perseverative errors were classified as either catastrophic or reflective:

Catastrophic errors were those which could be accounted for by the difficulty of the item, fatigue or failure to "equalize" after a previous failure. A conservative approach was adopted in which it was necessary to rule out these factors in order to escape this classification. Hence, it was necessary to demonstrate that the intended/required response was within the subject's accessible repertoire and did not immediately follow a failure or occur only at the end of a task before this "catastrophic" classification could be excluded.

If the above factors could be ruled out and the error was related to the introduction of the requirement for voluntary selection among variously activated and accessible responses (inherent in most tasks) the error was classified as reflective.

Associated signs were also only taken as indicative of a voluntary attention difficulty if catastrophic factors could be excluded. Thus, for example, severely reduced fluency was considered "catastrophic" if the subject was unable to demonstrate elsewhere that an adequate repertoire for the task was accessible and/or factors such as severe oral dyspraxia were involved.

Examples of this classificatory process are given in the results for each task.

III Severity

A. Normal performances

As noted in Section 6.1.1., a group of normal (non-brain damaged) subjects was included to demonstrate the level of difficulty of the tests and to serve as a general guide for the classification of errors. This was relevant to the classification of the severity of the errors made.

Consequently the results for the normal group are summarized below for each task. Full details of individual performances are presented in Appendix 13.

1. Sequential Tasks (Naming, Reading, Writing, Drawing)

(a) NAMING

Subject TQ, (Age 21) named all items correctly but on the second trial he gave the following self-corrected response to cross (+): "sq....ah, cross".

Subject QZ, (Age 44) named all items correctly except for the first trial of MOON:

"sun (E queries) moon!"

All other subjects named the items without error

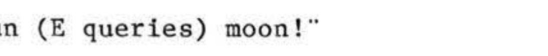
(b) READING, WRITING AND DRAWING

All subjects completed these tasks without error.

2. Conflict Tasks (Series Reversal, Sorting)

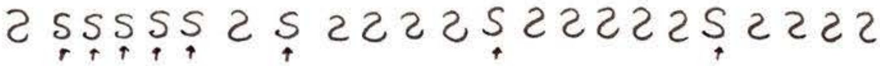
(a) SERIES REVERSAL

Subject TX (Age 43) used his non-preferred hand for written tasks. He made 2 errors in the reversal S series, recognizing each immediately and subsequently completing the task correctly:



All other series were reversed without difficulty by this subject.

Subject TY (Age 77) gave the following responses for reversal S:



She made no other errors on the series reversal tasks.

All other subjects completed the series reversal tasks correctly.

(b) SORTING

All subjects were able to sort the cards according to their concrete similarities and to recognize the colour sorting.

6/11 produced the colour sorting spontaneously

5/11 recognized the colour principle from one group and completed the other 2 groups

5 subjects also gave the shape sorting.

3. <u>Regulation Tasks</u> (Alternations, Verbal Fluency, 5 Dot Fluency, Trails A and B)

(a) ALTERNATIONS

All subjects completed the alternation tasks without error.

(b) VERBAL FLUENCY

Table 10 presents the results for the 3 animal verbal fluency tasks (animals, animals by size, animals by alphabet)

Tables 11 and 12 present the analagous data for the 3 name fluency tasks and the F.A.S. tasks respectively.

Table 10 Mean, Standard Deviation and Range for the Normal Subjects (N=11) On The "Animal" Fluency Tasks (Correct Responses Only)

	Animals	Animals By Size	Animals By Alphabet
MEAN	25.4	15.7	15.5
S.D.	6.9	2.2	3.2
RANGE CORRECT RESP.	15-36	12-19	12-22

Table 11. Mean, Standard Deviation And Range For The Normal Subjects (N=11) On The "Male, Female, Altn." Fluency Tasks (Correct Responses)

	Male	Female	M-F Alternation
MEAN	23	22	22.1
S.D.	5.7	4.8	6.4
RANGE CORRECT RESP.	16-33	16-31	13-34

Table 12. Mean, Standard Deviation and Range For The Normal Subjects (N=11) On the F-A-S Fluency Tasks (Correct Responses)

	F	A	S
MEAN	16.8	13.6	17.4
S.D.	3.9	4.6	3.7
RANGE CORRECT RESP.	10-22	6-19	11-24

When individual protocols were examined it was found that perseverative and associated errors were uncommon and frequently self-corrected. Where they did occur, they generally represented less than 10 per cent of the total number of responses given. This was true for all subjects except Subject TY (Age 11) whose perseverative error and associated error on the "A" task each represented 12.5 per cent of the total (1/8). The data for perseverative and associated errors are presented in Table 13 below:

Table 13. The Number (N) of Normal Subjects Showing Perseverative and/or Associated Errors On The Verbal Fluency Tasks;(a) The Total No. Of Responses Given;(b)No. Of Errors and (c) Percentage Of Errors For Each Such Subject(S) On Each Task.

	Perseverative Errors					Associated Errors				
Tasks	N	S	(a)	(b)	(c)	N	S	(a)	(b)	(c)
Animals	2	TV TQ	32 25	1 2	3.1 8.0					
Animals by Size	1	OK	20	1	5.0	1	EO	17	1	5.8
Animals by Alphabet	1	TY	14	1	7.1					
Males										
Females	1	XN	18	1	5.5					
Male-Females						2	TQ NS	16 24	1 2	6.2 8.3
F	2	TQ NS	21 16	1 1	4.8 5.5					
A	3	TY TQ NS	8 11 15	1 1 1	12.5 9.1 6.6	2	TY TQ	8 11	1 1	12.5 9.1
S	2	NS TQ	19 16	1 1	5.2 6.3	1	TV	23	1	4.3

(c) 5 DOT FLUENCY

Table 14 presents the results for the normal subjects on the 5 Dot Fluency task:

Table 14. Normal Subjects' Performances On The 5 Dot Fluency Test

Subjects	Age	Total No Of Designs	No. Of Repetit'ns	% Repetit'n	% Correct
TY	77	28	0	0	100
XY	82	24	2	8.3	91.7
TV	33	47	0	0	100
TX	43	49	0	0	100
TQ	21	71	1	1.4	98.6
NS	33	64	0	0	100
NT	62	38	0	0	100
QZ	44	52	0	0	100
XN	58	67	5	7.5	92.5
OK	54	62	2	3.3	93.3*
EO	62	60	6	9.7	90.3

* 2 Errors were also made.

(d) TRAILS A AND B

All subjects completed Trails A without error. Trails B were also completed without error by all subjects except Subject TY (Age 77) who made one minor error: Having reached 7-> G she lifted her pencil while searching for 8 and, upon finding it, moved again from 7 rather than from G. No further errors were made.

Since time taken was not scored in the analysis of the brain-damaged patients (due to the possible confounding by motor difficulties see p.102), times are not reported for the normals here. However, it can be noted that all normals performed within standard time limits for their age except where arthritis or other peripheral factors slowed their qualitatively correct performances (2 subjects scored at the 10-25 percentile for these reasons, all others scored at or above the 50th percentile).

General Comment: From the above results and Appendix 13 it can be noted that a high proportion of normal subjects made at least one perseverative error or associated sign. For example, 7/11 normals made perseverative or associated errors on the verbal fluency tasks (Table 13). This is not inconsistent with the theoretical model proposed earlier. It was noted there, and in the literature review, that perseveration is a normal phenomenon which occurs especially under conditions of stress or fatigue and on tasks requiring either rapid or conflicting responses. Hence, some perseveration would be expected among normals on the perseveration battery used here.

Such errors do not imply a permanent deficit in voluntary attention. Rather, they imply a temporary lapse or insufficient supply of attention/concentration on a particular item. That the voluntary attention mechanism was intact was shown by examination of the individual protocols. In all cases, perseverative and associated errors were uncommon and they usually occurred in isolation. Such errors accounted for less than 10 per cent of the total number of responses on each task for all normal subjects (except TY whose perseverative errors were noted above to represent 12.5 percent of the total on one task). Furthermore, the subjects were generally able to recognize their errors and were always able to correct them without assistance.

B. Severity Classification

On the basis of the normal results, together with a certain arbitrariness by the author, all perseverative errors were classified in terms of severity according to the following criteria:

(1) MILD - intrusion of an incorrect response which the subject is able to correct spontaneously, without recurrence and/or seen in controls of the same age.

(2) MODERATE - intrusion of incorrect response(s) which

(a) the subject is able to correct spontaneously but

(i) recurrences occur

or (ii) occur in the context of frequent similar errors, i.e. between 10 and 25% of the total responses.

or (b) requires the examiner to indicate the error but corrects it by self and (c) is not seen in controls of same age.

(3) SEVERE - intrusion of incorrect response(s) which

(a) the subject is unable to correct

or (b) can only correct when the examiner structures the response

or (c) occurs in the context of pervasive similar errors i.e. $\geq$ 25% of total responses.

and (d) is not seen in normals of the same age.

Associated errors were defined earlier and were not classified further.

Reduced fluency was defined earlier as "severely reduced output". On the basis of the performance of the normal subjects, a cut-off point of five or fewer responses in 60 seconds was set as a sign of severely reduced fluency. This was considered to be a conservative value - no normal subject scored within this range on any of the verbal fluency tasks and it was more than two standard deviations from the mean on all tasks (except "A" where the mean minus two standard deviations was 4.4).

IV Error Pattern

The overall pattern of performances across tasks was examined for each subject and classified as either suggestive of a deficit in voluntary attention ("regulation deficit pattern") or not. A regulation deficit pattern was noted when best performances were seen on tasks which least required regulation and poor performances (reflective perseveration and/or associated signs) were seen on tasks which required active selection and internal structuring (e.g. automatic network verbal fluency tasks vs. regulation verbal fluency tasks respectively). In this manner, evidence for and against the integrity of the voluntary attention system was noted by examination not only of the patient's errors, but also by his/her successful performances. Since each patient was expected to vary regarding which tasks would cause greatest difficulty (even among regulation tasks) and how many such tasks would be poorly performed, the regulation deficit pattern could not be specified more precisely but it was necessary that all performances were consistent with such a deficit.

6.3 Procedure

Brain-damaged subjects were tested over four sessions, each lasting approximately one hour (varying to suit patients' capabilities). Normals were given all tests in one (two-and-a-half-hours) or two (one hour) sessions. Breaks were included whenever appropriate. All tests were administered in the same order to all subjects as follows:

SESSION I

1. Brief interview explaining the study and procedure, obtaining demographic information and sampling of subject's spontaneous speech.
2. Series Reversal
   - (a) Days of the Week - forward then backwards
   - (b) Counting 1-20 - forward then backwards
   - (c) Writing SSSS - forward then backwards
   - (d) Writing 7777 - forward then backwards
3. Sequential Tasks
   - (a) Naming
   - (b) Writing
   - (c) Reading
   - (d) Drawing
4. Sorting
5. Stick Test: Items 1,2,6,5,9,10,14,13,17,18,21,22,26,27
6. Alternations
   - (a) □ ▫ □ ▫ ...
   - (b) ABCD abcd...
   - (c) m m m m .....

     w w w w .....

     m w m w .....
   - (d) ↑ ↑ → ....

SESSION II

1. Purdue Pegboard
2. W.M.S. Stories (Logical Memory subtest)- immediate recall
3. Verbal Fluency
   (a) Animals
   (b) Animals by size
   (c) Animals by alphabet
   (d) Males
   (e) Females
   (f) Male-Female
   (g) F.A.S.
4. 5 Dot Fluency
5. Trails A and B
6. W.M.S. Stories - delayed recall

SESSION III

1. Raven Coloured Progressive Matrices
2. Nelson Adult Reading Test
3. Block Design
4. Vocabulary
5. W.M.S. (excluding Logical Memory)

SESSION IV

1. Benton Visual Retention Test
2. Rey Auditory-Verbal Learning Test
3. (optional) - further investigation if required e.g. variations of item order, re-presentation to clarify ambiguous task findings or more extensive assessment of general neuropsychological status.

7. QUESTION 1: Can Perseveration in Patients with Nonfrontal Lesions be Shown to be Related to a Deficit in Voluntary Attention?

7.1 Results

There were 18 posterior (nonfrontal) patients. Perseverative errors were seen in 17/18 (94.4 per cent) of these patients.

Since "mild" errors may be found in normals (by definition) and therefore make the imputation of an acquired deficit questionable, only moderate and severe perseveration were considered in the investigation of this and the following question.

Moderate and/or severe perseveration was seen in 14/18 (77.8 per cent) of the posterior patients and 11 of these patients (61 per cent) perseverated on more than one task.

The protocols of each of the posterior patients were examined for positive and negative evidence of a deficit in voluntary attention as outlined in Section 5.2. In other words, each error was classified as to whether:

(a) it could be accounted for by the difficulty of the item, fatigue or a failure to "equalize" after a previous failure (catastrophic perseveration). If these factors could be ruled out this was taken as evidence that the alternative hypothesis could not satisfactorily account for the error (negative evidence).

(b) it was related to the introduction of the requirement for voluntary selection among variously activated and accessible responses - reflective perseveration (positive evidence).

(c) it occurred in the context of other errors or performances associated with a deficit of voluntary attention - associated signs (positive evidence).

The performance of the frontal patients on the same tasks was examined in the same manner and both qualitative and quantitative comparisons were made.

7.1.1 Error Analysis

The results for each task are presented below, together with examples of the various classifications. Examples of the errors made by frontal patients are also given in order to compare the qualitative nature of the errors seen in frontal and nonfrontal patients. Full details of the results for each frontal patient are given in Appendix 14 and for each nonfrontal patient in Appendices 15-17 inclusive.

(1) SEQUENTIAL TASKS (Naming, Reading, Writing, Drawing)

(a) Naming

Table 15 shows the number of subjects demonstrating reflective perseveration on the naming task in each group. The number of subjects showing catastrophic perseveration (where this could not be ruled out) is shown in brackets. The table also shows the absence of associated signs on this task.

Table 15. Number of Subjects In Each Group Showing Reflective Perseveration And Associated Signs On The Naming Task. Catastrophic Errors Are Shown In Brackets.

Group	N	Perseveration Severe	Perseveration Moderate	%	Associated Signs
Frontal (F)	7	0	1	14.2	0
Shallow (S)	6	0	0	0	0
Deep (D)	6	1	1	33.3	0
Combined (C)	6	1 (1)	1	33.3 (16.7)	0
Total Posterior	18	2 (1)	2	22.2 (5.5)	0

Example 1. Patient US (Group C)

Patient US showed severe phonemic perseveration on this task. Ten out of eighteen (55.6 per cent) of his responses began with p or pl. Only 1 correct response was give spontaneously, although he was able to repeat 3 others and correctly completed 2 cueing sentences:

e.g. E: "you eat an .....?"

Patient US: "apple"

All responses were effortful, as was spontaneous speech.

Since there was no evidence that most of the responses were within his repertoire and the task was clearly extremely difficult for this patient, the possibility that the perseveration was a reaction to this difficulty could not be ruled out. Although the improved performance with external cueing on 2 items is consistent with a deficit in voluntary selection, there was insufficient evidence that such a deficit accounted for the other perseverative errors.

Classification: Severe perseveration, associated with difficulty i.e. catastrophic perseveration.

Example 2. Patient VI (Group D)

Table 16. Response Sheet For Patient VI On The Naming Task. [Stimuli Were Presented As Line Drawings. Examiner Cues In Brackets]

Trial 1			Trial 2	
	Stimulus	Response	Stimulus	Response
1.	Square	✓	10. Banana	✓
2.	Circle	square..um..apple ...round...circle	11. Cross	✓
3.	Cross	✓	12. Square	✓
4.	Knife	✓	13. Spoon	✓
5.	Spoon	✓	14. Sun	✓
6.	Moon	✓	15. Apple	✓
7.	Banana	leaf? (told banana)	16. Circle	square...um,oh... sq..around..sun.. not quite sun..circle
8.	Apple	✓	17. Knife	✓
9.	Sun	✓	18. Moon	oh did I say that before? banana... square,ah circle (M) Moon!

It can be seen from Table 16 that Patient VI was able to name 15/18 (83.3 per cent) of the items without hesitation (leaf is considered a reasonable answer on first presentation of ). This argues against overwhelming difficulty of the task as a whole. The three perseverative errors each followed a correct response and so can not be explained as a "failure to equalize".

In her attempts to name the circle, VI was clearly aware that her initial, perseverative response of the previously activated, semantically similar "square" was incorrect. Rather than a defence against confronting a difficult item this perseveration is followed by a series of approximations in which the item is reattempted several times - shifting from a semantically similar network to a visually similar network (also activated by the items before the subject) and eventually to the correct response. The correct response is thus demonstrated to be within the subject's repertoire and was recognized as correct by the subject. Further evidence that this response did not present overwhelming difficulty per se is seen in the fact that it became a perseverate in her later response to moon. That "moon" was within her repertoire is evidenced by the fact that she had given that response without hesitation on the first trial. That she was able to supply the response once cued by the first letter supports the notion that a deficit in voluntary search and activation was related to the perseverative errors made on this item. Indeed, her successive attempts to reach the required responses, on all three perseverative items, could be viewed as her own efforts to compensate for this deficit. It could be argued that these errors represent word finding difficulty in a mildly aphasic patient, rather than perseveration. However, the errors meet the definition of perseveration used in the current study. Furthermore, under either label, the errors represent a difficulty in voluntary activation of an available (though weakly activated) response and provide information regarding the inappropriate selection of other responses, including their relationship to the target and to preceding stimulus-response events (discussed further in Section 9.4). Hence the errors represent positive evidence of a voluntary attention deficit irrespective of semantic arguments regarding the definition of perseveration.

<u>Classification:</u> (a) Severe perseveration, not adequately accounted for by difficulty (negative evidence)
(b) Associated with failure to select an available (but less activated) response i.e. reflective perseveration (positive evidence).

It can be seen from Table 15 that reflective perseveration was also seen in one frontal patient on this task. Examination of this patient's protocol reveals that the nature of the error was similar to that seen in Patient VI above (although the severity classification is moderate since no external cues were required):

Example 3: Patient NP (Group F)

Patient NP gave six correct responses but on coming to the seventh item (Banana) he responded as follows:

"knife...no it's not! a canoe or a banana"

This was followed by correct responses to all the remaining items including the second trial of banana when it was named correctly and without hesitation.

Clearly "banana" was an available response within this patient's repertoire. The perseverative error can not be adequately explained therefore, by the difficulty of the item nor by the difficulty of the task as a whole, nor fatigue. It is consistent with a failure to actively select a response and the consequent intrusion of a previously activated response. As with Patient VI the error is lexical and is followed by a shift to a visually similar network and then, finally, selection of the correct response.

<u>Classification:</u> (a) Moderate perseverative error, not associated with difficulty (negative evidence)
(b) Consistent with a failure to actively select an available response in the context of previously activated responses - reflective perseveration (positive evidence).

(b) Reading

Table 17 shows the number of subjects showing reflective perseveration and associated errors on the reading task. Catastrophic perseveration is shown in brackets.

Table 17. Number Of Patients In Each Group Showing Reflective Peseveration And Associated Errors On The Reading Task. Catastrophic Perseveration Is Shown In Brackets

Group	N	Perseveration Severe	Moderate	%	Associated Errors	%
Frontal (F)	7	0	1	14.2	1	14.2
Shallow (S)	6	0	0	0	0	
Deep (D)	6	0	2	33.3	0	
Combined(C)	6	0	2 (2)	33.3 (33.3)	0	
Total Posterior	18	0	4 (2)	22.2 (11.1)	0	

Example 1. Patient SD (Group C)

Patient SD gave 14 correct responses before giving the following:

15. Apple = "spoon..no! s-p-p...apple
16. Circle = "criss"
17. Knife = "spoon"
18. Moon = "sp....moon!"

Although all items were read correctly on the first trial, they were given with much hesitancy and effort. Furthermore, dyslexia was considered to be this patient's major deficit by her speech therapist and her identification of letters was unreliable. During this task she assisted herself by finger-tracing of the words (kinesthetic feedback). This raises the question of the contribution of difficulty to her perseverative errors. Moreover, since the errors occurred only on the last four items it could be argued that they were related to fatigue and/or distress at the end of a stressful task or to a failure to equalize after the initial error. (It can be noted that a deficit in active selection can also account for these errors but difficulty can not be ruled out).

Classification: Moderate perseveration associated with difficulty catastrophic perseveration.

Example 2. Patient PW (Group C)

Patient PW gave 13 correct responses without hesitation but his response to the 14th item (sun) on the second trial was;

"apple...apple (E. queries) sun!"

This was followed by correct responses to the remaining four items.

Since the patient was able to read 17/18 items without difficulty, read sun on the first trial without hesitation and was able to correct his error eventually on the second trial, there is little evidence to suggest that the perseveration was a reaction to the overwhelming difficulty of the item or the task as a whole. His success on the final four items argues against fatigue.

The error is consistent with a deficit in voluntary attention in which an incorrect but more strongly activated response is given. The additional time spent studying the item may have provided sufficient activation for the correct response to dominate and finally be given (? also external structuring from E to redirect attention).

Classification: (a) Moderate perseveration, not adequately accounted for by difficulty (negative evidence)
(b) Consistent with a deficit in voluntary attention - reflective perseveration (positive evidence)

From Table 17 it can be seen that perseveration was also seen in a frontal patient on this task. Unlike the posterior subjects an associated error was also made by a frontal patient on this task. These errors are described below.

Example 3. Patient VX (Group F)

Patient VX correctly read all the items on the first trial but on the second trial she read moon as "spoon" without spontaneous correction. When queried by the examiner, she immediately corrected her response.

Her performance on the first trial and correction on the second trial clearly indicate that the item was within her repertoire. The error is consistent with a failure to actively select an available response and the intrusion of a recently activated, orthographically similar response.

<u>Classification:</u> (a) Moderate perseveration, not associated with difficulty (negative evidence)
(b) Consistent with a failure to actively monitor and select a response - reflective perseveration (positive evidence)

It is of interest to note that similar "moon <-> spoon" errors were common on this task among the posterior subjects - although in most cases the errors were spontaneously corrected and hence classified as mild:

Shallow -	3/6	made	spoon->	moon,	or	vice	versa	errors	(all mild)
Deep -	2/6	"	"	"	"	"	"	"	(1 moderate)
Combined-	3/6	"	"	"	"	"	"	"	(1 moderate)

Example 4. Patient WN (Group F)

Patient WN correctly read all items but she was unable to inhibit the occasional intrusion of the numbers written beside the words. She was aware that this was not part of the task and was reminded to read only the words after the first number intrusion. Thereafter she read the words alone on most items, indicating that she understood the task requirements, but the numbers were again read aloud on several subsequent items.

Classification: Associated error - the intrusion of a strongly activated response despite knowledge that the response was incorrect (dissociation between knowing and doing) (positive evidence).

(c) Writing

Table 18 presents the numbers of patients showing reflective perseverative errors in each group on the writing task. Catastrophic perseveration is shown in brackets. The absence of associated errors is also shown.

Table 18. Number Of Patients In Each Group Showing Reflective Perseveration Or Associated Errors On The Writing Task. Catastrophic Perseveration Is Shown In Brackets.

Group	N	Perseveration Severe	Moderate	%	Associated Errors	%
Frontal (F)	7	2	1	42.8	0	0
Shallow (S)	6	0	2	33.3	0	0
Deep (D)	6	0 (1)	1	16.7 (16.7)	0	0
Combined(C)	6	1 (2)	1	33.3 (33.3)	0	0
Total Posterior	18	1 (3)	4	27.7 (16.7)	0	0

Example 1. Patient PW (Group C)

Patient PW was only able to correctly write 8 of the 18 items and demonstrated considerable effort and difficulty on all items. His responses are shown in Figure 7.

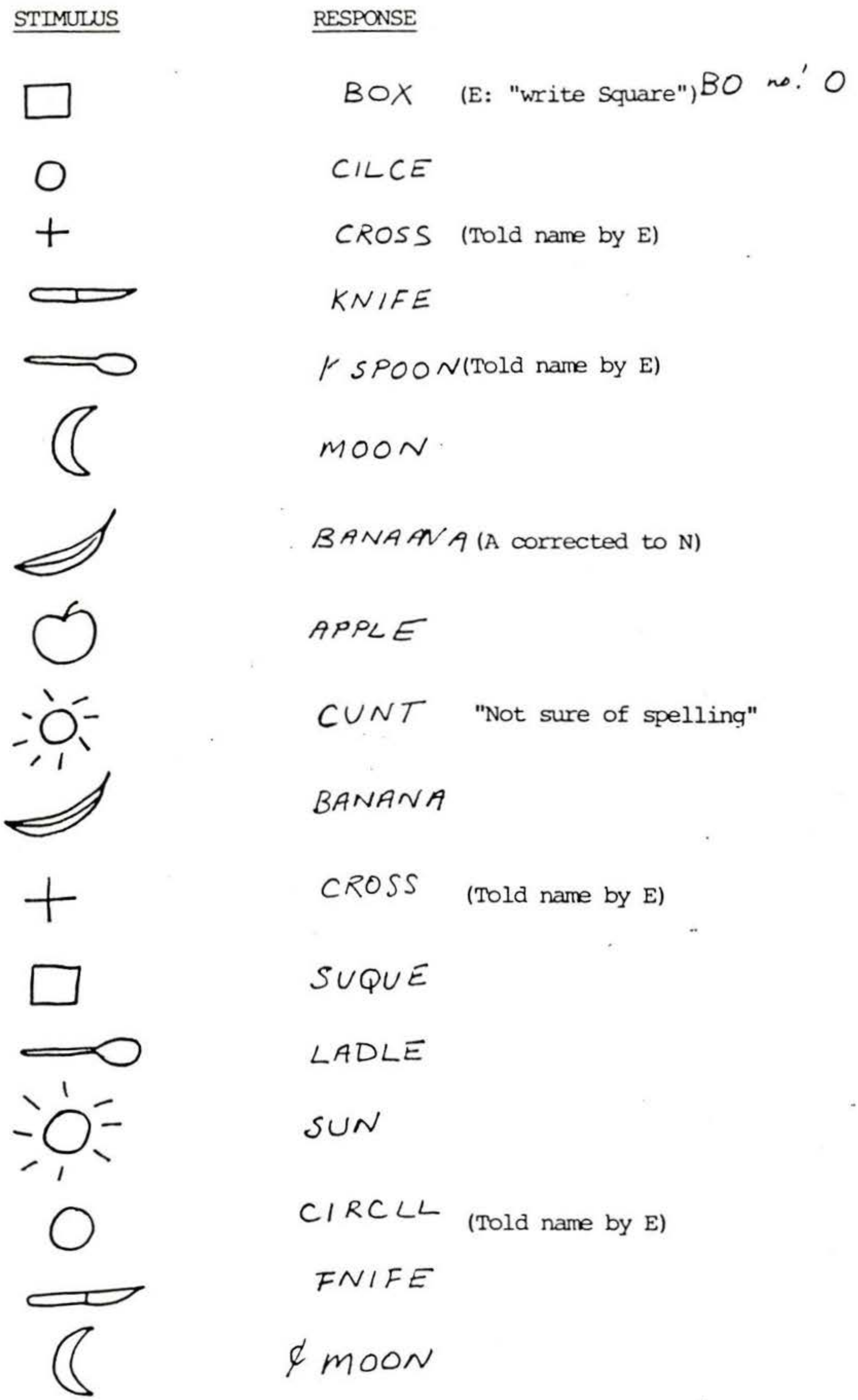


FIGURE 7. Response Sheet for Patient PW on the Writing Task

Patient PW clearly had great difficulty with this task. Although a deficit in selective attention could account for the perseverative errors (and is supported by the intrusion of the automatic response "cunt" in his initial attempt to spell sun) the contribution of difficulty can not be ruled out as the underlying mechanism in these responses. For example, square was not correctly spellt on trial 2 and therefore may have proved too difficult in the perseverative trial 1. Similarly circle was not spellt correctly on either trial and hence circll may represent a spelling error rather than perseveration associated with selective failure.

Classification: Severe; associated with difficulty - catastrophic perseveration

Example 2. Patient NO

Patient NO wrote all answers without hesitation or effort but on the second trial he wrote "circle" when the E pointed to the square. At the end of the task E repeated this item and NO said aloud "cir...oh! square!" then wrote square correctly and without effort.

Since NO had correctly named the square on both trials of the naming task and wrote it correctly on both the first trial of this task and on the third presentation, it is unlikely that his perseverative error was a response to the overwhelming difficulty of this item. There is also no evidence of fatigue in his later responses. A more acceptable explanation is that there was at least a temporary failure to selectively attend to the required response and the consequent intrusion of a semantically similar and more recently activated response.

Classification: (a) Moderate perseverative error; not adequately accounted for by difficulty (negative evidence)
(b) Consistent with a failure in selective attention - reflective perseveration (positive evidence)

From Table 18 it can be seen that reflective perseveration was also seen in three frontal patients on this task. No associated errors were demonstrated. Examination of the test protocols revealed that Patient XH (Group F) made the same error as that described for Patient NO (Group D) above, i.e., on the second trial she wrote "cirkel" for square despite the fact that she had correctly identified the square on the first trial and on both trials of the naming task.

Patient NP (Group F) made a qualitatively similar error on the second trial of sun where he wrote moon. He immediately recognized his error but was unable to shift despite this recognition; "moon...ah, what's that!... moon....no....."

Patient WN made several perseverative errors as seen in Figure 8. There are three different forms of perseveration seen in this protocol:

(i) lexical perseveration, as seen in Patient NO (Group D) and the other two frontal patients described above. This refers to the substitution of a prior item, or part thereof, usually a semantically similar item (square-circle, sun-moon). In Figure 8 it can be seen that Patient WN began to write ci (presumably beginning circle) for the second trial of square and S (possibly beginning Sun) and then altered to Banana on the second trial of moon.

(ii) perseveration of a letter within a response e.g. spooon, mooon, bannana - also seen in Patient PW (Group C) described above.

(iii) perseveration of the numbers preceding each response. This was not part of the task but the patient chose to number her responses. It can be noted that this patient was able to count from 1 to 20 without difficulty but became stuck on a number for several items when writing on this task. Patient WN was the only subject to demonstrate this error.

