The Behavioural Assessment of Unilateral Visual Neglect

by Peter W. Halligan

This thesis is submittted to the Council for National Academic Awards (CNAA), in partial fulfilment of the requirements for the degree of Doctor of Philosophy

Oxford Polytechnic

Rivermead Rehabilitation Centre

August 1989

DEDICATION

To my Parents,

Michael and Maureen Halligan.

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Acknowledgements

I should like to express my appreciation to all those who have offered support, advice and encouragement throughout the preparation of this thesis.

I would like to thank my Director of Studies, Dr Roger Lindsay, Principal Lecturer at the Psychology Unit, for his generous help, guidance and advice throughout, and for providing facilities at the Oxford Polytechnic.

I owe a particular debt of gratitude to Dr Barbara Wilson, Director of Rehabilitation Studies, University of Southampton for introducing me to the topic of neglect and for her overall motivating influence on the project.

I was fortunate in having Dr John C. Marshall, Co-Director of the M.R.C. Neuropsychology Unit, University of Oxford, as my clinical supervisor. His enthusiastic discussions and advice at all stages have been invaluable.

I am also grateful to the following:-
Dr. Derick Wade, Consultant Neurologist, for providing access to patients and testing facilities at Rivermead Rehabilitation Centre.

Mrs Janet Cockburn, Research Psychologist, for helpful discussions and advice over the past 4 years.

Dr John Hall, District Psychologist for his advice and support especially in the early stages of the thesis.

Thanks are also due to the patients and control subjects who freely gave their time, and to the Oxford Regional Health Authority and Chest, Heart and Stroke Association for providing financial support.

Declaration

The candidate, Peter Halligan, while registered for the degree of Doctor of Philosophy, was not registered for another award of the C.N.A.A. or of a university during the research programme.

The candidate, Peter Halligan, while registered for the degree of Doctor of Philosophy, completed a course of advanced studies in connection with the programme of research in partial fulfilment of the requirements of the degree.

Peter Halligan August 1989

ABSTRACT

THE BEHAVIOURAL ASSESSMENT OF UNILATERAL VISUAL NEGLECT

PETER W. HALLIGAN

Unilateral spatial neglect is one of the most striking consequences of right-sided brain damage and is characterised by the patient's failure to respond to stimuli on the side contralateral to the cerebral lesion. Visual neglect disrupts many aspects of daily living such as mobility, dressing and reading, yet the underlying mechanisms remain poorly understood. Previous attempts to explain the condition have resulted in a wide variety of terms and test procedures. An adequate theoretical account of neglect requires a data-base that represents the basic patterns of impaired and preserved performance within and between individuals. Despite considerable interest in neglect, no such large scale data-base currently exists. A consideration of the factors and difficulties that contribute to this situation are reviewed in Chapter 2.

The present thesis describes the development, standardisation and validation of a test battery designed to identify a wide variety of neglect behaviours observed in clinical practice. The Behavioural Inattention Test (BIT) which was standardised using a large stroke population (80) is described. Unlike existing studies of visual neglect the BIT relates test results to functional assessment and the rehabilitation of the patient. Using the test battery and normative data from 50 age matched controls, 30 patients were classified as demonstrating neglect. Neglect is more frequent and severe following right rather than left sided lesions. Inter-rater, test-retest, and parallel forms of the test show the neglect battery to be a reliable measure of patient performance. Evidence from factor analysis and correlations with "conventional" and clinical judgments demonstrate the underlying validity of the battery.

Detailed group and single case studies are used to show how results from the test battery contribute and redefine current conceptions of visual neglect. These studies address aspects of visual neglect, such as the effects of line length and hemispatial position in the case of line bisection performance. They also consider vertical dimensions of visual neglect and present evidence to suggest that what is "neglected in visual neglect may still influence patient's judgments and behaviour". It is concluded that recent developments within clinical assessment and cognitive neuropsychology provide a conceptual framework within which to investigate and characterise the condition in a manner that underpins rehabilitation programmes.

Neuropsychological Disorders Following Stroke

Chapter 1

1.1 Introduction

Cerebrovascular accidents (C.V.A.) or strokes remain the third major cause of death in the U.K. (OPCS, 1978) and U.S.A. (Rose, 1986), and the most frequent source of chronic disability, necessitating considerable expenditure both in terms of human and material resources. (Hartunian, Smart and Thompson 1980; Adelman, 1981; Carstairs, 1976). The mortality rate is approximately 35-40% in the first month after stroke. (Langton Hewer, 1982).

Those who survive tend to live, on average another seven years and almost half of these patients exhibit some form of neurological deficit. (Langton Hewer, 1982; Gordon and Diller, 1983). Many patients who survive are left with a wide range of residual disabilities which are related to the extent and location of the brain lesion. Paralysis in the form of hemiplegia has traditionally been regarded as the most disabling consequence. (Gianutsos and Grynbaun, 1983). In addition, those patients with left brain damage tend to manifest communication difficulties. However, many recent rehabilitation studies have come to recognize the significance of what Adams and Hurwitz referred to in their 1963 Lancet article as the "mental barriers to recovery". Such barriers may exert more of a disrupting effect on the patient's life than is often readily apparent. (Isaacs, 1971; Feignenson, McDowell, Meese, McCarthy and Greenberg, 1977; Gianutsos and Grynbaun, 1983; Kinsella and Ford, 1980; Gordon and Diller, 1983; Lorenz and Cancro, 1962; Wade, Wood and Langton Hewer, 1985).

Visuospatial disorders, commonly encountered after right hemisphere strokes have been shown to constitute a substantial component of such barriers. They can operate as critical factors in limiting the effectiveness of rehabilitation often to a greater extent than more obvious motor, sensory and speech deficits. (Isaacs, 1971; Diller and Weinberg, 1977; Ratcliff, 1980; Taylor, Schaeffer, Blumenthal and Grisel, 1971; Bechlinger and Tallis, 1986).

One particularly debilitating consequence of right hemisphere stroke is unilateral spatial neglect. "Visual neglect" or "hemi-inattention" are terms commonly used within neurology to describe the constellation of related spatial disorders, whereby the patient fails to

> "... report, respond or orient to stimuli presented to the side contralateral to a cerebral lesion" (Heilman, 1979).

In such patients, unawareness of the deficit, often appears to be a central feature of the condition. These patients often believe that they have an appropriate representation of their environment, and consequently problems of denial and/or minimization emerge. (Gordon and Diller, 1983).

Despite constituting one of the most striking phenomenon associated with right hemisphere damage, the condition has tended to remain relatively obscure within clinical neurology and has only recently began to attract the attention of psychologists. (Kinsbourne, 1977; Diller and Weinberg, 1977; Riddoch and Humphreys, 1983; Gianutsos, Glosser, Elbaum and Vroman, 1983; Posner, Walker, Friedrick and Rafal, 1984).

At present the use of simple visuomotor tasks to assess visual neglect are primarily concerned with issues of detection and lateralization.

However, given the growing awareness of the need for relevant neuropsychological assessments in current medical rehabilitation (Costa, 1983; Diller and Gordon, 1981; Caplan, 1982) and the need to develop more ecologically valid measures within neuropsychology. (Powell, 1981, Miller, 1985; Sundet, Finset and Reinvang, 1988), it is surprising that as yet no standardized test exists which permits an assessment of visual neglect with some degree of "real world" relevance. (Caplan, 1987).

Traditional medical and neuropsychological diagnoses have tended to offer a conceptual framework which was primarily directed towards delineating the major structural impairments involved. However, the current emphasis on functional components attempts to bridge the gap between theory and practise by addressing the issues posed by the "disability rather than the disease". (Diller and Gordon, 1981; Diller, 1987; Heaton and Pendleton, 1981; Golden, 1978; Walsh, 1978; Ben-Yishay and Diller, 1981; Hart and Hayden, 1986; Gordon and Diller, 1983).

The present thesis develops a short set of behavioural tasks, based on clinical findings, which should be capable of facilitating therapy by adumbrating the functional difficulties found on a selection of daily activities.

A major concern of the early chapters will be to provide a description of the main features of visual neglect, within a sufficiently broad clinical and theoretical framework. As the assessment and rehabilitation of visual neglect is commonly associated with stroke, a logical starting point is a brief consideration of the structure and pathology of the cerebrovascular system.

1.2 Stroke

The importance of understanding the basic rudiments of cerebral circulation disorders has been stressed by Walsh (1978) who points out that while they remain the single most common cause of lesion in the brain, they have often received insufficient attention from neuropsychologists. Furthermore,

> "in no other area of brain impairment are neuropsychological deficits so likely to be overlooked or underestimated than in cerebrovascular disorders where striking neurological disorders such as hemiplegia capture the attention of clinicans, yet a full appreciation of these disorders of higher function may play a vital role in determining the success or otherwise of management and rehabilitation." (Walsh, 1985)

A technical description of cerebral circulation and its vicissitudes is beyond the scope of this thesis. However, this section will provide a general outline of some of the structural, pathophysiological and rehabilitational features, relevant to stroke management.

The term "stroke" in the sense of cerebral infarct was first cited in 1599 to describe what the early Greeks had come to regard as a sudden inexplicable paralysis by a supernatural power (Dirckx, 1986). It was not until the mid - 17th century that autopsy findings indicated vascular insufficiency as the probable cause. (Licht, 1973).

While "stroke" describes one of the well known disorders of the nervous system, it is not primarily a neurological disease, but one in which nervous tissue is damaged as a result of a disruption of the blood transporting vessels (Pansky and Allen, 1980). The term "stroke" may be generally applied to any disorder of brain functioning that results from vascular pathology lasting more than 24 hours. (Wade et al, 1985). It consists of the abrupt development of a focal neurological deficit, whose origin can be traced to either an occlusion of a cerebral artery or the spontaneous rupture of an intercranial vessel with subsequent haemorrhage. The condition is commonly associated with atherosleros is, where atheromas plaques develop at certain vunerable sites in the cerebral vasculature and appear to insidiously reduce the cross-sectional size of the arterial flow thereby increasing the chance of occlusion.

Blood Supply to the Brain

The blood supplying the brain originates from lateralized pairs of vertebral and internal carotid arteries. The respective internal carotid arteries divide into two branches, the large middle cerebral artery and the smaller anterior cerebral artery. The single basilar artery formed by the two vertebral arteries supplies the brain stem and cerebellum before terminating in the inferior surfaces of the cerebrum. The surface branches of the anterior cerebral artery supply the cortex and white matter of the inferior frontal lobes and the medial surface of the frontal and parietal lobes.

The large surface tributaries of the middle cerebral arteries, account for over 75% of total blood flow to the hemispheres, as it irrigates most of the cerebral cortex and white matter of the frontal,parietal and temporal lobes, together with the deep penetrating branches of the lower diencephalic structures. Whilst these vascular territories represent the dominant patterns of vascularization, they do not account for much of the individual variation and overlapping that occurs between arterial tree supplies (Damasio, 1983).

Unlike other organs of the body which require varying albeit smaller amounts of oxygenated blood, the normal adult brain requires almost 20% of cardiac output. The brain employs oxygen in the metabolism of glucose and because of its limited storage capacity, disturbances in cerebral blood flow can easily compromize the metabolic process underlying neural functioning. This peculiar sensitivity to cerebral blood flow together with the respective arterial territories involved, provides the framework for the variety of clinical patterns commonly associated with stroke (Walsh, 1978).

1.3 The Nature of Vascular Disruption

In the case of major stroke, a serious diminution of blood supply whether as a result of an infarct or haemorrage can result in the failure of autoregulation in the focal area involved. This results in a cascade of biochemical changes leading to cellular necrosis and various behavioural manifestations commonly associated with acute stroke (Barnath, Stein, Mohr, and Yatsu, 1986). The extent of the brain damage is determined largely by the residual perfusion, collateral circulation, the territory of ischema and the duration of flow reduction. (Olser, 1986).

The vast majority of strokes result from thrombo-embolic infarctions.

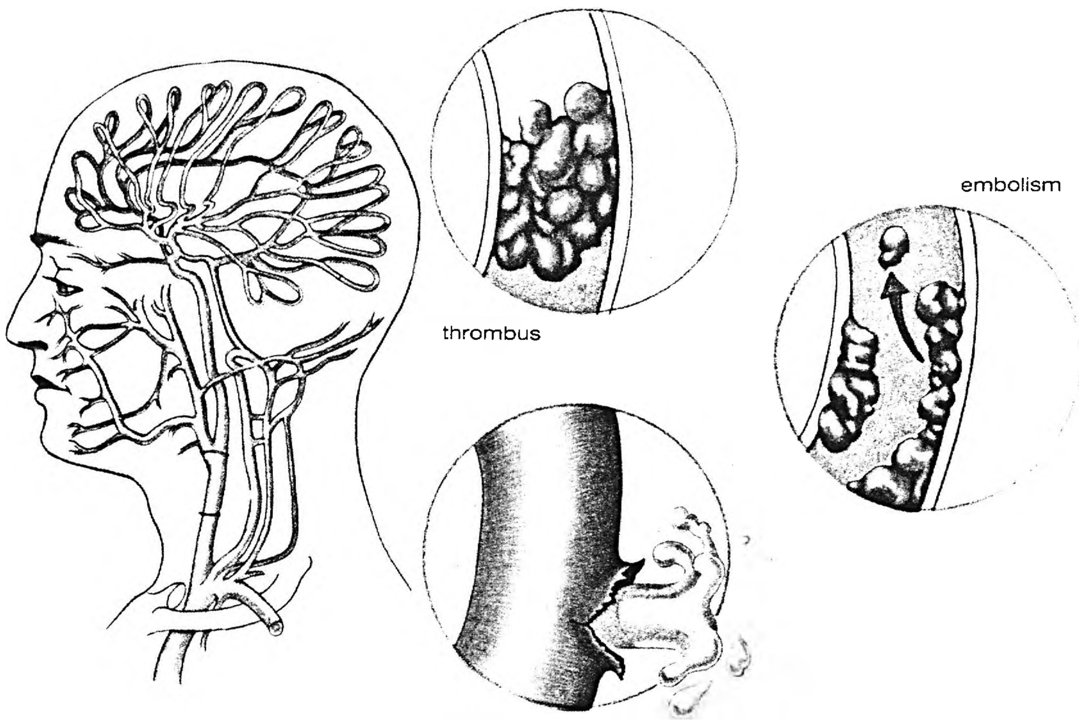


Fig 1.0 Common causes of Stroke

Brain infarction refers to the localized destruction of brain tissue, whereby as a result of severe and prolonged ischemia, neurons and other cerebral cellular elements die. As the brain has limited reserves of glucose and oxygen, and since its metabolic output is high, insufficient blood nutrients or ischemia for over 10 seconds results in the diminution of electrical activity and interneural communication. Metabolic studies have shown a rapid decrease of high energy intermediatories and a move towards the reduction of mitochondrial respiratory chain metabolites (Barnett, Stein, Mohr and Yatsu, 1986). After 30 seconds the sodium pump begins to fail. Within 60 seconds glucose and glycogen concentrates are severely reduced, while other more potentially toxic metabolites such as lactic acid continue to rise.

Recent evidence by Olser (1986) suggests that in the case of middle cerebral artery infarcts, occlusions may be tolerated up to 30 minutes without the onset of permanent tissue damage.

> "It is generally agreed that the triggering factor which eventually leads to irreversible damage is the rapid and severe depletion of cerebral energy metabolites". (Barnett, Stein, Muir and Yatsu, 1986)

After irreversible damage, the membranes burst releasing their contents, which in turn produce and magnify the effect on surrounding cell systems. During the acute phase, secondary diffuse effects due to oedema and other physiological reactions often contribute symptoms of widespread brain pathology (Lezak, 1983). The resulting oedema, by increasing intercranial pressure, can cause more diffuse damage than the stroke itself and may result in death (Olser, 1986). Research into the pathophysiology of stroke has been facilitated by a number of innovative techniques.