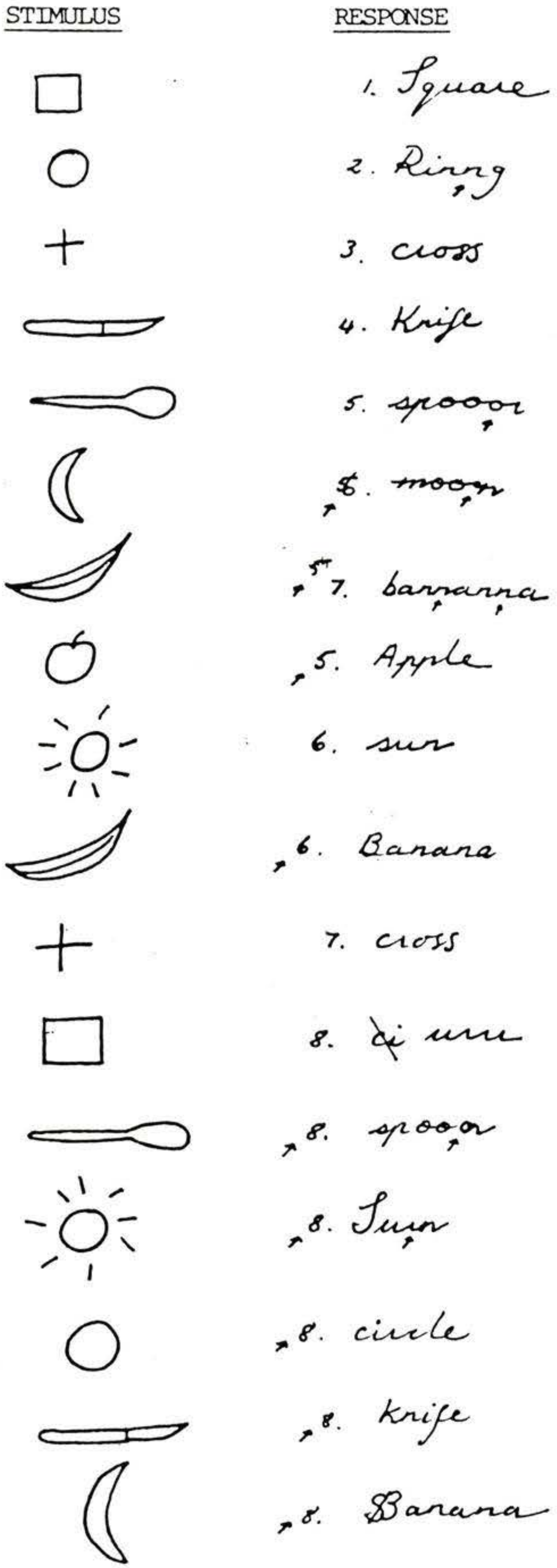


FIGURE 8 . Writing Task Responses for Patient WN (Group F)

(d) Drawing

Table 19 presents the number of subjects in each group demonstrating reflective perseveration and/or associated errors on the drawing task. Catastrophic perseveration is shown in brackets:

Table 19. Number of Patients In Each Group Showing Reflective Perseveration And/Or Associated Errors On The Drawing Task. Catastrophic Perseveration Shown In Brackets.

Group	N	Perseveration			Associated	
		Severe	Moderate	%	Errors	%
Frontal (F)	7	1	0	14.2	0	0
Shallow (S)	6	0	1 (1)	16.7 (16.7)	0	0
Deep (D)	6	1	0	16.7	1	16.7
Combined(C)	6	3	2	83.3	1	16.7
Total Posterior	18	4	3 (1)	38.9 (5.5)	2	11.1

Example 1. Patient WS (Group S)

On the drawing task Patient WS passed all items except moon where he drew a circle. Although a full moon could be represented this way he had been instructed to draw the items as they had been presented on the previous tasks (i.e. ). When asked to draw a "crescent moon" his attempt was a combination of a circle and a crescent  . He repeated the full circle when moon was administered again on the second trial.

However, Patient WS also demonstrated severe visuospatial difficulties on R.C.P.M., Block Design and the Stick Test (both Copy and Recall) and his visual memory was severely impaired (W.M.S. and B.V.R.T.) so that such errors may reflect his inability to recall the shape required or his difficulty in executing such a shape rather than a failure to select that response.

Classification: Associated with difficulty - catastrophic perseveration.

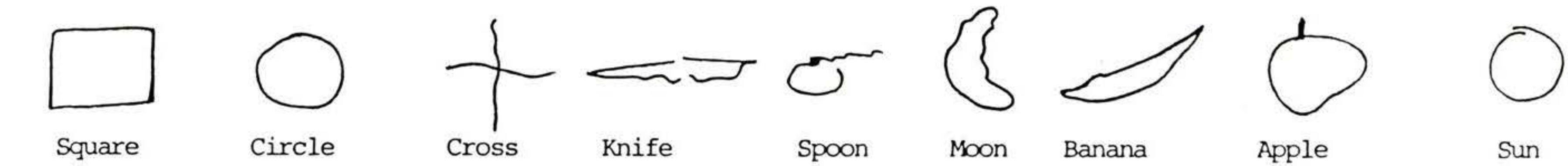
Example 2. Patient US (Group C)

The responses of this patient are shown in Figure 9. As seen in this figure, Patient US was able to successfully draw all the items on Trial 1 except for the rays of the sun. However, on Trial 2 he perseverated on both cross and square, drawing circles for both, and substituted a square for circle. Clearly all the responses (except for perhaps sun) were within this patient's repertoire and his initial responses indicate that he was able to attach them to their correct names - this was further demonstrated in a subsequent test asking him to point to each drawing as it was named; square, cross and circle were correctly indicated on both trials. The difficulty of the perseverated items is therefore an unsatisfactory explanation of these errors; fatigue is also not convincing since the last two items were drawn correctly. It would appear that insufficient attention was given to the required (and available) responses so that a more strongly activated, semantically similar, response dominated.

Classification: Severe perseveration.

(a) Difficulty - insufficient explanation (negative evidence)

(b) Consistent with failure of voluntary attention reflective perseveration (positive evidence)



TRIAL 2

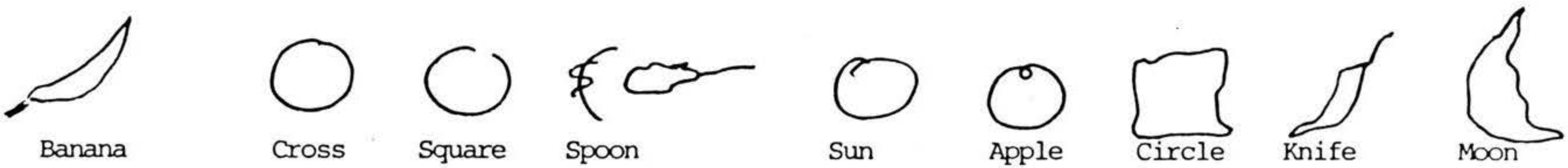


FIGURE 9. Patient US, Drawing to Dictation

Example 3. Patient WN (Group F)

From Table 19 it can be noted that the combined (C) group showed the greatest perseveration on this task - 5/6 (83.3 per cent)- but that a frontal patient also demonstrated severe perseveration. The quality of this frontal perseveration, reproduced in Figure 10, is similar to that seen in the posterior Patient US discussed above. For example, having demonstrated that square and apple were within the patient's repertoire, the later perseveration of the cross when these items were re-presented can not be explained by the difficulty or inaccessability of these responses.

<u>Classification:</u> (a) Severe perseveration not accounted for by difficulty (negative evidence)

(b) Consistent with a failure to actively select an available response in the context of previously activated responses - reflective perseveration (positive evidence)

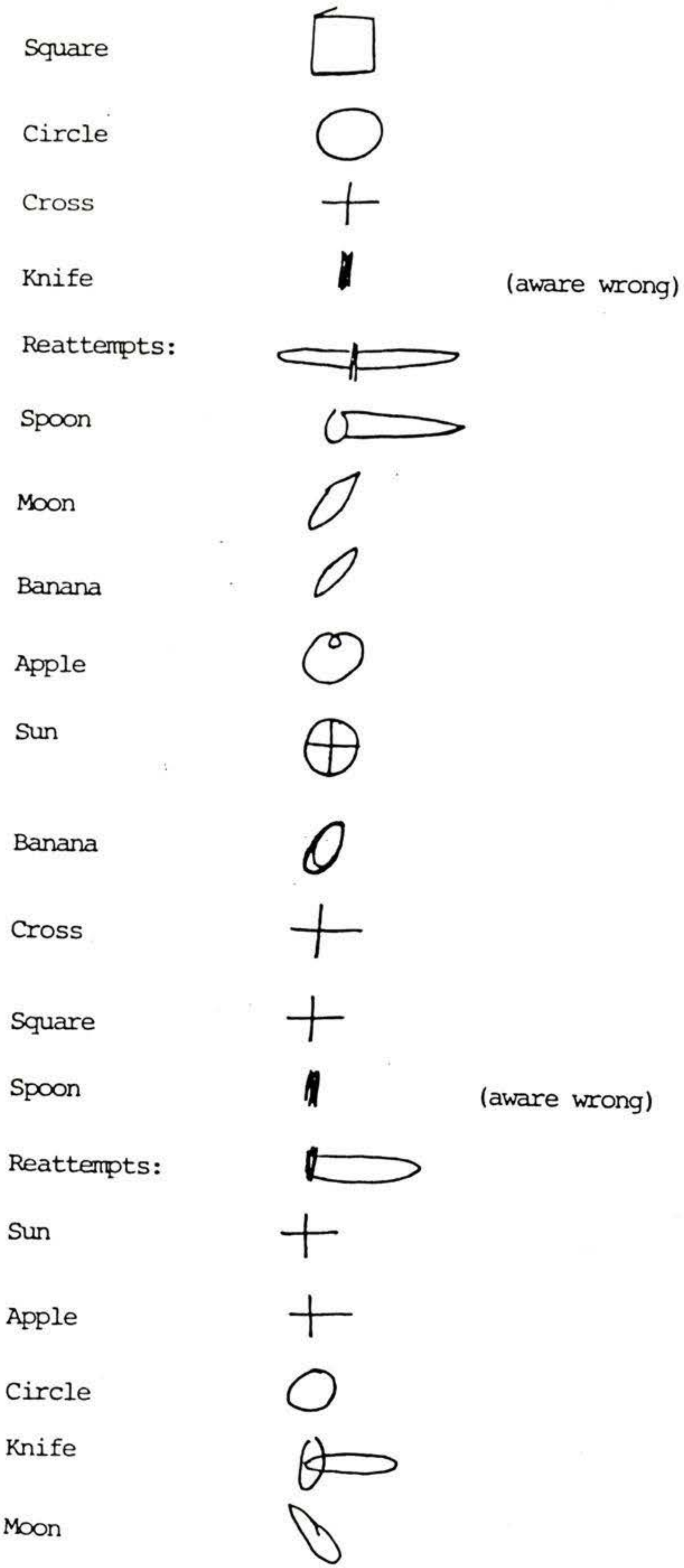


FIGURE 10. Patient WN , Drawing to Dictation

General Comments:

Although at least one frontal patient perseverated on each task, no frontal patient perseverated on all four sequential tasks and the pattern of perseveration across tasks was different in each case. Three of the seven (42.6 per cent) frontal patients did not perseverate on any of the four tasks.

Similarly, at least one posterior patient perseverated on each task but the pattern of perseveration varied considerably - perseveration on one task did not predict perseveration on any other. Six of the eighteen (33.3 per cent) posterior patients did not perseverate on any of the four tasks (although all the combined (C) patients did so on at least one task). Three patients (one deep, one combined) perseverated on all four tasks (with reflective perseveration on at least one task in each case).

(2) CONFLICT TASKS (Series Reversal, Sorting)

(a) Series Reversal

Table 20 presents the results for each group on the series reversal tasks.

Table 20. Number Of Subjects In Each Group Showing Reflective Perseveration And/Or Associated Signs On The Series Reversal Tasks. Catastrophic Errors Shown In Brackets.

Group	N	Perseveration Severe	Moderate	%	Associated Errors	%
Frontal (F)	7	1	1	28.6	0	0
Shallow (S)	6	1 (1)	0	16.6 (16.6)	0	0
Deep (D)	6	0	0 (1)	0 (16.6)	0	0
Combined(C)	6	1 (1)	1	33.3	1(1)	16.7 (16.7)
Total Posterior	18	2 (2)	1 (1)	16.7 (16.7)	1 (1)	5.5 (5.5)

Example 1. Patient WS (Group S)

As noted earlier this patient had severe visuospatial difficulties even when copying the Stick Test designs. He was able to draw a series of S forwards but was unable to spontaneously reverse this S and also had difficulty copying a model of a reversed S. His perseverative errors on S-reversal can not therefore exclude overwhelming difficulty as a contributory factor.

Classification: Associated with difficulty - catastrophic perseveration.

Example 2. Patient PW (Group C)

This patient was able to count from 1 to 20 without difficulty, i.e., each item of this series was within his repertoire. However when asked to reverse this series his responses were as follows:

(a) 20 21 no!

(b) 20 22 23 24

(c) (E begins 20 19 18) 20 19 18 19 17 17 18 19 no! 19 19 no!

In the first two attempts there was intrusion of an automatic series, rather than perseveration[1] of prior responses. Although aware that this was incorrect he was unable to shift from this habitual order (enduring disposition) and selectively order the items. External structuring by the examiner assisted but perseveration emerged as the automatic series continued to dominate his responses.

Classification: (a) Severe, not accounted for by difficulty of items (negative evidence).

(b) Associated with the introduction of requirements for voluntary selection in conflict with an enduring disposition - reflective perseveration (positive evidence)

(c) Associated errors - intrusion of an automatic

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[1] Although previous responses are not repeated this could be classified as perseveration of activities but within the definition used here it is classified as an associated error.

response not given previously (positive evidence)

Two frontal patients also perseverated on these tasks. The following descriptions illustrate a similar quality to the reflective errors described above.

Example 3. Patient VX (Group F)

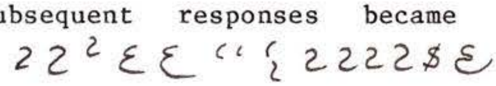
Patient VX was able to recite the days of the week without hesitation. Upon instruction to reverse the order, Patient VX began as follows: "Sunday, Monday, Tuesday..... (E re-instructs)
"Sunday, Saturday, Friday, Thursday,
Wednesday......Friday no! that's wrong!"

Beginning again she reversed the order without error.

Clearly the items involved in this task were within this patient's repertoire and her final performance demonstrates her capacity to do the task. However, the requirement to selectively order the items introduced a conflict between the habitual order (enduring disposition) and the intended order (momentary intention) and the dominance of the enduring disposition can be seen in her first two attempts.

Classification: (a) Moderate peseveration, not associated with difficulty (negative evidence)
(b) Related to the introduction of a requirement to selectively order available responses - reflective perseveration (positive evidence)

Example 4. Patient WN (Group F)

Patient WN perseverated on both the reversal of the days of the week and reversed S. On the reversed S task she was able to perform the first two elements of the series correctly demonstrating that the task was not too difficult for her. However she was unable to maintain the reversal and subsequent responses became contaminated by the habitual forward S: 

When asked to reverse the days of the week she was unable to begin until the E prompted her with "Sunday" (She had recited all the days forwards without hesitation). She then began as follows:

> "Sunday, Saturday, Friday, Thursday, Fri..oh I can't. (E: "What comes before Thursday?) Wednesday, Thursday oh no! (E: before Wednesday?) Tuesday, Wednesday oh no! (before Tuesday) before Tuesday um... Wednesday no!

She clearly understood the task and was aware of her errors; indeed, rather than defending against anxiety her perseveration seems to have caused any distress on this task. Although able to perform the task with external structuring she was unable to structure her responses internally.

Classification: (a) Severe perseveration, not associated with difficulty (negative evidence)
(b) Related to the introduction of requirements to internally structure available responses - reflective perseveration (positive evidence).

(b) Sorting.

Table 21 presents the number of patients demonstrating perseverative and associated errors on the sorting task.

Table 21. Number of Subjects In Each Group Showing Reflective Perseveration And/Or Associated Errors On The Sorting Task. Catastrophic Errors Are Shown In Brackets.

Group	N	Perseveration			Associated	
		Severe	Moderate	%	Errors	%
Frontal (F)	7	2(1)	0	28.6 (14.3)	0	0
Shallow (S)	6	1	0	16.7	0	0
Deep (D)	6	2	0	33.3	0	0
Combined (C)	6	3	1	66.6	1	16.7
Total Posterior	18	6	1	38.6	1	5.5

Example 1 Patient ZN (Group C)

On being asked to sort the cards into groups, Patient ZN immediately replied "Do you mean colour or shape?"

He was asked to begin with one of these principles and he sorted the cards according to colour without hesitation.

However, when asked to sort in a different manner he began again to sort by colour. The instruction was repeated and ZN indicated that he understood the requirements, appearing impatient with himself for his error. He began to name the shape of each item, noting that there were three categories: "round, straight and curved." However, despite correctly naming each shape he failed to group similar shapes together. While continuing to identify the shape of each item, he began to group the cards by colour, finishing with a complete repetition of the colour sorting. He looked puzzled and stated "I intended to sort differently!"

Beginning again he repeated this performance, i.e., naming each shape but placing similar colours together. He stopped and stated "I am confused. I don't know if I'm choosing form or colour." He was asked to try again to sort by shape and again named each shape, finally placing the spoon and knife together - nominated as "long", followed by moon, circle, sun and apple together, cross and square together and banana alone.

In this performance we see a classic example of the "dissociation between knowing and doing" characteristic of a deficit in voluntary regulation of behaviour. Although verbalizing his intention to sort by shape he was unable to subordinate his responses to this intention. His actions were dominated instead by his first sorting. His clear identification of the shape of each item and his final sorting demonstrate that the shape classification was not too difficult and there is no evidence to suggest that difficulty or fatigue can account for the perseverative intrusion of the colour sorting.

<u>Classification:</u> (a) Not explained by difficulty (negative evidence)

(b) Perseveration related to the requirement for voluntary regulation of behaviour in conflict with a prior response (positive evidence)

(c) Associated error - dissociation between knowing and doing (positive evidence).

Example 2 Patient WS

Patient WS first sorted the cards according to their concrete associations (the most common sorting principle seen in all groups, including normals): the knife and spoon were together (nominated as "something to eat with"); moon and sun were together, ("something in the sky"); banana and apple, ("something to eat, fruit") and circle, square, cross ("just think they should belong together").

When asked to sort in a different way, Patient WS began to repeat his initial sorting, placing the sun and moon together and the apple and banana together. At this point he commented "I'm doing it the same way again." He was asked if he could see a different way to do it; he replied "no" and continued his initial sorting except the square was left apart. Asked what he had done he stated "I've done it the same way."

The instruction was repeated and he sorted as follows;

(i) knife, apple, banana - "knife cuts these"

(ii) sun } "seperate because one shines at night and

(iii) moon } one during the day."

(iv) spoon - "something to eat <u>or</u> stir with, therefore by itself"

He was unable to change the geometric figure group.

When the colour grouping was demonstrated, the patient was asked if he could see any reason at all for them to be put together in that manner. He was unable to do so, referring again to their concrete differences.

All normal subjects were able to recognize the colour sorting and this very basic perception was assumed to be within the repertoire of all subjects. In other words, failure to recognize the colour grouping when presented was not considered to be adequately explained by difficulty (except in cases of colour agnosia). The patient was unable to shift from his concrete perception of the items and could not recognize another aspect of the items when this conflicted with the concrete interpretaion.

Classification: (a) Not associated with difficulty (negative evidence)
(b) Consistent with a failure to voluntarily select an available response when it conflicts with a prior response (positive evidence).

Three frontal patients perseverated on this task; one was classified as catastrophic perseveration i.e. related to the difficulty of the task, while the other two were considered to be reflective perseverative errors:

Example 3 Patient WN (Group F)

Patient WN was unable to sort the cards into groups, remaining fixed on their individual concrete representation. She was also unable to recognize the most simple grouping when it was presented to her, e.g., when the E placed the apple & banana together she named them but was unable to identify any reason for them to be placed in the same group. Similarly, she was unable to recognize the colour grouping when it was demonstrated to her.

Although there was clearly severe rigidity of thought in this case, the task of sorting per se was arguably too difficult for her and hence can not be ruled out as the underlying factor causing this rigidity.

Classification: Associated with difficulty - catastrophic perseveration.

Example 4. Patient TX (Group F)

As with Patient WS (Group S) discussed above, Patient TX initially sorted the cards according to their concrete similarities:

banana - apple - nominated as "fruit"
knife - spoon - "eating utensils"
square-cross-circle - "in the same group"
moon- sun - "sun during the day, moon at night"

Upon instruction to sort in a different way, he combined the fruit and utensils, saying "eat them, I suppose" but repeated the other two groupings. He was unable to recognize the colour sorting when it was demonstrated to him, though he had no difficulty identifying the colours themselves. In this case the patient was clearly able to understand and perform the sorting instruction but was unable to shift from an immediate impression to an alternative within his repertoire.

Classification: (a) Not associated with difficulty (negative evidence)
(b) Related to failure to voluntarily regulate behaviour in the context of a strong prior response - reflective perseveration (positive evidence)

General Comments:

Only one frontal patient (14.3 per cent) perseverated on both conflict tasks, with one of these classified as catastrophic (see above). Three (42.6 per cent) perseverated on neither task.

Similarly, only four posterior patients (22.2 per cent) perseverated on both conflict tasks, three of these showing catastrophic perseveration on one task. Nine (50 per cent) perseverated on neither task.

(3) REGULATION TASKS. (Alternation, Verbal Fluency, 5 Dot Fluency, Trails)

(a) Alternations

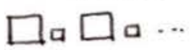
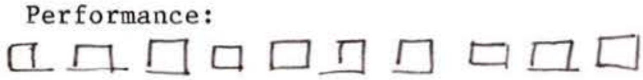
The results for the alternations tasks are presented in Table 22.

Table 22. Number Of Subjects In Each Group Showing Reflective Perseveration And/Or Associated Errors On the Alternations Task. Catastrophic Perseveration Is Shown In Brackets.

Group	N	Perseveration			Associated	
		Severe	Moderate	%	Errors	%
Frontal (F)	7	1	2	42.8	1	14.3
Shallow (S)	6	(1)	1	16.6 (16.6)	0	0
Deep (D)	6	1	1	33.3	1	16.6
Combined (C)	6	2	1	50.0	0	0
Total Posterior	18	3 (1)	3	33.3 (5.5)	1	8.3

Example 1. Patient WS (Group S)

Model: Performance:

Although WS failed to continue the pattern of alternation his severe visuospatial difficulties, noted earlier, raise the question of his ability to make the required spatial judgements.

Classification: Associated with difficulty - catastrophic perseveration

Example 2. Patient ZX (Group D)

Model:	Performance:
ABCDabcd	ABCDabcd ABCDabcd
	ABCDabcd ABCDabcd ABCDABCD
	ABCDabcd ABCDabcd ABCDABCD

Clearly the required alternation was within this patient's capabilities. However he perseverated with capital letters on two occasions. The first is consistent with at least temporary failure to actively select his responses in favour of a combination of the required smaller size and the previous, more strongly activated letter case. The second error may represent the same process, although the patient may also have fallen into a direct copying mode, again indicating a failure to actively select the responses and compare them with intentions.

Classification: (a) Not adequately explained by difficulty (negative evidence)

(b) Related to a requirement to actively select less activated responses - reflective perseveration (positive evidence)

Three frontal patients also perseverated on this task (Table 22). Their errors were very similar to those seen in posterior patients:

Example 3. Patient IN (Group F)

Model: Performance:

ABCDabcd ABCDabCD ABCDABCD ABCDabcd ABCDabcd ABCDabcd..correct

As with Patient ZX (Group D), this patient was clearly capable of the task but his first two responses reveal difficulty in the active regulation of conflicting responses.

Classification: (a) Not associated with difficulty (negative evidence)

(b) Failure to actively select an available response - reflective perseveration (positive evidence)

Example 4. Patient WN (Group F)

When asked to alternate M and W after successfully writing a series of each alone Patient WN wrote: m m m w w w m m m m m w

Patient WN demonstrated that both items could be executed without difficulty but she was unable to alternate the items.

Classification: (a) not associated with difficulty (negative evidence)

(b) Failure to actively regulate behaviour according to intentions - reflective perseveration (positive evidence)

(b) Verbal Fluency

Table 23, 24, 25 show the percentage of patients in each group showing reflective perseveration (moderate or severe), associated errors and severely reduced fluency (not associated with difficulty) on each of the nine verbal fluency tests. Table 23 presents the data for the three animal fluency tests: the automatic network task, animals and the two regulation tasks, animals by size and animals by alphabet. Table 24 presents the data for the three name tests: the automatic network tasks, males and females and the regulation task, male-female alternation. Table 25 presents the data for the three regulation tasks: F, A, and S (Controlled Word Association).

Catastrophic errors and catastrophic reduced fluency are not shown in these tables but it may be noted that they were made by at least one subject in each group in at least one of the nine verbal fluency tests (See Appendices 18 to 26 inclusive)

Table 23. Percentage Of Subjects In Each Group Showing Moderate Or Severe Reflective Perseveration And/Or Associated Signs On The 3 Animal Fluency Tests. A=Animals S=Size AL=Alphabet

Group	N	Perseveration			Associated Errors			Reduced Fluency		
		A	S	AL	A	S	AL	A	S	AL
Frontal	7	28.6	14.3	14.3	14.3	57	57	28.6	28.6	71.4
Shallow	6	16.7	0	0	0	16.7	0	0	0	16.7
Deep	6	16.7	16.7	16.7	0	33	33	0	0	16.7
Combined	6	16.7	0	0	0	16.7	83	0	0	50
Total Posterior	18	16.7	5.5	5.5	0	22.2	38.9	0	0	22.3

Table 24. Percentage Of Subjects In Each Group Showing Moderate Or Severe Reflective Perseveration And/Or Associated Signs On The 3 Name Fluency Tests.

Group	N	Perseveration			Associated Errors			Reduced Fluency		
		M	F	M-F	M	F	M-F	M	F	M-F
Frontal	7	42.8	14.3	14.3	0	0	42.8	0	0	42.8
Shallow	6	16.7	16.7	0	0	0	0	0	0	0
Deep	6	0	0	16.7	0	0	33	0	0	0
Combined	6	16.7	33	33	0	0	16.7	0	0	16.7
Total Posterior	18	11.1	16.7	16.7	0	0	16.7	0	0	5.5

Table 25. Percentage Of Subjects In Each Group Showing Moderate Or Severe Reflective Perseveration And/Or Associated Signs On The F.A.S. Fluency Tests.

Group	N	Perseveration			Associated Errors			Reduced Fluency		
		F	A	S	F	A	S	F	A	S
Frontal	7	28.6	0	28.6	28.6	28.6	14.3	28.6	57	28.6
Shallow	6	0	0	0	0	0	0	16.7	0	16.7
Deep	6	16.7	16.7	16.7	16.7	16.7	16.7	16.7	16.7	0
Combined	6	33	16.7	33	33	50	0	16.7	33	50
Total Posterior	18	16.7	11	16.7	16.7	22.2	8.3	11	16.7	22.2

Example 1. Patient PX (Group D)

Patient PX was able to give 11 animals, with 2 repetitions (15.4 percent perseveration) on the automatic network task, "animals". He gave 2 additional animals on the "animals by size" task where he was able to correctly order 9 different animals. However, his responses to "animals by alphabet" were as follows:

Ape

Cat

Dog

Emu

Hippo "I'm getting too big too early"

Rhino "that's in the wrong place"

When asked what the instructions had been at the completion of this task he replied: "Alphabetical order".

He was able to repeat the alphabet without error in 6.7 seconds on the W.M.S. This performance was analysed as follows:

(a) As the repetitions on the "animals" task were given as the last two items it is possible that they reflect fatigue or difficulty as the patient neared the limit of his automatic network.

However, he was able to give 14 different animals without hesitation on the first two tasks, indicating an adequate repertoire.

(b) His initial responses on the "animals by alphabet" task indicate that he understood the instructions and his performance on the W.M.S. indicates that he had no difficulty accessing the alphabet in correct order. His performance cannot be explained by an inability to remember the task, since he was able to repeat the instructions at the end of the task. Despite this, he was only able to give 5 responses in correct alphabetical order, omitting B, F and G although he had previously given Bull, Bandicoot and Goat. More importantly, having given a large animal (Hippo) he reverted to the earlier rule of "animals by size" ("getting too big too early") and followed with a closely related animal (Rhino) even though he was aware that this was not appropriate i.e. dissociation between knowing and doing (associated error).

Classification: (a)Perseveration on animals - possibly associated with difficulty/fatigue. - catastrophic perseveration.

(b) "Animals by Size" -

(i) Cannot be explained by difficulty (negative evidence)

(ii) Perseveration related to the failure of active selection in the presence of a strongly activated association with prior activity - reflective perseveration (positive evidence)

(iii) Associated error - dissociation between knowing and doing (positive evidence).

Example 2. Patient PW (Group C)

Patient PW gave only 3 items on the regulation task, male-female alternation. However, on the automatic task, males, he was only able to give the following:

John
Robert
* Robert
* Robert oh!
* John
Jack
Tom
Toony
* Toony

Clearly this performance is insufficient to establish that the patient has access to an adequate repertoire and hence overwhelming difficulty can not be ruled out as a contributing factor to the emergence of the perseveration. Similarly, only four names were given for females, so that the markedly reduced fluency on the male-female regulation task (three items) cannot be assumed to be a selection deficit but, rather, may merely reflect the paucity of the patient's available responses. Spontaneous speech was effortful and non-fluent, supporting this notion.

<u>Classification:</u> Associated with difficulty - catastrophic perseveration

In contrast, the same patient's responses on the F.A.S. tasks, while again markedly reduced in number (possibly related to paucity of repertoire) also introduce associated errors which indicate a failure in active regulation of response selection:

After the instructions were given, emphasizing that names were no longer permitted, the patient indicated that he understood the task and proceeded thus for F:

* Freddy
* Freddo
no!

The patient was re-instructed before beginning again for the letter A:

'allo (patient smiles)
* How are you
* G'day
* How are you
* (softly to self: F, F.....)

The patient was asked what he was meant to be doing and replied "telling the names of people". Asked if this is what he had done, he replied "yes".

He was reinstructed and indicated that he recognized the rules. He assured the examiner that he had understood the instructions before and began again for S:

Scissors
Soldiers
S......

Although paucity of repertoire may account for the reduced fluency and perseveration of these performances (and so must be classified as such) there is also clear rule-breaking and dissociation between his actions and report of those actions - characteristic of a deficit in voluntary regulation of behaviour. The responses for A are particularly interesting in this regard, where the patient begins with a correct (though rather coy) response but then becomes distracted by strongly associated but incorrect responses (consistent with enduring dispositions overcoming momentary intentions).

Classification: (a) Reduced fluency and perseveration possibly associated with difficulty - catastrophic

(b) Associated errors indicative of a deficit in voluntary attention.

In comparing the performance of frontal and posterior patients on the verbal fluency tasks both the quality of the errors and the pattern of performances across automatic and regulation tasks was considered. The quality of errors was similar in both frontal and posterior patients as seen by the following examples:

Example 3. Patient VX (Group F)

Patient VX was able to give 15 animals without hesitation on the automatic network task, animals. When asked to order by size, she added three further animals to this list when giving the following six (correct) responses.

Mouse
Rat
Possum
Cat
Dog - "of course, there's all different kinds"
"I'm trying to go round the zoo"
Monkey

However, when asked to order by alphabet she responded as follows:

Ant
Bat
Cat
* Possum - no I'm going the wrong way where did I get to ? (E informs)
Dog

This is very similar to the performance of patient PX (Group D) described above. An adequate repertoire is clearly available. The patient was able to recite the alphabet without difficulty and understood the task. As with patient PX, this patient apparently became distracted by the prior association (from the preceding task) between Cat and Possum, so that "Possum" was given even though the patient was aware that this was "breaking the rule" (i.e. stronger activation overcoming intentions).

Example 4. Patient NP (Group F)

Patient NP demonstrated marked perseveration and/or classical dissociation between knowing and doing on all the verbal fluency tasks. The failure to regulate behaviour according to intentions seen, for instance, in his responses to the regulation tasks F.A.S. is clearly similar in quality to the disregulation described above for Patient PW (Group C) on the same tasks:

Patient NP was able to repeat the instructions before beginning correctly on F; however, he quickly lost control of his responses:

For
* For about an hour
We
Waited
About
Until we saw somebody
Coming down the street
Who we knew
Or thought we knew

(E: what are you doing? Patient NP: I'm telling you a story of what's happening to me in the middle of the day. E: is that what you were meant to be doing? NP: yes).

As the patient appeared fatigued the session was discontinued at this point and the F.A.S. task was administered as the first tests of the subsequent session the following morning. The second trial for F resulted in different content but was equally indicative of the impaired voluntary control over his responses; again beginning correctly but rapidly deteriorating: Fume

Florid

* Frankenpance (E queries) is that one, oh well we'll try it!

Forerunner

Floosy - no that's wrong

* Fopengay

* Fuderoy

* Fort Worth

* Fameshay

He was asked to repeat the instruction and replied "Don't use the same letter and can't use names"

This was followed immediately by A:

* Alice - That's a noun!

* Alfredo - that's another one

Almanac

* Alouiscious

Alimony

Ancient

Anchovy

* Ancharista - that's a new one!

Alchemist

* Alchemical

He again repeated the instruction and went on to S:

* Snotgrass

Spaniel

Superb

Superior

Semicolon

* Semi - oh, get away from the semi's

* Senolia

* Sigmalina

Signora

* Signorima

* Signorinetta

* Isn't it funny I'm going into Italian!

General Comments:

The pattern of performance across tasks for each group can be seen in Tables 24, 25 and 26, presented earlier.

Considering first the three animal fluency tests (Table 23), it can be noted that there was no variation in the incidence of perseveration across the three tasks for the frontal group but a marked increase in the percentage of patients showing associated errors and reduced fluency on the regulation tests (animals by size and by alphabet) compared with the automatic network task (animals). A similar pattern of increased associated signs on the regulation tests can be noted in both the deep (D) and combined (C) posterior groups.

From Table 24 it can be seen that a higher percentage of frontal patients perseverated on males than on the other two name tasks but that a marked increase in the percentage showing associated errors and reduced fluency was again seen in moving from the automatic tasks (M,F) to the regulation task (M-F) in this group. This pattern of increased associated signs on the M-F task was also seen, although less markedly, in the deep (D) and combined (C) posterior groups.

Table 25 shows that there was considerable variation in the percentage of frontal patients showing perseverative errors and/or associated signs across the F.A.S. tasks and that similar variation occurred in the posterior groups (especially the combined group C). It can be noted that there were no associated signs (errors or reduced fluency) by posterior subjects on the three automatic network tasks (animals, M and F) but between 8.3 per cent and 22.2 per cent showed such signs on the F.A.S. tasks (50 per cent of the combined group).

Examination of individual profiles revealed that all seven frontal patients showed an associated sign on at least one regulation verbal fluency task. Eleven of the 18 posterior patients made an associated sign on at least one regulation task (2/6 Shallow, 4/6 Deep, 5/6 Combined).

(c) 5 Dot Fluency

Table 26 shows the results for each group on the 5 dot fluency task.

Table 26. Number Of Subjects In Each Group Showing Reflective Perseveration On The 5 Dot Fluency Test. Catastrophic Perseveration Shown In Brackets.

Group	N	Perseveration Severe	Perseveration Moderate	%
Frontal	7	4	0	57
Shallow	6	0 (1)	1	16.7 (16.7)
Deep	6	2	1	50
Combined	6	2 (1)	2	66.7
Total Posterior	18	4 (2)	4	44.4

Example 1. Patient WS (Group S)

Patient WS drew a total of only 13 designs including four repetitions (30.7 per cent) which is classified as severe perseveration. However, as was noted earlier, this patient had severe visuo-spatial difficulties to the extent that he was unable to copy many of the Stick Test designs - nor to recognize his errors. Consequently a task such as 5 dot fluency could be expected to present great difficulty for this patient and it can not be assumed that he was capable of the judgements required to monitor repetitions.

<u>Classification:</u> Associated with difficulty - catastrophic perseveration.

Example 2. Patient PX (Group D)

Patient PX drew a total of 51 designs but 30 of these (58.8 per cent) were repetitions. This patient was able to obtain a score of 12 (High Average) on Block Design and made no errors on the Stick Test. There was no evidence to suggest that this fluency task should present overwhelming difficulty for him in terms of the visuo-spatial judgements required. His performance is consistent with a failure to monitor his responses and the dominance of strongly activated designs over the active search for novel (less activated) ones. Fatigue is not relevant as the repetitions were dispersed throughout the task.

Classification: Severe perseveration

(a) Not adequately explained by difficulty (negative evidence)

(b) Consistent with a deficit in voluntary attention - reflective perseveration (positive evidence).

From Table 26 it can be seen that 57 per cent of the frontal patients demonstrated reflective perseveration on this task and that similar proportions were seen in the deep (50 per cent) and combined (66.7 per cent) groups of posterior patients.

(d) Trails A and B

Table 27 presents the number of subjects with associated errors on Trails A and B for each group. Visual difficulties (acuity, hemianopia, neglect) prevented the valid administration of these tasks for 5 posterior patients (2 shallow, 1 deep and 2 combined); percentages are taken from the number of subjects who could validly attempt the task.

Table 27. Number Of Subjects Showing Associated Errors On Trails A and Trails B. Catastrophic Errors Shown In Brackets.

Group	N	Trails A		Trails B	
		No. of Ss	%	No. of Ss	%
Frontal (F)	7	1	14.3	6	85.7
Shallow (S)	4	0	0	0	0
Deep (D)	5	1	20	3	60
Combined (C)	4	1 (2)	25 (50)	1 (2)	25 (50)
Total Posterior	13	2 (2)	15.4 (15.4)	4 (2)	30.8 (15.4)

Example 1. Patient US

Patient US had such severe perseveration in his speech that he was unable to repeat the alphabet nor count from 1 to 20 and hence could not demonstrate that these series remained in his repertoire. He was unable to complete the sample for Trails A without assistance. Therefore his performances on Trails B could not be assumed to be due to regulation deficits but could be accounted for by the overwhelming difficulty of the tasks.

Classification: Associated with difficulty (catastrophic).

Example 2. Patient VI.

Patient VI was able to count from 1 to 20 with ease and repeated the alphabet correctly in 8.9 seconds. She could read both numbers and letters. She was able to complete Trails A in 85.1 seconds (50th percentile for adults over 14 years; Patient VI was 78 years old) although she missed 2 numbers, noting her errors at the completion of the task.

She made numerous errors on Trails B, abandoning the task after 177.6 seconds. When asked to do the task verbally she did so without error and with apparant ease. However, when asked to put her verbalization into action she was unable to do so, perseverating on single series instead of alternating, e.g., having reached 4 she instructed herself with "letter... (her pencil moves to) 5...no!" and after a letter "number now...(her pencil moves to G) G...no!".

The patient demonstrated that all the required abilities were well within her capacities but was unable to guide her responses by her verbalizations - another classic example of a dissociation between knowing and doing.

Classification: (a) not accounted for by difficulty (negative evidence)
(b) associated error - dissociation between knowing and doing, not explained by difficulty (positive evidence).

Frontal patients showed similar errors, that is, they were unable to regulate their behaviour when required to alternate the two series on Trails B despite access to the items of both series.

It can be seen from Table 27 that 85.7 per cent of frontal patients showed associated errors on Trails B and that 60 per cent of the deep posterior group (D) did so. Twenty-five percent of the combined group (C) also showed such errors with a further 50 per cent showing catastrophic errors.

General Comments:

From the data presented in Tables 15 to 27, the tasks most frequently eliciting reflective perseveration and/or associated signs were rank ordered for each group (where a patient committed both perseveration <u>and</u> associated sign(s) s/he was only counted once). Table 28 presents the tasks eliciting more than 50 per cent perseveration and/or associated signs in rank order for each group.

Table 28. Rank Ordering Of Tasks Eliciting More Than 50 per cent Reflective Perseveration and/or Associated Signs In Each Group

Frontal N=7	Deep N=6	Combined N=6	Shallow N=6
Trails B 86%	Trails B 60%	An'ls by Al. 83%	None
An'ls by Size 71%	5 Dot Flue. 50%	Drawing 83%	
" by Al. 71%	An'ls by Size 50%	5 Dot Flue. 66%	
5 Dot Flue. 57%	Male-Female 50%	Sorting 66.%	
Male-Female 57%		F. 66%	
F. 57%		S. 66%	
A. 57%		Male-Female 50%	
S. 57%		A. 50%	
		Alternations 50%	

From this table a remarkable similarity can be noted between the tasks most frequently eliciting signs of attentional dysfunction in the frontal group and those eliciting such signs in the deep and combined non-frontal groups.

7.1.2 Subject Analysis

The errors of each protocol were analyzed in the above manner, always in the context of the patient's general cognitive characteristics and specific deficits. A conservative approach was adopted whenever the influence of difficulty was unclear, even if the evidence was equally supportive of a deficit in voluntary, selective attention.

Table 29 summarizes the results of these analyses for each posterior patient. This table indicates the number of tasks on which moderate or severe reflective perseveration was seen. In other words, perseveration which

(a) could not be accounted for by difficulty and

(b) was consistent with a deficit in selective attention.

Table 29 also shows the number of tasks on which associated signs of a deficit in voluntary attention were seen. The number of tasks where difficulty could account for the errors or poor performances (i.e. catastrophic signs) are presented in brackets.

Table 29 also presents the rank order of the patients for both perseverative errors (ranked on severe perseveration with moderate perseveration discriminating tied severe scores) and associated signs (ranked on associated errors, with reduced fluency scores discriminating tied error scores).

Table 29. Number Of Tasks Showing Perseverative Errors and Associated Signs and Rank Order for Each Posterior Patient. Catastrophic Errors are shown in Brackets

Group		Reflective Perseverative Error			Associated Signs		
		Severe	Moderate	Rank	Assoc. Errors	Severely Reduced Flu.	Rank
PW	C	6 (3)	1	1	7 (1)	0 (9)	1
PX	D	4 (1)	7 (1)	2	6	3	2
VI	D	4 (1)	2 (2)	3	4 (1)	0 (9)	4
PD	C	3 (1)	1	4	5	4	3
PD	C	2	7 (2)	5	1	3	8
ZN	C	2	5	6	3	3	5
IH	C	2	4	7	1	0	10
PI	S	1 (1)	5 (1)	8	0	1	13
XN	D	1	1	10	2	0	6.5
US	C	1 (14)	1	10	0 (1)	0 (9)	16
WS	S	1 (3)	1 (1)	10	0 (2)	4 (1)	12
NO	D	0	1	13	0	0	16
YX	S	0	1	13	0	0	16
PS	S	0	1	13	1	0	10
ZX	D	0	0	16.5	1	0	10
UX	S	0	0	16.5	0	0	16
QN	D	0	0	16.5	2	0	6.5
TH	S	0	0	16.5	0	0	16

$r_s = 0.72$ ($p < 0.01$)

From this table it can be seen that catastrophic perseverative errors (shown in brackets) were seen in only 8/18 patients (44.4 percent). This represented 27 per cent of the total number of perseverative errors. When difficulty - related errors were excluded, all of these 8 patients continued to show at least one reflective perseverative error. A further 6 patients showed reflective perseverative errors only. Hence, although difficulty can not be ruled out as a factor in <u>some</u> perseveration seen in posterior patients, it was unable to account for the majority of such perseverative errors in this sample.

Furthermore, at least one associated sign was seen in 13/18 (71.5 per cent) of these patients, providing additional evidence of a deficit in voluntary attention.

A Spearman rank correlation coefficient (corrected for tied observations) was calculated in order to examine the relationship between the incidence of reflective perseverative errors and the incidence of associated signs (i.e., accepted signs of a deficit in voluntary attention). This correlation coefficient was 0.72 ($p < 0.01$). In other words, there was a strong positive association between these two manifestations of system breakdown, supporting the concept of a common underlying mechanism.

Table 30 presents the analagous data for each frontal patient.

<u>Table 30.</u> Number Of Tasks Showing Reflective Perseverative Errors And Associated Signs And Rank Order For Each Frontal Patient. Catastrophic Signs Are Shown In Brackets.

Patient	Perseverative Errors			Associated Signs		
	Severe	Moderate	Rank	Errors	Reduced Fluency	Rank
NP	6	2	1	8	5	1
WN	6 (5)	0	2	3 (2)	2 (7)	4
UV	3	3	3	7	3	2
XH	1	3	4.5	1	3	6
VX	1	3	4.5	4	5	3
TX	1	1	6	1	0	7
ZW	0	0	7	2	2	5

$r_s = 0.74 (p < 0.05)$

From this table it can be seen that catastrophic signs were seen in only one frontal patient. As with the posterior patients, this frontal patient also demonstrated reflective perseveration and associated signs.

A Spearman rank correlation coefficient was calculated in the same manner as for the posterior patients and found to be 0.74 ($p < 0.05$), demonstrating a similar relationship between reflective perseveration and associated signs in both the frontal and posterior patients.

Comparing Tables 29 and 30 it can be noted that there was considerable variation in the number of errors and signs seen across patients in both the posterior and frontal groups and that the range was similar in each group.

From the data presented earlier for each task, it is clear that there was considerable individual variation within both frontal and posterior groups regarding which tasks would elicit perseverative and/or associated signs. That is, although certain tasks elicited such signs in more than half of the subjects in a particular group (these tasks being similar in the frontal, deep and combined groups - Table 28), there was no single test on which <u>all</u> patients in a group or sub-group perseverated (or made associated signs). Similarly, no two patients obtained an identical perseveration profile across the test battery.

However, at least one frontal and one posterior patient made similar errors on each task. More importantly, the overall pattern of performances across tasks was strongly suggestive of a deficit in voluntary regulation/attention for six of the seven frontal patients. In these six patients best performances were seen on tasks which least required such regulation and worst performances (reflective perseveration and/or associated signs)were seen on tasks which required active selection and internal structuring, providing further evidence of the validity of the inferences made regarding these signs. The remaining frontal patient performed poorly on both automatic and regulation tasks so that the <u>pattern</u> of performance was less informative but the quality of the errors were strongly suggestive of an attentional deficit (see Appendix 14 for details of individual profiles).

This regulation deficit pattern was seen in nine of the eighteen posterior patients (1/6 shallow, 3/6 deep, 5/6 combined). Two further patients (1 deep, 1 combined) performed poorly on both automatic and regulation tasks but demonstrated qualitative evidence of a regulation deficit. Of the remaining seven posterior patients, two (both shallow) made no perseverative or associated errors and 4 (2 shallow, 2 deep) made isolated and qualitatively mild (or at most moderate) errors in the context of good performances on the regulation tasks which most frequently caused difficulties for the frontal patients (see Table 28). One shallow patient (PI) made a number of (mostly moderate) perseverative errors but with the opposite pattern of better performances on regulation tasks and poor performances on automatic tasks, with no associated signs.

7.2. Discussion

In the earlier review of the literature (Chapter 2), it was noted that marked perseveration, in the absence of general dementia, has been generally accepted as a sign of frontal lobe pathology. On the other hand, a number of authors have pointed to the frequency with which perseveration occurs with nonfrontal lesions (e.g. Brunner, Kornhuber, Seemuller & Wallesch 1982; Buckingham, Whitaker & Whitaker 1979; Pick, 1931/1973;).

The present investigation provided further evidence that perseveration is a common feature of patients with focal, nonfrontal lesions. The results presented in Section 7.1 revealed that 77.8 per cent of the 18 nonfrontal patients examined in this study perseverated (at a moderate and/or severe level) on at least one task (vs. 85.7 per cent of the 7 frontal patients). Furthermore "pervasive" perseveration (across a wide variety of tasks) was not pathognomic of frontal pathology. From Table 29 it can be seen that 10/18 nonfrontal patients (55.5 per cent) perseverated on more than four tasks (i.e. more than 25 per cent of the tasks on which perseveration was scored). Table 30 shows that 5/7 frontal patients

(71.4 per cent) perseverated on four or more tasks. These results confirm previous suggestions that perseveration *per se* can not be taken as a localizing sign of frontal lobe pathology even when such perseveration occurs across a variety of tasks.

The argument that the current sample of nonfrontal patients may have had unsuspected frontal involvement is difficult to refute in the absence of post-mortem examinations. However, this possibility was minimized in the current study by the inclusion criteria: all nonfrontal patients had CT scan documentation of the lesion, were tested at least 6 weeks post onset (or post surgery) and showed no evidence of generalized dementia.

The question of underlying mechanisms in frontal and nonfrontal perseveration has been the subject of considerable controversy in the past. It was noted in the earlier literature review (Section 2.7) that three major propositions have been put forward in the past. For ease of discussion these are briefly recapitulated below:

Model I - all perseveration (frontal and non-frontal) is related to the organism's response to overwhelming difficulty and fatigue (Goldstein's (1944) catastrophic reaction hypothesis) i.e. perseveration defends against catastrophe.

Model II - avoidance of catastrophe underlies perseveration in nonfrontal patients but frontal patients perseverate because of a deficit in voluntary attention (Luria, 1965; Milner, 1964).

Model III - a disturbance in "recall processing" underlies both frontal and nonfrontal perseveration (although catastrophic factors may also be involved in some perseveration in both groups) (Hudson, 1968; Yamadori, 1981)

The model proposed here rejected the idea that nonfrontal perseveration is explained by avoidance of catastrophe alone (i.e. Models I and II) and replaced Model III's vague notion of "recall processing" with a detailed account of the breakdown of the system regulating voluntary attention, perseveration being one manifestation of such breakdown. Since the system involves a number of different components, each assumed to be related to a different neuroanatomical substrate, it followed that perseveration could occur with disruption of any one of these components. Catastrophic perseveration was viewed as the result of a temporary disruption of this system due to over or underarousal (associated with anxiety/distress and fatigue respectively). Reflective perseveration was considered to result from actual damage to a system component. The model proposes that both frontal and nonfrontal lesions could result in component damage and, hence, that a deficit in voluntary attention could be the underlying mechanism of perseveration in at least some nonfrontal patients.

The results of the current study strongly support such a contention. Support came in the form of both positive evidence of an attentional/regulatory deficit and negative evidence that alternative hypotheses were not viable. This evidence is discussed more fully below.

7.2.1 Positive Evidence

Qualitative analysis of each patient's test protocol revealed that the majority of the perseverative errors made by nonfrontal patients were strongly suggestive of a breakdown in voluntary selection of responses not accounted for by temporary "arousal" factors. This was demonstrated at the level of both:

(i) the individual task, where catastrophic factors were ruled out and the nature of the task was such that it involved a shift of attention from strongly to weakly activated responses (83 per cent of perseverative errors) and

(ii) the pattern of performances across tasks, that is, the regulation deficit pattern in which tasks requiring greatest voluntary regulation were poorly performed while relatively automatic tasks were least impaired (9/18 nonfrontal patients showed this pattern). This is consistent with previous reports regarding perseveration in aphasic patients (largely nonfrontal) where the tasks eliciting most perseveration were described as "least automatic" (Allison & Hurwitz, 1967).

Further evidence that these errors reflected a deficit in voluntary attention was provided by their strong positive association with other signs of such a deficit. A patient demonstrating pervasive reflective perseveration was also likely to demonstrate reduced capacity for controlled word association ("fluency") and/or various other signs of a dissociation between "knowing" (i.e. momentary intention in the current model) and "doing".

Finally, when the same tasks were administered to a series of frontal patients, similar errors were seen. The errors were qualitatively similar and similar in terms of both their pattern across tasks and their relationship with other signs of attentional deficits. Since a deficit in voluntary attention is considered to be a characteristic feature of frontal dysfunction (Luria, 1973; Walsh, 1978; Fuster, 1981), this similarity of performance supports the face validity of the contention that such a deficit also underlies perseveration in nonfrontal patients.

7.2.2 Negative Evidence

The current study also demonstrated that the alternative hypothesis of avoidance of catastrophe was not sufficient to account for the perseverative errors seen in nonfrontal patients. Only 27 per cent of perseverative errors could be accounted for by difficulty, fatigue or "failure to equalize", even though such factors had to be positively excluded before the catastrophic classification was escaped.

Table 29 revealed that for eight of the nonfrontal patients the majority of their perseverative errors (moderate or severe) could not be accounted for by catastrophic factors. This contradicts the proposals of both Models I and II described above from the previous literature. Model III, advocated by Hudson (1968) and Yamadori (1981) was not directly excluded by this investigation. This model's proposals were criticized in the earlier review and it was not considered a viable explanation in its current form. Further evidence to exclude Model III as an alternative explanation of perseverative mechanisms was garnered in the third investigation presented in this dissertation and is discussed in Section 9.4.1. It is sufficient here to note that previous hypotheses regarding the underlying mechanisms in perseveration were unable to account either for previous findings (Model III) or the results of the current study (Models I and II), whereas the proposed model was strongly supported by such findings.

8. QUESTION 2: Can the Deficit in Voluntary Attention in Nonfrontal Patients be shown to be related to Involvement of Deep Midline Structures?

8.1 Results

Table 31 presents the number of instances of reflective perseveration seen in each subgroup of nonfrontal patients, together with the number of instances of other signs of a deficit in voluntary attention (i.e. associated errors and reduced fluency not attributed to difficulty).

Figure 11 presents the same information in graph form.

Table 31. Number Of Instances Of Reflective Perseveration And Associated Signs For Each Posterior Group

Group	Instances of Reflective Perseveration			Instances Of Associated Signs			Total Number of Signs 1
	Severe	Moderate	Total	Errors	Fluency	Total	
Shallow (S) N=6	2	8	10	1	5	6	16
Deep (D) N=6	9	11	20	13	3	16	36
Combined (C) N=6	15	19	34	17	10	27	61

1. Total No. Of Signs = Total perseverative errors and Total associated signs

From Table 31 it can be seen that the combined group (C) showed the greatest number of signs of a deficit of voluntary attention (both for reflective perseveration and associated signs) followed by the deep group (D), with the shallow group (S) demonstrating the fewest such signs.

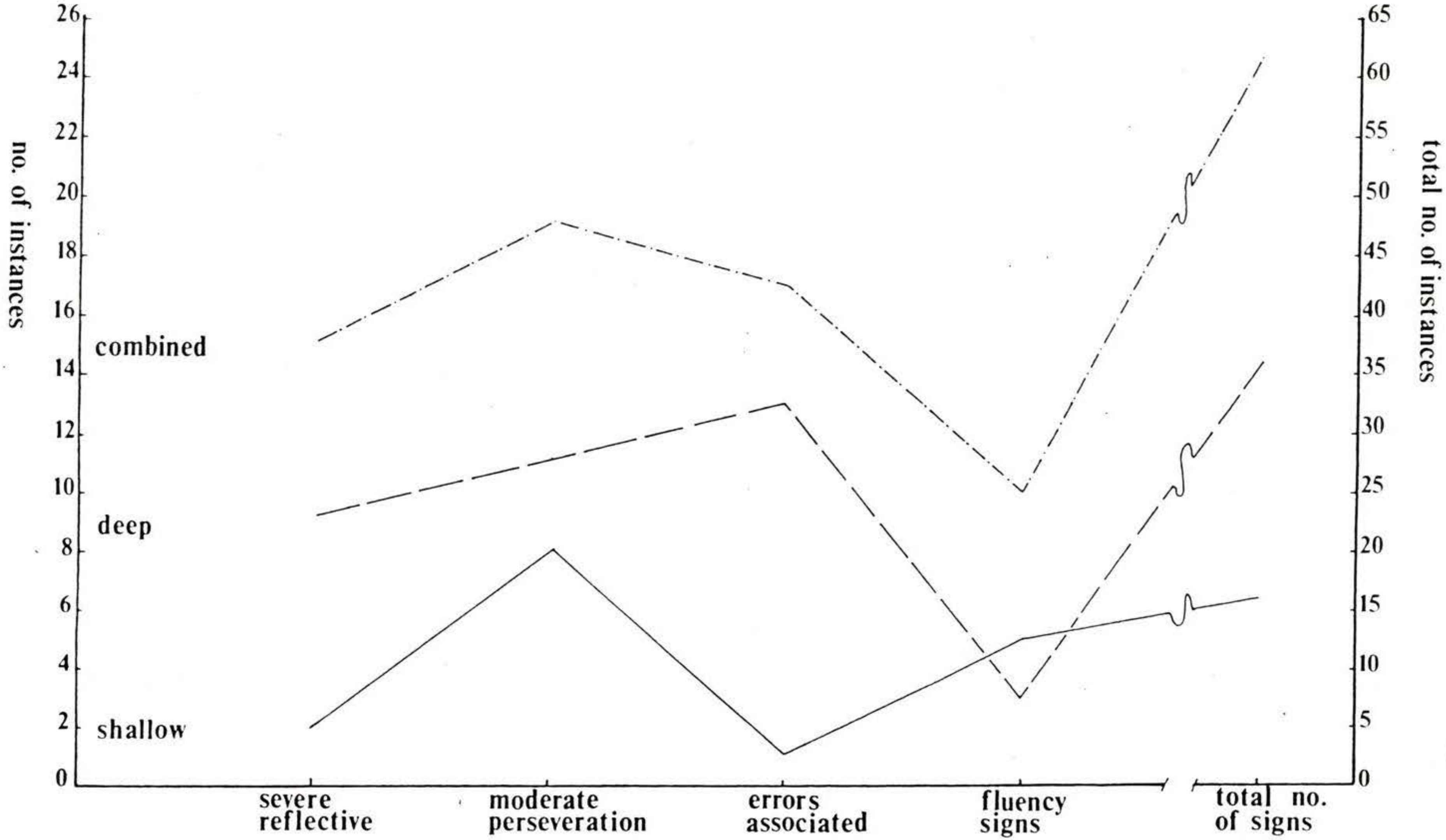


FIGURE 11. Number of Instances of Reflective Perseveration and Associated Signs and Total Number of Signs of a Deficit in Voluntary Attention for Each Posterior Group

Table 32 shows the rankings of subjects in each group with respect to total number of signs (reflective perseveration and associated signs).

Table 32. Rankings within each of the three posterior groups with respect to total number of signs.

Shallow (S) N=6	Deep (D) N=6	Combined (C) N=6
12	18	17
7	4	15
1.5	9	15
10.5	13	7
4	7	10.5
1.5	4	15

$H=6.04$, $X^2=5.99$, $p<0.05$, 2d.f.

A Kruskal-Wallis one-way analysis of variance by ranks (Siegal, 1956) rejected the null hypothesis, that the three groups showed no significant differences in total number of signs, at the 0.05 level (corrected for ties). ($H=6.04$, $X^2=5.99$, $p<0.05$, 2d.f.)

It is necessary to interpret these results in the context of a more detailed analysis of individual subjects within each group. From the results presented in Section 7.1.2 it can be noted that, when the number of signs, the quality of the errors and the pattern across tasks were considered for each individual, 11/18 posterior patients demonstrated strong evidence of a deficit in voluntary attention distributed across the groups as follows:

1 Shallow 4 Deep 6 Combined

This is consistent with the results in Table 31. However, evidence for a deficit in voluntary attention in even one shallow patient must be explained by the a priori features of the model; failure to do so must call at least part of the model into question.

Furthermore, since there were uneven numbers of left and right hemisphere lesioned patients among the groups, introducing a possible confounding factor, the results must be considered according to laterality.

The results for each patient with a left hemisphere lesion are summarized below, followed by the results for right hemisphere lesioned patients. The results for frontal patients are also presented, according to laterality, for comparison. Where relevant, information from a patient's history and test protocol are described to clarify the summarized results.

8.1.1 Left Hemisphere Lesions

Table 33 presents the results for each subject with a left hemisphere lesion.

Table 34 presents the ranks for the total number of signs of a deficit of voluntary attention (i.e. reflective perseveration and associated signs) for each subject with a left hemisphere lesion.

Figure 12 presents the left hemisphere results graphically.

Table 33. Number Of Tasks Showing Reflective Perseveration And Associated Signs And Presence/Absence Of A Regulation Deficit Pattern Across Tasks For Each Patient With A Left Hemisphere Lesion (Catastrophic Signs Shown In Brackets)

Group	Pat.	Perseverative Errors Severe	Perseverative Errors Moderate	Perseverative Errors Total	Associated Signs Errors	Associated Signs Fluency	Associated Signs Tot.	Total No. Of Signs	RDP
S	PS	0	1	1	1	0	1	2	NO
N=3	PI	1 (1)	5 (1)	6 (2)	0	1	1	7	NO
	YX	0	1	1	0	0	0	1	NO
D	PX	4 (1)	7 (1)	11 (2)	6	3	9	20	YES
N=3	ZX	0	0	0	1	0	1	1	NO
	VI	4 (1)	2 (2)	6 (3)	4 (1)	0 (9)	4 (10)	10	QUAL.
C	PW	6 (3)	1	7 (3)	7 (1)	0 (9)	7 (10)	14	YES
N=5	ZN	2	5	7	3	3	6	13	YES
	US	1 (14)	1	2 (14)	0 (1)	0 (9)	0 (10)	2	QUAL.
	IH	2	4	6	1	0	1	7	YES
	SD	2	7 (2)	9 (2)	1	3	4	13	YES
F	NP	6	2	8	8	5	8	21	YES
N=3	WN	6 (5)	0	6 (5)	3 (2)	2 (7)	5 (8)	11	QUAL.
	UV	3	3	6	7	3	7	16	YES

1. RDP = regulation deficit pattern

2. QUAL=Qualitative features strongly suggestive of regulation deficit in otherwise generally depressed profile.

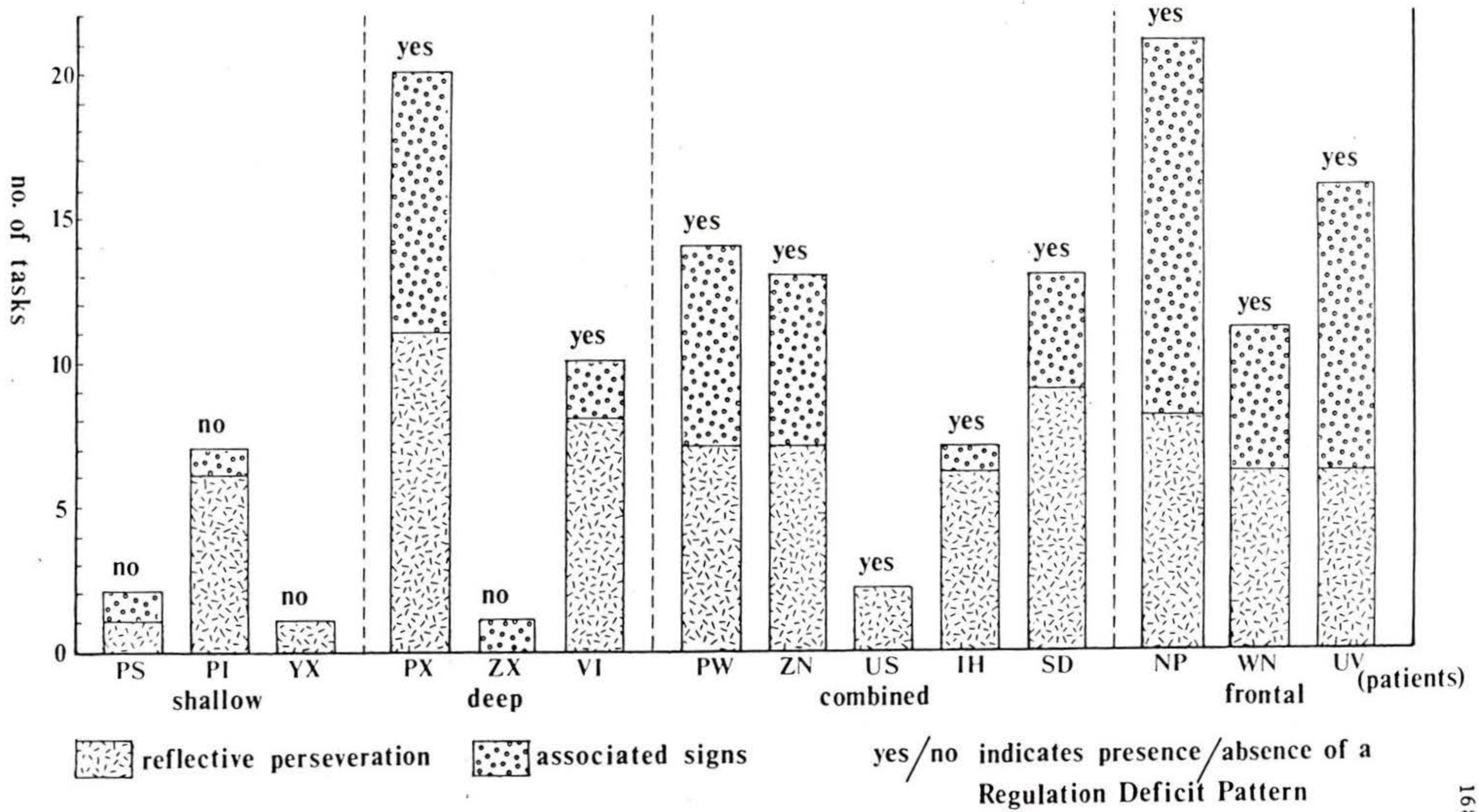


FIGURE 12. Total Number of Reflective Perseveration and/or Associated Signs for Each Patient with a Left Hemisphere Lesion

Table 34. Ranks of Left Hemisphere Subjects within Each Nonfrontal Group Regarding Total Number of Signs.