Since the mid-seventies, it has been possible using computer axial tomography to visualize the extent and location of the structural components underlying the lesion. However, like the angiogram, and isotope scan, the C.A.T. scan only provides an outline of the structural area that is abnormal at the time of screening on the basis of differential tissue densities. (Sandercock, Molyneux, and Warlow, 1985). Recent publications indicate that such scans can fail to show any discernable abnormality in approximately 20-40% of acute stroke presentations (Wade, Langton Hewer, Skilbeck and David, 1985).

1.4 Clinical Presentation and Rehabilitation

Despite the increasing availability of new imaging techniques, the diagnosis of stroke is "essentially and certainly initially", clinical (Wade et al, 1985). The clinical presentation of stroke varies, and depends upon the extent and nature of the underlying pathology. It is typically diagnosed on the basis of clinical history and neurological examination. The importance of the former is highlighted by Allen's study (1983) which showed that the rate of false positive identifications in a large group of admitted patients rose as a function of the fall off in the quality of the clinical history.

The reported incidence of stroke is thought to vary between 150/200 per 100,000 per year, as compared with 500/100,000 for myocardial infarction. (Aho, Harmsen, Hatano, Marquartsen, Smirnov, and Strasser, 1980). However, as stroke is predominantly a disease of the elderly, it is not surprising that the relevant incidence rates rise from 60-180/100,000 for the 45-54 year old group to 4000/100,000 at the age of 85+ (Wade et al, 1985). Cf. Table 1.1 Oxfordshire Community Stroke Study (Warlow, 1983).

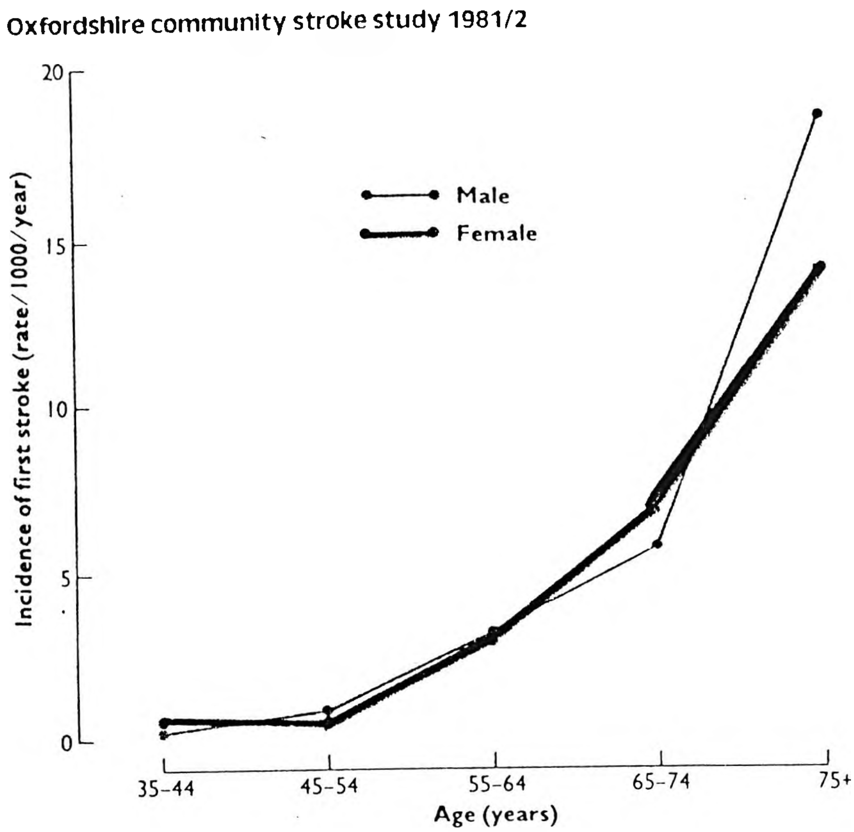


Table 1.1 Incidence of first stroke according to age and sex in Oxfordshire.

Many patients who survive a unilateral disturbance of blood supply to the brain are left with a myriad of complex residual disabilities, the more obvious of which include hemiplegia, hemianopsia, dysphasia, incontenence and depression. The condition is often complicated by a range of other problems such as sensory and proprioceptive loss together with less obvious disorders of memory, speech, perception and intellectual functioning. (Wade et al, 1985).

Many of the survivors of stroke receive expensive and often labour intensive rehabilitation, in an attempt to reduce and overcome these disabilities, (Diller and Gordon, 1981). At present, there is considerable speculation and controversy regarding the effectiveness of stroke rehabilitation. (Millikan, 1979; Lind, 1982; Dombovy, Sandok and Basford, 1986; Wade, Skillbeck, Langton Hewer, and Wood, 1984, Smith, Garraway, Smith and Akhtar, 1982; Garraway, 1985). As yet

> "no treatment has been demonstrated to affect the degree of neurological deficit ... anticoagulants vasodilators, antiedema agents, oxygen therapy and hemorheological agents are of theoretical but unproven benefit". (Norris and Hachinski, 1986).

For the majority of patients, treatment concerns generally revolve around issues of patient management and the prevention of secondary systematic complications such as cardiac failure, bronchopneumonia, deep vein thrombosis, pulmonary emboli and reactive depression (Norris and Hachinski, 1986).

Currently, the care and treatment of stroke patients consumes a large proportion of hospital finances and medical resources. (Drummond and Ward, 1986). The economic and social impacts of stroke can be great and may be expected to take up approximately 12% of a general physican's acute beds. (Wade, Langton Hewer, Skillbeck, Bainton and Burns-Cox, 1985). Overall, they account for approximately 5% of the national health service expenditure (Carstairs, 1976, Wade, Wood and Langton Hewer, 1985).

Despite the uncertainty surrounding the effectiveness of stroke intervention, rehabilitation medicine normally directs its resources towards overt disabilities such as reducing spasticity and stimulating activity in the paralysed muscles. Indeed, this orientation is reflected in many treatment programs which limit intervention to motor problems (Gresham, Fitzpatrick, Wolf, McNamara, Kannel and Dawber, 1975; Hayes and Carroll, 1986; Denes, Semeza, Stoppa and Lis, 1982; Diller and Weinberg, 1977; Kinsella and Ford, 1980). For most patients physiotherapy remains the standard treatment.

It is somewhat surprising therefore that despite their obvious face validity numerous therapeutic trials have indicated little evidence to suggest that physiotherapy significantly improves upon the natural recovery seen after stroke (Wade, Skillbeck, Langton Hewer, and Wood, 1984; Garraway, 1985; Smith, Goldenberg, and Asburn et al, 1981).

Of the several reasons that may account for this finding not the least, is the fact that attempts to access the effectiveness of physiotherapy is compounded by a lack of standardization regarding both the diagnosis and evaluation of stroke patients (Norris and Hachinski, 1986, Keith, 1984).

Another reason which has recently assumed importance in the rehabilitation literature concerns that of the often critical effects of neuropsychological disorders on the patient's potential for recovery. (Kotila, Waltimo, Niemi, Laaksonon and Lempinen, 1984; Lehman et al. 1975; Issacs and Marks, 1973; Andrews, Brocklehurst, Richards and Laycock, 1980; Feigenson, McDowell Meese, McCarthy, Greenberg and Ferguson, 1977). Unfortunately, many patients evidence these concomitant disorders which because they are often not immediately apparent to the patient or clinican, have tended to receive little attention in the normal medical examination. Most clinicans however now appreciate ...

> "that many stroke patients suffer from disturbances of perception, interpretation and conceptualization and that these disorders are more important in determining the patient's success in regaining functional independence than is the more obvious loss of motor power." (Isaacs, 1971).

In other words, by decoupling the assessment of treatment targets from the cognitive and perceptual complexities of the condition, many therapists have failed to consider disorders which "... may have more of a disrupting effect on a patient's recovery than is readily apparent". (Delis, Robertson and Balliet, 1985) ... "even if the motor impairments resolve fully, the person may not function well". (Gianutsos and Grynbaun, 1983; Mosmowitz, Lightbody, and Freitag, 1972.)

The presence of neuropsychological disorders following stroke have in recent years been shown to adversely influence the effectiveness of therapy. (Adams and Hurwitz 1963; Knapp, 1959; Lawson, 1962; Hurwitz and Adams, 1976; Piggott and Brickett, 1966; Diller and Weinberg, 1977; Diller, 1980; Ratcliff 1980). Such disorders often result in the patient's failure to respond adequately to the daily demands of their environment. Indeed, these cognitive/ affective disorders are currently viewed as the major secondary disabilities which remain in hemiplegic patients who have made rehabilitation progress (Diller, Goodgold and Brown, R & T. Annual Progress Report, 1986; Fugl-Meyer and Jaasko, 1980).

The cognitive and perceptual deficits that follow stroke are varied and relate to the extent, location and hemisphere involved. The study of neuropsychological disorders following acquired brain damage originated in the late 19th century from the clinical observations of neurologists such as Broca and Wernike, and were further developed in the early part of this century by Goldstein, Head, Kleist, Zangwill, Teuber, Millner, Hecaen and Luria (Fredricks, 1985).

1.5 Hemispheric Differences

From its modest beginnings in the late part of the 19th century, the field of neuropsychology has become one of the most dynamic subspecialities concerned with the study, assessment and, more recently, the treatment of brain-damage related behaviours. (Lezak, 1983). Its rapid evolution in the last two decades as a separate area of specialization within both neurology and psychology can be seen in the current proliferation of texts. (Hecaen and Albert, 1978; Heilman and Valenstein, 1979; Lezak, 1983; Walsh, 1978; Beaumont, 1983; Dimond, 1972; Kolb and Whishaw, 1985; Filskov and Boll, 1985).

As a discipline which proposes models for relating brain damage to observable empirically described behavioural deficits, neuropsychology is a growing field with roots in many diverse disciplines including neurology, clinical psychology, neurophysiology, neuropharmacology, neuroradiology, and more recently molecular biology. (Jeeves and Baumgarter, 1986). The principle unifying theme that connects these multiple disciplines remains the study of the relationship between brain structures and psychological processes.

Many of the

> "concepts in human neuropsychology have arisen largely from early experience with naturally occurring brain lesions, supplemented by extrapolations from animal experimentation" (Campbell, Bogen and Smith, 1981).

Probably the most significant and pervasive concept is the characteristic lateralization of function observed in the two cerebral hemispheres.

The notion of laterality remains one of the most important concepts in modern clinical neuropsychology and behavioural neurology. In the case of the human brain, it refers to the functional asymmetries whereby some functions are subserved primarily by one side rather than the other. (This was summarized in a figure by Sperry, 1974) - Fig 1.1.

Contemporary interest in left and right hemisphere specialization can be dated from the French physician Paul Broca's published study of 8 right handed left hemisphere damaged patients in the mid 19th century. Broca's observations of these patients with "aphemia" were taken as demonstrating that the faculty of articulate language was localized in the left hemisphere. "Faculty psychology" popularized in Gall's system of phrenology proposed that specific psychological functions were localized in specific areas of the cortex.

> "By the 1860's the asymmetry problem had forced a transformation in the way neurologists regarded higher mental functioning in the human brain ... Subsequent research by Wernicke (1874) and later others, indicated the left hemispheres' involvement in sensory aphasia, skilled movements, and the cognitive activities of reading and writing; thus providing the basis for the term "left hemisphere dominance". Harrington, (1985)

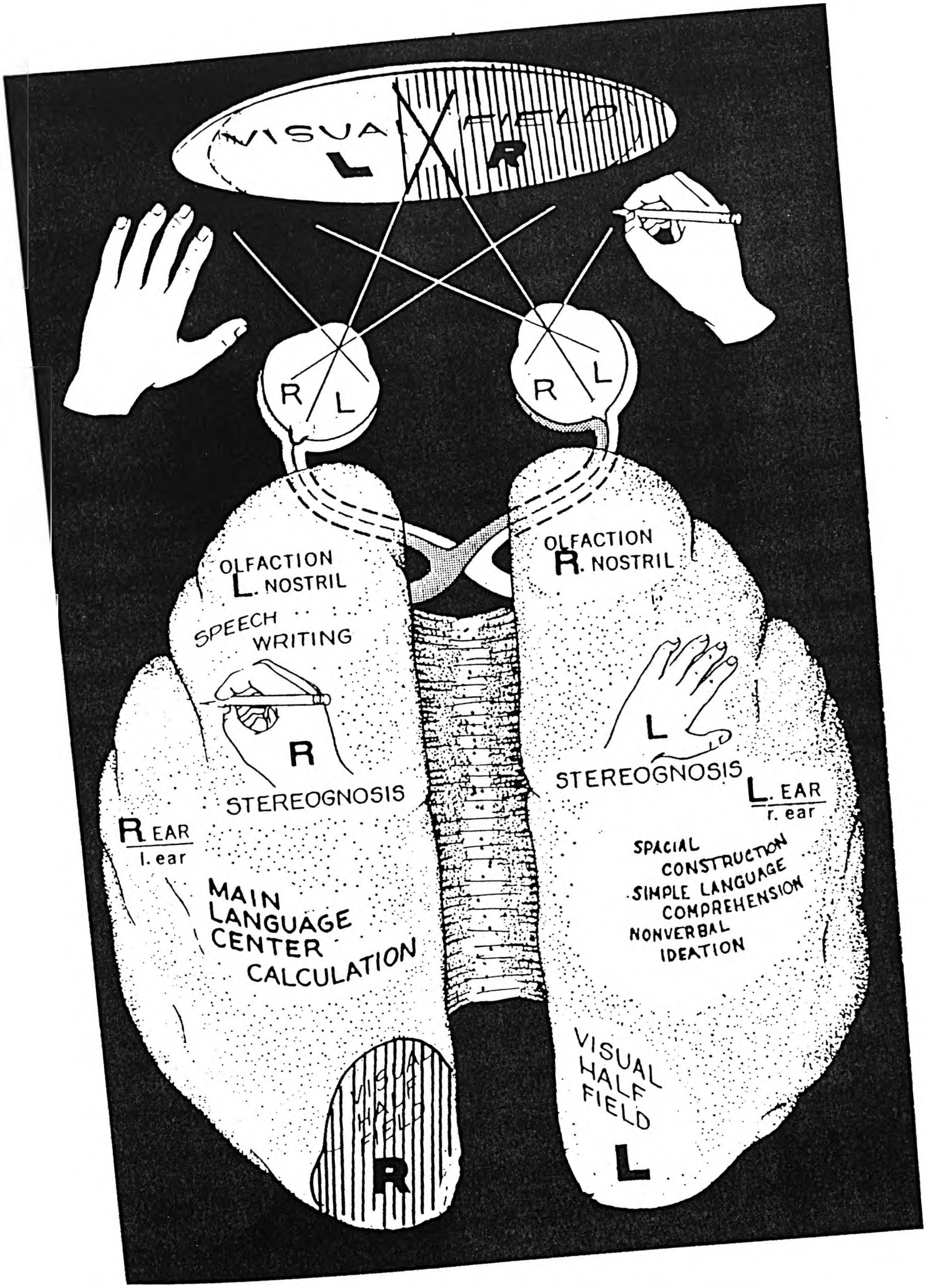


Fig 1:1 Roger Sperry's simplified illustration of hemispheric specialization (1974).

This term remains an accepted medical dictum. (Heilman, Bowers, Valenstein and Watson, 1986)

Consequently, the effects of lesions on the left hemisphere became better known and studied in the late 19th century attempts to localize higher functions. Describing this imbalance, Sacks (1986), recently remarked that

> "the entire history of neurology and neuropsychology can be seen as a history of the investigation of the left hemisphere".

The reasons for this emphasis on the left hemisphere stems from the fact that language loss besides being more obviously incapacitating, was less difficult to demonstrate and localize. Furthermore, the structure of language contains temporally discrete entities, such as phonemes and words, which are readily observable, and may break down in well defined ways thus facilitating the development of reliable aphasic taxonamies and neuropsychological models of language. (Delis, Robertson and Balliet, 1984).