Shallow (S) N=3	Deep (D) N=3	Combined (C) N=5
3.5	11	10
5.5	1.5	8.5
1.5	7	3.5
		5.5
		8.5

H=2.48, p>.109

A Kruskal-Wallis one-way analysis of variance by ranks for small samples (corrected for ties) (Siegal, 1956) was calculated for the total number of signs shown by each left, nonfrontal subject. No significant differences were found among these nonfrontal groups by this test (H=2.48, p>0.05). However, closer examination of individual results permits a number of observations to be made which suggest that such analysis of the total number of signs masks important features of the performances of subjects within each group. For example, from the results presented in Table 33 and Figure 12, together with additional qualitative information from the individual test protocols, it was noted that

(i) there was considerable variation across subjects within each group but a general paucity of severe reflective perseveration and associated signs in the shallow group (S) (Table 33)

(ii) a high incidence of both reflective perseveration and other signs of a deficit in voluntary attention was seen in two of the three patients with circumscribed lesions of the deep structures (Patients PX, VI) and in four of the five patients with combined lesions (Patients PW, ZN, IH and SD). Furthermore, these signs were distributed across the tasks in a pattern consistent with such a deficit (or had qualitative features strongly suggestive of such a deficit in the case of Patient VI). No shallow patient showed both perseverative and associated errors in this manner, whereas all three frontal patients did so.

In other words, when the number, quality and pattern of errors were considered, the presence of either a frontal or a deep (alone or combined with cortical involvement) lesion was necessary (and sufficient) for a deficit in voluntary attention to be demonstrated; no shallow patient demonstrated consistent evidence of such a deficit.

(iii) On the other hand, the presence of a deep lesion, with (Group C) or without (Group D) cortical involvement, did not ensure the pervasive occurrence of reflective perseveration or other signs of a deficit in voluntary attention e.g. Patients ZX (Group D) and US (Group C)

Patient ZX was not considered to show sufficient evidence of such a deficit when the quality and pattern were also considered, whereas Patient US showed qualitative features suggestive of an attentional deficit despite a generally depressed profile. In the latter case verbal output was so effortful and restricted that the severe perseveration seen on all expressive verbal tasks was attributed to difficulty (although equally consistent with a severe deficit in voluntary attention or a combination of both). Output was so limited, even on automatic tasks that there were few opportunities for definitive reflective perseveration or associated signs to be demonstrated. It was noted, however, that reflective perseveration was seen on two tasks where expressive speech was not required i.e. drawing (see page 129) and 5 dot fluency (20 percent repetition, moderate perseveration) giving qualitative support for a regulatory deficit.

(iv) Although the shallow patients showed few severe reflective errors and associated signs, Patient PI scored a total of 7 signs of a voluntary attention deficit (1 severe perseveration, 5 moderate perseveration and 1 reduced fluency). However, the pattern of his errors across the tasks was not considered to be consistent with a regulation deficit. Given the importance of a shallow patient demonstrating a voluntary attention deficit, the evidence for this conclusion will be considered more fully below:

From Patient PI's protocol it was noted that perseveration on verbal fluency tasks was seen more frequently on the automatic network tasks than on the regulation tasks. Moderate perseveration was seen on animals (14 + 4 repetitions) whereas animals by size

(10) and by alphabet (12) were performed well and without repetitions. Similarly perseveration was seen on males (14 + 3 repetitions) and females (5 +1 repetition) but male-female alternation was performed well (12, no repetitions). (At a subsequent session PI was able to give 16 female names indicating that the earlier reduced fluency and perseveration on this task was not due to impoverished repertoire). There were no associated errors in his protocol. This is in marked contrast to patients in the deep, combined and frontal groups where greatest difficulty (i.e. reflective perseverative errors and, more particularly, associated signs) occurred most frequently on the regulation tasks and less so on the automatic tasks (see Tables 23-25) as would be expected with a deficit in voluntary regulation.

Patient PI also showed severe perseveration on reversed S, where he was unable to maintain the reversal without the aid of a model series but he had no difficulty with reversed days or counting. Sorting and alternations were performed without difficulty.

These features suggest that voluntary regulation was largely intact (given his good performances on regulation and conflict tasks) but was inconsistently applied, particularly when the patient perceived the task as an automatic or easy one. When task instructions indicated the need for self-regulation, using the same material, he was able to initiate and maintain such voluntary control.

(v) Catastrophic perseveration was seen in all groups. Closer examination of the protocols indicated that a high incidence of catastrophic perseveration was associated with expressive speech deficits and, as explained in Patient US above, tended to restrict the opportunities for reflective perseveration to be demonstrated (only catastrophic perseveration <u>or</u> reflective perseveration being scored for any one task). The incidence of catastrophic perseveration (and other signs) was least in the shallow group, so this can not be used to explain the paucity of severe reflective perseveration and associated signs in this group.

8.1.2 Right Hemisphere Lesions

Table 35 presents the results for each subject with a right hemisphere lesion.

Table 36 shows the ranks for the total number of signs of a deficit of voluntary attention (reflective errors and associated signs) for each subject with a right hemisphere lesion.

Figure 13 presents the right hemisphere results graphically.

Table 35. No. Of Tasks Showing Reflective Perseveration And Associated Signs For Each Patient With A Right Hemisphere Lesion. (Catastrophic Perseveration and Signs Shown In Brackets)

Group	Pat.	Perseverative Errors Severe	Moderate	Total	Associated Signs Errors	Fluency	Tot.	Total No. Of Signs	RDP
S	WS	1 (3)	1 (1)	2 (4)	0 (2)	4 (1)	4 (3)	6	YES
N=3	TH	0	0	0	0	0	0	0	NO
	UX	0	0	0	0	0	0	0	NO
D	NO	0	1	1	0	0	0	1	NO
N=3	XN	1	1	2	2	0	2	4	YES
	QN	0	0	0	2	0	2	2	YES
C	PD	3 (1)	1	4 (1)	5	4	9	13	YES
N=1									
F	TX	1	1	2	1	0	1	3	YES
N=4	VX	1	3	4	4	5	9	13	YES
	ZW	0	0	0	2	2	4	4	YES
	XH	1	3	4	1	3	4	8	YES

RDP= Regulation Deficit Pattern

Table 36. Ranks of Left Hemisphere Subjects within each Non-frontal Group Regarding Total Number of Signs.

Shallow (S) N=3	Deep (D) N=3	Combined (C) N=1
6	3	7
1.5	5	
1.5	4	

H=2.6, p>.129

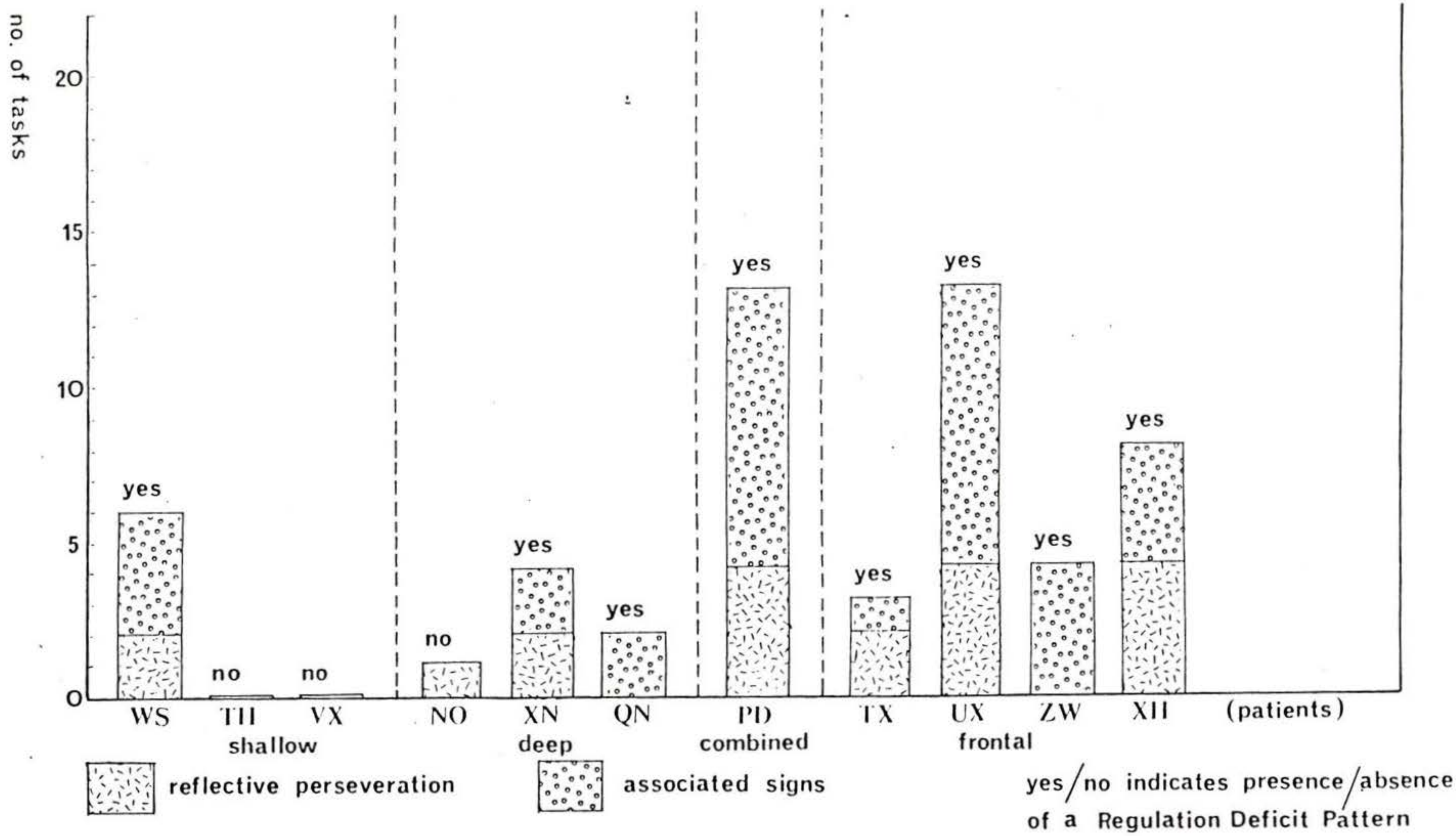


FIGURE 13. Total Number of Reflective Perseveration and/or Associated Signs for each Patient with a Right Hemisphere Lesion.

A Kruskal-Wallis one-way analysis of variance by ranks for small samples was calculated for the total number of signs shown by each non-frontal subject. No significant differences between the three non-frontal groups were found by this test ($H=2.6$, $p>0.05$, $n=3,3,1$).

However, closer examination of the individual profiles and test protocols revealed the following features:

(i) As with left hemisphere lesions, there was considerable variation across subjects within each group.

(ii) Associated errors were seen only in patients with deep, combined or frontal lesions, although reduced fluency (an associated sign) was seen in one patient (WS) with a shallow lesion.

(iii) Although a number of signs of attentional dysfunction were seen in a patient with a circumscribed deep lesion (Patient XN), a deep lesion did not ensure such signs would be demonstrated e.g. Patient NO showed only one instance of moderate perseveration and no associated errors.

(iv) Although two of the three shallow patients showed no signs of voluntary attentional dysfunction (neither reflective perseveration nor associated signs) Patient WS demonstrated severe reflective perseveration on one task and moderate perseveration on another task, together with severely reduced fluency on four tasks.
Examination of his history and protocol revealed that Patient WS had severe visuo-spatial deficits which could not be ruled out as the underlying factor in perseverative and associated errors on several tasks (such errors were classified as catastrophic and are shown in brackets in Table 35). However, specific deficits could not explain his severely reduced fluency on the regulation verbal fluency tasks of animals by alphabet (4), F(2), A(2) and S (3) in the context of good performances on the automatic network tasks such as animals (10). Similarly, reflective perseveration was seen on writing and sorting. In other words, the pattern of his errors conformed with the regulation deficit pattern seen in frontal patients. This contradicts the prediction made by the current model with respect to shallow patients and is discussed further in Section 8.2.1.

(v) Catastrophic perseveration was seen in both a shallow patient and the combined patient (but not in the deep or frontal groups) and was related to visuo-spatial deficits in both cases.

(vi) Although there was considerable variation across both left (Table 33) and right (Table 35) hemisphere patients, the range of the number of signs of attentional dysfunction was generally lower in the right hemisphere groups, especially for the deep group. However, the findings were essentially the same in both left and right hemisphere groups when number, quality and pattern of signs were considered. Although the lower range in right lesioned patients may reflect the verbal bias of the test battery it can be noted that Patient PD (right combined) and Patient UX (right frontal) showed signs of attentional dysfunction across a wide variety of tasks, equivalent to or greater in number than the majority of their left-hemisphere counterparts and distributed in the regulation deficit pattern. Furthermore, examination of individual protocols revealed that all right hemisphere patients who showed any signs of attentional dysfunction did so on at least one verbal task.

8.2 Discussion

8.2.1 Nonfrontal Group Comparisons.

When the number, quality and pattern of the errors made by each nonfrontal subject were considered, it was found that a circumscribed lesion of the deep structures was sufficient to produce signs of an acquired deficit in voluntary attention (although not every deep lesioned patient showed such a deficit). This was true for both left and right hemisphere lesioned patients. This supports the contention that the deep midline structures constitute an important component in the functional system for the regulation of attention, as predicted by the current model. The particular importance of these structures was further supported by a comparison of patients with lesions of the posterior cortex divided into two groups - those without (shallow) and those with (combined) concurrent involvement of deep midline structures. When number, quality and pattern of the errors were again considered all those with involvement of deep structures (n=6:5 left, 1 right) were found to show signs of attentional dysfunction whereas only one (right hemisphere) shallow lesion patient did so. The latter patient (Patient WS) requires further discussion, however, since the model can not account for pervasive signs of attentional dysfunction in a strictly defined shallow patient.

Patient WS was a 49 year old factory worker who suffered a right parieto-occipital infarction eight weeks prior to testing. The CT scan showed an infarct at the parieto-occipital junction. There was no evidence of left hemisphere involvement. The infarct included both grey and white matter (corona radiata) in a wedge-shaped lesion extending to the trigone of the lateral ventricle but did not involve deep midline structures (see Appendix 1.1). For the purposes of the current, exploratory, study, this patient fulfilled the criteria for classification as a shallow subject. However, problems in precise lesion location (especially in the absence of post-mortem results) and in the definition of "shallow" used in the present study, become evident when his data are considered more closely.

First of all, this patient had a history of myocardial infarction and transient numbness of the right arm, some two years prior to the current infarct. As noted, there was no evidence of left hemisphere involvement on CT scan or neurological examination, satisfying the current criteria for inclusion in the right hemisphere shallow group. However, since small lesions may remain undetected with the present CT scan resolution, the possibility of a small (but functionally important) left hemisphere lesion in the frontal or deep midline structures can not be positively ruled out in this context.

Secondly, the right hemisphere infarct was reported to be wedge-shaped and to extend to the level of the lateral ventricle. The scan was performed the day of hospital admission but the patient described symptoms of one week's duration upon admission. Assuming this means the scan was conducted approximately seven days after onset, the possibility of small infarct(s) in the deep structures (i.e. from the posterior choroidal branches of the infarcting posterior cerebral artery) is reduced - such small infarcts may be missed in the first day or two after onset but become increasingly apparent from two to seven or ten days, although even then they cannot be ruled out (New & Scott, 1975). However the possibility that the involvement of a substantial amount of white matter may have disconnected the deep structures from cortical regions must also be considered. The definition used in the current study for shallow lesions was that the lesion did not include deep midline structures (subcortical grey matter). This definition allowed patients with varying amounts of white matter involvement to be included. The looseness of this criterion reflected the difficulty of finding purely cortical lesions in the clinical population sampled. This problem has been common in similar research comparisons where "cortical" and "subcortical" groups have been analagously defined as those which are larger in size laterally or medially, respectively (e.g. Naeser, Alexander, Helm-Estabrooks, Levine, Laughlin & Geschwind, 1982) or those without and with involvement of deep structures, respectively (e.g. Brunner, Kornhumber, Seemuller & Wallesch, 1982). In the current study this definition allowed for a test of the model at a "general trend" level but, although disconnection of the deep structures is considered to be of potential importance within the model's framework, it did not allow for an adequate test of this disconnection component. Examination of the individual data suggests that such disconnection needs to be relatively extensive before attentional deficits become marked but precise documentation of the involvement of the projection fibres from the various deep structures was not conducted, leaving this question open to future research.

In the case of Patient WS, the cortical region involved was the "zone of overlapping" (Walsh, 1978), that is, the parieto-occipital junction, known to be involved in higher level, multi-model integration (Luria, 1973). Of perhaps greater relevance to his test performances is the fact that this region has also been considered to be important in arousal (Heilman, 1979). Heilman introduced the concept of the right inferior parietal lobe as being "dominant" for mediating an attention-arousal response. This involves the preparation of both hemispheres for action in a reticular-cortical loop. The right parietal lobe is considered to prepare both hemispheres for action, processing information from both fields, whereas the left hemisphere processes information only from the right field and prepares only the left hemisphere. Heilman uses this notion in his explanation of neglect; that is, when the left parietal lobe is injured the right parietal lobe continues to process ipsilateral stimuli and prepares both hemispheres for action. However, since the left hemisphere cannot process ipsilateral stimuli, lesions of the right hemisphere induce a profound deficit in the attentional-arousal response. Patient WS not only showed neglect but also the emotional flattening and lack of insight noted by Heilman to accompany this attentional-arousal deficit. Patient WS was notably adynamic, requiring constant external structuring to initiate and maintain activity. This was particularly so on the regulation tests (e.g. he gave less than 5 responses on five of the six regulation verbal fluency tests but gave 7 to 11 responses on the automatic fluency tests). He was also noted to be adynamic by his treatment staff. If it can be assumed that regulation tasks (vs. relatively automatic tasks) require the active participation of both hemispheres (discussed further below, see Section 8.2.3), then Patient WS's performances would be consistent with Heilman's attention-arousal deficit hypothesis and would represent damage to, or structural disruption of the arousal component of the current model (rather than the temporary disruption due to catastrophic factors seen in the other shallow patients). If this can be confirmed in subsequent research the model could be refined to include the role of the right parietal region in the regulation of arousal and hemispheric activation.

Future research is clearly needed with regard to shallow lesions, preferably with post-mortem pathological verification of the lesion locus and the fibre pathways that have been interrupted. To some extent this must await further advances in our neuroanatomical knowledge regarding cortico-subcortico connections. However, given the exploratory nature of the current study, the findings regarding the three non-frontal groups were generally supportive of the model and suggest that further exploration of its proposals is worthwhile. The discovery of a patient with a purely cortical lesion (not involving the right inferior parietal lobe) who demonstrates clear signs of voluntary attentional dysfunction, of the type described here, would clearly require a major revision of the model as it now stands.

The argument that the greater occurrence of signs of attentional dysfunction in deep and combined lesion subjects may be related to differences in general intellectual ability and/or education rather than neuroanatomical differences can be countered by reference to Tables 6 and 8. It can be seen from these tables that the deep and combined groups had more subjects in the higher ranges of estimated I.Q. score and educational ratings which would work against the predictions if such factors were important.

The argument that size of lesion may have confounded the results is more difficult to refute in the absence of precise size measurements for each patient (preferably at post-mortem). However, from the scan images and reports (Appendix 1) it can be noted that the shallow lesion patients had extensive lesions, often including large portions of more than one lobe. In contrast the deep lesion patients (Appendix 2) were often described as circumscribed lesions and were unlikely to be larger than the lesions of the shallow lesion group. For example, the most pervasive signs of attentional dysfunction in the deep lesion group were seen in Patient PX whose lesion was a haemorrhage in the region of the left external capsule. In comparison, Patient YX, who had a shallow lesion which extended from the insula to the parietal lobe, demonstrated little or no evidence of attentional dysfunction.

8.2.2 Frontal - Nonfrontal Comparisons.

Further support for the importance of deep midline structures in the regulation of voluntary attention is found in the comparisons with the frontal lesion patients' performances on the same tests.

The frontal patients were included as a validation comparison group. It was assumed that frontal dysfunction commonly leads to a breakdown of the regulation of voluntary attention.

Hence, it follows that the performance of the deep and combined patients should be similar to the frontal group, while the shallow group should demonstrate a different profile. This was found to be so when a number of different aspects of performances were examined. For example, Table 28 shows that there was a marked similarity in the tasks which most frequently elicited perseverative and/or associated signs in the frontal, deep and combined groups, while the shallow group was not particularly sensitive to any task. Furthermore, it is notable that these high-frequency tasks, causing trouble for most frontal and deep patients, are the tasks requiring the most active regulation of attention.

Further evidence of the similarity between patients with frontal and deep lesions was found when the types of perseverative errors seen in each group was examined (Question 3). This evidence is presented and discussed in the following chapter.

8.2.3 Right and Left Hemisphere Comparisons

The current model was proposed to account for both left and right hemisphere regulation of attentional resources, each representing a separate, but mutually interactive, system. It was noted that these systems may involve different processing modes, but they are assumed to be identical in terms of the planning and allocation of resources to those processes. It was proposed, therefore, that perseveration is frequently associated with a deficit in voluntary attention in both left and right hemisphere patients and that, where this was so in non-frontal patients, the deep midline structures would be involved. Consequently, Question 2 was investigated for left and right lesioned patients separately. The results generally supported such proposals. As noted earlier, a circumscribed lesion of the deep structures was sufficient to produce signs of an acquired deficit in voluntary attention in both left and right hemisphere subjects (although the left hemisphere subjects tended to show more such signs on the current test battery). Similarly, although there was only one right hemisphere combined (C) patient, that patient showed pervasive signs of attentional dysfunction to the same extent as his left hemisphere counterparts. The single shallow patient showing such signs (Patient WS) has already been discussed.

It is of interest to note that, while catastrophic perseveration was related to specific deficits of the patient or was at least material-specific (i.e., left hemisphere patients made catastrophic errors on "verbal" tasks and right hemisphere patients made such errors on "visuospatial" tasks), reflective perseveration was not so easily related to deficits or hemispheric involvement. For example, left hemisphere patients with verbal deficits but no evidence of visuospatial difficulties (on Block Design, Stick Test and R.C.P.M.) perseverated on the 5 dot fluency test. Similarly, right hemisphere patients with visuospatial deficits but good performances on verbal tasks such as the N.A.R.T. and Vocabulary and no other linguistic errors on the verbal tasks of the perseveration battery, made perseverative and/or associated errors on these latter tasks. Associated errors on the regulation verbal fluency tests were the most common errors - see Appendices 14-17. This was true for both frontal and non-frontal patients.

Although a number of authors have pointed to similar findings for frontal patients (e.g. Corkin, 1965; Jones-Gotman & Milner, 1977; Milner, 1964; Perret, 1974), these results contrast with previous findings regarding non-frontal patients. For example, Allison & Hurwitz (1967) found perseverative errors to be strictly deficit-specific in a group of aphasics and Brunner, Kornhuber, Seemuller & Wallesch, (1982) reported an absence of language abnormalities of the repetitive type in a preliminary investigation of patients with lesions in the vicinity of the right basal ganglia.

The finding that frontal patients perseverate across a wide variety of tasks has usually been accompanied by the further finding that the deficit will be more severe on verbal tasks with left frontal lesions and more severe on non-verbal tasks with right frontal lesions (Corkin, 1965; Jones-Gotman & Milner 1977; Milner, 1964; Perret, 1974; Regard, 1981). This has been suggested to reflect the combination of two, additive, deficits: a general inflexibility component associated with the frontal lesion and a material-specific deficit associated with the hemisphere involved

(Milner, 1964; Perret, 1974). Implicit in this explanation is the proposal that both frontal lobes are required, to a greater or lesser extent, for the adequate performance of a task requiring flexible operations (i.e., active regulation of attention). Generalizing from this to the current model it can be suggested that regulation tasks involve the voluntary attention systems (frontal -> deep midline -> posterior cortex) of both hemispheres and that damage to either of these systems will result in impairment in the subjects ability to perform such tasks. The nature of the contribution of each system may be different and the ratio of the two contributions may vary depending on the specific nature of the task. This would explain the findings of the current study regarding the impaired performance of patients with deep midline lesions across both "verbal" and "non-verbal" regulation tasks. This study focussed on the <u>number</u> of instances of attentional dysfunction across these tasks rather than comparisons of the severity of the deficit on particular tasks for left and right hemisphere patients. Hence the data relates more to the "general" regulation deficit rather than possible hemispheric augmentation of that deficit for particular task content. Future studies might address this issue in more detail, with larger samples. Such studies would be of particular interest if appropriate "non-verbal" tests could be developed. The test battery used in the current study had a clear verbal bias. Difficulty in developing purely non-verbal tests has been reported elsewhere (e.g. Jones-Gotman & Milner, 1977; Regard, 1981) and was an unresolved problem in the current study. Recent studies of hemispheric differences have suggested that the verbal/non-verbal distinction may be less pertinent than more essential differences in the "mode" of processing; that is, analytic, sequential processing of familiar material on the left and "hypothesis-testing," simultaneous processing of novel material on the right (e.g. Bradshaw & Nettleton 1980; Goldberg & Costa, 1981;). The consideration of these concepts in test development may throw more light on the question of hemispheric augmentation of the more general "regulation deficit", that is, the breakdown of this deficit into its hemispheric components, in the future. This could then lead to refinements of the current very general laterality proposals of the present model.

8.2.4 Functional Differentiation of Deep Midline Structures.

The current study investigated deep midline structures in general, including any limbic and/or basal ganglia lesions, without further specification. It was postulated in the earlier discussion of the model that such structures may be differentiated in terms of their roles in the allocation of resources - some being more centrally involved than others or involved only in the allocation of specific resources in a multiple resource system. Hence, it was expected that there would be considerable individual variation among deep and combined lesion patients, depending on which particular structures had been involved. Such variation was evident in the current sample. Inferences regarding specific structures are difficult because in most cases a number of structures, and surrounding white matter, were involved - the close proximity of deep structures to each other making pure lesions of a single body rare.

Previous research regarding perseveration in deep midline structures, reviewed earlier, pointed to the importance of the thalamus in this context (e.g. Fedio & Van Buren, 1975; Luria, 1977; Mohr et al., 1975; Ojemann, 1975; Reynolds et al., 1979; Shaltenbrand, 1975;) although most of these studies suffer from similar problems of multiple structure involvement. In contrast, Brunner, Kornhuber, Seemuller & Wallesch, (1982) considered the basal ganglia, in particular the left lentiform nucleus, to be of central importance in repetitive verbal behaviour, only one of their sample having a lesion extending to and including, the thalamus. As Damasio and his colleagues recently commented, the basal ganglia are no longer regarded as pure motor structures:

> Rather, the striatum receives input from all the major sensory, suprasensory (multimodal) and limbic areas of the cerebral cortex and is a high-level integrative organ (Damasio, Damasio, Rizzo, Varney & Gersh, 1982, p.20).

This is consistent with the role of the basal ganglia in the current model. The thalamus can be similarly described, however, leading to the inclusion of both structures at the current stage of the model's development.

On the other hand, a number of different syndromes have been reported both with lesions in the basal ganglia and with lesions in the thalamus and perseveration has not been a universal symptom of lesions in either of these structures (e.g. Damasio et al., 1982; Kirshners & Kistler, 1982; Naeser et al., 1982). This again is likely to be due to the inevitable variation in the combination of structures involved in each study. As Damasio and his colleagues (1982) point out, final clarification of the nature of the functional pathology resulting from white matter disconnection or grey-matter damage depends on the ultimate but unlikely discovery of a lesion exclusive to these particular structures.

In the absence of such exclusive lesions, progress can be made by the convergence of evidence from patients with various lesion combinations. In the current study four of the six deep (D) patients (2 left, 2 right) had lesions involving the lentiform nucleus, some with and other apparently without thalamic involvement. All four showed convincing evidence of an attentional deficit. The remaining two deep lesion patients, i.e. without definite involvement of the lentiform nucleus, were Patients NO and ZX. Patient NO was diagnosed to have a lacunar infarct of the right internal capsule. No CT scan was performed (nuclear brain scan and angiography only) but the lacunar nature suggests that this lesion may have been so small as to not involve neighbouring structures. Patient ZX's CT scan was originally reported as follows:

> There is an irregular area of haemorrhage in the posterior aspect of the left basal ganglia and the left thalamus. This is surrounded by a poorly defined irregular low density area and causes no mass effect. This is probably a haemorrhagic infarct rather than an intracerebral haemorrhage. (see Appendix 2.6).

However, when a neuro-radiologist was consulted to clarify the basal ganglia involvement the scan was interpreted as showing a lesion restricted to the thalamus with only questionable involvement of other structures and was considered to represent an intracerebral haemorrhage rather than an infarct. This again points to the problems of precise lesion localization on the basis of CT scan interpretation rather than post-mortem results. However, thalamic involvement was unquestioned in both reports for the patient. Neither of these two patients demonstrated signs of an attentional deficit.

Inferences from these results are extremely tentative due to the many problems in specifying the structures involved in each case and the possible importance of other common bodies, including white matter bundles. However, in the context of the previous findings reviewed above, they appear to support the proposal of Brunner and his colleagues (1982) that the lentiform nucleus (unspecified in terms of its component bodies i.e. the putamen and pallidum) is of particular importance in repetitive behaviour and, hence, suggests this structure might require differentiation in future modifications of the current model. In contrast, the current study questions the role of the thalamus in the regulation of attention (though not in other aspects of cognitive processing). Further investigation of these two structures, preferably with precisely defined lesions documented at autopsy, may clarify these suggestions and lead to significant refinement of this aspect of the model.

9. QUESTION 3. What Types of Perseverative Errors can be Distinguished when a Variety of Patients and of Tasks are Examined?

The quality of the errors in each task was examined and analysed in terms of the three classificatory frameworks outlined in Chapter 5:

(i) the temporal relationship between a perseverated response (perseverate) and its original stimulus, or its original execution.

(ii) the relationship between the current stimulus (or target response) and the perseverate it elicits.

(iii) the nature of the perseverate - classified in terms of the Goldberg and Tucker typology.

The results for each task are presented below.

9.1 Sequential Tasks (Naming, Reading, Writing, Drawing)

(a) NAMING

(i) The Temporal Relationship Between a Perseverate and its Original Stimulus or Original Execution.

Three types of errors could be distinguished in terms of this temporal relationship. Their similarity to the types described for aphasics by Yamadori (1981) led to the adoption of the same descriptive nomenclature but variations from the Yamadori definitions are noted below:

1. Stuck - this occurred when the same response (or part of it) was given repeatedly to a single stimulus. On the naming task this usually occurred in the context of attempts to correct the response (rather than a failure to terminate the response). In Yamadori's description the stuck response occurred in the context of a re-presentation of the stimulus, whereas here there was continuous presentation but a re-attempt by the patient.

This can be represented schematically as follows:

STIMULUS/TARGET	RESPONSE
A	X (recognized as), X,X... incorrect

An example of this type of error can be seen in Patient PW's (combined group) protocol:

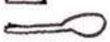
STIMULUS	RESPONSE
	apple, no!.. apple, apple, apple no!

This type of error was seen in combined patients only on this task.

2. Immediate - this referred to the repetition of response, or part of a response, on successive items. In Yamadori's description the original response was correct; however, in the current study this was not necessarily the case. This form can be represented schematically as follows:

STIMULUS/TARGET	RESPONSE
A	A (or X)
B	A (or X)

For example, Patient ZN (Group C) gave the following response:

	STIMULUS	RESPONSE
Item 12.		square
Item 13.		square

and Patient US (Group C) the following:

	STIMULUS	RESPONSE
Item 1.		paind (told square), Shown, plain
Item 2.		plain

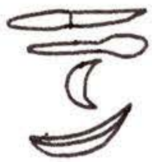
This type of error was seen in frontal, deep and combined groups.

3. Delayed - this referred to the repetition of a response, or part of a response, after one or more other responses had been given. Again, none of the responses were necessarily correct in this sequence (in contrast to Yamadori's definition). This type can be represented as follows:

STIMULUS/TARGET	RESPONSE
A	A (or X)
B	B (or Y)
C	A (or X)

For example, Patient NP (frontal) responded as follows:

STIMULUS



RESPONSE

knife
spoon
moon
knife no! its's not.. a canoe or a banana

and Patient PW (combined):

STIMULUS

RESPONSE

apple, ..apple, apple (stuck) (repeats circle correctly).
square (E queries) oh, well, I'll say it was a ..square (stuck) (repeats cross)
spoon
moon
banana
apple
banana (delayed) ..banana oh! ba.. b.. b.. (stuck) (repeats sun)
banana
apple (delayed) no! cross.

Delayed perseveration was seen in all groups, including normals (see Section 6.2.3).

As the above example illustrates more than one type of error could be seen in the same patient and even in response to a single item i.e. an immediate or delayed perseverative error may then become stuck, or vice versa.

(ii) The Relationship Between the Stimulus or Target Response and the Perseverate.

In a number of cases similarities could be noted between the stimulus and the perseverate that it elicited. In these cases it was usually only this related stimulus that would elicit the particular perseverate, indicating that the connection was not fortuitous. These similarities were classified into four types, listed below in order of frequency:

1. Semantic - where there was a semantic connection between the stimulus (target response) and the perseverate elicited.

e.g.

	STIMULUS/TARGET	RESPONSE
(a)	 (knife)	spoon
(b)	 (cross)	square
(c)	 (sun)	moon

2. Shape - where there was a visual similarity between the current stimulus and the perseverate's original stimulus.

e.g.

	STIMULUS/TARGET	RESPONSE/ORIGINAL STIMULUS
(a)	 (banana)	moon
(b)	 (circle)	apple

3. Colour - this was less clearly a determinant but it is possible that the similarity in colour between, for example, the sun and banana (both yellow), may have elicited the perseverate "banana" when the sun was presented (Patient PW, combined) and vice versa (Patient XN, combined).

4. Prior Association - where a response, having been given to a particular stimulus, even if it is recognized as incorrect, is given again when that stimulus is subsequently re-presented:

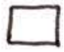
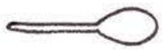
e.g.	STIMULUS/TARGET	RESPONSE
Patient VI (deep)	 (circle)	square..um apple..round..circle
		square..um oh! apple..round.. ..sun, not quite a sun..circle!

(semantic and visual factors can also be seen in this example)

or when a related stimulus is subsequently presented:

	STIMULUS/TARGET	RESPONSE
Patient PW (combined)	 (circle)	apple
	 (circle)	circle
	 (cross)	apple

In some instances no stimulus-perseverate relationship could be readily implicated to account for the particular perseverate elicited. In many of these, temporal factors seemed more important than the stimulus per se (i.e. cases of immediate perseveration),

e.g.	STIMULUS	RESPONSE
(Patient VI)		square
		square

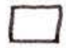
In some cases it took the form of a recurring utterance (stuck perseveration & immediate perseveration) e.g. Patient US (combined) gave responses beginning with P (mostly neologistic) to 55.6 per cent of the stimuli.

In other cases the response appeared to be arbitrarily elicited (less commonly seen):

e.g.	STIMULUS/TARGET	RESPONSE	
(a) Patient PW (combined)	 (knife)	sun	(delayed perseveration)
(b) Patient NP (frontal)	 (banana)	knife	(delayed perseverate)

(iii) <u>The Nature of the Perseverate</u>

All perseverative errors on this task could be classified as <u>perseveration of elements</u> i.e. the repetition of the specific components of a prior response - either the whole response (lexical) or fragments (phonemic) of that response were repeated.

e.g.	STIMULUS	RESPONSE
(a) Patient ZN		square
(combined)		square (lexical)
(b) Patient SD		spoon
(combined)		sp..moon (phonemic)
(c) Patient PW		banana
(combined)		banana (lexical) banana (lexical) oh ba...b....b.. (phonemic)

Perseveration of elements was seen in all groups, including normals. Perseveration of features and of activities were not seen on this task.

(b) READING

(i) The Temporal Relationship Between a Perseverate and its Original Stimulus or Original Execution.

When classified according to this temporal relationship, two types of errors could be found on this task. They were the same as those described on the naming task for the stuck and delayed forms. No immediate perseveration was seen in this sample on the reading task.

1. Stuck - as for naming, this could be represented as:

	STIMULUS	RESPONSE
	A	X (recognized as incorrect) X, X...

e.g.	STIMULUS	RESPONSE
(a) Patient PW	sun	apple..apple.
(combined)		(E queries)..sun!

(b) Patient US (combined)	All items	recurring utterances (neologistic)

This form was seen in the combined group only.

2. Delayed - as for naming, represented by:

	STIMULUS	RESPONSE
	A	A
	B	B
	C	A

e.g.	STIMULUS	RESPONSE
(a) Patient PD	Item 6. Moon	moon
(combined)	Item 7 - 12	All correct
	Item 13. Spoon	moon
(b) Patient IH	Item 14 Sun	sun
(combined)	Items 15 - 17	all correct
	Item 18 Moon	su - moon!

Delayed perseveration was seen in all experimental groups on this task.

(ii) The Relationship Between the Stimulus (Target Response) and the Perseverate.

Two stimulus-perseverate relationships which might account for the particular perseverate elicited were seen on this task:

1. Semantic - as for naming

e.g.	STIMULUS	RESPONSE
(a) Patient IH	moon	su - moon
(b) Patient SD	knife	spoon

2. Orthographic - where the stimulus and perseverate resembled each other in form:

e.g.	STIMULUS	RESPONSE
(a)Patients PS, XN ZX, VI, SD	moon	spoon
(b)Patient WS, PI, PD	spoon	moon

(iii) The Nature of the Perseverate

Most errors could be classified as perseveration of elements, i.e., specific components of a prior response were repeated - either the whole response (lexical) or part of the response (phonemic) was repeated.

e.g.	STIMULUS	RESPONSE
(a)	moon	spoon (lexical)
(b)	moon	su - moon (phonemic)

It is possible that the perseverate "spoon", given when moon was presented on the second trial, represents perseveration of features since the preceding item was "knife"; the repetition of "spoon" may reflect the selection of the most appropriate (orthographically similar) response from the perseverated semantic category of "cutlery". However, since "spoon" had been previously activated it is difficult to clarify the classification of this response as perseveration of elements, features or both.

Patient WN (frontal) continued to read the numbers, although aware this was not part of the task (see page 125). Although classified as an associated error, this could also be considered to be perseveration of activities.

(c) WRITING

(i) The Temporal Relationship Between a Perseverate and its Original Stimulus or Original Execution

The three types of temporal relationships described for the naming task were also seen in the writing task i.e. stuck, immediate and delayed:

1. <u>Stuck</u> - represented as before as:

STIMULUS	RESPONSE
A	X (recognized) X, X... (as incorrect)

e.g. Patient IH (combined)

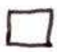
STIMULUS	RESPONSE
	

Stuck perseveration was seen in the frontal and combined groups only.

2. <u>Immediate</u> - represented, as before, as:

STIMULUS	RESPONSE
A	A (or X)
B	A (or X)

e.g. Patient PW (combined)

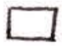
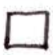
STIMULUS	RESPONSE
	box
E. "write square"	bo..o

Immediate perseveration was seen in the deep and combined groups.

3. <u>Delayed</u> - represented as:

STIMULUS	RESPONSE
A	A (or X)
B	B (or Y)
C	A (or X)

e.g. Patient NO (deep)

STIMULUS	RESPONSE
(1) 	square
(2) 	<u>circle</u>
(3) to (11)	all correct
(12) 	<u>circle</u>

Delayed perseveration was seen in all experimental groups on this task.

4. A fourth type, similar to that described earlier as type I, efferent continuous or hyperkinesia-like motor perseveration, was also seen on the writing task. In this form, rather than a re-attempted response as seen in the stuck type, there appeared to be a failure to inhibit a component within a response.

STIMULUS	RESPONSE
A B C	A B B B C

e.g. Patient WN (frontal)

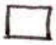
STIMULUS/TARGET	RESPONSE
 (moon)	mooon

This continuous perseveration was seen in the frontal and combined groups only.

(ii) <u>The Relationship Between the Stimulus (Target Response) and the Perseverate.</u>

Most perseverates were <u>semantically</u> related to the stimulus eliciting them

e.g.

STIMULUS	RESPONSE	
 (moon)	sun	(and vice versa)
 (square)	circle	
 (spoon)	knife	

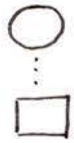
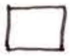
Other errors appeared to be determined by temporal factors (immediate perseveration) rather than the specific stimulus.

(iii) <u>The Nature of the Perseverate.</u>

The three sub-types of perseverative errors described by Goldberg and Tucker could be seen in this task. All errors could be classified under one of these types:

1. <u>Perseveration of Elements</u>

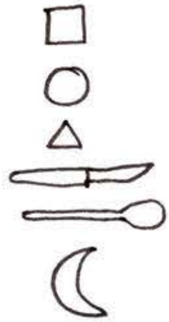
These errors involved the repetition of all or part of a prior response (where each response is terminated appropriately)

e.g.		STIMULUS	RESPONSE
	(a)		circle
			circle
	(b)		box
		square	bo

Perseveration of elements was seen in all experimental groups.

2. Perseveration of Features

Patient PX gave the following response:

STIMULUS	RESPONSE
	ƧGUARE CIRCKLE ZANGE NIFE ƧPONE MONE

Note: When  and  were re-presented on Trial 2 he wrote ƧPOON and MOON.

Although the suffix E could be classified as perseveration of elements in that this component is combined with the target response, it could also be argued that these responses represent perseveration of features in that the "form" of the word is perseverated, while the specific response is altered according to the stimulus.

3. Perseveration of Activities

When Patient PX was given the pen and asked to write the names of the stimuli, he responded to the first item by directly copying the stimulus() rather than writing its name. This may have been due to a comprehension problem, although he did not have difficulty following any other instruction, or it may have reflected the dominance of the immediate stimuli (identity response) over the required non-identity response.

He was re-instructed to write the name which he did:

2bUARE

The instructions were repeated, emphasizing that he should write only (pointing to his written response to □). The next stimulus (○) was presented and named by the patient. He was told to "write circle", to which he responded with both drawing and writing:

STIMULUS	RESPONSE
	 CIRCKLE

The instructions were repeated and all further responses were written only.

It can be argued that, having written 2bUARE the patient understood the task; this was supported by clinical impression and by his subsequent responses. His combined response to the circle could therefore be classified as perseveration of activities i.e. perseveration of the strongly activated copying (drawing) response mode combined with the appropriate written response.

This form of perseveration was only seen in this patient on this task.

(d) DRAWING

(i) The Temporal Relationship Between the Perseverate and its Original Stimulus.

The four types of temporal relationship described for writing were again found in the drawing task.

1. Continuous - the apparent failure to terminate a response

	STIMULUS	RESPONSE
	A	A, A, A
e.g. Patient PS (combined)	sun	

Continuous perseveration was seen in the frontal and combined groups only.

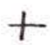
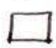
2. <u>Stuck</u> - i.e. the repetition of a response in an attempt to correct it:

	STIMULUS	RESPONSE
	A	X (recognized) X, X.. (as incorrect)
e.g. Patient WN (frontal)	spoon	 

3. <u>Immediate</u> - represented as before:

	STIMULUS	RESPONSE
	A	A (or X)
	B	A (or X)
e.g. Patient US	sun	
(combined)	apple	

Patient PW (combined) demonstrated that the perseverate does not have to be initially executed i.e. that an unexecuted response to a prior stimulus may be given at a subsequent item:

	STIMULUS	RESPONSE
	A	X
	B	A
e.g. Patient PW	square	
	circle	

(both square and circle were correctly drawn on Trial 2)

Immediate perseveration was seen in the frontal and combined groups only.

4. <u>Delayed</u>

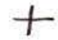
STIMULUS	RESPONSE
A	A
B	B
C	A

e.g. Patient PS	(5) moon	
(Combined)	(6) - (8)	all correct
	(9) sun	
	(10) - (13)	all correct
	(14) sun	

Delayed perseveration was seen in all experimental groups.

(ii) <u>The Relationship Between the Stimulus and the Perseverate</u>

As with the other sequential tasks the most common stimulus - perseverate relationship was a <u>semantic</u> one i.e. a stimulus tended to elicit a semantically-related prior response.

e.g.	STIMULUS	RESPONSE
	(a) moon	
	(b) square	
	(c) knife	

There were also perseverates which appear to be unrelated to the stimulus and to have been determined either by temporal factors (i.e. immediate perseveration) or arbitrarily.

e.g.	STIMULUS	RESPONSE
	sun	

(iii) <u>The Nature of the Perseverate.</u>

The following types of error were observed:

1. <u>Perseveration of Elements</u> - repetition of a response, or part of a response. The response was repeated in full or either combined or blended with components of the target response:

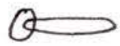
e.g.	STIMULUS	RESPONSE
(a) Patient WN	cross	
(frontal)	sun	
(b) Patient PS	moon	
(combined)	sun	

(c) Patient VI	spoon	
(deep)	banana	
	banana	

Perseveration of elements was seen in all experimental groups on this task.

2. Perseveration of Features.

Patient WN drew the following for "knife" on Trial 1: Subsequently she perseverated on several items, drawing a cross ( ) instead of the sun, square, the sun again, and an apple, with occassional correct responses interspersed. The second trial for "knife" followed "sun" "apple" and "circle" as follows:

STIMULUS	RESPONSE
sun	
apple	
circle	
knife	

In this response to knife there is not the perseveration of the specific graphic components (elements) of the preceding responses but perseveration of the general form of the cross (two components at right angles) together with the closed form of the circle.

Perseveration of features was seen in frontal and combined groups. There were no instances of perseveration of activities.

9.2 Conflict Tasks (Series Reversal, Sorting)

(a) SERIES REVERSAL

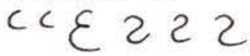
(i) The Temporal Relationship Between a Perseverated Response and its Original Execution.

Perseverated responses on the series reversal tasks showed the same variation in temporal relationships as the sequential tasks.

1. Stuck - this form was seen when an incorrect response was repeated within an attempt to correct it:

A (recognized as incorrect) A, A...

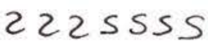
e.g. Patient WN on reversed S:



Patient PW on reversed counting: ...18, 19 no! 19 19 no!

Seen in frontal and combined groups only.

2. Immediate - where a response is repeated successively when a new response is called for: A B B B or A A A A

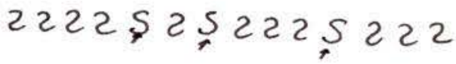
e.g. Patient SD: 

Patient PW: 19, 17, 17

Seen in all groups.

3. Delayed - where a response is repeated after one or more other responses have been given: A B C D ---> A B C A

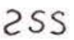
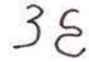
e.g. Patient PW: 20, 19, 18, 19

Patient TX: ...... 

Seen in all groups

(ii) The Nature of the Perseverate

1. Perseveration of Elements

This could take the form of complete repetition e.g.  or the blending of the perseverate and correct response e.g. 
Seen in all groups.

2. Perseveration of Activities

Although classified as an associated error, reflecting the intrusion of an automatic series, it could be argued that the following response from Patient PW represented perseveration of the prior activity of counting forwards:

Counting 1 - 20

Reverse: 20 21 no!

20 22 23 24

Similarly, although an element is repeated, reversion to the forward series rather than reversal may be considered perseveration of activities e.g. Sun, Sat, Fri, Thurs, Wed, Thurs no! Tues, Wed no!
Seen in frontal and combined groups only

(b) SORTING

The nature of this task made it difficult to classify the errors according to the considerations outlined earlier. Failure to recognize the colour principle after sorting the cards in another way is probably best described as "immediate perseveration". All errors reflected difficulty in "letting go" of a strong perceptual set and shifting to a different set, when asked to do so.

9.3 Regulation Tasks (Alternations, Verbal Fluency, 5 Dot Fluency)

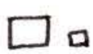
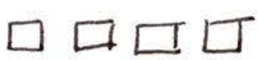
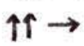
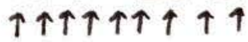
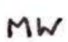
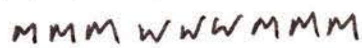
(a) ALTERNATIONS

The following types of errors were seen on the alternation tasks:

(i) Temporal Relationship Between a Perseverated Response and its Original Execution.

1. Continuous
e.g. Patient PD: 
Seen in frontal and combined groups.

2. Stuck/immediate - given that there was only one stimulus the stuck and immediate distinctions made earlier become blurred. In this form the patient repeated an item on successive responses:

e.g.	MODEL	RESPONSE
Patient PW:		
Patient VI:		
Patient WN:		

Seen in all experimental groups.

3. Delayed - where a response is repeated after one or more other responses have been given

e.g. Patient UV: ABCD abCD

Patient VI: ABCD abcD

Seen in all experimental groups.

(ii) Nature of the Perseverate

1. Perseveration of Elements

e.g. Patient WN: m m m w w w m m

Patient VI: ABCD abcD

Seen in all experimental groups.

2. Perseveration of Features

This was seen on the alphabet alternation where the upper case form of the first series is perseverated for the small series i.e. ABCD ABCD

In other words, the case (feature) is perseverated while the size is not.

Seen in frontal and shallow patients.

3. Perseveration of Activities

Although classified as an associated error (intrusion of an automatic response), several patients gave the following response which might be considered as the perseveration of the activity of writing the alphabet: ABCDE or abcde

Seen in all experimental groups.

(b) VERBAL FLUENCY

(i) The Temporal Relationship Between a Perseverated Response and its Original Execution.

1. Stuck - A (recognized as incorrect) A, A

e.g. Patient PX: hero no! her no! her no!
(animals by size)
Seen in frontal and deep groups.

2. Immediate - A A A instead of A B C
e.g. Patient ZN: John ("did I say that already?" E; Yes)
(male-female) John no!

Patient NP: Bandicoot is one
(animals) Bandicoot is another
Seen in all experimental groups

3. Delayed - A B C A
e.g. Patient PX: Fumigate
(F) Feel well
Fumi .. oh no!
Feeling
Fumigate no! I said that!
Seen in all groups, including normals.

(ii) The Nature of the Perseverate

1. Perseveration of Elements

Repetition of a specific response, or fragments thereof:

e.g. (a) John / John no! (b) Fumigate / Fumi ... no!

Seen in all groups, including normals.

2. Perseveration of Features

Although the fragment -"ant" is repeated and the perseveration could therefore be classified as perseveration of elements, the following responses by Patient NP appear to be more a perseveration of the higher level of the form of the word and hence may be thought of as perseveration of features:

animals by alphabet: Cormorant

D....ant (incoherent)

- that's a small animal

Danderant

Granderant - no doesn't fit in!

Hoverant

Similarly his responses to the "S" task show perseveration of the "Italian" sound:- Senolia

Sigmalina

Signora

Signorema

Signorimetta

Isn't it funny I'm going into Italian!

Seen in frontal group only.

3. Perseveration of Activities

This could be seen on the regulation tasks. For example, when instructed to alternate male-female names, the patient may begin correctly but then give a series of female names only.

e.g. Patient NP: Merv

Billi (his wife's name)

Geoff

Bron

Di

Leanne

Leslie

Flora

Dianne

A further example was seen in Patient ZN who completed animals by alphabet and shifted to males and females without difficulty but when beginning the male-female alternation he perseverated the activity of ordering by alphabet: "Allegra is A"

Similarly Patient PS began animals by alphabet correctly but reverted to the activity of animals by size midway through this task (after giving a large animal):

"Ape
Cat
Dog
Emu
Hippo "I'm getting too big too early"
Rhino

Seen in frontal, deep and combined groups.

(c) 5 DOT FLUENCY

(i) The Temporal Relationship Between a Perseverate and its Original Execution.

1. Stuck/immediate i.e. successive repetitions.

e.g. Patient XN drew a row of the same design; others repeated a design once or twice before shifting to a new design.

Patient PD became so "stuck" on her initial design (X) that she abandoned the task after drawing only five designs, including three repetitions of X, stating that "all the rest would be the same! I keep getting X and that's no good."

2. Delayed - where several different designs intervene before a design is repeated e.g. Patient PX (a)=(d)

(a)  (b)  (c)  (d) 

(ii) The Nature of the Perseverate

The scoring system allows only for perseveration of elements i.e. repetition of a design.

9.4 Discussion

In reviewing the literature regarding perseveration it was noted that, although a number of different types of perseverative errors had been distinguished, there had been very limited investigation of these types across tasks or across patients with a variety of diagnoses. The current study attempted to redress this problem. The three frameworks used in previous studies were examined in order to confirm the breakdown of error types previously reported in each and to investigate their generalizability across patients and tasks. The results of these investigations are discussed below for each framework. Since any model of the underlying mechanisms of perseveration must account for such types of errors, the implications of these results for the current model are also discussed.

9.4.1 The Temporal Relationship Between a Perseverate and its Original Stimulus or Original Execution.

One of the earliest distinctions to be made within perseverative errors was that between "efferent," "continuous," "type I," "hyperkinesia-like" perseveration and "intentional," "discontinuous," "type II" perseveration (e.g. Helmick & Berg, 1976; Luria, 1965) (See Section 2.3.2). Efferent or continuous perseveration has been less frequently studied than intentional perseveration in the past. It was noted by Luria (1965) who considered the two types to be associated with frontal lesions that do (efferent) and do not (intentional) extend to the basal ganglia. Goldberg & Tucker (1979) also described this form in frontal patients but did not discuss the basal ganglia involvement. Helmick & Berg (1976), using a mixed "brain-damaged" sample, studied this form in a somewhat more detailed manner, again distinguishing it from the second "intentional" or "repetitious" type. They noted that continuous perseveration occurred significantly less frequently than the repetitious type (although they excluded one subject, with generalized cerebral atrophy, who exhibited a majority of continuous perseverative responses, from this comparison).

The present study also found that continuous perseveration occurred less frequently than the intentional form. Continuous perseveration was noted on only three tasks (writing, drawing and alternations) and was demonstrated only by frontal and combined patients. All patients showing continuous perseveration also showed intentional/type II perseveration, whereas the reverse was not true. Helmick & Berg (1976) also reported that continuous perseveration was always accompanied by "repetitious" perseveration. They further noted that continuous perseveration was the predominant type in the first and third highest perseverators in their group. Examination of the files of the current sample revealed, similarly, that the frontal and combined patients who demonstrated continuous perseveration on more than one task (Patient NP and Patients PW & PD respectively) were amongst the most severe and frequent perseverators (and also showed a high number of associated signs).

In the light of their findings, Helmick & Berg suggested that continuous perseveration was indicative of a more severely disorganized brain than repetitious perseveration. That is, they consider the two types were different levels (one more severe) of the same behaviour, rather than two different behaviours as suggested by Luria (1965). This would be consistent with the finding by Goldberg & Tucker (1979) that, whenever continuous hyperkinesia-like perseveration occurred, it always recovered before any accompanying intentional perseveration.

The current model was developed to account for the second (intentional) type rather than the continuous form. However, if future research confirms these suggestions that continuous perseveration is a more severe form of intentional perseveration, it will be necessary for the model to be able to incorporate this concept. The major distinction between the two forms is the failure to terminate a response (continuous) vs. the failure to select a new response (intentional). The model would be able to account for the above findings if it is assumed that the termination of a response is a relatively automatic task but requires a certain amount of voluntary attention. It would then be likely to withstand certain fluctuations of attentional control but could be disturbed with severe disturbances of the attentional system. In this context, Luria's observation regarding the involvement of the basal ganglia in continuous perseveration may reflect the greater disruption to voluntary attention when two components of the system are damaged (frontal and deep midline) rather than the essentially motor role he ascribed to these deep structures. More detailed consideration of the processes involved during and after the execution of a response (e.g. corollary discharge, peripheral motor mechanisms, response monitoring etc.) will be required in future versions of the model in order to specify the points at which voluntary attention might be most crucial in this final phase of response execution. However, this serves to demonstrate that the model is able to incorporate the findings regarding continuous perseveration at least at this general level.

The second "intention"/"discontinuous"/"repetitious" type of perseverative error has been the subject of more detailed investigation in the past.

Helmick and Berg (1976) noted that this type may occur immediately after the response has been executed (i.e. successive responses) or it may occur after several other, possibly correct, responses have been given. Yamadori (1981) elaborated this observation by distinguishing three sub-types of intentional verbal perseveration in a group of aphasic patients, based on the temporal relationship of the perseverate to the original stimulus i.e. stuck, immediate and delayed. Three very similar types of errors were observed in the current study across a wide variety of tasks and patients. This similarity led to the adoption of the same terminology although some variations from Yamadori's definitions were noted. The primary difference between the definitions was with regard to the first sub-type i.e. the "stuck" perseverative error. In Yamadori's study, (in which verbal repetition was the only task examined) stuck perseveration was defined as occurring if an incorrect response was repeated when the same stimulus was presented again, that is:

A ----------- X

A ----------- X

In the current study "stuck" perseveration referred to the repetition of an incorrect response when the subject was attempting to correct it, that is, the stimulus was present throughout but the subject responded to it again, after recognizing his/her first response was incorrect, that is,

A ------- X, (recognized as incorrect), X, X....

The correct response (or some other response) may or may not be eventually given.

This was distinguished from continuous (hyperkinesia-like) perseveration, discussed above, in which there was a failure to terminate a response. In the stuck type the initial response was completed satisfactorily but was subsequently rejected by the subject who then re-attempted the task. Although aware that the response is incorrect and "intending" to give a different response, the subject was unable to subordinate his/her response to the intention.

The immediate and delayed types were very similar to those described by Yamadori (and by Helmick & Berg (1976) previously). Two features of the present data suggest, however, that Yamadori's definitions were somewhat narrow - probably reflecting the limitations of his task and subject sampling. First, Yamadori stated that in both the immediate and delayed types, a portion of the correct response would be combined with part of the previous (perseverated) response. This blending has been noted elsewhere (Allison & Hurwitz 1967; Goldberg & Tucker, 1979) and was also seen in the current study. However, the findings of the current study demonstrate that the perseverate may be repeated in whole or part without any part of the correct response being given. This was also noted by Allison & Hurwitz (1967) and Goldberg & Tucker (1979). This is consistent with the current model's conceptualization of the production of perseveration. In this model the response given will be composed of the most strongly activated units. It was noted in Section 4.1 that a previously activated response may be the most strongly activated network in working memory when:

(a) there had been insufficient time for significant decay of this network and, by the same token, insufficient time to build up the required strength of activation, conduct the search and/or perform the required operations, for the required response. In this case, the perseverate may appear alone, without the correct response or any portion of it,

and/or

(b) the perseverated network was re-activated, in part or whole, by the presentation of the new stimulus or the activation of the required response. Such re-activation might be due to a direct association with the stimulus (an old, well-established habit or recently formed link) or it may be due to overlap among newly activated networks and the re-activated (previously primed) network (spread of activation). In this case, a blend of the two responses, representing their overlap may appear.

Second, Yamadori (and a number of other authors e.g. Brunner et al., 1982; Ojemann, 1975b) define perseveration of the immediate and delayed type as the repetition of an initially correct response. Indeed, Leicester, Sidman, Stoddard & Mohr (1971) considered such initial success to be a major factor in the response's subsequent repetition. However, the current study found that such initial success was not necessary; that is, an originally incorrect response may become a perseverate, even when the subject is clearly aware that it had not been correct in the first instance. Furthermore, the response may not have been initially executed at all; a response which is clearly associated with a prior stimulus, but was not given in response to that stimulus, may be given in response to a subsequent stimulus. Buckingham, Whitaker & Whitaker (1979) also noted these features and Yamadori recognized the latter possibility but did not include it in his definition. The current study used a broad definition of perseveration which allowed for such variation. Their observation in this study adds weight to previous reports and argues that the broad definition should be adopted in future studies.

Although most error types were seen at least once in each group, general trends could be noted in the data. Table 37 summarizes the results regarding the types of perseverative errors seen in each group. It can be noted that continuous (hyperkinetic or type I) and stuck perseveration were seen most frequently in frontal and combined groups, as were perseveration of features and of activities. Delayed perseveration and perseveration of elements were common in all groups and were the only types seen in the normal subjects.

Table 37. Error Subtype Frequency Across Groups

KEY: ✓, FREQUENT X, INFREQUENT

GROUP / ERROR SUBTYPE	NORMAL	SHALLOW	FRONTAL	COMBINED	DEEP
CONTINUOUS	X	X	✓	✓	X
STUCK	X	X	✓	✓	X
IMMEDIATE	X	X	✓	✓	✓
DELAYED	✓	✓	✓	✓	✓
ELEMENTS	✓	✓	✓	✓	✓
FEATURES	X	X	✓	✓	✓
ACTIVITIES	X	X	✓	✓	✓

These groups comparisons are limited by the small sample size of each group and further research with larger samples is clearly required to confirm such patterns. However, the similarities between frontal, deep and combined groups and between shallow and normal groups seen in these results are consistent with the model's proposals regarding the factors underlying perseveration in each group. This provides further evidence for the proposal investigated in Question 2 (as mentioned in Section 8.2.2).