By comparison, while clinicans were fully aware of contralateral sensory and motor losses following right hemisphere lesions, the typical role attributed to the right hemisphere was that of a "mute, unthinking, subhuman automaton, quite lacking in independent cognitive capacities". (Bradshaw and Nettleton, 1981). However, as early as 1864 the English neurologist Hughlings Jackson had already indicated the possible role of the right hemisphere in mediating visuo-perceptual functions. Nevertheless, it was not until the early fifties of the 20th century that the emergence of large scale studies confirmed this suggestion. (Hecaen, Ajuriagurra, De., Massonet, 1951; Hecaen, Penfield, Bertrand, and Malma, 1956; Ettlinger, Warrington and Zangwill, 1957; McFie and Zangwill, 1960).

Subsequent clinical and experimental observations have indicated that the right hemisphere may in fact be dominant for pattern recognition, spatial construction, drawing abilities, emotional expression, dressing praxis, perception of emotions, spatial relationships and attentional arousal (Kertesz 1983). Disturbances of the right hemisphere may give rise to constructional apraxia (Piercy, Hecaen and Ajuriagurra,1960); dressing apraxia, (Hecaen, 1962); deficits in cube counting and spatial appreciation (McFie, Piercy and Zangwill; 1950); failure to appreciate one's own disabilities (Denny Brown et al., 1952, Gainotti 1972); asymmetry in drawings (Warrington, James and Kinsbourne, 1966); decreased ability to express and evaluate affective tones in communication (Ross and Mesulam, 1979); and unilateral spatial neglect (Brain, 1941; Crithley, 1953; Heilman et al. 1979). Benton (1969) provides a comprehensive summary of these right hemisphere disorders.

While this comparison of patients with hemispherically localized damage provided much of the evidence that suggested a possible perceptual "dominance" by the minor hemisphere. (Joynt and Goldstein 1972), it was the commissurotomy studies of the early 60's which confirmed the complementary specialization of the right hemisphere for visuospatial functions. (Gazzaniga, 1970, Bogen, 1985). These studies, besides demonstrating the sharp breakdown in interhemisphere communication of visual somotasensory motor and cognitive information, used novel procedures to show right hemisphere superiority in spatial tasks such as copying geometric designs or matching complex patterns.

These early clinical findings from both hemispheres set the scene for the emergence of clinical neuropsychology. This new discipline developed out of the need to catalogue and explain the range of deficits following brain damage and the growing importance of theoretical models capable of cross-relating neurological damage and specific psychological deficits. The development of standardized assessment procedures directed towards the description, identification and measurement of these changes on behaviour resulted in useful inferences regarding patients probable success in everyday functioning.

Many of these inferences regarding the "functional architecture" of neuropsychological disorders have more recently come from the work of cognitive psychologists.

> "The contribution of cognitive psychology to the fractionation of deficits in such basic skills as reading, writing and spelling. (Coltheart, Patterson and Marshall, 1980, Ellis, 1982) and remembering (Shallice, 1979; Cernak, 1982; Squire, 1982) is now well established. Disorders of object recognition (Ratcliff and Newcombe, 1982; Warrington; 1982) are now placed within a heuristic conceptual framework likewise derived from cognitive psychology (Marr and Nishihara, 1978; Marr, 1980)" (Newcombe, 1985).

This progress towards the development of a conceptual framework within which right hemisphere deficits could more readily be explained has in turn led to an emphasis shift in neuro-rehabilitation, towards the assessment and treatment of non-dominant hemisphere dysfunctions. This movement can be seen to have arisen in part from the influence of detailed commissurotomy studies (Bogen, 1985; Gazzaniga and Le Doux, 1978) and the recent proliferation of clinical and neurological reports indicating that many visuo-perceptual/spatial impairments can operate as critical factors in the patient's effort to regain functional independence. (Lorenze and Cancro, 1962; Taylor, Schaeffer, Blumenthal and Grissell, 1971; Kinsella and Ford, 1980; Weinberg, Piasetsky, Diller and Gordon, 1982; Weinberg and Diller, 1977; Bechlinger and Tallis, 1986; Chakravorky, 1982; Hurvitz and Adams, 1972; Van Ravensberg, Tydesley, Rozendal and Whiting, 1984).

1.6 Categories of Perceptual/Spatial Disorders

Many of these perceptual studies are, however, difficult to compare as they often employ a variety of unstandardized clinical tests and criteria, (Isaacs, 1971, Hecaen, 1962; Oxbury, Campbell and Oxbury, 1974). A major reason for this lack of generally accepted assessment procedures for perceptual disorders is that there is little agreement among clinicans as to the best classification system for such disorders. (Wade, Langton-Hewer, Skillbeck and David , 1985, Bhavnani, Cockburn, Whiting and Lincoln, 1983).

The diversity of phenomena is often compounded by the confusion in terminology that accompanies it:

> "In many cases what one writer calls the deficit; another describes as its defining characteristic, a third regards merely as an associated feature and a fourth regards as the underlying mechanism". (Bechlinger and Tallis, 1986).

In an effort to clarify this situation, disorders of visual perception have been subdivided into two broad categories, those of recognition and those involving the capacity to appreciate spatial relationships (Benton, 1985). This distinction arose initially from the analysis of several empirical studies such as Newcombe and Russell (1969) which indicated that for many right brain damaged patients, performance levels on non-spatial tasks were dissociable from those on spatial tasks.

Mishkin and others (Ungerleider and Mishkin, 1982) working with higher primates have suggested, in keeping with these clinical findings, that the striate cortex is the source of two major cortical association fibre tracts. The ventral tract or inferior longitudinal fasciculus connects the occipital striate, prestriate and inferior temporal areas and was found to be specialized for object recognition and pattern discrimination. The dorsal pathway or superior longitudinal fasciculus joins both striate and prestriate to parietal lobe and would appear to be specialized for spatial processing in man. These anatomical structures are shown in Fig. 1.2.

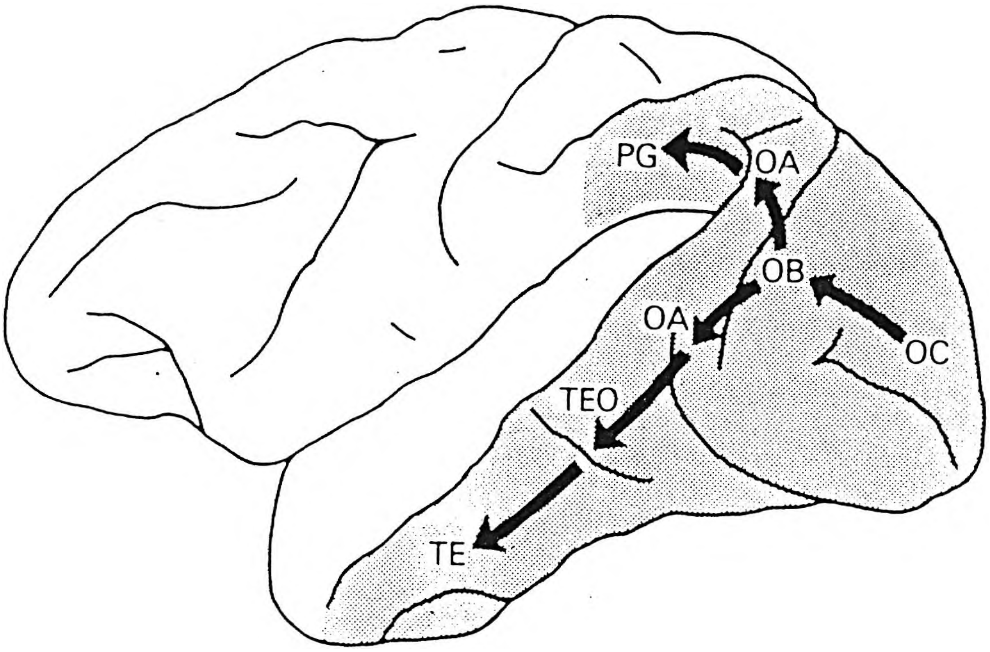


Fig.1.2 *Lateral view of the left hemisphere of a rhesus monkey. The shaded area defines the cortical visual tissue in the occipital, temporal and parietal lobes. Arrows schematize two cortical visual pathways, each beginning in primary visual cortex (area OC), diverging within prestriate cortex (areas OB and OA), and then coursing either ventrally into the inferior temporal cortex (areas TEO and TE) or dorsally into the inferior parietal cortex (area PG). Both cortical visual pathways are crucial for higher visual function, the ventral pathway for object vision and the dorsal pathway for spatial vision.*

(p.414, TINS, October 1983)

In studies of lower primates, a similar distinction between spatial and non-spatial components led to the development of the concept of two relatively independent visual processing systems in the late 60's (Schneider, 1967). The first, described as the "what it is" system was seen to depend on the geniculo-striate pathway and was believed to be concerned with object identification and pattern discrimination. The second, phylogenetically older, tecto-pulvinar system was claimed to be specialized for the detection of objects, their location in space and the control of visual attention - and was described as the "where it is system" (Fig. 1.3).

Whilst current research into higher primates (Ungerleider and Miskin 1982) confirms the existence of the two cortical association pathways as mediating both types of vision, others continue to stress the role of the sub-cortical system especially for aspects of spatial vision and detection. (Weiskrantz, Warrington, Sanders and Marshall, 1974; Zill and Von Cramon, 1979; Denny-Brown, and Chambers, 1976; Heywood and Cowey, 1985).

The latter system has been investigated recently in developmental studies of infant vision. An attempt is made to explain some of the marked changes observed around the second month post-natally, as the result of the late myelination of the phylogenetically later geniculostriate system. Behavioural and electrophysiological features of visual functioning in the newborn are thought to be mediated by this subcortical visual system. (Atkinson; 1984, Dubowitz et al, 1986). Furthermore, the studies of

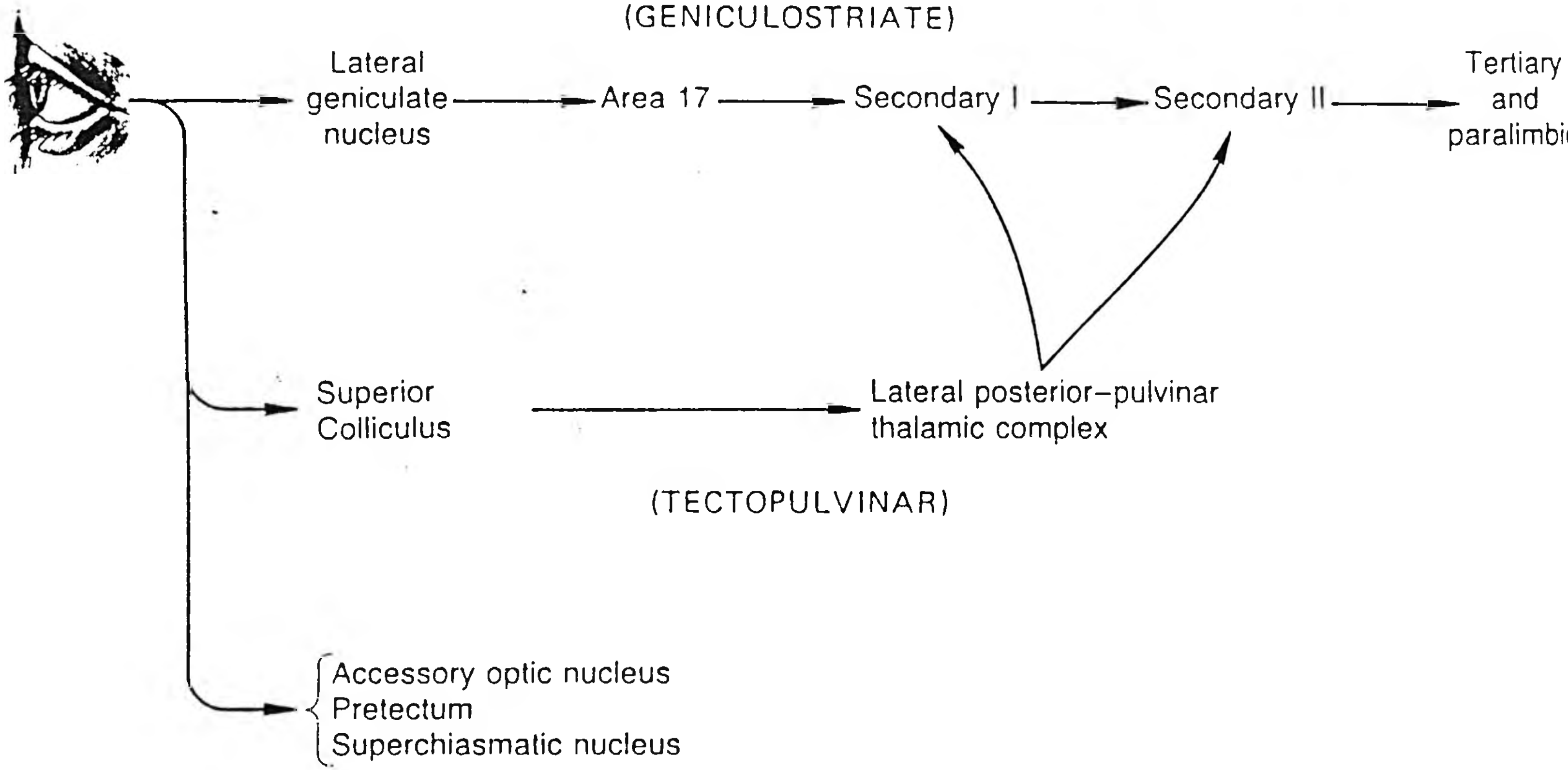


FIGURE 1.3 The connections of the visual system. One subsystem, the geniculostriate system, is specialized for pattern analysis; the other, the tectopulvinar system, is specialized for the detection of and orientation to visual stimuli. Note that the systems converge in the tertiary visual cortex.

split brain patients reveal a similar processing dissociation, whereby although visual information is not transferable between areas subserving explicit stimulus identification, integration of spatial information may occur across the visual midline for the control of selective visual attention. (Holtzman, Volpe and Gazzaniga 1980).

Disorders of the first "what it is", or recognition system include visual object agnosia, a comparatively rare condition where the patients inability to recognize an object cannot be explained solely at the level of sensory or linguistic deficits. Other disorders of this group include prosopagnosia, colour agnosia, simultanagnosia and include figure ground discrimination difficulties. The underlying characteristics of this group is an apparent defective visual analysis and synthesis process in the presence of an apparently intact sensory input system.

1.7 Visuospatial Disorders

Visuospatial disorders constitute Benton's second category. Compared to the perceptual disorders, disturbances of spatial functioning have often been overlooked in favour of more prominent perceptual features. Visuospatial dysfunction refers to the patient's impaired ability to perceive and construct spatial configurations.

Hughlings Jackson (1876) was one of the first clinicians to document the significance of visuospatial disorders. Jackson used the term 'imperception' to describe such spatial difficulties as the inability to find one's way around, or dress oneself correctly. Despite these early speculations, the investigation of spatial disorders remained relatively neglected until the second half of this century (Delis Robertson and Balliet, 1985; De Renzi, 1982).

Unlike the componential and more readily observable structures of language, the elusive character of visuospatial processes ...

> "sometimes hinders the appreciation and identification of the factors underlying spatially oriented behaviour and the mechanisms subserving them. (De Renzi, 1982)

All forms of cognitive or manipulative activities involve some spatial components. Where visuospatial abilities are disrupted by brain damage, the subsequent behaviours and the presence of compensatory adaptions, are often difficult to identify or characterize in a precise manner, and they often have to be inferred from perceptual judgments and visual spatial constructions.

In the past, one of the contributing difficulties stemmed from the use of tasks derived from intelligence tests (eg. Wechsler performance subtests) which attempted to study spatial abilities of a complex character. As a result, many of these findings were deceptive in that it was often difficult to differentiate spatial features per se from factors of intelligence and memory. (De Renzi, 1982). The development of such tests, arose in part from the then prevailing conception of spatial abilities as a unitary phenomenon. As the fractionation of these disorders proceeded, it became more useful to investigate discrete aspects by employing simple tasks specifically designed for that purpose.