Although the model predicts this similarity in test profile among certain groups, the specific types of errors that would be seen in each profile was not an a priori prediction of the current study. Hence, post hoc explanations of these findings are required. The Goldberg-Tucker typology is discussed in Section 9.4.3. In order to account for the temporal subtype findings shown in Figure 36 it would be necessary to include a further comparative stage of processing prior to response emission within the model's structure. This would involve a decision as to whether the selected response has been recently emitted and is therefore inappropriate. One way to conceptualize this would be to suggest that a comparison is made between the level of activation of the item and the strength of its association with the situational/contextual network activated by the particular task in the particular setting. It can be assumed that such an association would be formed when an item is attended to in that setting but would, in the absence of further processing, decay with time (this was referred to briefly in the earlier presentation of the model). Hence, items that have been emitted (or attended to and rejected) immediately preceding the current decision would have strong contextual associations and the decision would be an easy one (i.e. require minimum attentional resources). On the other hand, a response which was emitted some time beforehand would have only weak contextual associations, making the decision a more difficult one. (i.e. requiring increased attention to determine their significance). Failure to reject the former item, with strong associations, would result in stuck or immediate perseveration, and suggests severe breakdown in the voluntary attention system (i.e., total failure to monitor contextual associations), whereas failure to reject an item with decayed associations would result in delayed perseveration and could occur with relatively mild disruption of voluntary attention (e.g. failure to allocate sufficient resources for the decision to be made). This would account for the common occurrence of delayed perseveration among all groups but the relative absence of stuck and immediate perseveration in the shallow and normal groups.

Finally, it was noted in Section 7.2.2 that the alternative explanation of perseverative mechanisms forwarded by Hudson (1968) (referred to as Model III in this dissertation) was not directly excluded by the first investigation, although it had been criticized on logical grounds in the earlier review. Further evidence of this model's inadequacy was found in the current investigation:

It was noted that all three temporal subtypes of discontinuous (type II) perseveration (i.e. stuck, immediate and delayed) could be demonstrated by a single patient - both within a task and across tasks. Yamadori (1981) noted these sub-types (or very similar types) of perseverative errors and proposed that the disturbed recall processing model could account for them by assuming that they represented different degrees of severity of the disruption of the inhibitory mechanism in such recall processing. This explanation becomes inadequate when all three forms are demonstrated by a single patient and even within a single task, as found in the current study, since the severity of the damage should be static for a particular subject.

The current model is able to incorporate these findings. In this model the perseverate elicited will depend on a number of factors which influence the strength of activation of various responses. The strongest item may be the immediately preceding response but it may also be a response given earlier which is initially less activated than more recent responses but may be augmented by overlap of networks (spread of activation) with the current stimulus. In the absence (or impairment) of the capacity to voluntarily activate the required response or to block ("gate") the execution of a strong but incorrect response, the strongest item will be given. If this is the immediately preceding response, stuck or immediate perseveration will result. If an earlier, augmented response is strongest, delayed perseveration will result.

9.4.2 The Relationship Between the Stimulus (or Target Response) and the Perseverate Elicited.

In the review of the literature presented earlier it was noted that certain tasks have been noted to elicit perseveration more readily than others. Allison & Hurwitz (1967) pointed to the degree of "automaticity" as an important factor in this context, noting that perseveration increased (and recovery became less rapid) in moving from tasks described as "most automatic" to the "least automatic" (more reflective) tasks. This is clearly consistent with the current model's conceptualization of the underlying mechanisms in perseveration. As discussed earlier, the results of the first investigation again demonstrated that the "least automatic" tasks elicited perseveration most frequently (Table 28). As with previous studies, there was considerable variation across tasks and subjects with regard to the occurrence of perseveration. Perseveration was rarely encountered on all tasks and subjects differed as to which tasks or items elicited a high percentage of perseverative responses.

In addition to noting the tasks which elicited perseveration, the current study investigated the relationship between the particular perseverate given and the item which elicited it. The nature of the test battery meant that this investigation was relevant to the sequential tasks only. Several parameters were noted, although the nature of these tasks determined the opportunity for certain parameters to be involved (e.g. colour was not varied in the reading stimuli - such variations would be of interest in future studies). The most common relationship between the stimulus and the perseverate was a semantic one but it was also occasionally based on similarities in shape (or orthographic features), colour and prior association. In a number of cases there was no apparent relationship between stimulus and perseverate, temporal factors usually appearing to be more important (i.e. successive responses). Clearly the parameters noted do not represent all possible parameters but they are of interest as illustrations of the implications such observations can have for the model or, more particularly, the representation of "knowledge" within this model.

It will be remembered that stored knowledge (long term memory) is viewed in the current model as a system of units or logogens, forming networks of associated units and being organized at various, possibly hierarchical, levels within each network. This conceptualization was based on recent work in the field of normal cognition. As discussed in the preceding section, the selection of a prior response might be due to insufficient time for it to decay and for the alternative response to be activated (together with a failure to reject it on the basis of contextual associations), in which case temporal factors are likely to be of greater importance than the particular stimulus presented. This explains why some perseverates in the current study appeared to bear no relationship to the stimulus. However, a prior response might also be selected because its activation level has been augmented by "spread of activation" among associated networks (i.e. because of interconnections between the stimulus' network and the perseverate's network). Hence, the relationship between the stimulus and the resultant perseverate can provide an insight into the features of the stimuli that are encoded and stored in long term memory, that is, the nature of the informational networks. For example, the current results suggest that stimuli are classified and stored according to more general semantic categories, colour and visual form (orthographic form in the case of written stimuli). That prior association also appeared to result in network connection (giving rise to the spread of activation across networks) points to the manner in which the rich interconnections between networks are continuously built up.

Hence, according to the current model, examination of stimulus - perseverate relationships can reveal the codes by which stimuli are represented in long term memory (and the dynamic nature of the connections among such codes). This is similar to the approach by Goldberg and Tucker (1979) to visual codes, except that they studied the features that were perseverated across responses. Both approaches point to the potential of neuropsychological data for providing information relevant to normal cognition.

9.4.3 The Nature of the Perseverate itself

Goldberg & Tucker (1979) provided a detailed classification of type II (intentional) perseverative errors, describing three sub-types:

1. perseveration of elements

2. perseveration of features, and
3. perseveration of activities

Although this was the most comprehensive analysis of the nature of perseverative errors reported to date, it was based on responses to a graphic task (drawing geometric designs) and a sample of frontal patients only. The current study investigated the application of this typology across a variety of tasks and of patients (frontal and non-frontal).

It was found that all perseverative errors given in the current study could be classified according to the Goldberg-Tucker typology, thus confirming its generalizability across tasks and patients. Perseveration of elements was the most frequent form seen, in which all or part of the actual components of the response were repeated. As noted earlier, the response may be repeated alone or blended with part of the correct response.

Section 9.4.1 discussed the finding that peserveration of elements was common to all groups (including normals) but that perseveration of features and activities were seen only in the frontal, deep and combined groups (see previous Table 36). As with the temporal sub-types it was noted that, although the group similarity was predicted, the particular types seen in each group requires post hoc explanation. This can be provided without changing the model's premises as follows:

Goldberg & Tucker (1979) demonstrated that perseveration of activities, features and elements may reflect impairment at three hierarchical stages of cognitive processing:

1. the general category of information must be addressed (perseveration of activities);
2. the engram describing the appropriate type (or class) of item must be accessed (perseveration of features);
3. specific metrics must be imposed on the engram and it has to be converted into a motor sequence (perseveration of elements).

In terms of the current model these stages of cognitive processing can be viewed as the activation of the appropriate network and then successive activation at each level within the network until the final selection of the specific element(s) is made. It seems reasonable to suggest that the more specific the selection/activation procedure, the greater the requirement for the involvement of voluntary attention. In other words, as the process progresses through these stages there would be an increasing demand for voluntary regulation of attention to avoid error. Hence, one would expect the last stage (imposition of specific metric/selection of specific elements) to be most susceptible to the breakdown of voluntary attention and the first stage (addressing the general category/network) to be affected only when voluntary attention was severely disrupted. This would explain the findings described above, that perseveration of elements was most common and was seen in all groups, whereas perseveration of features and activities were rarely seen in shallow or normal groups but were found in frontal and deep midline groups (those predicted to show severe deficits in voluntary attention).

Although further analysis of the features perseverated on various tasks, as discussed by Goldberg and Tucker for simple visual forms, was not conducted in the current study, the evidence for the generalizability of perseveration of features across tasks suggests that such analysis may be fruitful in the future. Test batteries which focus on a particular response domain (rather than the diverse array of the current battery) may provide further insights into the structure of the long term memory store for each of these domains using both this approach and that discussed in the preceding section.

10. SUMMARY AND CONCLUSIONS

In the first chapter the current dissertation was described as having two primary aims. First, to provide a systematic theoretical model of the mechanisms underlying perseveration and, hence, of the functional roles of the frontal and fronto-limbic systems. Second, to demonstrate how empirical data from neuropsychology can be used by cognitive psychologists to formulate how information is normally processed and organized. The approach to both these aims was based on the assumption that perseveration, and other symptoms of brain pathology, represent the disintegration or dissociation of the components of normal information processing. Under this assumption, a model representing normal processing (and normal brain-behaviour relationships) but which could account for the known characteristics of such pathological behaviour, was developed and empirically explored.

The assumption that brain pathology results in disrupted rather than distorted or rearranged cognition has been common in both neuropsychological and cognitive psychological research in the past. However, the difficulty of "proving" the validity of such an assumption in each case means that such a model must remain a hypothetical construction. The hypothetical nature of the current model has been emphasized throughout. On the other hand, the model's capacity to account for both cognitive psychological findings and neuropsychological data, together with its heuristic value in generating testable hypotheses were considered to justify this approach in an attempt to fulfill the project's aims.

The dissertation was divided into three major parts - a review of the relevant literature; the development of the theoretical model and the presentation of three preliminary investigations of that model:

Having critically reviewed the previous literature regarding perseveration it was noted that a systematic theoretical model of the underlying mechanisms was lacking, although three poorly elaborated post hoc explanations had been forwarded. The review suggested that a more detailed investigation of the role of voluntary and involuntary attention would be worthwhile. This was followed by an examination of the cognitive literature regarding attentional mechanisms and the development of a model to represent the processes regulating voluntary attention to (activation of) mental activity. Integration of established brain-behaviour relationships led to the proposal of a neurocognitive model of such a regulatory system.

This model rests on a "functional systems" view of the brain. That is, it assumes that complex mental activities are not conducted in discrete regions of the brain but involve a system of component processes which are distributed throughout a number of different regions, each component making a different contribution (in parallel or succession) to the final "function". This approach leads naturally to the idea that the function may break down (to a greater or lesser extent) when there is damage to any of these components, although the quality of the resultant "broken" behaviour is likely to differ depending on which component is disturbed or missing. Although such an approach to brain function has become a cornerstone of modern neuropsychological thought (or at least one "school" of such thought), it had not been used, in an a priori fashion, in previous explanations of perseverative behaviour. In other words, discrete regions of the brain (e.g. the frontal lobes, thalamus, basal ganglia, posterior cortex) had been noted previously to give rise to such behaviour but explanations based on the individual "function" of each region were proposed, rather than a consideration of how these regions might work in concert to a common behavioural end.

The current functional systems model was shown to be capable of accounting for the previous findings regarding perseveration. This model was explored empirically through the investigation of three research questions. The questions were posed in general terms, both as a reflection of the preliminary stage of the model's development and in an attempt to collect a large amount of data which might be used in its future refinement.

Methodological problems were discussed and a multiple case study research design was proposed for the first investigation. The second investigation maintained a multiple case analysis approach but incorporated the cases into broad groups to allow general neuroanatomical trends to be explored. The final investigation was a qualitative study of the errors made by the subjects in the first study. Although this allowed maximum flexibility in terms of data analysis, a number of methodological problems remained unresolved. For example, one of the major difficulties encountered was in the investigation of the model's neuroanatomical correlates (Question 2). This was due, in large part, to the inevitable reliance in such research on naturally occurring lesions and, hence, to the paucity of patients with circumscribed lesions limited to the structures of interest (e.g. purely cortical lesions, lesions restricted to a single deep midline structure). This was aggravated by reliance on neuroradiological findings for lesion localization. Although there has been increasing enthusiasm regarding the use of CT scans in brain-behaviour studies recently, and there can be little argument that such techniques have improved the validity and reliability of clinical localization, this enthusiasm appears to have masked the continuing problems of these procedures. It must be remembered that CT scans are a "tool" in the diagnostic armamentarium and are subject to human interpretation (and, consequently, debate). The scans used in the current study were frequently interpreted differently by different neuro-radiologists. The unreliability and subjective factors involved in such interpretations, especially regarding precise structure (or sub-structure) involvement, has rarely been taken into account in neuropsychological studies. Furthermore, the resolution of scans has yet to be refined to the point where all pathology (including small lesions, subtle extensions of infarctions etc.) is likely to be evident. In the absence of post-mortem examinations, these techniques (supplemented with medical history, neurological examination, angiography and surgical exploration where possible) remain our "best available" criteria for lesion localization. However, the probabilistic nature of such criteria should not be forgotten. These lesion locus problems meant that the neuroanatomical investigations of the current study were limited to "general trends" and tentative speculations. Future research with well-documented (preferably by post-mortem) and circumscribed lesions will be required to confirm these trends and extend them to more precise structure specification.

Further examination of laterality differences would also be worthwhile. The current study was biased towards investigation of left hemisphere function, both by the higher number of left hemisphere lesions and the preponderance of verbal tasks in the test battery. These imbalances were taken into consideration in the analysis and discussion of the results, but future research should attempt to avoid such bias. The exploration of laterality differences in the context of this model might serve to provide important insights into the nature of hemispheric asymmetries in general.

Despite these and other, less crucial, methodological problems (discussed in the text), the results of the current investigations provided strong support for the general premises of the model. They also initiated several elaborations to the model in order to incorporate new findings and established a basis for future investigations in a number of directions.

The proposition that a breakdown of the regulation of voluntary attention underlies perseveration in both frontal and non-frontal patients was supported by evidence from a number of converging sources. Furthermore, given the limitations discussed above, the model's neuroanatomical correlates were given tentative support by the findings that nonfrontal patients with deep midline involvement appear to demonstrate signs of such a voluntary attention deficit, whereas those with "shallow" lesions tended to show only "normal" perseverative errors, related to difficulty and fatigue. The possible importance of the lentiform nucleus in attentional regulation was raised and the role of the thalamus (previously the focus of speculation in this area) was questioned.

The study also investigated three classification systems for perseverative errors. The data regarding continuous perseveration in this and previous studies raised the question of it being a more severe form of intentional perseveration, rather than a separate behaviour as previously assumed. The model was able to incorporate this concept at a general level but further consideration of the processes involved in response termination is clearly required. This would be another area of interest for future research.

Three further subtypes related to temporal factors were observed, confirming an earlier report with an aphasic sample but extending the classification to a variety of verbal and non-verbal tasks and across both aphasic and non-aphasic patients. Similarly, an earlier typology of the nature of the perseverate, reported for frontal patients on a graphic task, was confirmed and extended across tasks and patients. The findings regarding group differences in the frequency of occurrence of these various subtypes led to post hoc elaborations of the processes involved in response selection which should be incorporated in future versions of the model. Analyses of the features of the perseverates and the stimulus-perseverate relationships were shown to be potential avenues for the investigation of the structure of semantic long term memory.

These analyses of perseverative error subtypes provide a more comprehensive analysis of such errors than has been reported previously. However, the diverse array of tasks included in the test battery limited the investigation of particular response domains in any depth and the discovery of further subtypes (and/or stimulus-response characteristics) is considered likely in future, more focussed, research. However, the fact that such detailed examination of errors is a rich source for insights into normal cognition was again demonstrated by this aspect of the study.

Although the current model was developed to explain perseveration, it clearly represents a more general paradigm for the investigation of a number of cognitive processes and neuropsychological symptoms. Future investigation of the contribution of disturbances in the regulation of voluntary attention in aphasic, apraxic and amnestic patients, for example, might be able to utilize the model as a theoretical framework.

In conclusion, it has been emphasized throughout that the purpose of a model such as the one forwarded here is not to provide an all-encompassing image of "reality" but to provide a vehicle for the advancement of our knowledge of brain-behaviour relationships in both the normal and brain-damaged populations. It is hoped that this dissertation has served that purpose.

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Appendix 1. Neurological Details Of Each Shallow Patient (Group S):

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1. Patient WS

CT Scan for Pt. WS.

Relevant Information

AGE; 49 Years EDUCATION; Merit (Grade 9) OCCUPATION; Factory Worker

HISTORY; 1977 Beginning of hypertensive history: 1978 - Myocardial infarct and numbness of right arm. 1982 - Presented with one week history of left facial droop, slurred speech, numbness of left face and arm. Some focal fits secondary to stroke.

NEUROLOGICAL EXAMINATION: Increased tone; decreased strength, stereognosis and plantar responses on the left.

CT SCAN REPORT: Right parieto-occipital infarction - posterior parietal and anterior occipital lobe involvement.

NEURO-RADIOLOGIST COMMENTS: Infarct at the parieto-occipital junction on the right. No evidence of left hemisphere involvement. Wedge-shaped infarct involving grey and white matter (corona radiata). Extends to the trigone of the lateral ventricle but no deep structure involvement.

OTHER INVESTIGATIONS: Carotid angiogram: Infarction of right posterior cerebral artery.

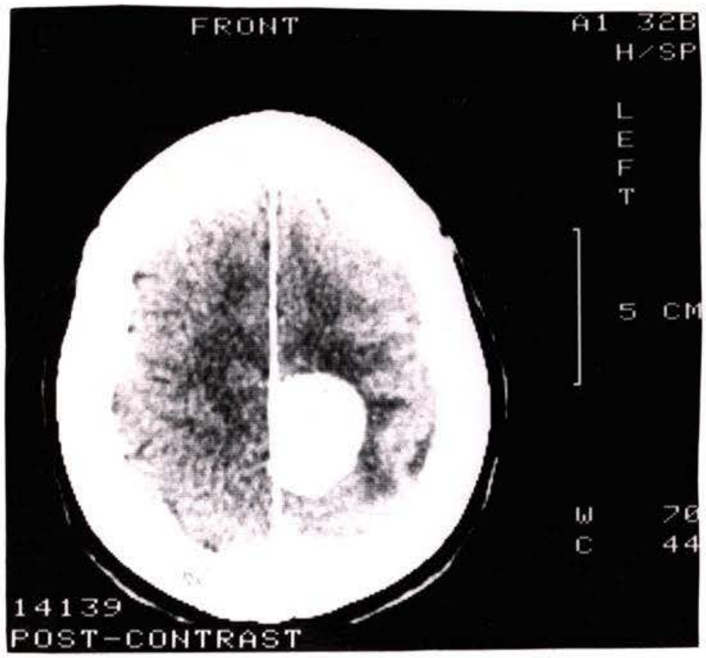
ADMISSION TO CT SCAN: Same day

ADMISSION TO TESTING: 8 weeks

Appendix 1. (cont.) Shallow (cont.)

2. Patient PS

CT Scan for Pt. PS



Relevant Information

AGE: 52 Years EDUCATION: Form 2 (Grade 8) OCCUPATION: Turner for 15 years then army Warrant Officer, Class 2, (20 years) retired.

HISTORY: nil relevant

NEUROLOGICAL EXAMINATION: Mild neurological signs; mild right parasthesia esp. of lower limb; mild upper motor neurone signs on right lower limb.

CT SCAN: Left falcine (parietal)meningioma

ANGIOGRAPHY: A mass lesion is discernable in an anterior parietal location which is superior and parafalcine...........meningioma

NEUROSURGERY: A 5-6 cm diameter meningioma was found at a depth of 5 cms arising from the left side of the falx and projecting into the substance of the parietal lobe. The parietal lobe was retracted from the midline and the entire tumour was removed. A medium-sized branch of the left middle cerebral artery was taken.

POST-SURGICAL: Excellent recovery; no complications, continued parasthesia of right lower limb, especially foot.

SURGERY TO TESTING: 8-10 weeks.

Appendix 1. (cont.) Shallow (cont.)

3. Patient TH

CT Scan for Pt. TH.

Relevant Information

AGE: 33 Years EDUCATION: Form 2 (Grade 8) OCCUPATION: Cleaner (Janitor)

HISTORY: Neurological history; nil relevant. Psychiatric history; anxiety diagnosed as situational reaction with anxiety and prolonged grief (2 years earlier)

CT SCAN: Small haemorrhage in the right parietal lobe.

NEUROLOGICAL COMMENT: Right anterior parietal haematoma superficially placed i.e. high convexity medially situated lesion.

ANGIOGRAPHY: No definite abnormality displayed, some stretching of peripheral anterior cerebral arteries in the medial part of the right parietal lobe anteriorly, consistent with haematoma.

NEUROSURGERY: Evacuation of haematoma in anterior parietal lobe.

SURGERY TO TESTING: 10 weeks

OTHER: Left handed

Appendix 1. (cont.) Shallow (cont.)

4. Patient PI

CT Scan for Pt. PI

Relevant Information

AGE: 83 Years EDUCATION: Grade 7 OCCUPATION: Small goodsman (supervisor) now retired

HISTORY: Ischaemic heart disease, hypertension-controlled on Lanoxin.

CT SCAN: Zone of decreased attenuation in the left occipital lobe consistent with previous infarction.

NEURORADIOLOGIST COMMENT: Left temporal and occipital abnormalities; shallow with no involvement of deep structures. Atrophy consistent with age.

NEUROLOGICAL EXAMINATION: Convergent squint (longstanding) with decreased acuity in left eye and right hemianopia.

ONSET TO SCAN: Same day

ONSET TO TESTING: 5 months

5. Patient YX

CT Scan for Pt. YX

Relevant Information

AGE: 55 years EDUCATION:Form 3, later night school to become Radio Officer Merchant Navy.

OCCUPATION: Clerk now retired

HISTORY: Antero-septal myocardial infarction 1981; ischaemic heart disease; presented with sudden onset "expressive dysphasia"; confusion, falling to right.

NEUROLOGICAL EXAMINATION: Upper motor neuron facial paralysis on the right, otherwise function of upper and lower limbs was normal. Tone normal; power normal, reflexes intact; flexor Babinskis; sensation showed no deficit

CT SCAN: There is an area of reduced attenuation in the left parieto-temporal region extending from the insula to the outer cortex. Conclusion; Infarct in the middle cerebral artery territory with no midline shift.

NEURORADIOLOGIST COMMENT: Extends from insula to parietal cortex but does not penetrate to deep structures.

ANGIOGRAM: Left carotid angiography showed small dilated vessel in the corony sinus with ? plaque formation at the origin of the carotid artery. Mild irregularity at the left common carotid artery consistent with atheroma - unlikely to be haemodynamically significant. Anterior and middle cerebral arteries shared no evidence of irregularity or stenosis. Conclusion: Likely to have had an embolus from recent myocardial infarction. ONSET TO SCAN: Same day ONSET TO TESTING: 12 months

Appendix 1. (cont.) Shallow (cont.)

6. Patient UX

CT Scan for Pt. UX

Relevant Information

AGE: 56 Years EDUCATION: Diploma of Education and Graduate Diploma in Special Education (14 years) OCCUPATION: Retired Special Education Teacher, principal of school for mentally retarded.

HISTORY: Previously N.A.D. except for mild head injury 2 years ago; presented with sudden onset headache, left arm and facial weakness (numbness). Signs extended to lower limb over days prior to surgery.

CT SCAN: A non-contrast study was performed. In the right parietal region there is an elliptical area of increased attenuation surrounded by some oedema. It extends in both grey and white matter. Some sub-falcine shift towards the left. No extra axial collections are identified. No other areas of abnormal attenuation are identified. The site is appropriate for a hypertensive bleed.

NEURORADIOLOGIST COMMENT: Above the level of basal ganglia i.e. peripheral and not involving central grey structures (approx. 40mm depth before lesion disappears).

NEUROSURGERY: Evacuation of left parietal haematoma, with excellent post-surgical recovery.

ONSET TO CT SCAN: 2 days

ONSET TO TESTING: 8 weeks.

Appendix 2. Neurological Details of each Deep Patient (Group D).

1. Patient PX

CT Scan for Pt. PX

Relevant Information

AGE: 57 Years EDUCATION: Form 5 (11 years) OCCUPATION: Builder/Carpenter/ Timber salesman.

HISTORY: Nil relevant prior to presentation with dense left hemi-paresis and severe speech difficulties.

NEUROLOGICAL EXAMINATION: Right upper motor neuron (7th cranial nerve) facial palsy; inability to swallow (8, 9, 10th cranial nerves); tongue deviation to the right (12th nerve); decreased power, increased tone and decreased reflexes on the right upper and lower limbs, some sensory neglect on the right, both limbs.

CT SCAN: Large intracerebral haemorrhage in the region of the left external capsule.

OTHER: Remains densely paretic but regained some power in right limbs. Emotional lability. ONSET TO CT SCAN: 2 days ONSET TO TESTING: 18 months

2. Patient NO

Nuclear Brain Scan Only (no CT scan)

Relevant Information

AGE: 64 Years EDUCATION: 3 years Medical School (interrupted by war)

OCCUPATION: Railway Guard

HISTORY: Previous admission (1980) with severe hypertension, transient weakness of right hand and mild congestive cardiac failure - resolved; hypertensive heart disease with hypoplastic left kidney, diabetes mellitus.

NEUROLOGICAL EXAMINATION: Moderately dense left hemiparesis predominantly involving the upper limb. Left sided upper motor neuron signs. No hemianopia. No sensory loss. Brisk reflexes on right.

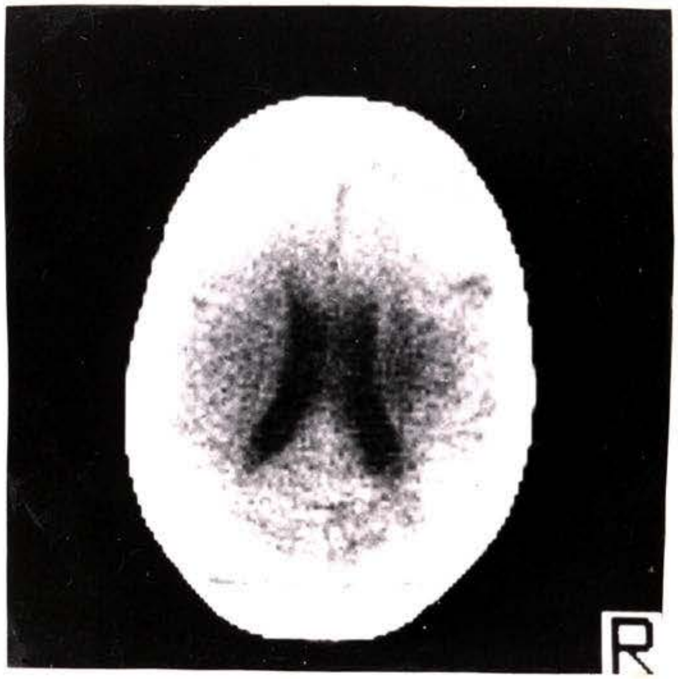
NUCLEAR BRAIN SCAN: Suggested right lacunar infarct of the internal capsule. Anterior circulatory flow was normal.

ONSET TO SCAN: 3 days

ONSET TO TESTING: 18 months

Appendix 2. (cont.) Deep (cont.)

3. Patient XN



CT Scan for Pt. XN

Relevant information

AGE: 54 Years EDUCATION: Grade 8 OCCUPATION: Dry Cleaning Manageress.

HISTORY: Nil relevant

NEUROLOGICAL EXAMINATION: Dense left hemiplegia, incomplete left homonomous hemianopia.

CT SCAN: Ill-defined area of decreased density in the right internal capsule with the appearance of an infarct.

NEURORADIOLOGIST COMMENT: Largely in corona radiata but descends into the internal capsule and lentiform nucleus; no thalamic involvement.

ONSET TO CT SCAN: 21 days

ONSET TO TESTING: 10 months

Appendix 2. (cont.) Deep (cont.)

4. Patient VI

CT Scan for Pt. VI

Relevant Information

AGE: 78 Years EDUCATION: Junior Technical School (left at 16 years)

OCCUPATION: Clerk (retired)

HISTORY: Nil relevant until sudden onset of right sided weakness and expressive speech difficulties.

NEUROLOGICAL EXAMINATION: Right facial palsy (right upper motor neuron, 7th cranial nerve) right upper and lower long track signs but apparantly normal sensation. No hemianopia.

CT SCAN: There is an ill-defined area of reduced attenuation in the region of the genu of the internal capsule. There may be a small amount of mass effect and the appearances are those of a recent infarct. There are similar areas elsewhere mainly in the right occipital lobe and right temporal lobe.

There is no evidence of haemorrhage.

NEURORADIOLOGIST COMMENTS: Right insular and its opercular and left lentiform infarct; minimal atrophy, no frontal involvement.

ONSET TO CT SCAN: ? same day

ONSET TO TESTING: 3.5 months.

Appendix 2. (cont.) Deep (cont.)

6. Patient ZX

CT Scan for Pt. ZX

Relevant Information

AGE: 72 Years EDUCATION: B. Chemistry degree OCCUPATION: Retired engineer

HISTORY: Nil relevant until sudden onset right hemiplegia

NEUROLOGICAL EXAMINATION: Dense right hemiplegia (improved to paresis), hemianesthesia, mild dysarthria, right upper motor neuron 7th nerve palsy, decreased rate of tongue movement.

CT SCAN: Non contrast 10mm slices show an irregular area of haemorrhage in the posterior aspect of the left basal ganglia and the left thalamus. This is surrounded by a poorly defined irregular low density area and causes no mass effect. This is probably a haemorrhagic infarct rather that an intracerebral haemorrhage. The ventricular system appears normal.

NEURORADIOLOGIST COMMENT: Haemorrhage rather than infarct.

ONSET TO CT SCAN: 4 days

ONSET TO TESTING: 4 months

Appendix 3. Neurological Details for each Combined Patient (Group C)

1. Patient PW

CT Scan for Pt. PW

Relevent Information

AGE: 65 Years EDUCATION: Merit (Grade 9) later Grade 12 as adult.

OCCUPATION: Public Servant (Head of Department)

HISTORY: Nil relevant until sudden onset of left C.V.A.

NEUROLOGICAL EXAMINATION: Right hemiplegia and hemianesthesia, right homonymous hemianopia, right 7th upper motor neuron signs and aphasia.

CT SCAN: An extensive area of infarction involving the internal capsule, thalamus, putamen, caudate nucleus and left posterior temporal lobe. No evidence of haemorrhage.

ONSET TO CT SCAN: 6 days

ONSET TO TESTING: 5 months

Appendix 3. (cont.) Combined (cont.)

2. Patient PD

CT Scan not available for publication

Relevant Information

AGE: 66 Years EDUCATION: Grade 6 OCCUPATION: Farmer/housewife

HISTORY: Nil relevant until sudden onset of left hemiplegia with probable hypertensive extension 8 weeks later.

CT SCAN: (i) 2cm area of deceased absorption involving the mid-portion and posterior limb of the right internal capsule. Infarct with no evidence of haemorrhage.

(ii) 8 weeks later extensive area of decreased absorption in the right cerebral hemisphere from the temporal to the posterior parietal region - extensive infarct; slight mass effect with displacement of pineal from right to left of 4mm. Some cerebral oedema in higher cuts (sulci reduced and slight effacement of right lateral ventricle)

ONSET TO SCAN: (i) Same day

(ii) two day after signs of extension

ONSET TO TESTING: 5 months (from extension)

Appendix 3. (cont.) Combined (cont.)

3. Patient ZN

CT Scan for Pt. ZN

Relevant Information

AGE: 81 Years

EDUCATION: Matriculation (Gr. 12)

OCCUPATION: Customs agent (13 yrs), Chief cashier (13 yrs), Manager, Clerk (semi-retired)

HISTORY: Nil relevant until onset of right-sided weakness. Visual impairment: cataract in left eye, glaucoma in right eye. Left parietal meningioma diagnosed and removed prior to testing. Three months after testing he was readmitted with a recurrence and died 2 weeks after second surgery to remove recurrent tumour.

CT SCAN: (i) prior to testing; Contrast enhanced scans demonstrate the presence of a 5cm high density mass within the left parietal lobe. Areas of low density within the mass are consistent with necrosis and areas of low density surrounding the mass represent oedema..........the broad base of the lesion on the skull vault in Section 9 and the mild degree of hypertosis both indicate that this lesion almost certainly represents a meningioma rather than glioma (confirmed at surgery)

(ii) after testing: A 5cm diameter densely enhancing lesion is situated in the posterior parietal region on the left side. It extends from the midline to the surface of the brain, it compresses the posterior hem of the lateral ventricle and has a narrow rim of oedema surrounding it. Midline displaced by 8mm.

NEURORADIOLOGIST COMMENT: Rare malignant meningioma extending to deep structures at the level of the thalamus.

SURG. TO TESTING: 2 months (3 months prior to diagnosis of recurrence)

Appendix 3. (cont.) Combined (cont.)

4. Patient US

CT Scan for Pt. US

Relevant Information

AGE: 72 Years EDUCATION: B.Arts Degree OCCUPATION: Meteorologist

HISTORY: Embolus from heart, secondary to atrial fibrillation.

CT SCAN: Large haemorrhagic infarct in the region of the left middle cerebral artery. Slight compression of ipsilateral ventricle; includes basal ganglia.

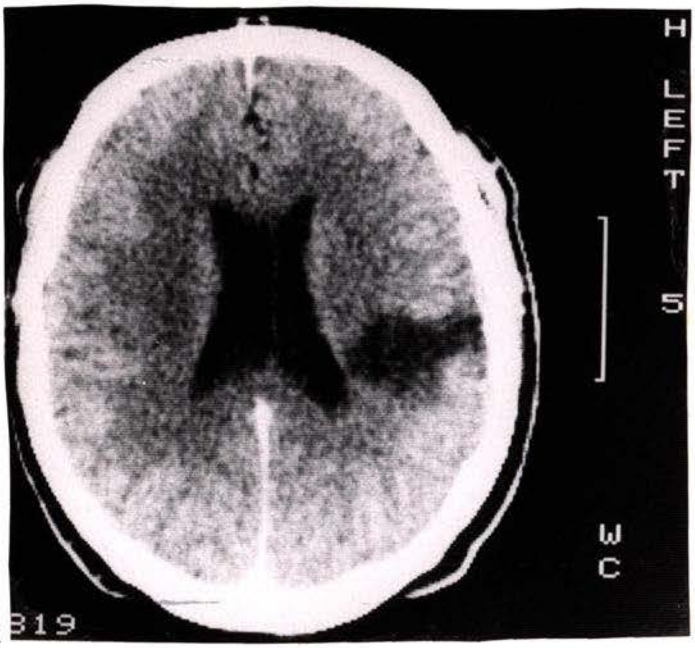
ONSET TO CT SCAN: 1 day

ONSET TO TESTING: 2 years

Appendix 3. (cont.) Combined (cont.)

5. Patient IH

CT Scan for Pt. IH



Relevant Information

AGE: 54 Years EDUCATION: Grade 7 OCCUPATION: Unskilled labourer

HISTORY: Nil relevant until sudden onset of decreased sensation in right hand and foot.

NEUROLOGICAL EXAMINATION: Decreased sensation right hand and foot (aware of pain, unable to localize) decreased proprioception, right hand difficulty discriminating temperature.

CT SCAN: (i) Scans before and after contrast enhancement show loss of definition of the cortical grey matter over the left temporo-parietal region consistent with a recent infarct. The brain appears otherwise normal with no evidence of haemorrhage or evidence of aneurysm seen.

(ii) (7 weeks later, ?extension) There is a relatively large area of decreased absorption value in the left temporo-parietal region, extending from the cortex and also involving a portion of the basal ganglia and also a portion on the internal capsule. Appearances are consistent with the past infarct. Elsewhere the brain and ventricular system show no further abnormality.

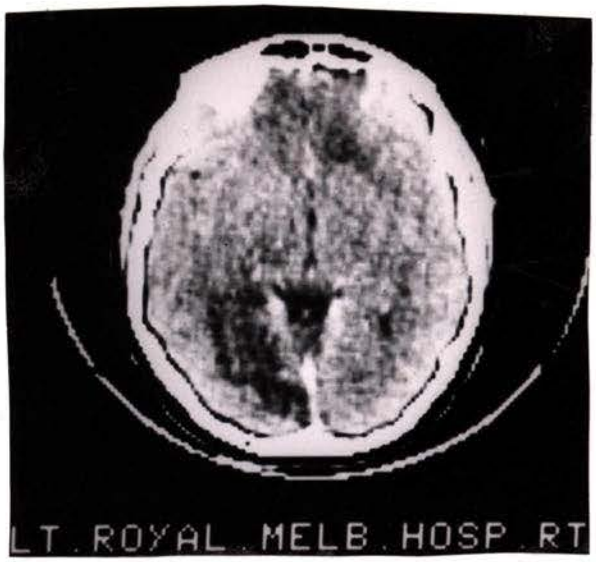
ONSET TO SCAN: ? days

ONSET TO TESTING: 2 months after extension (4 months after initial admission)

Appendix 3. (cont.) Combined (cont.)

6. Patient SD

CT Scan for Pt. SD



Relevant Information

AGE: 52 Years EDUCATION: Grade 8 (incomplete) OCCUPATION: Machine operator

HISTORY: Nil until onset of parasthesia and paresis on the right.

NEUROLOGICAL EXAMINATION: Right homonymous hemianopia; decreased sensation in right arm and leg and ? paresis ($^4/_5$ vs $^5/_5$);

CT SCAN: Parieto-occipital infarct in the region of the posterior cerebral artery.

NEURORADIOLOGIST COMMENT; Extends to include the body of the left thalamus.

ONSET TO SCAN: 10 days

ONSET TO TESTING: 10 weeks

Appendix 4. Neurological Details For Each Frontal Patient (Group F).

1. Patient TX

CT Scan for Pt. TX

Relevant Information

AGE: 42 EDUCATION: Grade 8 OCCUPATION: Unskilled labourer

HISTORY: Head injury

CT REPORT: A shallow convexity collection over the right frontal region (40mm extended to 60mm at second scan one week later). Right ventricle slightly compressed, left hemisphere appears normal. No significant displacement of septum pallidum.

CONCLUSION: Right frontal subdural haematoma.

ONSET TO SCANS: 1 and 2 weeks.

ONSET TO TESTING: 6 months

Appendix 4. (cont.) Frontal (cont.)

2. Patient NP

CT Scan for Pt. NP

Relevant Information

AGE: 62 Years EDUCATION: To 14 years OCCUPATION: Service engineer

CT SCAN: A large left intracerebral haematoma is present in the left frontal lobe. This measures approx. 7cm X 3cm. There is a moderate cuff surrounding oedema and there is considerable mass effect with displacement of the lateral ventricle from left to right and effacement of the frontal horn and portion of the body of the left lateral ventricle due to the considerable mass effect. No other focal intra-cerebral abnormality is demonstrated.

ANGIOGRAM: Aneurysm in the left frontal region, anteriorally and inferomedially situated ...... part of an inferiorally placed dural arterio-venous malformation.

ONSET TO SCAN: 3 days

ONSET TO TESTING: 10 to 14 days

Confirmed at surgery after testing.

Appendix 4. (cont.) Frontal (cont.)

5. Patient ZW

CT Scan for Pt. ZW

Relevant Information

AGE: 57 Years EDUCATION: Intermediate (Gr 10) OCCUPATION: Security guard

HISTORY: Nil relevant until presentation with loss of consciousness

NEUROLOGICAL EXAMINATION: Diplopia, inappropriate comments, confusion and memory difficulty (resolved on steroids)

CT SCAN: Before and after contrast. There is a very large lesion of low attenuation in the right frontal lobe. Postero-medially, in and adjacent to the frontal horn of the lateral ventricle, it shows dense modular and irregular ring enhancement but the bulk of the lesion consists of surrounding oedema. There is a very considerable mass effect. This appearance is typical of a malignant tumour probably glioma of high grade.

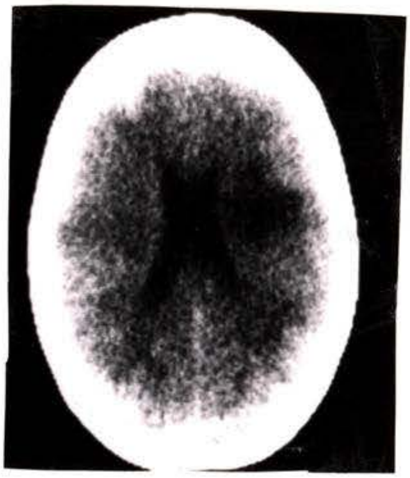
BIOPSY: Grade 3/4 Astrocytoma.

TESTING: Conducted after resolution of confusion with steroids.

Appendix 4. (cont.) Frontal (cont.)

6. Patient XH

CT Scan for Pt. XH



Relevant Information

AGE: 47 Years EDUCATION: to 14 years OCCUPATION: Factory worker

HISTORY: Nil relevant until sudden onset.

NEUROLOGICAL EXAMINATION: Left hemiparesis; arm much greater than leg (flaccid), left neglect; left facial palsy; subarachnoid haematoma.

CT SCAN: Unenhanced scan only. There is a low-density area in the right parietal region at the level of the lateral ventricle. The ventricles are of normal size and midline. There is no high density seen in the subarachnoid space at this examination.

CONCLUSION: Appearances are consistent with a right parietal infarct.

NEURORADIOLOGIST COMMENT: This is posterior frontal rather than parietal.

ANGIOGRAM: A selective injection of the right carotid territory demonstrated a single chambered 10mm X 6mm aneurysm at the bifurcation of the right internal carotid artery. It is arising from the posterior wall of the internal carotid immediately proximal to its bifuracation. A posterior communicating artery aneurysm is demonstrated. Examination had to be discontinued as the patient experienced a transient neurological event whilst an attempt was being made to catheterize the left vertebral artery. This artery is noted to be of very small calibre.

NEUROSURGERY: Clipping of 2 aneurysms via a right fronto-temporal craniotomy. Anterior temporal pole resected for access.

ONSET TO CT SCAN: 10 days SURGERY TO TESTING: 3 months

Appendix 4. (cont.) Frontal (cont.)

7. Patient WN

CT Scan not available for publication

Relevant Information

AGE: 66 Years EDUCATION: Grade 8 OCCUPATION: Technical Assistant (clerical) in Government Dept.

HISTORY: Hypertension for 10-15 years sudden onset of right hemi-paresis mainly of leg, aphasia.

CT SCAN: There is an extensive area of decreased absorption values in the left frontal region, extending from the brain surface and abutting the frontal horn and the lateral ventricle and also those of infarction. Elsewhere the brain and ventricular system appear normal on scans made before and after enhancement. There is no evidence of a space occupying lesion or of a recent haemorrhage.

ONSET TO CT SCAN: 5 days

ONSET TO TESTING: 3 weeks

KEY TO APPENDICES 5 TO 9

L, R, B in corner of subject identification column refers to left, right or bilateral lesion locus respectively.

TEST ABBREVIATIONS:

PURDUE: Purdue Pegboard scores; L=left hand alone, R=right hand alone, B=both hands simultaneously.

ST: Goldstein-Scheerer Stick Test, number of errors shown

MQ: Wechsler Memory Scale Memory Quotient

Imm: Immediate Recall scores for the 2 stories of the logical memory subtest of the W.M.S.

Del: Delayed recall scores for the 2 stories of the logical memory subtest of the W.M.S.

RLT: Rey Auditory-Verbal Learning Test: Recognition score and number of false positives on the Recognition trial (E).

BVR: Benton Visual Retention Test; number of errors.

RM: Raven's Coloured Progressive Matrices: percentile score.

NR: Nelson Adult Reading Test; Estimated I.Q. score equivalent.

BD: W.A.I.S. Block Design age corrected scaled score.

V: W.A.I.S. Vocabulary, age corrected scaled score.

I.Q. Estim: Estimated premorbid I.Q. score range

- DA: Dull-normal/Average
- BN: Bright-Normal
- S: Superior

APPENDIX 5. RESULTS OF EACH NORMAL SUBJECT ON THE "COGNITIVE CHARACTERISTICS" TESTS.

SUBJECT N=11	L	R	B	ST	MQ	Imm	DEL	RLT	BVR	RM	NR	BD	V	I.Q. ESTIM.
TY	15	16.5	10.5	0	-	18 11	14 8	14	0	85	106	15	14	BN
XY	11.5	10	7.5*	0	-	13 9	11 8	14 1E	6	85	114	15	15	BN
TV	15.5	18	14	0	140	17 13	9.5 10	15	0	85	123	13	17	S
TX	15.5	15.5	11	0	111	15.5 12.5	14 10	15	2	90	110	13	13	BN
TQ	15	16.5	12	0	129	16 13	-	15 1E	1	90	104	15	13	BN
NS	15	15.5	12.5	0	132	14.5 16	12 13.5	15	1	100	121	15	16	S
NT	15.5	17	11	0	125	11 9	10 6	14	4	90	120	13	17	S
QZ	19.5	19.5	14.5	0	143	16.5 9	11.5 5.5	12 2E	2	100	119	11	14	BN
XN	15.5	13.5	11	0	143	14 9	9 8.5	15	7	90	124	17	14	S
OK	13.5	15	10	0	140	19.5 13.5	12.5 13.5	15 1E	6	55	125	10	16	S
EO	14.5	15.5	12	0	143	18 11	18.5 11	15	2	90	125	17	13	S

Missing data:

TY, XY, TQ; time limitations and subject fatigue prevented administration of some of the W.M.S subtests.

* XY had arthritis lowering Purdue scores.

APPENDIX 6. RESULTS OF EACH FRONTAL SUBJECT ON THE "COGNITIVE CHARACTERISTICS" TESTS.

SUBJECT N=7	PURDUE L	R	B	ST	MQ	Imm	DEL	RLT	BVR	RM	NR	BD	V	I.Q. ESTIM
TX R	11	9*	7.5	2	100	12 10	11.5 10	13 1E	8	40	99	8	10	DA
NP L	12.5	12.5	8	0	-	7 2	-	7 1E	8	70	112	11	10	BN
UV B	13	11.5	9.5	2	69	5 5.5	7 1.5	14 7E	8	30	-	10	6	DA
VX R	8	12.5	5.5	1	89	6 4	5.5 1.5	10	10	25	114	8	11	BN
ZW R	10	12	8	1	114	12 15.5	8.5 7	12 3E	8	40	115	11	13	BN
XH R	1.5	13.5	1.5	2	106	13.5 10.5	8.5 3	11	10	10	-	7	-	DA
WN L	10	9	7	0	62	2 1	1 0	4	19	40	108	6	8	DA

Missing data:

NP: Time constraints and patient fatigue prevented administrtion of the W.M.S. apart from Immediate recall of Logical Memory stories.

UV: Long standing (familial)dyslexia made administration of N.A.R.T. invalid as estimate of premorbid I.Q.

XH: Native tongue was Dutch, making N.A.R.T. and vocabulary invalid as estimates of premorbid I.Q. (English sufficient for all other tests.)

* TX's right hand was injured.

APPENDIX 7. RESULTS FOR EACH SHALLOW SUBJECT ON THE "COGNITIVE CHATACTERISTICS" TESTS

SUBJECT N=7	PURDUE L	R	B	ST	MQ	Imm	DEL	RLT	BVR	RM	NR	BD	V	I.Q. ESTIM
WS	8	10.5	4.5		68	9	6	13	14	<10	91	7	9	DA
R						5	5							
PS	14	15	12	1	143	17	13	13	4	90	109	12	13	BN
L						14.5	12							
TH	13	14	11	0	98	14	9.5	14	1	70	100	9	10	DA
R						6	5							
PI	9	10	7.5	0	93	8.5		13	9	40	106	15	13	BN
L						5		4E						
YX	13.5	14.5	12	0	143	12	12	13	1	85	122	17	17	S
L						16	10.5							
UX	12.5	16.5	9	0	143	12.5	8.5	14	1	65	124	15	16	S
R						12	9							

APPENDIX 8. RESULTS FOR EACH DEEP SUBJECT ON THE "COGNITIVE CHARACTERISTICS" TESTS

SUBJECT N=6	PURDUE L	R	B	ST	MQ	Imm	DEL	RLT	BVR	RM	NR	BD	V	I.Q. ESTIM.
PX L	11.5	0.5	0	0	73	3 3.5		8 2E	16	50	94	12	8	BN
NO R	8	10.5	6*	0	108	8.5 4	6 3	11	5	65	-	12	11	BN
XN R	0	11.5	0	0	102	13 8	12.5 4	14 1E	10	10	105	10	13	BN
VI B	10	10.5	5.5	1	67				13	<10	107	6	11	BN
QN R	0	14	0	0	116	16 10	9 6	12 1E	6	80	116	11	16	S
ZX L	11	4.5	3.5	0	140	16 10	9 6	15 1E	6	95	117	14	17	S

Missing Data

NO: Native tongue was Polish, English excellent ut N.A.R.T. was considered invalid as an estimate of premorbid I.Q.

* NO had arthiritis, lowering Purdue performance.

APPENDIX 9. RESULTS FOR EACH COMBINED SUBJECT ON THE "COGNITIVE CHARACTERISTICS" TESTS

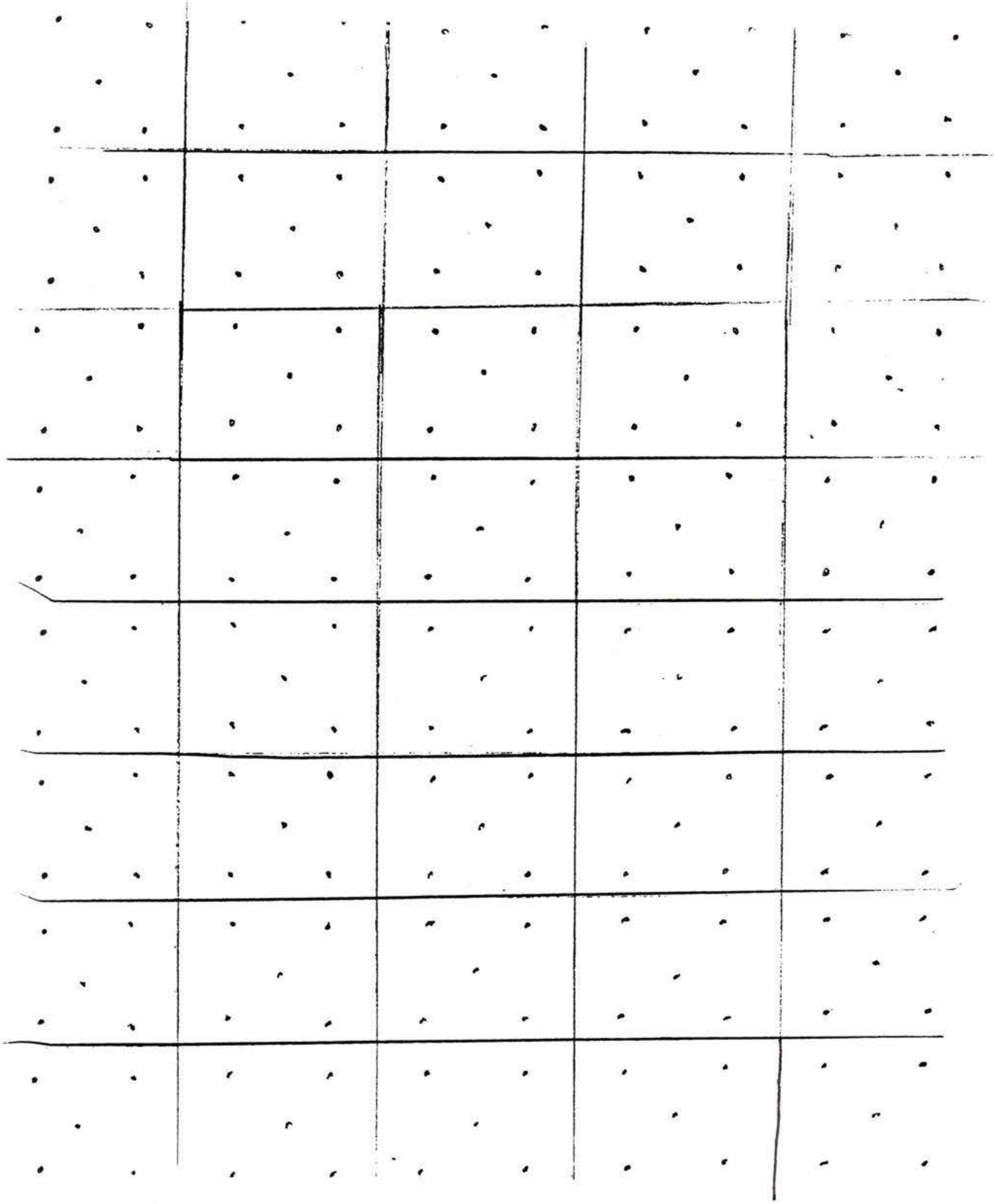
SUBJECT N=6	PURDUE L	R	B	ST	MQ	Imm	DEL	RLT	BVR	RM	NR	BD	V	I.Q. ESTIM.
PW	11	0	0	0	59	1	1	7	12	40	100	8		DA
L						0	0	7E						
PD	0	11	0	3	-	12	8	11		<10	-			DA
R						5	4	1E						
ZN	10	2	0	1	89	11	5	11	9	20	111	-	15	BN
L						1.5	2.5	1E						
US	11	0	0	1					10	<10		8		S
L														
IH	15	13.5	9	0	93	6	6	15	6	75	105	12	11	BN
L						7	5	7E						
SD	13	9.5	7	0	73	2	0	7	12	80		7	10	BN
L						4	0	4E						

Missing Data

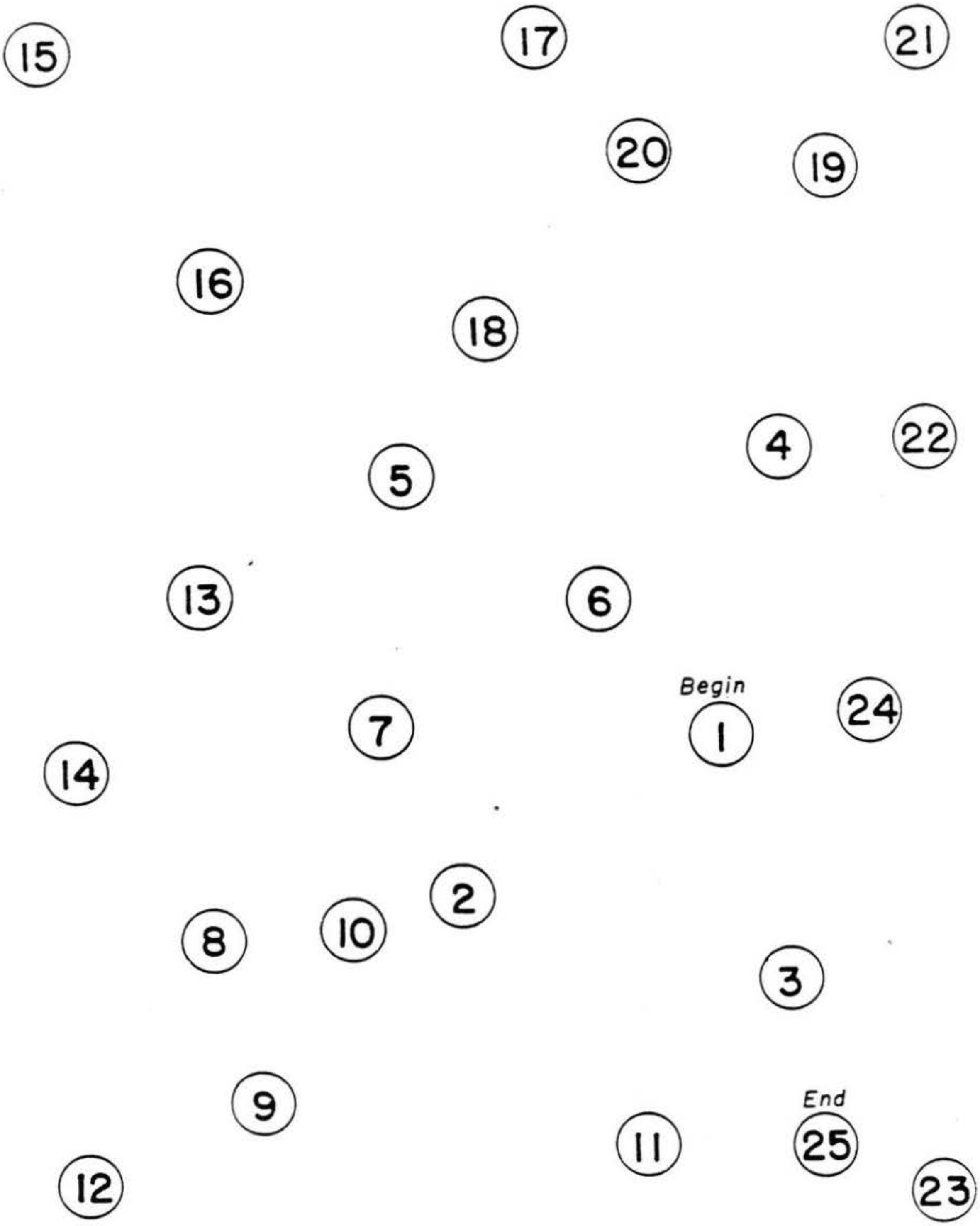
PD: Native language was Dutch; Vocabulary and N.A.R.T. considered invalid as estimates of premorbid I.Q. (English adequate for all other tests) Time limitations and patient fatigue prevented administration of all the W.M.S. subtests and the B.V.R.T.

ZN: Vision too poor for valid performance on Block Design (sufficient for all other tests although scores may be lowered by this factor in some cases)

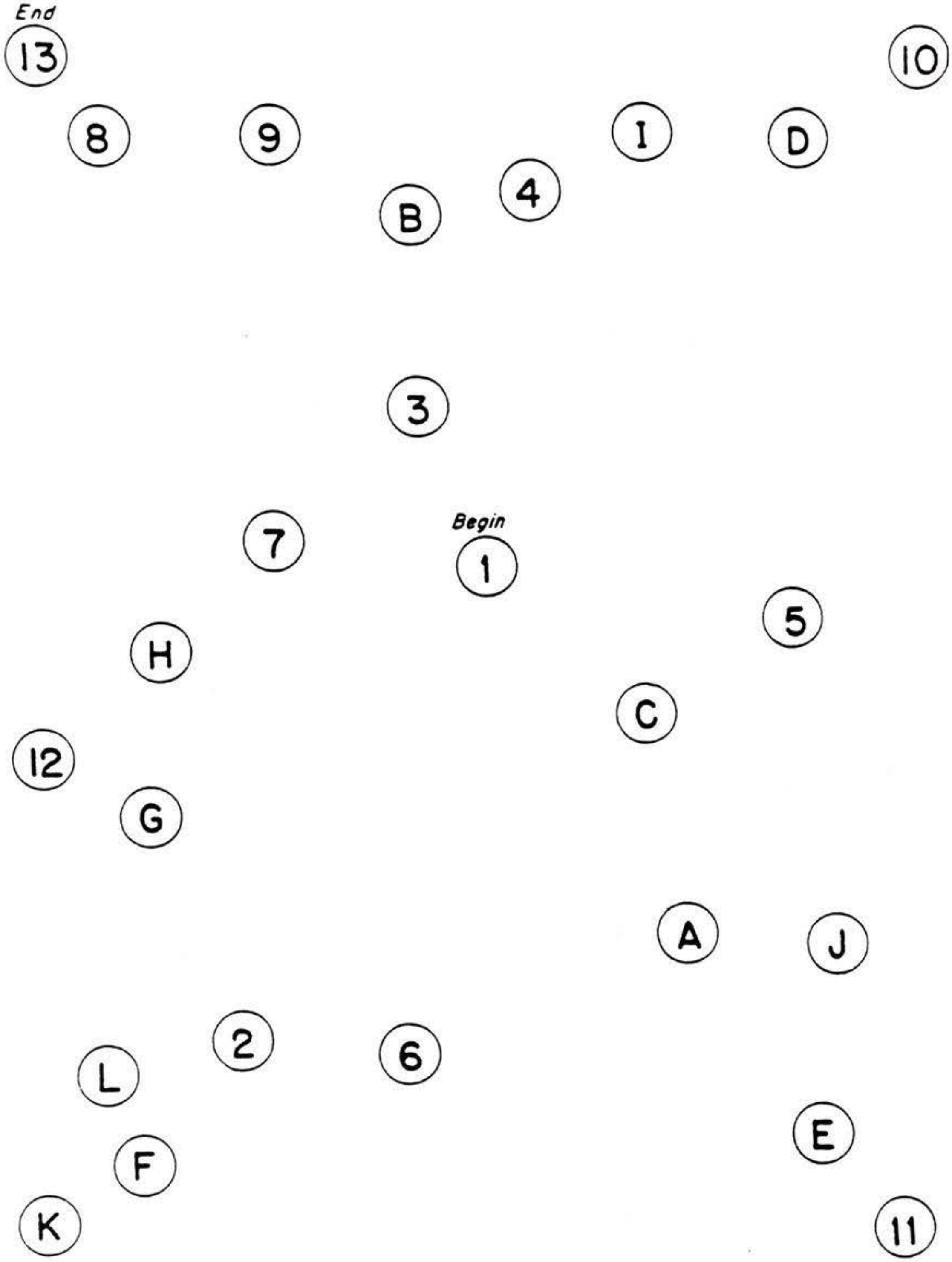
APPENDIX 10. 5 DOT TEST FORM



APPENDIX 11. TRAILS A



APPENDIX 12. TRAILS B



KEY TO APPENDICES 5 TO 9

L, R, B in corner of subject identification column refers to left, right or bilateral lesion locus respectively.

TEST ABBREVIATIONS:

PURDUE: Purdue Pegboard scores; L=left hand alone, R=right hand alone, B=both hands simultaneously.

ST: Goldstein-Scheerer Stick Test, number of errors shown

MQ: Wechsler Memory Scale Memory Quotient

Imm: Immediate Recall scores for the 2 stories of the logical memory subtest of the W.M.S.

Del: Delayed recall scores for the 2 stories of the logical memory subtest of the W.M.S.

RLT: Rey Auditory-Verbal Learning Test: Recognition score and number of false positives on the Recognition trial (E).

BVR: Benton Visual Retention Test; number of errors.

RM: Raven's Coloured Progressive Matrices: percentile score.

NR: Nelson Adult Reading Test; Estimated I.Q. score equivalent.

BD: W.A.I.S. Block Design age corrected scaled score.

V: W.A.I.S. Vocabulary, age corrected scaled score.

I.Q. Estim: Estimated premorbid I.Q. score range
- DA: Dull-normal/Average
- BN: Bright-Normal
- S: Superior

APPENDIX 5. RESULTS OF EACH NORMAL SUBJECT ON THE "COGNITIVE CHARACTERISTICS" TESTS.