As a result of clinical and qualitative assessments several classifications of spatial disorders now exist. One of the most comprehensive of these classifications remains that of De Renzi (1982) who from the vantage point of clinical neurology distinguishes 6 basic types of related dysfunctions. These range from impairments of

> "space exploration, spatial perception, personal space cognition, and constructional ability, to deficits of spatial thought and memory".

The importance of spatial disturbances lies in their functional and behavioural consequences. Adequate visual perception and spatial analysis appear necessary for most daily activities, dressing, object manipulation, drawing, spatial orientation and co-ordination, reading, walking and acquiring new motor skills. Visuospatial disorders may not only compromise the patient in activities directly dependent on spatial skills but may also affect other activities of which spatial functioning may be only one of several necessary cognitive components, eg. accurate perception of complex social discourse (Delis, Roberston, and Balliet, 1985; Kinsella and Ford, 1985). These disorders may be implicated in the patient's inability to adapt or respond adequately to conventional treatments despite retaining a high verbal intelligence. (Van Ravesberg, Tyldesley, Rozenthal and Whiting, 1984; Chakravosky, 1982, Gianutsos, Glosser, Elbaum and Vromam, 1983).

The importance of considering visuospatial deficits in stroke patients has been suggested by several studies which indicated that such deficits may account for the unexpected poor prognosis that appears to follow many right hemisphere damaged patients. (Held, Pierrot-Deseilligny, Bussall Perrigot and Malier 1975; Diller, Ben-Y-Shay, Gerstman, Goodkin, Gordon and Weinberg, 1974). This is surprising as deficits of motor abilities in the preferred hand with accompanying language disturbance and/or dyspraxic disorders in the case of many left brain damaged patients may be expected to delay or interfere with rehabilitation outcome to a greater extent.

Evidence from several studies however indicate that one of the main disruptive features in patients who sustain right unilateral cerebrovascular accidents is the presence of unilateral visuo-spatial neglect. (Oxbury, Campbell and Oxbury, 1974; Denes, Semenza, Stoppa and Lis, 1982; Kinsella and Ford 1980; Weinberg, Diller, Gordon, Gerstman, Lieberman, Lakin, Hodges and Ezrachi, 1977; Chakravorty, 1982; Gordon and Diller, 1983; Piasetsky, Ben-Yeshav, Weinberg and Diller, 1982 ; Riddoch and Humphreys, 1986).

1.8 Phenomenological features of neglect

"Unilateral spatial neglect" or "hemi-inattention" are terms commonly used in neurology to describe the often debilitating spatial disorders observed in many patients after right hemisphere damage. These patients fail to report or attend to stimuli located on the side contralateral to a cerebral lesion. In severe cases,

> "... the patient may behave almost as if half of the universe has abruptly ceased to exist in any meaningful form" (Mesulam, 1985).

Since its initial description in late 19th century clinical case histories, this curious phenomenon has attracted intense speculation from a minority of neurologists ...

> "who needed a respite from the intricacies of aphasic localization and classification, and wondered how the other half of the brain lived. The manifestations of hemi-inattention have also excited the imagination of those who marvelled that one could exist in a demi-world where laterally determined reality." (Weinstein and Friedland, 1977)

Unilateral neglect can be defined as a condition whereby a person with intact sensory and motor systems fails to orient towards or respond to information on one side. (Mesulam, 1985). It is commonly associated with a constellation of sensory and motor deficits such as homonymous hemianopia, decreased, tactile stereognosis and proprioceptual perception.

Neglect in some cases may encompass several sensory modalities (Friedland and Weinstein, 1977) and involve aspects of personal, extrapersonal and intrapsychic representational space. (Halsband, Gruhn and Ettlinger, 1985).

Clinically, neglect is often associated in its acute phase with a marked deviation of the head, eyes and trunk towards the ipsalateral field, i.e. away from the contra-lateral field. Careful observation of scanning eye saccades during visual tasks indicate that most eye movements are restricted to "ipsilateral space" (Rubens, 1985; Hornak, 1982), despite the fact that oculomotor examination often shows normal extraocular movements. (Mesulam, 1985). In severe cases, patients may fail to recognize their contralateral extremities as their own, and in general may only attend to those events and people situated on the good side ipsilateral to the lesion.

Less severe manifestations are relatively common and can be detected by observing the patient's everyday interactions. Some patients will shave, or groom only the right side of the body; they may fail to eat food placed on the left side of the plate; fill out one half of a form; neglect to wear one sleeve or slipper; forget to place one foot on the wheelchair rest; and often loose their way travelling between hospital departments. They often collide with or ignore people and objects on the affected side, and in general their spontaneous behaviour is characterized by a gross inattention to the left side. (Adams and Hurvitz, 1963; Crithley, 1953; Heilman and Valenstein, 1985; Friedland and Weinstein, 1977).

Not surprisingly, such patients also manifest difficulties with the basic skills of reading, writing, and drawing. Drawing and constructional tasks often reveal some of the clearest features of this curious phenomenon. Some of these are shown in Figures 1:4 A/B., 1:5.

When copying and drawing from memory, patients tend to confine their productions to the right side of the page. The drawings themselves often include adequate representation of the right side of the object with the left side entirely omitted or grossly distorted, despite the model

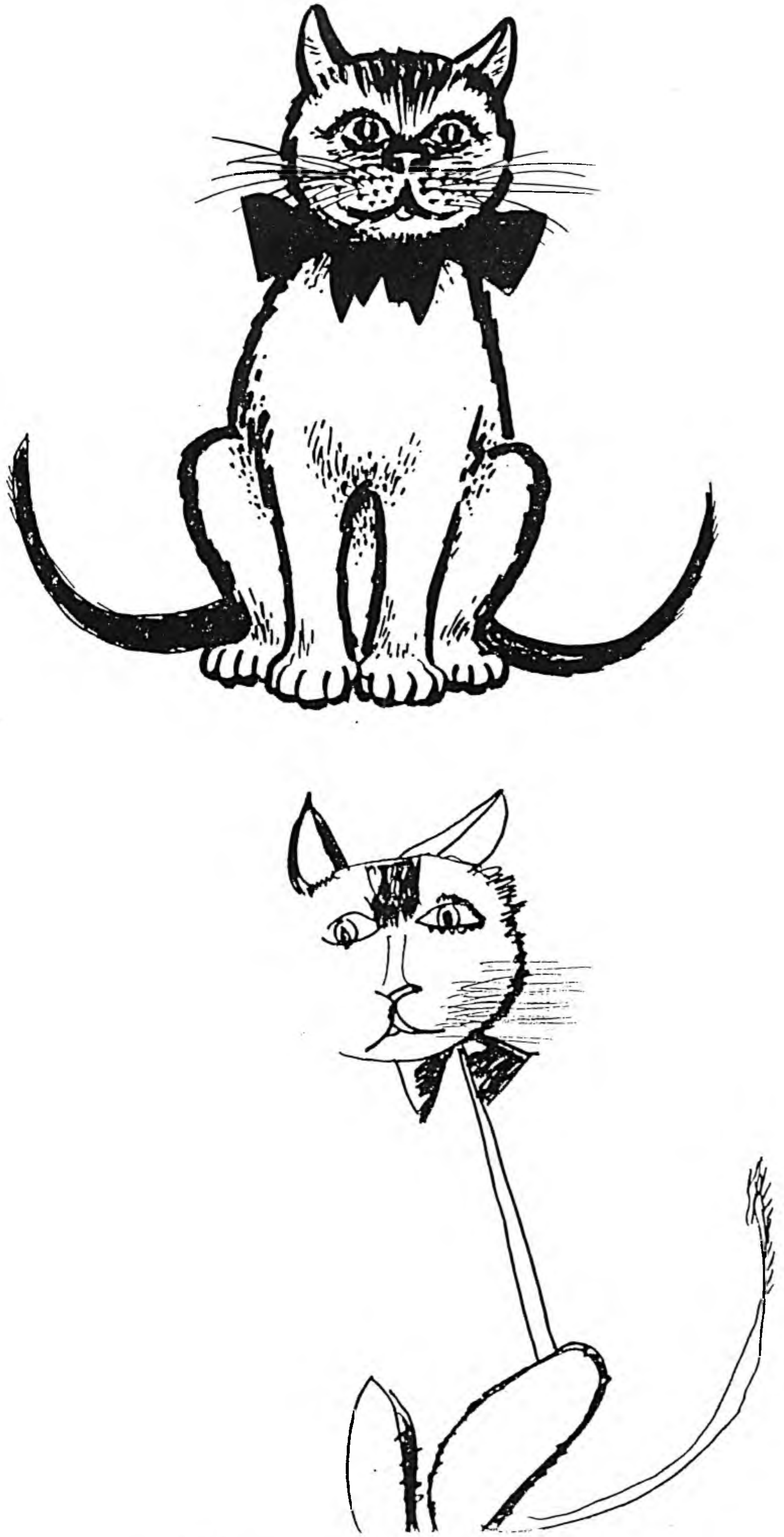


Fig 1.4 (A) Stimulus (CAT); 1.4 (B) Patient's Copy

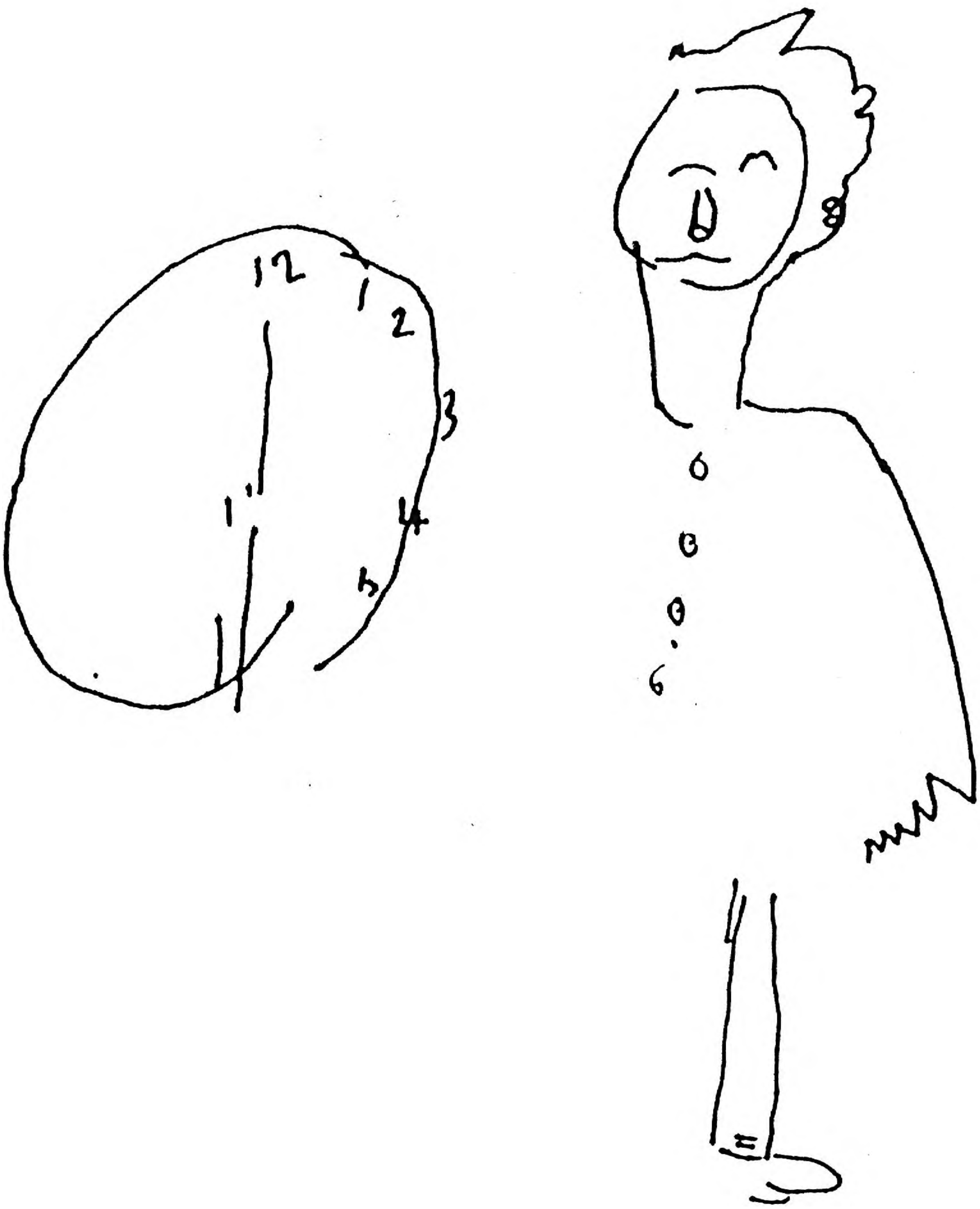


Fig 1.5 Freehand Drawing of Clock Face and Woman

being a well known symmetrical configuration, such as a clock face, which should implicitly suggest its completion. (cf. Fig. 1:6).

On reading tasks, the patient may fail to read part of a word or sentence (Paralexia; Heilman and Valenstein, 1985;) often beginning in the central columns of a newspaper article. Writing may also be compromized, where as a result of an uncommonly wide left sided margin, most of the text is squeezed into the right half of the page (Luria, 1972; Mesulam, 1985). (Fig. 1.7).

> "For example, when shown a picture of a bicycle a subject perceived only the elements of the right and called it a wheelbarrow; when shown the compound word 'screwdriver', he read it as driver" (Hecaen and Albert, 1978).

Unilateral presentation

Most of the clinical studies describing neglect have predominantly involved right hemisphere lesions, (Hecaen, 1962; Piercy, Hecaen and Ajuriaguerra, 1960; Critchley, 1953, Weinstein and Cole, 1964; Costa, Vaughan, Horwitz and Ritter, 1969; Heilman and Valenstein, 1972; De Renzi, Faglioni and Scotti, 1970; McFie and Zangwill, 1960; Oxbury, Campbell and Oxbury, 1974; Zarit and Kahn, 1974; Brain, 1941; Gainotti, 1968; Colombo, De Renzi, and Faglioni, 1976), although some reports have suggested an equal incidence between the hemispheres. (Battersby, Bender, Pollack and Kahn, 1956; Albert, 1973 and Ogden, 1985). The later studies suggest that because patients with left posterior lesions were frequently aphasic, there was a

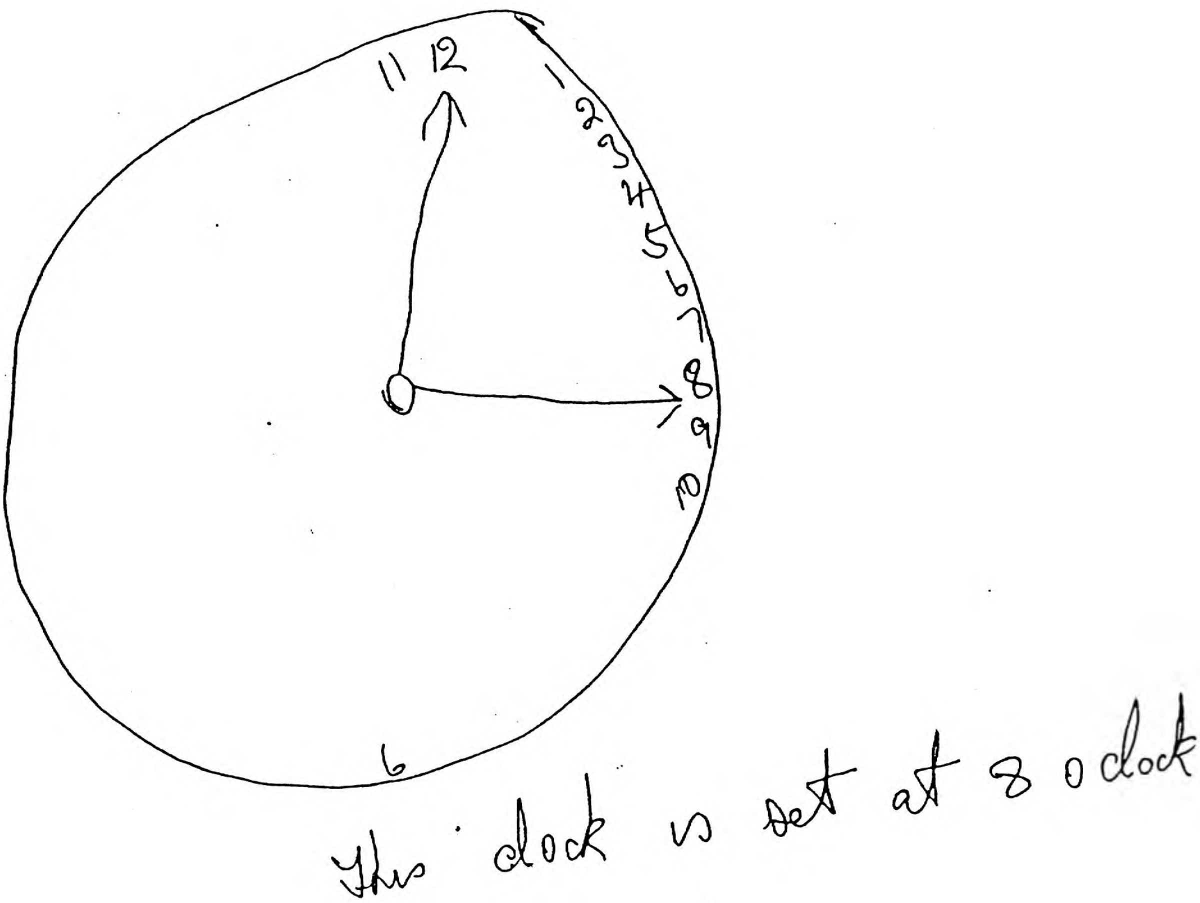


Fig 1.6 Neglect on a Clock Face Drawing

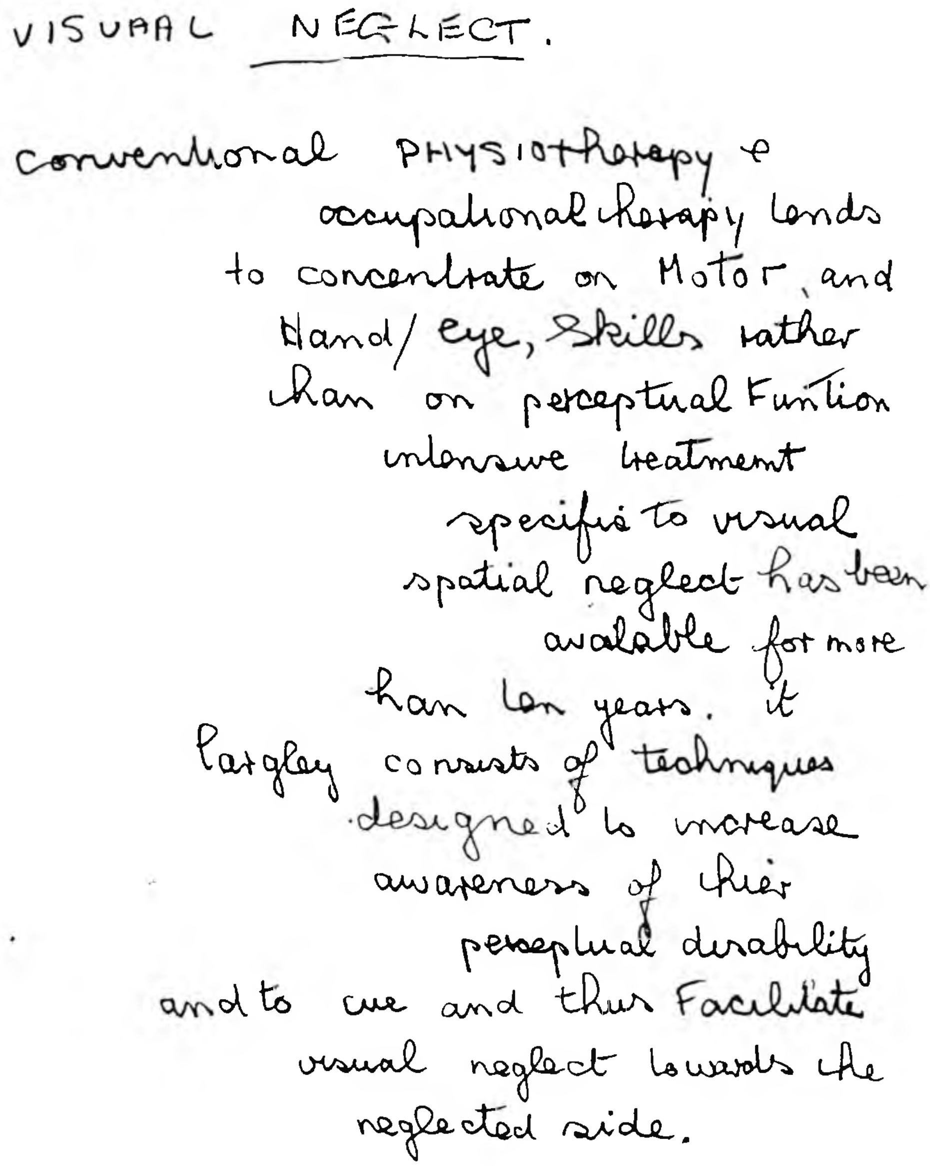


Fig 1.7 Neglect patient's written performance (Dictated passage)

tendency to exclude them from many studies investigating visual neglect. This caveat originally suggested by Brain as early as 1941 and later taken up by others (Battersby, Benders, Pollack and Kahn, 1956; Zarit and Kahn, 1974) was addressed by studies which deliberately employed simple test procedures and contents, not involving complex instructions or explicit verbal responses. These studies (eg. Colombo, De Renzi and Faglioni, 1976; Gainotti, Messali and Tissot, 1972) took into account the number of untestable left hemisphere patients. Nevertheless, they found that the proportion of visual neglect patients following right brain damage, continued to be significantly higher than in the left brain damaged.

While this left sided proclivity is now generally accepted (Heilman, Valenstein and Watson,1985) there still exists speculation regarding the overall incidence of the condition. Using complex cancellation tasks with hundreds of stroke patients, Diller and Gordon (1981) have estimated an incidence of approximately 40% in right hemisphere stroke patients. With these cancellation tasks, the patient is required to cross out all the target letters on a page containing several rows of randomly interspersed letters (cf fig. 1.8). Depending on the density and number of letters, this task can be quite demanding and is considered to be a sensitive test for screening gross lateralized visual neglect (Gordon et al, 1985). However, as a result of the variety of criteria and tests used, the incidence of neglect in patients with unilateral brain lesions has been reported to fluctuate between 14% (Hecaen, 1962) and 85% (Hier et al, 1983). While speculation still surrounds the

CANCEL "3 & 5"

2 5 9 6 8 5 8 6 5 7 9 3 8 5 9 3 2 4 1 3 8 6 2 5 4 1 3 4 1 6 3 9 8 3 6 5 2 1 6 5 1 3 6 3 8 2 4 3 6 7 8 5

3 1 8 5 6 1 3 4 3 6 5 8 2 6 3 1 4 5 8 1 5 9 5 7 4 5 7 8 2 3 1 7 3 9 5 8 3 9 5 6 8 9 3 4 2 3 7 6 4 5 2 1

5 2 3 1 6 3 2 5 8 6 1 5 6 5 7 3 8 7 4 5 8 2 1 5 7 4 1 3 8 5 2 1 5 4 7 3 4 1 6 3 2 9 6 5 1 4 3 2 5 1 3 7

3 4 7 1 3 8 5 6 2 3 1 6 5 1 2 6 3 8 4 5 6 3 7 1 3 2 5 4 3 6 1 8 5 8 5 6 4 9 3 8 2 9 5 2 3 1 8 3 4 5 6 2

1 3 2 3 7 2 9 5 8 1 3 1 6 3 9 3 1 2 5 7 6 2 5 6 1 5 1 2 7 3 7 6 1 3 4 2 5 2 3 8 6 5 1 4 8 3 1 9 5 6 5 7

5 4 8 2 3 1 4 7 5 1 4 6 5 2 5 9 7 1 3 7 5 4 1 3 8 7 5 4 3 1 2 1 5 6 2 3 8 4 1 3 7 2 5 8 3 4 6 5 8 1 9 5

Fig.1.8 Example of Cancellation task used in the Rivermead Perceptual Assessment Battery.(1985)

question of incidence, increasing numbers of studies are addressing the issue of the behavioural expression of visual neglect. The behavioural manifestations of visual neglect, commonly encountered in the early clinical presentation of stroke, vary considerably along a continuum of severity involving aspects of both personal and extra-personal space in the acute stage, to more milder symptoms which, with recovery, can be elicited by specific test procedures. (Mesulam, 1985). The majority of recent studies investigating the condition, do not conceive of neglect as an all or none phenomenon; rather, many of the documented signs and related symptoms are thought to manifest themselves differentially over a variety of stimulus and performance conditions.

Fortunately, for most patients, the severe symptoms in the early stages are often transitory. However, it appears that features of neglect can continue to be insidously disruptive in many areas of the patient's daily activities, long after the apparent resolution of its more florid symptoms. (Kinsella and Ford, 1988; Campbell and Oxbury, 1986; Colombo et al, 1982).

1.9 Significance of visuospatial neglect

In the last decade unilateral visual neglect has become one of the major topics of modern behavioural neurology and clinical neuropsychology (Mesulam, 1985, Heilman, Watson and Valenstein, 1985).

> "The reason for this is evident; investigations of unilateral neglect may provide substantial understanding of the mechanisms involved in spatial behaviour of complex organisms". (Bisiach and Berti, 1987)

However, until recently much of this research on neglect has originated from studies which tended to fall within the traditions of clinical neurology, e.g. (Hughlings Jackson, 1876; Balint, 1907; Zingerle, 1913; Lhermitte et al, 1928; Pineas, 1931; Scheller and Seidemann, 1931; Poppelreuter, 1917; Holmes, 1918; Riddoch, 1935; Brain, 1941; Critchley, 1953; Hecaen, 1962; Denny-Brown et al, 1952; Bender, 1952; Battersby et al, 1956; Gloning et al, 1968; De Renzi, 1970, 1982; Heilman, Watson, Valenstein, 1977; Oxbury et al, 1974; Weinstein, 1977; Mesulam, 1981).

While producing often detailed and lengthly clinical descriptions many of the early case reports appeared content to consider the phenomena of neglect as part of a more generalized visuospatial disturbance peculiar to "bilateral disease involving the occipital and posterior parietal and temporal areas" (Benton, 1982). Such studies usually took the form of case presentations together with discussions of their associated neuropathopathology, devoting only brief and often vague speculation to the nature of the deficit and its possible relationship to normal psychological structures. Later studies were not exempt from this criticism as indicated by Smith (1982).

> "It is tempting to see the post W.W. II discussions of an appropriate label for unilateral neglect as a collection of opinions, - each of which resulted from experiments on one particular aspect of neglect".

Many factors conspired to produce the relative obscurity in which visual neglect found itself until the early 70's, not least the difficulty in conceptualizing and attempting to explain this often dramatic and predominantly lateralized behaviour in patients who quite often retained impressive verbal and intellectual abilities.

Furthermore:

> "... an important feature of hemi-inattention is that the manifestations are selective. Neglect phenomena are variable for stimuli with different content; neglect is not an all or none phenomena ... The selective nature of hemineglect is also revealed in the observations that no patient is hemi-inattentive in all respects ... a patient may neglect one half of a visual display but draw a symmetrical clock ... Thus the manifestations of hemi-inattention cannot be ilicted with the same consistency as evidence of sensory or motor deficit alone". (Friedland and Weinstein, 1977).

Furthermore, examples of florid visual neglect appear qualitatively distinct from other visually mediated neuro-psychological phenomena such as the agnosias or disturbances of visual disorientation, all of which at least take for granted the existence of a spatial medium in which to manifest themselves. In many respects the patient with florid visual neglect appears to stand apart from other spatial disorders in that the neglecting patient is not simply unable to integrate stimuli falling into one half of space, into a coherent spatial framework, but appears to be unable to conceive and therefore be aware of both its existence and their omission. This central and novel aspect of neglect behaviour in an otherwise well oriented and intelligent patient, besides creating additional difficulties for recovery militates against involvement and success in many therapy programs and readily translates into the problems and frustrations described by both therapists and family.

In addition, visual neglect always exists within a presentation which includes many other visual, somatosensory psychological and occulomotor disorders and has to be studied in the context of the reaction of the whole system to the damage sustained. Cerebral lesions disrupt the "dynamic interplay of neural activity within and between widely reciprocating interconnected systems which are the very essence of brain function" (Mountcastle, 1979). In the visual modality, for example, information extracted from the retina is redistributed to no less than seven recipient cortical areas (Rodieck, 1979). As much of this visual information has been shown to be redundant (Levine, 1980), the interacting connections between the different cortical areas have important implications for the expression of and recovery from brain damage. In the case of right brain damaged patients, visual neglect is often compounded by visual field deficits and other visually mediated disorders. (Gianutsos and Matheson, 1986) (cf. Table 1.2).

> "Thus, an impaired behaviour may not uniquely reveal the particular function of the damaged area, and changes resulting from disruption in the interconnected processing structures not unaided by the lesion may also have to be taken into consideration for understanding the emergence of behavioural dysfunctions". (Sergent, 1984)

Surprisingly, few studies have attempted to chart the natural history or recovery of neglect. Gainotti (1968) claimed that the condition, while commonly present in the early stages of stroke, had completely resolved by three years. Others such as Zarit and Kahn (1974) refer to features of neglect persisting for up to 12 years, while Heilman et al, (1979) has suggested that complete recovery may never occur in some individuals.

BEHAVIOURAL ABNORMALITIES AFTER R.H. STROKE

N = 41 (31 infarcts $\bar{x}$ size 14.6 SD 15.3)

(10 haemorrhage $\bar{x}$ size 4.13 SD 2.25) Lesion size as % of total *

	Infarcts (1)	Haemorrhages (2)
1. Block design deficits	90%	5%
2. Neglect	51%	20%
3. Extinction to DSS	71%	40%
4. USND	97%	50%
5. VFD	52%	30%
6. Denial	31%	10%

Table 1.2 Some of the behavioural abnormalities that commonly follow right hemisphere stroke. (Adapted from Hier et al, 1983.)

* Lesion size as percentage of total right hemisphere supratentorial volume.

Columns 1 and 2 describe the percentage of patients in each group demonstrating the respective behavioural abnormalities.

These reports suggesting the persistence of neglect behaviour have significant ramifications for rehabilitation planning (Lawson, 1962; Diller and Gordon, 1981; Fullerton, McSherry and Stout, 1986; Riddoch and Humphreys, 1986) which, over the last decade, has become one of the major sources of interest underlying the current research on the subject. (Taylor, Schaeffer, Blumenthal and Grissell, 1971; Diller and Weinberg, 1982; Young, Collins and Hren, 1983; Riddoch and Humphrey, 1983, 1986; Rubens, 1985; Delis, Roberston and Balliet, 1985; Gianutsos and Grynbaum 1983).