SUBJECT N=11	L	R	B	ST	MQ	Imm	DEL	RLT	BVR	RM	NR	BD	V	I.Q. ESTIM.
TY	15	16.5	10.5	0	-	18 11	14 8	14	0	85	106	15	14	BN
XY	11.5	10	7.5*	0	-	13 9	11 8	14 1E	6	85	114	15	15	BN
TV	15.5	18	14	0	140	17 13	9.5 10	15	0	85	123	13	17	S
TX	15.5	15.5	11	0	111	15.5 12.5	14 10	15	2	90	110	13	13	BN
TQ	15	16.5	12	0	129	16 13	-	15 1E	1	90	104	15	13	BN
NS	15	15.5	12.5	0	132	14.5 16	12 13.5	15	1	100	121	15	16	S
NT	15.5	17	11	0	125	11 9	10 6	14	4	90	120	13	17	S
QZ	19.5	19.5	14.5	0	143	16.5 9	11.5 5.5	12 2E	2	100	119	11	14	BN
XN	15.5	13.5	11	0	143	14 9	9 8.5	15	7	90	124	17	14	S
OK	13.5	15	10	0	140	19.5 13.5	12.5 13.5	15 1E	6	55	125	10	16	S
EO	14.5	15.5	12	0	143	18 11	18.5 11	15	2	90	125	17	13	S

Missing data:

TY, XY, TQ; time limitations and subject fatigue prevented administration of some of the W.M.S subtests.

* XY had arthritis lowering Purdue scores.

APPENDIX 6. RESULTS OF EACH FRONTAL SUBJECT ON THE "COGNITIVE CHARACTERISTICS" TESTS.

SUBJECT N=7	PURDUE L	R	B	ST	MQ	Imm	DEL	RLT	BVR	RM	NR	BD	V	I.Q. ESTIM
TX R	11	9*	7.5	2	100	12 10	11.5 10	13 1E	8	40	99	8	10	DA
NP L	12.5	12.5	8	0	-	7 2	-	7 1E	8	70	112	11	10	BN
UV B	13	11.5	9.5	2	69	5 5.5	7 1.5	14 7E	8	30	-	10	6	DA
VX R	8	12.5	5.5	1	89	6 4	5.5 1.5	10	10	25	114	8	11	BN
ZW R	10	12	8	1	114	12 15.5	8.5 7	12 3E	8	40	115	11	13	BN
XH R	1.5	13.5	1.5	2	106	13.5 10.5	8.5 3	11	10	10	-	7	-	DA
WN L	10	9	7	0	62	2 1	1 0	4	19	40	108	6	8	DA

Missing data:

NP: Time constraints and patient fatigue prevented administrtion of the W.M.S. apart from Immediate recall of Logical Memory stories.

UV: Long standing (familial)dyslexia made administration of N.A.R.T. invalid as estimate of premorbid I.Q.

XH: Native tongue was Dutch, making N.A.R.T. and vocabulary invalid as estimates of premorbid I.Q. (English sufficient for all other tests.)

* TX's right hand was injured.

APPENDIX 7. RESULTS FOR EACH SHALLOW SUBJECT ON THE "COGNITIVE CHATACTERISTICS" TESTS

SUBJECT N=7	PURDUE L	R	B	ST	MQ	Imm	DEL	RLT	BVR	RM	NR	BD	V	I.Q. ESTIM
WS	8	10.5	4.5		68	9	6	13	14	<10	91	7	9	DA
R						5	5							
PS	14	15	12	1	143	17	13	13	4	90	109	12	13	BN
L						14.5	12							
TH	13	14	11	0	98	14	9.5	14	1	70	100	9	10	DA
R						6	5							
PI	9	10	7.5	0	93	8.5		13	9	40	106	15	13	BN
L						5		4E						
YX	13.5	14.5	12	0	143	12	12	13	1	85	122	17	17	S
L						16	10.5							
UX	12.5	16.5	9	0	143	12.5	8.5	14	1	65	124	15	16	S
R						12	9							

APPENDIX 8. RESULTS FOR EACH DEEP SUBJECT ON THE "COGNITIVE CHARACTERISTICS" TESTS

SUBJECT N=6	PURDUE L	R	B	ST	MQ	Imm	DEL	RLT	BVR	RM	NR	BD	V	I.Q. ESTIM.
PX L	11.5	0.5	0	0	73	3 3.5		8 2E	16	50	94	12	8	BN
NO R	8	10.5	6*	0	108	8.5 4	6 3	11	5	65	-	12	11	BN
XN R	0	11.5	0	0	102	13 8	12.5 4	14 1E	10	10	105	10	13	BN
VI B	10	10.5	5.5	1	67				13	<10	107	6	11	BN
QN R	0	14	0	0	116	16 10	9 6	12 1E	6	80	116	11	16	S
ZX L	11	4.5	3.5	0	140	16 10	9 6	15 1E	6	95	117	14	17	S

Missing Data

NO: Native tongue was Polish, English excellent ut N.A.R.T. was considered invalid as an estimate of premorbid I.Q.

* NO had arthiritis, lowering Purdue performance.

APPENDIX 9. RESULTS FOR EACH COMBINED SUBJECT ON THE "COGNITIVE CHARACTERISTICS" TESTS

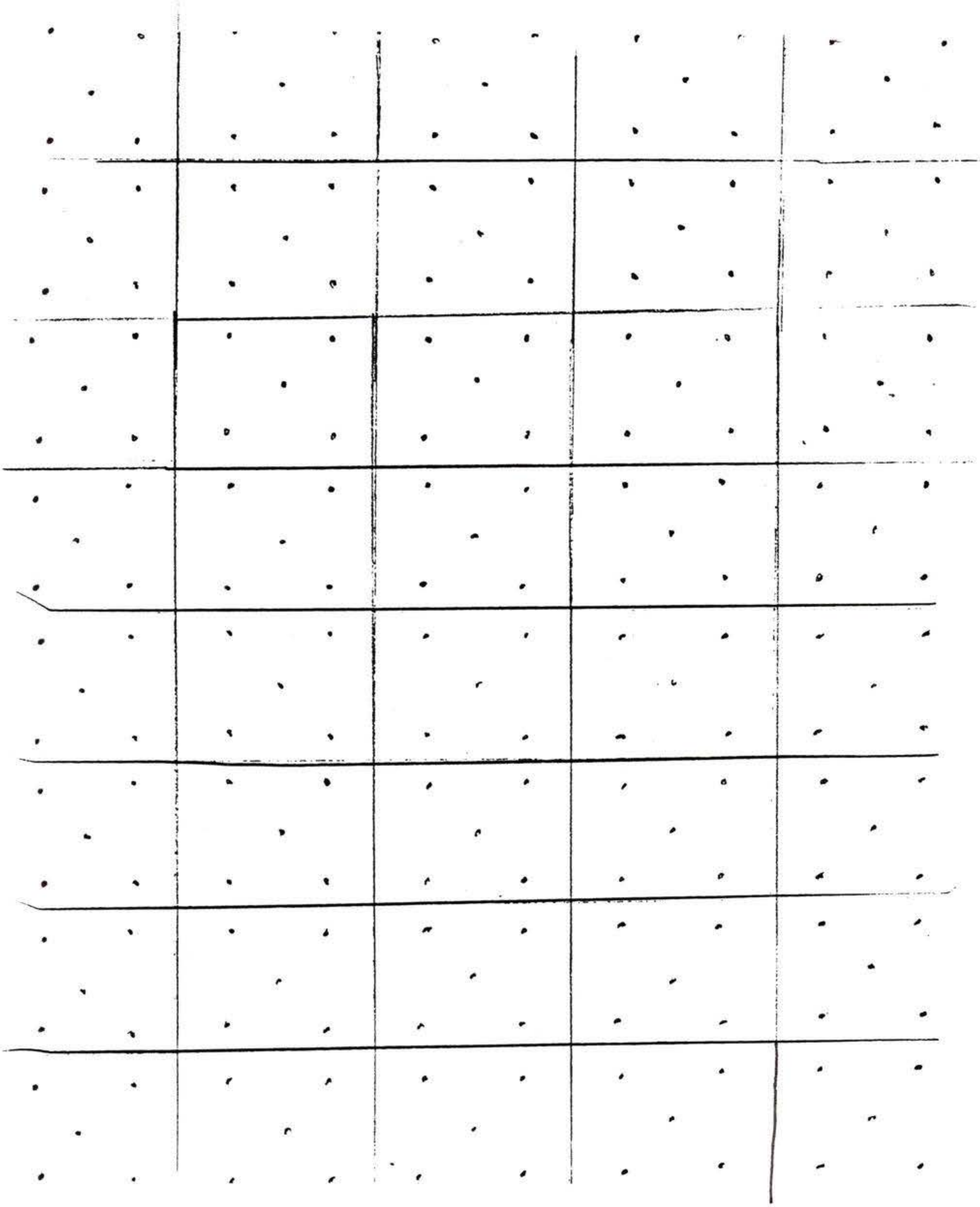
SUBJECT	PURDUE													I.Q.
N=6	L	R	B	ST	MQ	Imm	DEL	RLT	BVR	RM	NR	BD	V	ESTIM.
PW	11	0	0	0	59	1	1	7	12	40	100	8		DA
L						0	0	7E						
PD	0	11	0	3	-	12	8	11		<10	-			DA
R						5	4	1E						
ZN	10	2	0	1	89	11	5	11	9	20	111	-	15	BN
L						1.5	2.5	1E						
US	11	0	0	1					10	<10		8		S
L														
IH	15	13.5	9	0	93	6	6	15	6	75	105	12	11	BN
L						7	5	7E						
SD	13	9.5	7	0	73	2	0	7	12	80		7	10	BN
L						4	0	4E						

Missing Data

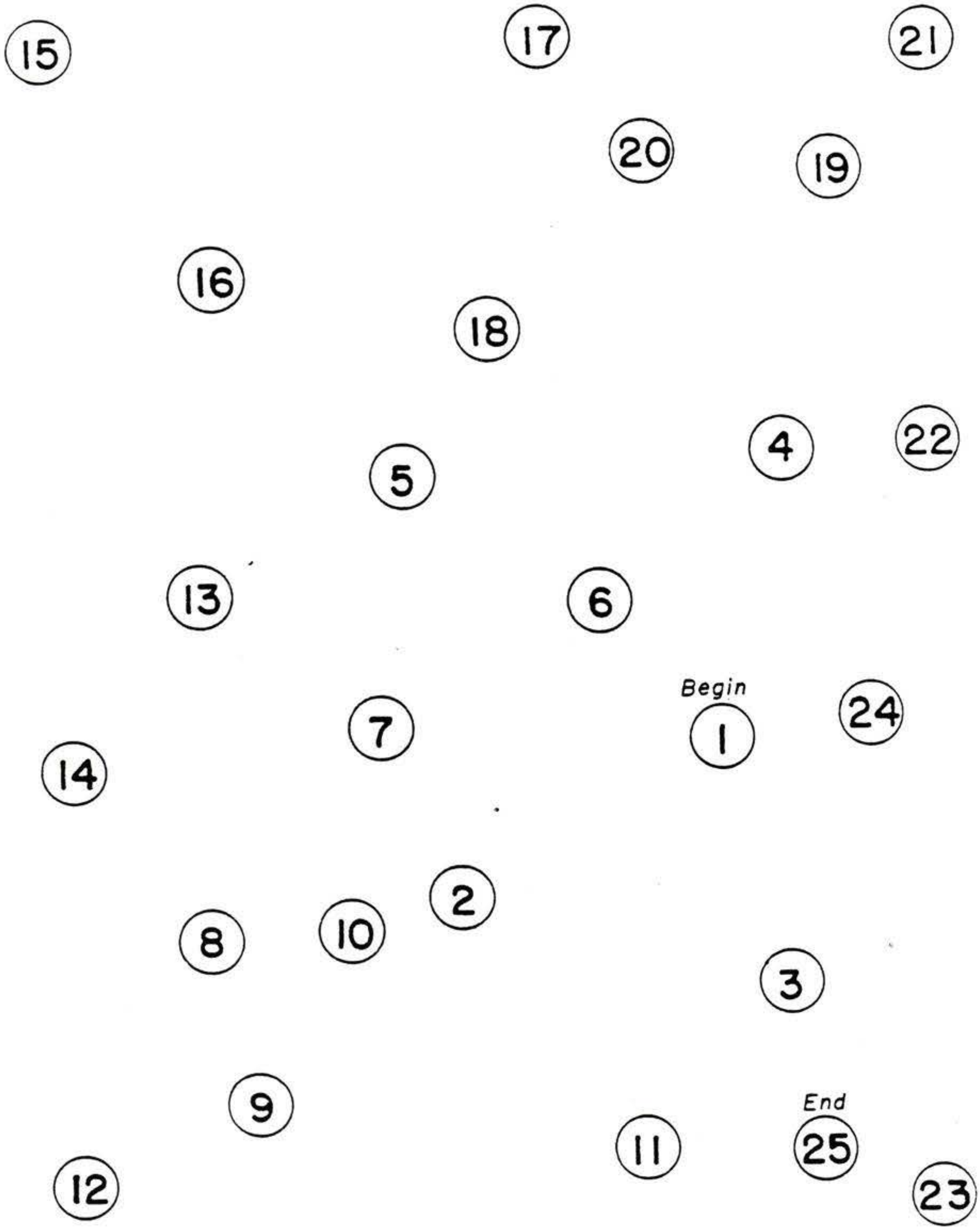
PD: Native language was Dutch; Vocabulary and N.A.R.T. considered invalid as estimates of premorbid I.Q. (English adequate for all other tests) Time limitations and patient fatigue prevented administration of all the W.M.S. subtests and the B.V.R.T.

ZN: Vision too poor for valid performance on Block Design (sufficient for all other tests although scores may be lowered by this factor in some cases)

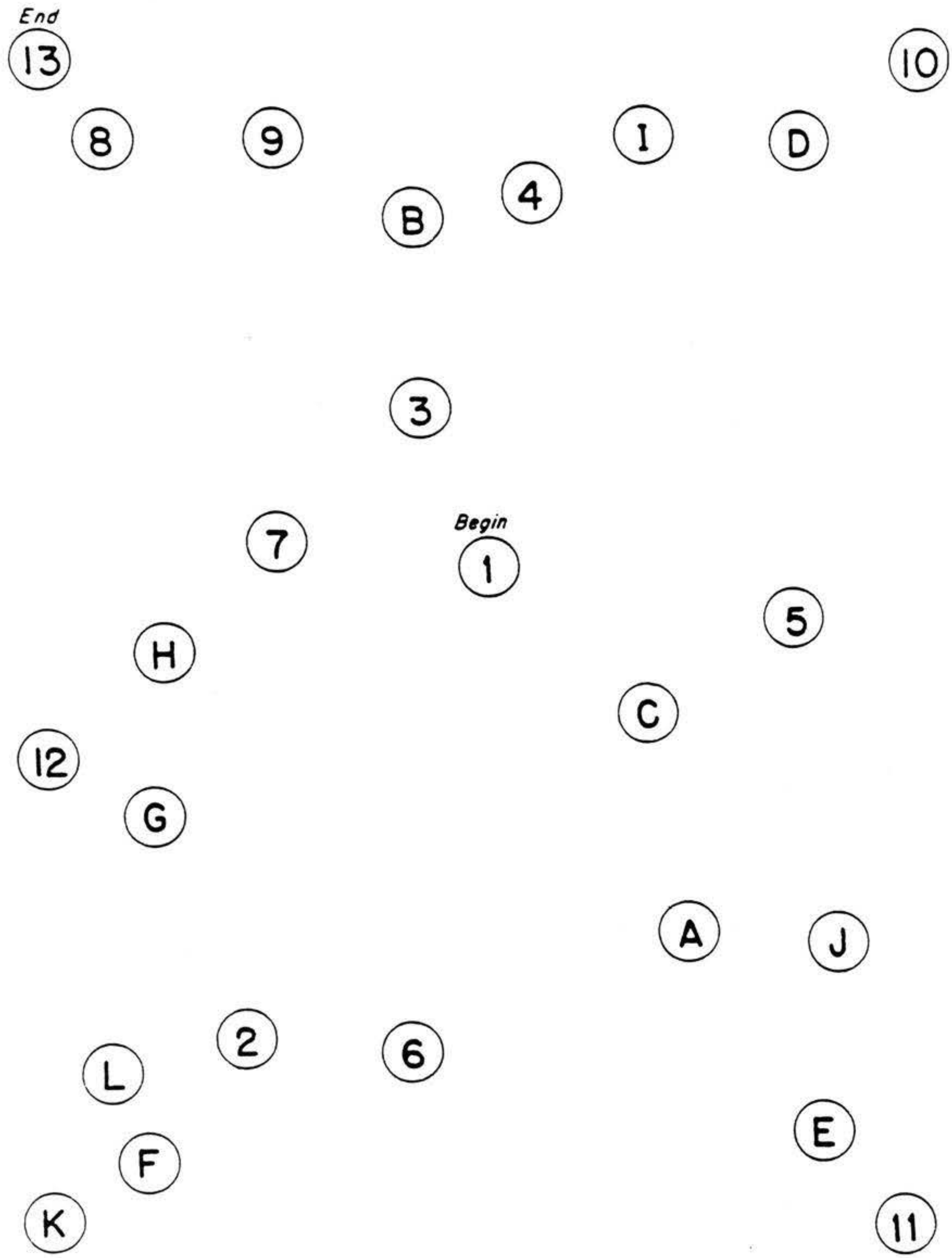
APPENDIX 10. 5 DOT TEST FORM



APPENDIX 11. TRAILS A



APPENDIX 12. TRAILS B



KEY TO APPENDICES 13 TO 17.

L,R,B in corner of subject identification column refers to left, right or bilateral lesion locus respectively.

TEST ABBREVIATIONS:

Sequential Tasks:

- N: Naming
- R: Reading
- W: Writing
- D: Drawing

Conflict Tasks:

- SR: Series Reversal
- SO: Sorting

Regulation Tasks:

- Alt: Alternations
- An: Animals
- Si: Animals by Size
- Al: Animals by Alphabet
- M: Males
- F: Females
- MF: Male-Female
- F:
- A: Control Word Fluency
- S:

For all Verbal Fluency tests the number of correct responses is shown; severely reduced fluency (<5 responses) is shown by an S beside the number of responses.

- 5D: 5 Dot Fluency
- TA: Trails A
- TB: Trails B.

FOR ALL TESTS:

- m: Mild perseveration
- M: Moderate perseveration
- S: Severe perseveration
- A: Associated sign(s)
- diff: Catastrophic factors could not be ruled out.
- /// : Catastrophic factors ruled out; signs of deficit in voluntary attention.

APPENDIX 13. SUMMARY OF TEST PROFILES ON THE "PERSEVERATION BATTERY" FOR THE NORMAL SUBJECTS.

	SEQUENTIAL CONFLICT							REGULATION											
SUBJECTS N=11	N	R	W	D	SR	SO	Alt	An	Si	Al	M	F	MF	F	A	S	5D	TA	TB
TY					m			15	15	13 m	21	16	18	10	6 m~~A~~	11			
XY								21	17	13	16	19	13	12	12	15	m		
TV								31 m	19	17	33	31	34	20	19	22 A			
TX					m			28	18	13	21	20	18	12	7	15			
TQ	m							23 m	14	18	23	20	15 ~~A~~	20 m	9 mA	15 m	m		
NS								26	15	16	29	24	21	17	18	18			
NT								24	14	20	18	18	22 ~~A~~	15 m	14 m	16 m			
QZ								36	14	22	33	29	33	22	15	24			
XN								29	12	15	21	17 m	20	21	19	22	m		
OK								27	19 m	12	17	21	22	18	12	16	m		
EO								19	16 ~~A~~	12	21	27	27	18	19	17	m		

APPENDIX 14. SUMMARY OF TEST PROFILES ON THE "PERSEVERATION BATTERY" FOR THE FRONTAL SUBJECTS.

	SEQUENTIAL CONFLICT								REGULATION										
SUBJECTS N=7	N	R	W	D	SR	SO	Alt	An	Si	Al	M	F	MF	F	A	S	5D	TA	TB
TX R					m	S	M	12	9 A	6	18	12	14	9	13	12	m		
NP L	M		S			S		2S A S	9 A	3S AS	7 M	5S A	4S A	5S A	7 A	S	S		A
UV B	m				m		M m	10	6 A	1S A	9 S	9	5S A M	7 A M	3S A	7 S	S	A	A
VX R		M			M		A	15	6	4S A	9	16	5S A	5S S	5S	4S M	m		A
ZW R	m							15	3S A	8	9	5S	8	7	8	9			A
XH R			M					13	7 M	5S	8 M	14	9	5S	0S	5S	S		A
WN L		A	S	S	S	S diff	S	1S S	5S A diffS	3S A	1S A	2S S	0S	3S S	2S S diff	1S S	S		A

APPENDIX 15. SUMMARY OF TEST PROFILES FOR THE SHALLOW SUBJECTS ON THE "PERSEVERATION BATTERY"

SEQUENTIAL CONFLICT								REGULATION											
SUBJECTS N=6	N	R	W	D	SR	SO	Alt	An	Si	Al	M	F	MF	F	A	S	5D	TA	TB
WS R			~~M~~	M diff	~~S~~	~~S~~	S A diff	10	5S A diff	~~4S~~	11	7	8	~~2S~~	~~2S~~	~~3S~~	S diff	neglect	
PS L		m		~~M~~				17	7 ~~A~~	10	12	16	16	13	9	23			
TH R	m	m						12	10	9	17	13	16	9	7	7	m		
PI L	m	m	~~M~~		~~S~~			14 ~~M~~	10	12	14 ~~M~~	5/16 ~~M~~	12	8 M diff	11	8 S diff	~~M~~	vision too poor	
YX L							~~M~~	20	10	10	16	17	16	9	7	12			
UX R								30	13	13	22	22	22	17	13	22			

APPENDIX 16. SUMMARY OF TEST PROFILES FOR THE DEEP SUBJECTS ON THE "PERSEVERATION BATTERY"

SEQUENTIAL CONFLICT								REGULATION											
SUBJECTS N=6	N	R	W	D	SR	SO	Alt	An	Si	Al	M	F	MF	F	A	S	5D	TA	TB
PX L	M	M	S diff	A		S	M	11 M diff	9 M	5S A_S	9	8	6 M	5S A_S	4S A_M	8 A_M	S		A
NO R			M				m	13	11	7	11	13	13	10	7	7	m		
XN R	m	m						21 M	15 A	9	15	13	12 A	20	13	19	S	neglect	
VI B	S	M	m	S	M diff	S	S	4S	5S A	3S A	4S M ←	4S	4S AS diff	2S	1S	3S →	M	A	A
QN R					m		m	11	10	9	12	10	13 A	11	13	17	m		A
ZX L	m	m					A	17	15	10	20	15	12	19	17	21			

APPENDIX 17. SUMMARY OF TEST PROFILES FOR THE COMBINED SUBJECTS ON THE "PERSEVERATION BATTERY"

SEQUENTIAL CONFLICT								REGULATION											
SUBJECTS N=6	N	R	W	D	SR	SO	Alt	An	Si	Al	M	F	MF	F	A	S	5D	TA	TB
PW	S	M	S	S	S	S	S	3S	4S	0S	5S	4S	3S	0S	0S	2S	S	A	A
L			A					S	A	A	S		A	A					
			diff					←					diff			→			
PD		M		S		S	S	9	8	5S	10	9	6	1S	1S	4S	S	neglect	
R									A	A			A	A	A				diff
ZN	m	m		M		A		10	10	4S	6	8	5S	7	6	4S	M	vision	
L						S		M		A		M	S	M	A			too poor	
US	S	S	S	S	S			←recurring utterances→									M		
L		diff			A					diff								diff	
					diff														
IH	m		S		M	M	m	17	9	6	12	15	12	11	6	7			
L										A	M				S	M			
SD	M	M	M	M			M	10	6	5S	9	11	11	6	1S	4S	S	diff	
L		diff						M		A		M	M	M		S			
								diff											

APPENDIX 18. NUMBER OF PATIENTS IN EACH GROUP SHOWING REFLECTIVE PERSEVERATION AND ASSOCIATED SIGNS ON THE AUTOMATIC NETWORK TASK: ANIMALS. CATASTROPHIC SIGNS SHOWN IN BRACKETS

GROUP	N	PERSEVERATION			ASSOCIATED SIGNS			
		SEVERE	MODERATE	TOTAL%	ERRORS	%	FLUENCY	%
FRONTAL	7	2	0	28.6	1	14.3	2	28.6
SHALLOW	6	0	1	16.7	0	0	0	0
DEEP	6	(1)	1(1)	16.7(33)	0	0	0(1)	0(16.7)
COMBINED	6	(1)	1(1)	16.7(50)	0	0	0(1)	0(16.7)
TOTAL POSTERIOR	18	(2)	3(2)	16.7(27.8)	0	0	0(2)	0(22.2)

APPENDIX 19. NUMBER OF PATIENTS IN EACH GROUP SHOWING REFLECTIVE PERSEVERATION AND ASSOCIATED SIGNS ON THE REGULATION TASK: ANIMALS BY SIZE. CATASTROPHIC SIGNS SHOWN IN BRACKETS

GROUP	N	PERSEVERATION			ASSOCIATED SIGNS			
		SEVERE	MODERATE	TOTAL%	ERRORS	%	FLUENCY	%
FRONTAL	7	(1)	1	14.3(14.3)	4(1)	57(14.3)	2	28.6
SHALLOW	6	0	0	0	1(1)	16.6(16.6)	0(1)	0(16.6)
DEEP	6	0	1	16.7	2	33	0(1)	0(16.6)
COMBINED	6	(1)	0	0(16.7)	2	16.6	0(2)	0 (33)
TOTAL POSTERIOR	18	(1)	1	5.5(5.5)	4(1)	22.2(5.5)	0(4)	0(22.2)

APPENDIX 20. NUMBER OF PATIENTS IN EACH GROUP SHOWING REFLECTIVE PERSEVERATION AND ASSOCIATED SIGNS ON THE REGULATION TASK: ANIMALS BY ALPHABET. CATASTROPHIC SIGNS SHOWN IN BRACKETS

GROUP	N	PERSEVERATION			ASSOCIATED SIGNS			
		SEVERE	MODERATE	TOTAL%	ERRORS	%	FLUENCY	%
FRONTAL	7	1	0	14.3	4	57	5	71.4
SHALLOW	6	0	0	0	0	0	1	16.6
DEEP	6	1	0	16.8	2	33	1(1)	16.6
COMBINED	6	(1)	0	0(16.8)	5	83	3(1)	50
TOTAL POSTERIOR	18	1(1)	0	5.5(5.5)	7	38.9	4(2)	22.2 (11.1)

APPENDIX 21. NUMBER OF PATIENTS IN EACH GROUP SHOWING REFLECTIVE PERSEVERATION AND ASSOCIATED SIGNS ON THE AUTOMATIC NETWORK TASK: MALES. CATASTROPHIC SIGNS SHOWN IN BRACKETS.

GROUP	N	PERSEVERATION			ASSOCIATED SIGNS			
		SEVERE	MODERATE	TOTAL%	ERRORS	%	FLUENCY	%
FRONTAL	7	2	1	42.8	0(1)	0(14.3)	0(1)	0(14.3)
SHALLOW	6	0	1	16.7	0	0	0	0
DEEP	6	0	(1)	0	0	0	0(1)	0(16.7)
COMBINED	6	(2)	1	16.7	0	0	0(1)	0(16.7)
TOTAL POSTERIOR	18	(2)	2(1)	11.1(5.5)	0	0	0(2)	0(11)

APPENDIX 22. NUMBER OF PATIENTS IN EACH GROUP SHOWING REFLECTIVE PERSEVERATION AND ASSOCIATED SIGNS ON THE "AUTOMATIC NETWORK" TASK: FEMALES. CATASTROPHIC SIGNS SHOWN IN BRACKETS.

GROUP	N	PERSEVERATION			ASSOCIATED SIGNS			
		SEVERE	MODERATE	TOTAL%	ERRORS	%	FLUENCY	%
FRONTAL	7	(1)	1	14.3(14.3)	0	0	1(1)	14.3(14.1)
SHALLOW	6	0	1	16.7	0	0	0	0
DEEP	6	0	0	0	0	0	0(1)	0(16.7)
COMBINED	6	(1)	2	33(16.7)	0	0	0(2)	0(33)
TOTAL POSTERIOR	18	(1)	3	16.7(5.5)	0	0	0(3)	0(16.7)

APPENDIX 23. NUMBER OF PATIENTS IN EACH GROUP SHOWING REFLECTIVE PERSEVERATION AND ASSOCIATED SIGNS ON THE REGULATION TASK: MALE-FEMALE. CATASTROPHIC SIGNS SHOWN IN BRACKETS.

GROUP	N	PERSEVERATION			ASSOCIATED SIGNS			
		SEVERE	MODERATE	TOTAL%	ERRORS	%	FLUENCY	%
FRONTAL	7	0	1	14.3	3	42.8	3(1)	42.8
SHALLOW	6	0	0	0	0	0	0	0
DEEP	6	(1)	1	14.3(14.3)	2(1)	33	0(1)	0
COMBINED	6	1	1	33	1	16.6	1(1)	16.6
TOTAL POSTERIOR	18	1(1)	2	16.8(5.5)	3(1)	16.8(5.5)	1(2)	5.5(11.1)

APPENDIX 24. NUMBER OF PATIENTS IN EACH GROUP SHOWING REFLECTIVE PERSEVERATION AND ASSOCIATED SIGNS ON THE REGULATION TASK; F. CATASTROPHIC SIGNS ARE SHOWN IN BRACKETS.

GROUP	N	PERSEVERATION SEVERE	MODERATE	TOTAL%	ASSOCIATED SIGNS ERRORS	%	FLUENCY	%
FRONTAL	7	1(1)	1	28.6	2	28.6	2(1)	16.6
SHALLOW	6	0	(1)	0(16.7)	1	16.7	1(1)	16.6(16.6)
DEEP	6	1	0	16.6	1	16.7	1(1)	16.6(16.6)
COMBINED	6	0(1)	2	33(16.7)	2	33	1(2)	16.6(33)
TOTAL POSTERIOR	18	1(1)	2	16.7(5.5)	3	16.7	2(3)	11(16.7)

APPENDIX 25. NO. OF PATIENTS IN EACH GROUP SHOWING REFLECTIVE PERSEVERATION AND ASSOCIATED SIGNS ON THE REGULATION TASK: A. CATASTROPHIC SIGNS SHOWN IN BRACKETS.

GROUP	N	PERSEVERATION SEVERE	MODERATE	TOTAL%	ASSOCIATED SIGNS ERRORS	%	FLUENCY	%
FRONTAL	7	(1)	0	0(14.3)	2	28.6	3(1)	42.8
SHALLOW	6	0	0	0	0	0	0(1)	0
DEEP	6	0	1	16.7	1	16.7	1(1)	16.6
COMBINED	6	1(1)	1	16.7(16.7)	3	50	2(2)	33
TOTAL POSTERIOR	18	1(1)	1	11(5.5)	4	22.2	3(4)	16.7(22.2)

APPENDIX 26. NUMBER OF PATIENTS IN EACH GROUP SHOWING REFLECTIVE PERSEVERATION AND ASSOCIATED SIGNS ON THE "REGULATION" TASK: S CATASTROPHIC SIGNS SHOWN IN BRACKETS.

GROUP	N	PERSEVERATION SEVERE	MODERATE	TOTAL%	ASSOCIATED SIGNS ERRORS	%	FLUENCY	%
FRONTAL	7	1(1)	1	28.6	1	14.3	2(1)	28.6
SHALLOW	6	0(1)	0	0	0	0	1	16.7
DEEP	6	0	1	16.7	1	16.7	0(1)	0
COMBINED	6	1	1	33	0	0	3(2)	50
TOTAL POSTERIOR	18	1(1)	2	16.7	1	8.3	4(3)	22.2

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1970-1973	Commonwealth Tertiary Scholarship
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1973	Australian Psychological Society Award
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1980-1983	University of Victoria Fellowship.