In the rehabilitation literature, neglect has been singled out as a negative prognostic variable (Fullerton, McSherry and Stout, 1986) which has profound effects upon patient management and treatment resources (Kinsella and Ford, 1980). Many such patients require supervision in their daily activities as they are particularly prone to accidents (Weinberg and Diller, 1984). Visual neglect imposes limitations on the degree of active participation in retraining programs and patients with neglect have been associated with poor performance on both functional recovery measures, (Kinsella and Ford, 1985) and general rehabilitation success. (Hurvitz and Adams, 1972, Denes, Semeza, Stoppa and Lis, 1982). A recent study by Kinsella and Ford (1980, 1985) using conventional measures of functional performance (ADL) shows the deleterious effects of neglect on a variety of self care activities. <u>Fig. 1.9</u> (A, B, C, D).

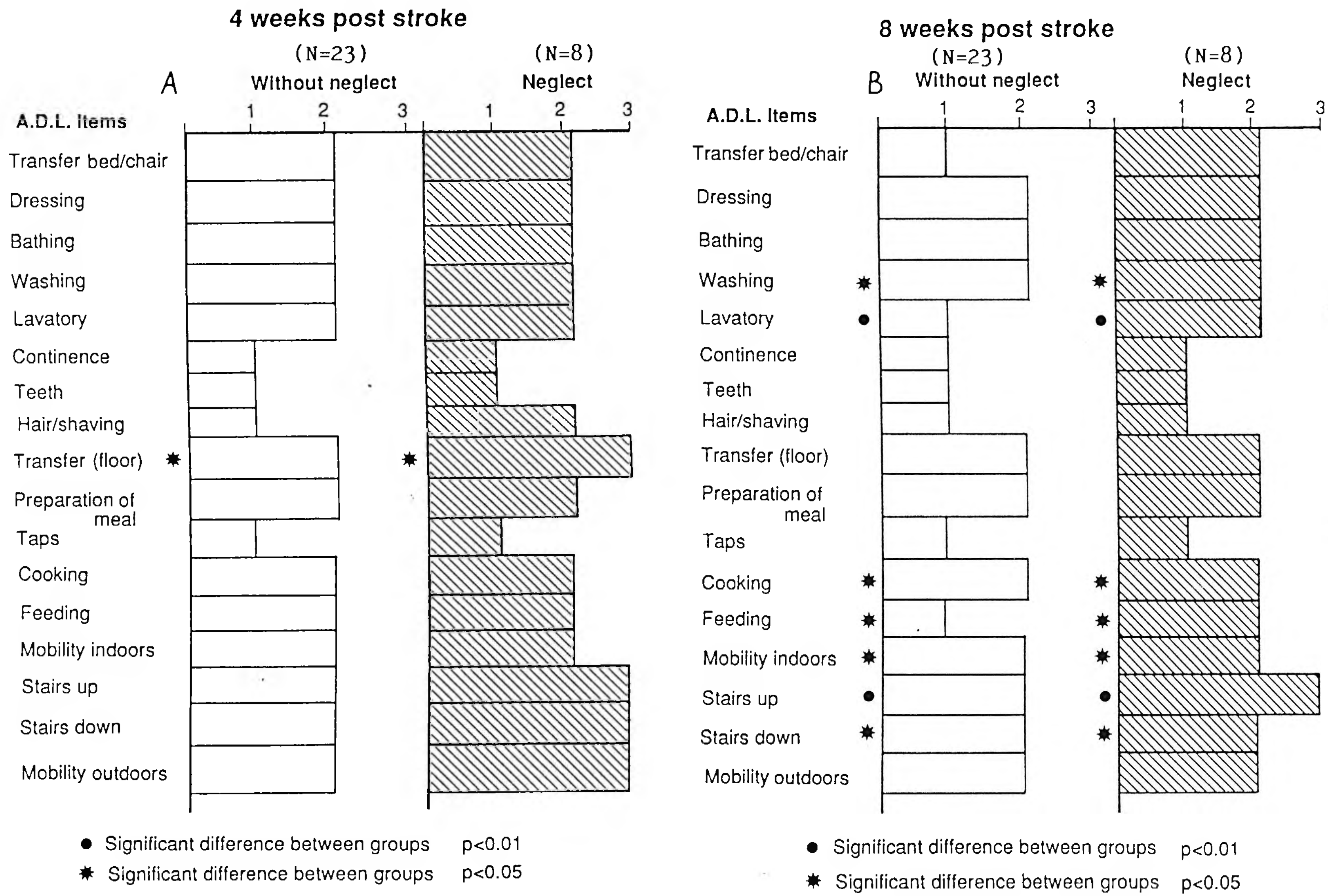


Fig. 1.9 Mean scores for individual items on the Northwick Park Activities of Daily living (ADL) Index at four and eight weeks post stroke. (Adapted from Kinsella and Ford,1980;1985).

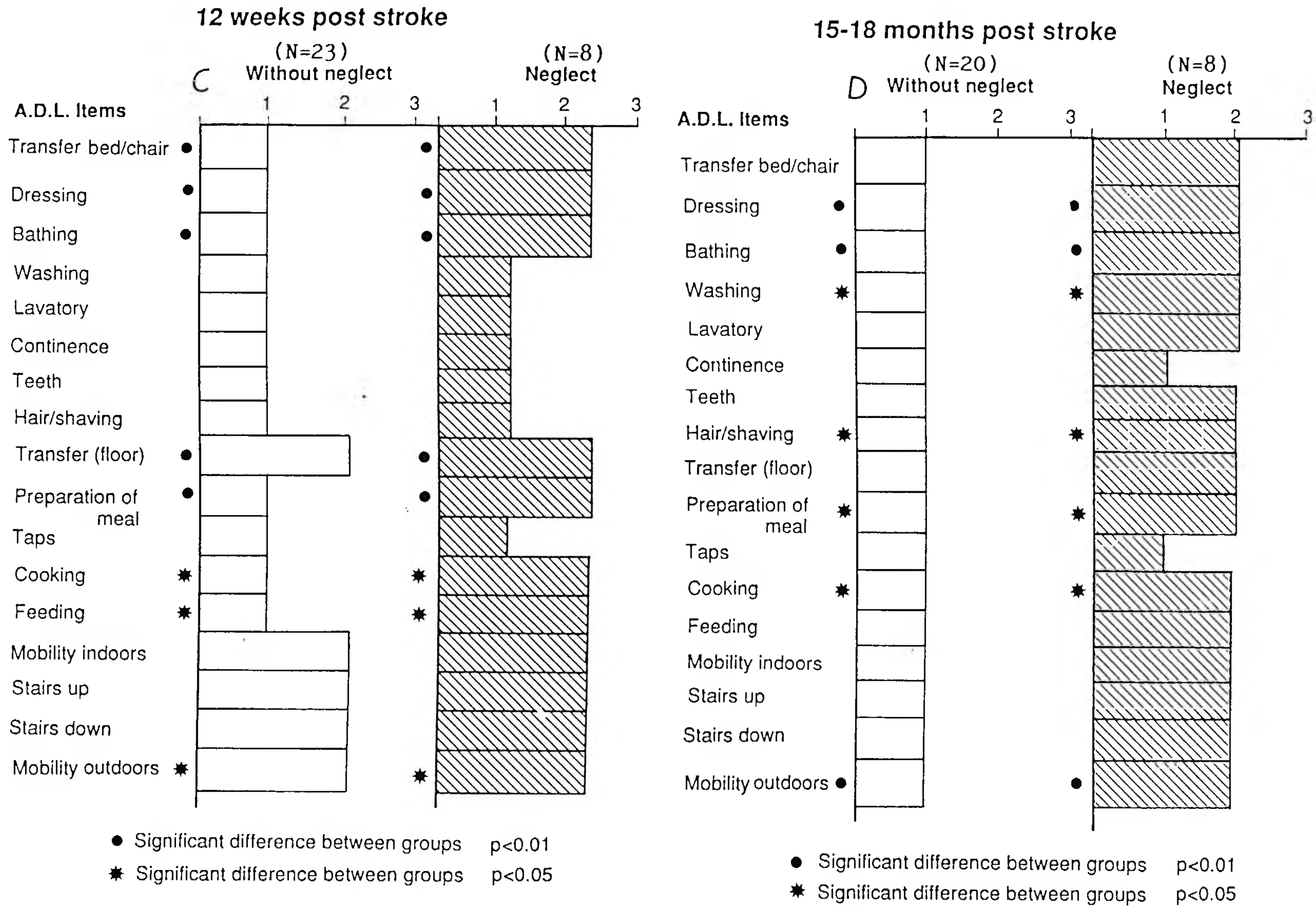


Fig.1.9 Mean scores for individual items on the Northwick Park Activities of Daily living (ADL)Index at twelve weeks and fifteen -eighteen months post stroke.

1.10 Assessment of Visual Neglect

The current interest in neglect has seen the re-introduction and construction of several clinical tests such as Albert's line crossing test (1973); Diller and Weinberg's, letter or number cancellation tasks (1970, 1977); line bisection, (Schenkenberg et al, 1980); Rey-Ostereith, (Pillon, 1981); Copying tasks (Patterson and Zangwill, 1944, Oxbury, Campbell and Oxbury, 1974); cross copying (Gainotti, 1968); visual search tasks (Chedru and LeBlanc and Lhermitte, 1973; Gainotti et al. 1986); and W.A.I.S.-subtests; picture arrangement, object assembly, and block design, (Battersby et al, 1956; McFie et al, 1950; Diller and Gordon, 1981) and Raven's Progressive Matrices (Gainotti, 1968). Most of these have not been relevantly standardized and do not appear to sample adequately the diversity of neglect behaviours other than to indicate a reduced performance on one side. Furthermore, there remains the largely unquestioned assumption evident through out most of the literature, that the various elementary assessment procedures all provide measures of the same underlying deficit. (Sunderland, 1984).

The primary purpose of these tests, in keeping with the more traditional role of neuropsychological assessment was largely confined to diagnosis and did not readily translate to issues of remediation or difficulties encountered in daily activities. However, with the increasing availability of sophisticated and safer neuroradiological procedures. (Computer Axial Tomography, Regional Cerebral blood flow, nuclear magnetic resonance, position emission transverse tomography, dynamic spatial reconstruction and compressed spectral array) formal neuropsychological testing as a indicator of lesion location now plays a reduced role in neurological diagnosis. (Caplan, 1982; Miller 1985; Heaton and Pendleton, 1981).

As pointed out in 1.5. the developing role of current neuropsychological testing has thus increasingly concerned itself with a more detailed understanding of the patient's behavioural deficits and competences. (Miller, 1980, 1985; Caplan, 1982; Goldstein, 1980). In keeping with this trend, several studies attempting to develop a more ecologically relevant analysis, have suggested that many of the conceptually driven assessment tasks fail to consider the complex features involved in actual human performance. Eysenck (1984) points out that cognitive process usually occur in the service of some higher purpose unlike many of the test requirements which function as ends in themselves. A further criticism put forward by Claxton (1970), refers to what he terms the "decoupling problem". This occurs when researchers wishing to explore one feature of a psychological process, attempt to do so by disentangling it from other confounding cognitive systems which may influence performance. As the perceptual system, for example operates naturally within a complex of interacting functional systems, the more we examine part of the process in isolation, the less our findings are likely to generalize beyond the study. This objection derives support from Bennett-Levy and Powell's (1980) work in the field of memory assessment. They have pointed out that many people who complain of poor memory in their daily lives test out within the normal range on laboratory based procedures. On the other hand, others who perform poorly on standard clinical laboratory type tests may complain of no memory problem in their normal working or home environment.

In the area of visual neglect there at present exist no standardized battery of tests which set out to quantify the more relevant behavioural effects of the condition.

The development of an objective, behavioural based test battery relevant to aspects of daily activities should provide therapists and clinicans with a more precise description of a patient's capabilities. Behavioural dependent measures choosen on the basis of clinical findings provide a useful tool for evaluating therapists interventions irrespective of the theoretical orientation taken. Furthermore, given the variety of potential deficits, a behavioural approach using readily understandable tasks will facilitate interprofessional communication and permit a more treatment-related basis for patient evaluation.

The aim of this thesis, then is to develop such a battery. However ,before considering the research design, the second chapter will provide an overview of the characteristics of visual neglect, including its development as a neurological condition, the associated neurophysiological and aetiological factors, together with a review of the incidence and assessments procedures currently used to detect and quantify neglect phenomena.

Characteristics of Visual Neglect

Chapter 2

2:1 Introduction

The absence of a concise operational definition or coherent explanation for neglect has its origins in the early studies of this century. In this chapter the developmental history of the condition and an examination of its relevant characteristics will be presented.

Although visual neglect constituted one of the most striking consequences of damage to the right hemisphere, it rarely achieved the attention devoted to rarer perceptual disorders such as the agnosias. This is surprising as both Russell Brain (1941) and Patterson and Zangwill (1945), early researchers in this field, pointed out that with the exception of

> "agnosia for the left half of space, there was no other clear cut symptom associated with lesions of the right parietal region that was not already described in cases of similar lesions on the left side".

In general, the study of visual neglect appears to have been hampered by the absence of any widely accepted definition, assessment procedure, or neuropsychological explanation (Campbell and Oxbury 1976; Johnston and Diller 1986; Baynes, Holtzman and Volpe, 1986; Anton, Hershler, Lloyd and Murray, 1988).

2:2 Diversity of Terms Used

Most of the early reports of neglect before the middle of this century comprised individual cases that employed a variety of assessment methods and criteria. The resultant plethora of neglect related-phenomena is indicative of what Bisiach and Berti (1987) have recently described as the "de-interpretative approach". Such an approach describes the shift in focus which can occur when mechanisms thought to underly a particular constellation of behaviours are interpreted in terms of component features in the belief

> "... that the general pattern being carried out by the former is opaque to the latter ... such having being the prevailing approach to unilateral neglect, the regrettable consequences which have ensued are threefold; first wrong interpretations have been fostered; second the cognitive aspects of this condition have been obscured and third; the contribution which the study of unilateral neglect can give to the reappraisal of theories about the activity of the brain as a whole has been delayed".

The production of misleading interpretations may have been facilitated by the use of the term "neglect" itself; which describes an involuntary lack of awareness, whereas normal usage suggests a voluntary decision not to respond. In general:

> "The term 'neglect' has been used very imprecisely in the literature especially in regard to animal experiments. Some researchers, for example have taken contralateral behavioural 'extinction' under conditons of double simultaneous stimulation as sufficient to demonstrate the presence of unilateral neglect, eg. Watson, Heilman, Cauthen and King, (1973). Others have used the phrase 'visual neglect' to refer to a lack of response to visual stimuli, despite arguing the case that this lack of response might be explicable in purely sensory terms. (Dean and Redgrave, 1985) Neither of these usages is fully consistent with clinical conceptions of neglect. (Friedland and Weinstein, 1977; De Renzi, 1982)"
>
> (Milner 1987).

One indication of the confusion that surrounds this issue of definition, can be found in the proliferation of terms used to describe the condition. A selection of these terms are shown in Table 2:1.

Table 2:1

DIVERSITY OF TERMS USED TO REFER TO NEGLECT PHENOMENA

PERSONAL / EXTRAPERSONAL 1876 - 1987

1. Imperception (Jackson, 1876)
2. Visual Inattention (Poppelreuter, 1917) (Holmes, 1918)
3. Hemidipersonalization (Ehrenwald, 1931)
4. Hemianopic weakness of attention (Poppelreuter, 1917)
5. Amnesia for body half. (Nielson, 1938)
6. Neglect of the left half of visual space (Brain, 1941)
7. Pseudohemianopia (Silberpfennig, 1941)
8. Agnosia for the left half of external space (Patterson and Zangwill, 1944)
9. Agnosia for the opposite half of space (Brain, 1945)
10. Visual extinction (Bender and Furlow, 1945)
11. Relative Hemianopia (Thiebaut and Guillaumet, 1945)
12. Unilateral visual inattention (Allen, 1948)
13. Unilateral spatial agnosia (Duke Elder, 1949)
14. Unilateral agnosia disabilities (Humphrey and Zangwill, 1951)
15. Amorphosynthesis (Denny Brown et al., 1954)
16. Extinction (Bender, 1952)
    (Visual Field Defect)
17. Neglect of one half of external space
    Imperception for one half of external space
    Unilateral spatial disregard (Critchley, 1953)
    Hemiasomatognosia
18. Unilateral spatial inattention
    Unilateral Spatial Deficit (Battersby et al., 1956)
19. Left sided spatial inattention (Apfeldorf, 1962)
20. Unilateral visual spatial agnosia (Wellman, 1969)
21. Visuospatial neglect (Costa et al., 1969)
22. Visual neglect (Leicester et al., 1969)
23. Left sided fixed hemianopia (Luria, 1972)
24. Spatial inattention (Zarit and Kahn, 1974)
25. Visual hemi-inattention (Rosenberger, 1974)
26. Unilateral spatial neglect (Oxbury et al., 1974)
    (Kinsella and Ford, 1980)
27. Hemi-inattention (Weinstein and Friedland, 1977)
28. Hemineglect (Kinsbourne, 1977)
29. Unilateral neglect (Hecaen and Albert, 1978)
30. Unilateral neglect of representational space (Bisiach and Luzzatti, 1978)
31. Hemispatial neglect (Heilman et al., 1978)
32. Unilateral spatial agnosia (Kinsella and Ford, 1980)
33. Pseudoneglect (Bowers and Heilman, 1980)
34. Unilateral visual neglect (Schenkenberg et al., 1980)
35. Hemispatial agnosia (Willanger et al., 1981)
36. Unilateral neglect - parietal
    - frontal
    - cingulate (Mesulam, 1981)
    - reticular
    - compound
37. Hemispatial neglect (Willanger et al., 1981)
38. Inattention (Piasetsky, 1982)
39. Visual hemi-inattention (De Renzi, 1982)
40. Left sided neglect (Ratcliff, 1982)

41. Spatial neglect (Jeannerod, 1987)
42. Unilaterial spatial neglect on drawing (Hier et al., 1983)
43. Neglect dysgraphia (Baxter and Warrington, 1983)
44. Left spatial hemi-imperception
    Foveal hemi-imperception (Gianutsos, 1983)
45. Left-side underestimation (LSU) (Bradshaw et al., 1983)
46. Unilateral neglect of space (Bisiach et al., 1984)
47. Contralesional neglect (Ogden, 1985A)
48. Hemiattentional neglect (Ogden, 1985B)
49. Neglect syndrome - hemi-inattention
    - extinction
    - hemiakinesia (Heilman, Watson and
    - allesthesia Valenstein, 1985)
    - hemispatial neglect
50. Perceptual neglect (Fullerton et al., 1986)
51. Left spatial neglect (Levine et al., 1986)
52. Dyschiria (Bisiach and Berti, 1987)
53. Neglect dyslexia (De Lacy Costello and Warrington, 1987)
54. Afferent Dysgraphia (Ellis, Young and Flude, 1987)

From an historical point of view, the terms 'neglect' or 'inattention' have been used to describe a whole set of behavioural manifestations, where the patients' actions (or absence thereof) can be interpreted as a failure to respond to or report novel or meaningful stimuli present on the side contralateral to a cerebral lesion.

However, within the clinical sphere, neglect is more commonly considered as a blanket term for describing several qualitatively distinct forms (Mesulam 1985) across a variety of modalities (Halsband et al., 1985) and distinguishable from the primary sensory and motor symptoms which commonly follow cortical lesions. This latter distinction

> "from which the neglect syndrome derives its name, is that in neglect a patient may verbally acknowledge an appendage or place, and yet completely fail to incorporate the appendage or place in ongoing behaviour." (Deuel et al., 1987)

However, the classical description of visual neglect which emerged after the Second World War defined the condition rather loosely, as a variable disturbance of visuospatial functions generally found within a larger constellation of sensory, motor and other spatial disorders. This type of confusion was not peculiar to neglect studies alone, and may be seen within the larger context of the problems surrounding early attempts to explain disorders in spatial orientation following right brain damage (De Renzi, 1982; Benton, 1982).

While changes in spatial cognition following brain damage have been commonly reported, their diversity, from the loss of a seemingly simple ability such as right/left discrimination to such complex tasks as map reading provided little agreement about the underlying functions that are impaired. (Semmes, Weinstein, Ghent and Weber, 1963). As a direct result, speculation regarding the commonly described disorders of topographical disorientation, loss of topographical memory, constructional apraxia, right/left disorientation, and autopagnosia varied between those positions which regarded them as separate and independent disturbances, to others which considered them as "expressions of a single fundamental deficit in spatial organization". (Lange, 1930; Stengel, 1944).

Central to this problem was the difficulty in defining the ubiquitous yet often elusive concept of space. Cassirer writing about this subject in the 1940's remarked that, perceptual space ...

"is not a simple sense datum, it is of a very complex nature containing elements of all the different kinds of sense experience - optical, tactual, acoustic, and kinasthetic. The manner in which all of these elements co-operate in the contribution of perceptual space has proven to be one of the most difficult questions of the modern psychology." (1944)

This problem, however was not confined to psychology alone, and would appear to have provided the basis for much of the discussion between metaphysicians and epistemologists dating back to classical Greece. (Jammer, 1969). Contemporary interest in the subject, dates from the work of the 18th Century German Philosopher Kant, whose epistemological theory attempted to take into account what appears to be, at one level, our intuitive appreciation of space, while at another level, our difficulty in conceptualizing its essence. Kant's solution envisaged space, (not unlike the concept of time,) to be an inherent cognitive organizing principle whereby sensations extracted from the physical world were mentally structured. Sensations were regarded as providing us with the empirical context and means by which to measure and estimate it. From a Kantian position, the understandable difficulty of any study which attempts to explain spatial behaviours resides in the fact that our intuition of space describes an essential process of perception rather than an object to be perceived. (O'Keefe and Nadel, 1982). Many of these difficulties can be seen reflected in much of the early literature describing the behavioural consequences of brain damage behaviour. (De Renzi, 1982).

2:3 Early descriptions of Spatial Disorders

A review of neurological thought on spatial disorders reveals that

> "a variety of symptoms and syndromes have come to be recognized, but the criteria of their diagnosis are frequently neither explicit nor generally agreed. It is not always clear ... whether different terms denote different disorders or different manifestations of the same underlying deficit or whether different authors have simply used different names for identical phenomena ... This confusing state of affairs makes it difficult to answer even such basic questions as whether a given disorder is more frequently associated with damage to one side or another of the cerebral hemisphere." (Radcliff, 1982).

As a result, compared with the aphasias and agnosias, the clinical manifestations of spatial disturbances (and the discovery of hemispheric asymmetry underlying them,) were recognized only after considerable delay. (De Renzi, 1982). The early studies describing features of the patients behaviour suggestive of neglect arose, then within the broader context of deficits in visual recognition. This can be seen from Table 2:1 where disturbances of neglect, retained the association with the term agnosia, up until the early 1970's. Indeed, compared with the spatial disorders, the study of the visual agnosias has received a disproportionate amount of clinical consideration relative to their actual incidence. This continues to be the case despite the fact, that because convincing cases of visual agnosia as a selective disorder are relatively rare, its very existence as a neurological explanation has been questioned. (Bay, 1953; McCarthy and Warrington, 1986).

Many of the early reports of patients manifesting visual agnosia, while referring ostensibly to their inability or difficulty recognizing familiar objects, frequently contained features of spatial disturbance (Balint, 1909; Zingerle, 1914; Scheller and Seidemann, 1931). Indeed, as early as 1910, several of these specific spatial deficits had been described. Some of these are listed in Table 2:2.

Table 2:2

SPATIAL PERFORMANCE DEFICITS DESCRIBED IN THE LITERATURE UP TO 1910

1. Inability to follow routes
2. Defective topographic/geographic memory
3. Difficulty in judging distance
4. Difficulty in reading
5. Misreading for objects
6. Dyspraxia for dressing
7. Difficulty in locating objects
8. Disturbance in ocular fixation
9. Inattention in left visual field

(from Benton, 1982)

Several studies have implicated visuospatial neglect or inattention as a contributing factor that is evident in a variety of other neuropsychological conditions, eg. reading disorders, (Weinberg et al., 1977); written arithmetic, (Humphrey and Zangwill, 1952); topographical memory loss, (McFie et al., 1950); constructional apraxia, (Gainotti, Messerli and Tissot, 1972); and perceptual tasks such as visual discriminations visual matching. (Oxbury et al., 1974) and visual reasoning (Delis, Roberston and Balliet, 1985).

Eventually, the distinction between the two disorders led to the term "visuospatial agnosia" (Patterson and

Zangwill, 1944) being used to describe under one heading the faulty appreciation of spatial aspects of visual experience. (Benton, 1969).

2:4 Early Single Case Studies

Studies describing visual neglect can best be organized into two phases.

(A) The early, single case studies

(B) The later, more comprehensive detailed group studies.

The former may be seen as illustrating the difficulties encountered by clinicians while attempting to formulate the basis for the coherent description of the condition. The majority of these fall within the background of clinical neurology and as such emphasize neuroanatomy and pathology. The later studies, on the other hand attempted to document the extent and types of visual neglect, using a wide variety of operational definitions and pathological groups.

One of the first reports to emphasize the spatial components of visual disorders and their relative independence from obvious concomitant sensory features can be found in Badel's (1888) paper entitled, "Contributions to the Study of Psychic Blindness; Alexia, Agraphaia, Inferior Hemianopsia, Disorders of the sense of Space. (In Benton and Meyers, 1956).

Although Badal's descriptions does not include visual neglect explicity, his descriptions served to highlight an "impairment in spatial perception that transcended the visual modality" (Benton, 1982). Later reports by Forester (1890) and Balint (1909) provided "convincing evidence for the existence of an autonomous spatial disorder" (De Renzi, 1982).

One of the earliest clinical accounts of visual neglect can be found among the papers of Huglings Jackson (1876). Using the collective term "imperception" to refer to a patient with topographical disorientation, visual neglect, dressing apraxia and signs of dementia, Jackson noted that when asked to read the Snellen visual acuity chart, the patient "... did not know how to set about it... (and) ... begin at the right lower corner and tried to read backwards". Other examples of what might now be termed neglect dyslexia (cf, Ellis et al., 1987) included the mis-reading and substitution of letters at the beginning of words.

The location of the lesion in the posterior part of the right temporal lobe appeared to confirm Jackson's earlier intuition (1874) regarding the possible role of the right hemisphere in visuospatial thought. It should be added, however that this case is far from being a representative description of the condition and Jackson's patient demonstrated many other symptoms not related to neglect.

Reports of visual neglect were also mentioned at about this time by several German neurologists, but typically only as a minor symptom within a more complex neurological condition. Anton, in a paper entitled <u>Beitrage zur klinischen Beurtheilung und zur Localisation der Muskel-</u>

sinnstorungen im Grosshirne. (1893) described four patients, two of whom could not perceive passive movements of their left-side limbs, and ignored what was happening on the left, following right sided lesions.

An early case of neglect dyslexia (with associated anosognosia) was reported by Pick, five years later in 1898 in his chapter Uber allegemeine Gedachtnisschwache als unmittelbare Folge cerebraler Herderkrankung. In 1909 a similar patient was described in detail by Balint.
In this case, apart from "psychic paralysis of gaze, optic ataxia and spatial impairment of attention" (Balint's Syndrome) considerable detail was given regarding the patient's reading errors. With single words, he only read the last letters located on the right; he failed to notice people on his left side despite intact visual fields, and preferred looking to his right. Interestingly Balint explains his patients' tendency to look to the right as resulting from right sided asymmetry in "musculo-ocular innervation, associated with a trend of attention" (Papagno and Bisiach, Note 1.) In 1913, Zingerle published a case study of a 45 year old man with hemiplegia, hemianesthesia and hemianopia following right hemisphere stroke whose neglect involved both personal and extra-personal space. Zingerle's distinctive contribution to this case was his subsequent analysis, which classified the patient's condition as not unlike those symptoms of "dyschiria" described earlier by Jones (1896) in the case of an hysterical patient who appeared to have a focal impairment in the appreciation of left sided personal space despite intact sensory abilities.

The advent of the First World War provided researchers with large numbers of young soldiers with relatively localized cerebral lesions. In particular, the systematic work of Walter Poppelreuter and Gordon Holmes led to considerable insights regarding the contributing factors that underly the complex syndrome variously described as visuoconstructive or visual-orientational disabilities.

In discussing the syndrome of "visual disorientation" or "defective spatial orientation" Holmes (1918) distinguished several component features. These included the inability to:

(1) Indicate correctly the location of objects in space. (Absolute localization)

(2) Indicate the nearer of two objects. (Relative localization)

(3) Determine the relative size or length of an object in association with

(4) Defective topographical memory, and

(5) Impairment of visual attention.

This componential analysis served two main purposes. Whereas before, "visual disorientation" was regarded as mainly a manifestation of visual agnosia, it was now possible to show that visual disorientation might occur without the presence of "object agnosia". Subsequently this provided the basis for a re-examination of the concept of "visual inattention".

In current neurological literature several authors single out Holmes as among the first to systematically study visual neglect. (eg. Heilman et al, 1985). However, Holmes's concept of "inattention" was similar to that of Poppelreuter (1917), which for the most part described the elicited response of "extinction" rather than the spontaneous clinical condition of visual neglect. The former phenomenon resulted from the application of two stimuli in the respective visual fields with control of the patient's fixation. Thus although both Holmes and Poppelreuter do refer to neglect type behaviours in patients they saw, for the most part, their systematic investigations, concerned the failure to attend to peripheral stimuli approaching from one side when stimuli from both sides were presented.

By contrast with Poppelreuter, Holme's description of "inattention" goes further than the elicited response of "extinction" and may more accurately be described as referring to the "limitation of visual attention to those objects within central vision" (Weinstein and Friedland, 1977). Describing one case Holmes and Horrax (1919) write

> "It is essentially a disturbance of visual attention. Retinal impressions no longer attract notice with normal facility, and if two or more images claim attention this is liable to concern itself exclusively with, and be absorbed in, that which is at the moment in macular vision..."

For Holmes, "inattention" was only one of several component features that contributed to a major disturbance of visual orientation. On several occasions Holmes goes so far as to specifically point out that inattention per se does not form an essential part of the condition, and may often occur independently of it. (Holmes, 1918; Holmes and Horrax, 1919; Holmes, 1919). Furthermore, Holmes analysis of inattention originated from and has to be situated within his general evaluation of visual disabilities following predominantly bilateral damage. Most of these descriptions emphasized that although there was "no demonstrable diminution of visual sensibility or restriction of the field, ... when the observers hands were held up, one on each side of the patient's visual axis, he (the patient) could instantly see the movement of either the right or left, but not simultaneously movement of both hands". (1919). The effect was not always limited to bilateral hand movements, and was reported to affect other aspects of the patient's behaviour. eg:

> "When asked to look at a needle placed on the table, he (the patient) often failed to detect a pencil placed on one side of it, or if there were two pencils, he could only see the one or the other. At one time ... while sitting in the ward, it was noticeable that the patient usually saw only what their eyes were directed on and that they took little interest in what was happening around them" (Holmes 1919) ... "attention lacked its normal spontaneity and facility in diverting itself to new objects". (Holmes and Horrax, 1919).

The first neurologist to use the term "neglect" was Pineas in a paper entitled, Ein Fall Von Raumlicher Orientierungsstorung mit Dyschirie in 1931. This paper described the case of a 60 year woman whose "Vernachlassigung" (neglect) of the left side was both severe and longlasting, despite the absence of a field deficit or sensory/motor loss. Pineas concluded, that the left half of the body schema and hemispace did not exist for the patient in any meaningful way. No indication of the lesion location was given.

Although Holmes (1918), Pineas (1931), Scheller and Seidemann (1931) documented some of the behavioural features of visual neglect and suggested an attentional explanation; it was not considered a necessary nor a sufficient feature of visual disorientation and it was not until the Second World War and the work of Russell Brain that visual neglect began to attract more widespread interest in its own right.

Brain's (1941) article remains an important milestone in the conceptualization of neglect as a neurological condition. The article set out to provide a coherent classification of the syndrome commonly referred to as "visual disorientation". As a clinical description Brain recognized that the term had become a "loose and comprehensive description covering a number of disorders of function differing in their nature". Although the article lists 9 different features, the major classification distinguished between "defective localization of objects" and what Brain described as "agnosia for the left half of space".

Three cases of each disorder were presented. In the second type, the condition presented were those patients who ignored the left side of space, and as a result tended to make right sided turns while following familiar routes. All three patients described, had large parieto-occipital lesions together with visual field deficits.

Brain's subsequent analysis of the three cases represents one of the first attempts to describe and explain visual neglect in terms of a disturbance of perceptual space. The main conclusions of the article have served as the basis for much of the recent revival of the subject.

Brain's conclusions' included:

(A) Indicating the strong association with posterior lesions of the non-dominant hemisphere.

(B) The demonstration of the inadequacy of a purely sensory explanation. Brain makes the point that left neglect could not be attributed to either "visual inattention" or to hemianopia in the left half fields. In the later case, Brain makes the point which McDonald Critchley would emphasize in his seminal work on the parietal lobes, ten years later, that

> "Patients with hemianopia may run into objects, but they do not get lost in their own homes. Evidently, we have to do with a disturbance of spatial orientation and not with a mere inability to see normally".

(C) Brain's paper distinguished between neglect and visual inattention (as assessed by confrontational testing), thereby positioning the deficit at the level of spatial awareness. This distinction was supported and further elaborated by the work of Critchley (1953) and Zangwill's group (1944-1960).

(D) Regarding theories of neglect, Brain indicated that the condition could not be solely accounted for, in terms of topographical memory loss, visual agnosia, or left/right discrimination problems. Instead, Brain choose to extend the older concept of body schema, introduced by neurologists almost 40 years before (Hartman, 1902) for these behaviours involving extra-personal space.

For Brain then,

> "the patients behaviour towards the left half of external space is similar to the attitude adopted towards the left half of the body ..., since each half of the body is a part of the corresponding half of external space, it is not surprising to find that perception of the body and perception of external space are closely related".

The concept of body schema or image has in the past provided the basis for several attempts to explain disturbances of body space. (Head and Holmes 1911; Benton 1982). The utility of this concept, however, has been open to question. More recently, Bisiach et al (1981) point out that far from being a redundant or ambiguous term, the concept of body schema together with those of "representational space" offers, one of the few realistic attempts to explain neglect. The chief difficulty with the earlier "body-schema" accounts in relation to neglect, stemmed from the fact that

> "they generally misused the concept of schema to describe a set of disorders, rather than arguing its necessity as an explanatory concept".

2:5 Group Studies

Since Brain's report (1941), a large number of investigations of visual neglect have appeared. Most of those have tended to fall within the tradition of clinical neurology rather than neuropsychology (Sunderland, 1984). Exceptions to this trend include the work of what may be de scribed as 'Zangwill's group' which between 1944 and 1960 investigated and reported several features of visual neglect behaviour. (Patterson and Zangwill, 1944; Patterson and Zangwill, 1945; McFie, Piercy and Zangwill, 1950; Ettlinger, Warrington and Zangwill, 1957; McFie and Zangwill, 1960).

Other noteworthy group studies include Battersby et al., 1956; Faglioni et al., 1971, Hecaen, 1962; Gainotti, 1968; Piercy et al., 1960; Oxbury et al., 1974; Zarit and Kahn, 1974. Most of these studies concluded that visual neglect occurred more frequently and with greater severity after right sided lesions. However, both the incidence and eventual interpretation of the types of neglect found have to be considered within the context of the criteria and tasks used. (Piasetsky, 1981).

In these early papers of 1944 and 1945, Patterson and Zangwill, for the first-time, employed a wide variety of verbal and visuoconstructive tasks designed to assess their patient's visuospatial disturbances. These included the use of the clock test, pointing tasks, drawing and 3D cube copying and were intended to further refine the concept of visuospatial disorientation. In their first paper, Patterson and Zangwill (1944) showed a dissociation between personal and extrapersonal neglect, thus questioning Brain's original contention which had suggested a strong association between visual neglect and a disturbance of body schema. Their findings also revealed the often variable effect of neglect on various everyday activities, thus confirming the clinical finding that neglect unlike more stable primary sensory/motor disorders was not an all-or-none phenomenon. Other findings included pointing out the effects of stimulus complexity, familarity, together with the explicit demand for visual exploration in patients drawings. In a subsequent paper, McFie, Piercy and Zangwill (1950) went on to show how in some patients the incomplete drawing performance may be dissociable from the verbally verified descriptions of the patient internal representation. In this case, the patient a 55 year old master printer, manifested difficulties representing the ground plan of his home, while at the same time, being able to verbally describe the layout in detail. Seven years later Ettlinger, Warrington and Zangwill (1957) showed the need to consider the spatial rather than the retinopic or sensory framework in attempting to explain neglect. In their view the essential deficit lay" ... not in a failure of sensory input but in a failure to make effective use of this input at a central level". They demonstrated this by showing that visual neglect continued to occur even under conditions in which the patient is forced by optic-kinetic nystagmus to fix the object in the left half of extra-personal space.

Although the conclusions of these early group studies provided researchers with a data base, that demonstrated the complexity of the condition, one has to wait until the early 1970's for the first major theoretical attempt at its explanation. Several factors contributed to the late emergence of theory and some of these will be addressed in the following sections.

2:6 Problems of Definition and Incidence

Despite the advent of large, often detailed, group studies, no widely accepted definition of neglect was agreed upon. As such it was not until the late 1970's, with the parallel development of other neuropsychological tests, that researchers in the field were prompted to address issues of definition and standardized assessment. This re-evalution was brought about in part by the steadily growing awareness of the condition both as a source of significant disability during the early stages of recovery and rehabilitation following stroke (Diller and Weinberg 1977), and the developing neuropsychological interest in the syndrome (Weinstein and Friedland, 1977; Radcliff, 1987; Bisiach et al., 1987; Posner et al., 1987).

Some of the definitions of visual spatial neglect that have been used include:

(1) The failure to perceive stimuli in a part of the contralateral visual field which is not perimetrically blind. (Smith, 1982)

(2) The failure to respond to single stimuli in the contralateral field. (Heilman and Valenstein, 1979; Smith and Latto, 1981)

(3) Asymmetrical performance on tasks in free vision. (Hornak, 1982)

(4) The failure to respond when both ipsilateral and contralateral stimuli are presented simultaneously (Allen, 1948; Bender, 1952)

(5) Many definitions of neglect have been based on the performance of individual visual search tasks. eg. Albert, 1973.

As a result of the lack of consensus regarding the definition of neglect, artificial differences have been created based upon a variety of different tasks. Diagnoses based upon such tasks are likely to give rise to reports of dramatic differences in prevalence across groups. Therefore studies reporting the frequency of neglect should be considered within the context of the particular criteria and tests employed. For example, tests such as Ravens Coloured Progressive Matrices (Response choice position preference task) and copying/drawing tasks (unilateral omissions) have been reported to demonstrate evidence of neglect more readily than others. (Columbo et al., 1976; Campbell and Oxbury, 1976; Gainotti et al., 1986). However, Ravens Coloured Progressive Matrices involves abilities quite unrelated to those involved a copying/drawing. In the later case, the criteria used typically involves evidence of absolute deficits only (Piasetsky, 1981). Added to this, problems of interpretation are created by the range of tests given to patients. (Schenkenberg et al., 1980; Ogden, 1985). Some of the tests used, required the patient to search or point to a visual stimulus on the contralateral side of space, some required spontaneous drawings and others required copying/drawing. A selection of some of the most common tests are tabulated in Table 2:3.

Table 2.3

Tests used to assess visual neglect

Line Bisection	(Schenkenberg et al., 1980)
Cancellation Tasks	(Weinberg et al., 1977)
Line Crossing	(Albert, 1973)
Copying tasks e.g. Rey Osterrieth	(Heir et al., 1983)
Drawing	(Oxbury et al., 1974)
Double Simultaneous Stimuli	(Smith et al., 1980)
Memory for Designs	(Zarit and Kahn, 1974)
Cross Copying	(Gainotti, 1968)
Matching Tasks	(Faglioni et al., 1969)

Visual Search Tasks	(Chedru et al., 1973)
Reading Tasks	(Caplan, 1987)
Block Design (WAIS)	(Diller et al., 1974)
Position Bias on R.C.P.M.	(Costa et al., 1969)
Computerized format	(Gianutsos., 1983)
Writing	(Levine et al., 1986)
Monitoring Eye Movements	(Johnston and Diller, 1986)
Verbal Recall of Imagined Scene	(Bisiach et al., 1981)

Given the differences so far outlined in the area of definition, assessment and criteria employed, it is not surprising that a review of those studies claiming to measure the condition over the past 40 years, should yield prevalence figures which range between 12% and 95%. A graduated table of over 40 of these studies involving over 5,000 patients of various aetiology is provided in Table 2:4.

Table 2.4

	N	%	Year	Authors
1	136	12%	1983	Smith, Akhtar and Garraway.
2	80	14%	1985	Halsband et al.
3	121	18%	1971	Faglioni et al.
4	103	23%	1976	Columbo et al.
5	106	24%	1986	Horner et al.
6	115	25%	1973	Chedru et al.
7	65	29%	1956	Battersby et al.
8	91	29%	1976	Chedru et al.
9	612	31%	1968	Gloning et al.
10	465	31%	1972	Hecaen et al.
11	50	32%	1981	Willanger et al.
12	48	33%	1982	Denes et al.
13	413	34%	1972	Gainotti et al.
14	357	34%	1963	Hecaen et al.
15	41	36%	1962	Lorenz and Cancro.
16	97	36%	1986	Bisiach et al.
17	66	37%	1973	Albert.
18	32	41%	1974	Oxbury et al.
19	172	41%	1986	Gainotti.
20	290	43%	1974	Zarit and Kahn.
21	110	43%	1986	Vallar and Perani.
22	190	44%	1970	Gainotti et al.
23	22	44%	1983	Girotti et al.
24	107	46%	1971	Gainotti and Tiacci.
25	66	46.5%	1987	Caplan.
26	248	48%	1977	Caltagione et al.
27	205	49%	1986	Fullerton et al.
28	20	50%	1974	Rosenberger.
29	101	50%	1985	Ogden.
30	210	53%	1983	Gianutsos et al.
31	110	54%	1968	Gainotti.
32	33	55%	1986	Motormura et al.
33	28	55%	1987	Wilson et al.
34	50	56%	1981	Bisiach et al.
35	31	57%	1980	Kinsella and Ford.
36	20	58%	1962	Warrington.
37	70	61%	1969	Costa et al.
38	29	67%	1944-60	Zangwill et al.
39	46	69%	1979	Chain et al.
40	29	72%	1986	Levine et al.
41	41	85%	1983	Hier et al.
42	40	95%	1980	Schenkenberg et al.

2:7 Relevant variables

The studies shown in Table 2.4 are particularly instructive in illustrating the degree to which the incidence of neglect has been confounded with various factors including time post onset, criteria and tests used. A consideration of some of these variables now follows.

(1) Time Post Onset : An important aspect that is seldom taken into account when prevalence figures are presented is that of the duration between onset and assessment.

> "Clinical experience suggests that in stroke patients, neglect is an ephemeral phenomenon, at least in its more dramatic manifestations which vanishes fairly rapidily. (Days/Weeks) though experimental evidence may show a long standing persistence of this deficit".
> (Vallar and Perani, 1987).

For example, Hier et al's (1983) study of 41 right hemisphere strokes reports a prevalence of 85% which has rarely been found in other stroke investigations using a copying task. Despite using omissions on the relatively complex Rey Ostereith figure as the criterion for visual neglect, Hier's data may be explained for the most part by the fact that all patients were seen within 7 days post stroke. A similar group of right hemisphere patients assessed by Horner et al., (1986) using a group of visuospatial tests, revealed a relative prevalence figure of just 24% with a mean post onset assessment at just under 2 months.

(2) Patient sample. The majority of studies which have described visual neglect have almost exclusively tested those patients admitted to hospital or rehabilitation

units. As such, the frequency of visual neglect tends to be inflated. However Sunderland, et al. (1987) has recently shown using a large representative sample of all new stroke cases in a regional health authority that the incidence of neglect as measured by position preference on Ravens Coloured Progressive Matrices, is between 8-11%, at 3 weeks post onset. Although this study was retrospective it made the point that realistic consideration of the actual prevalence should consider the extent and time course, together with the fact that by their very nature, hospital and rehabilitation based studies produce elevated figures based on a small minority of (in this case) stroke cases.

(3) Another factor closely related to time post onset is that of aetiology. For the most part

> "unilateral neglect arises as a consequence of local intraparenchymal lesions of the brain or as an ictal manifestation in patients with seizures ... (However) metabolic - toxic encephalopathy, subclinical hematoma, head injury, multifocal brain disease, which are all major causes of confusional states almost never gives rise to unilateral neglect" (Mesulam, 1985).

The most common cause of spatial neglect tends to be either tumoral or vascular in nature. Other reported sources include degenerative diseases such as Parkinsons disease (Villerdita et al, 1983); right temporal lobe seizures, (Heilman and Howell, 1980); right unilateral E.C.T. (Heilman et al, 1985) and right ventrolateral thalamotomy (Vilki, 1980).

As these conditions differ in their mode of onset and clinical course, their influence might be expected to effect the relationship between anatomical and clinical findings;

yet this consideration has rarely being taken into account on the majority of studies that have used heterogenous pathologies.

> "Cerebrovascular diseases such as infarction or haemorrage frequently have sudden onset. Conversely in the case of brain tumors, the neurological and neuro-psychological symptoms and signs tend to develop progressively in a sub - acute or even chronic fashion". (Vallar and Perani, 1987).

Unlike cerebrovascular accidents, where the acute dramatic manifestations fade rapidly in the majority of cases, the patient with a cerebral tumor generally runs a progressive course, complicated by the effects of edema, conpression and infiltration. (Kertesz et al, 1981). It is interesting to note that the three main studies (Albert, 1973; Battersby et al, 1956; and Ogden, 1985) which constitute a challenge to the prevailing opinion that neglect for the most part follows right hemisphere damage; comes from studies using samples among which tumor patients predominanted (Bisiach and Vallar, 1988). The suggestion is that the nature of the pathology, (in this case infiltrating rapidly growing malignant tumors) is more likely to provide evidence of ipsilateral visual neglect as against the more common finding of contralateral neglect in the majority of cerebrovascular studies.

(4) Furthermore, in keeping with this aetiological factor one must consider the age of the sample cohort. The mean age of the predominantly tumoral based subject reports (Albert, 1973; Ogden, 1985) tend to be almost 20 years younger than those of similar studies reporting neglect

after stroke. (Denes et al, 1982; Kinsella and Ford, 1980; Zarit and Kahn, 1974). The evidence from the clinical literature is that neglect in children (Ferro et al, 1983) and young adults (Rosenberger, 1981) is both rare and less severe. Age may therefore need to be considered as an important variable in studies reporting neglect. This suggestion receives support from two sources. The first is from Levine et al's study (1986) which showed that the degree of premorbid brain atrophy was an important variable in determining the severity and potential for improvement of left spatial neglect patients following stroke. The second source can be found in a report by Mehler et al, (1985) which found a very strong relationship between impaired performance on a selection of visuospatial tasks and idiopathic falling in a group of elderly non-patients who did not manifest any obvious clinical or radiological signs of stroke upon examination.

(5) Neuropathology. While many features of spatial neglect have been critically evaluated over the last two decades, few reports have openly questioned the traditionally ascribed relationship between neglect and lesions of the right retro-rolandic hemisphere, and in particular the parietal lobe. (Brain, 1941; Critchley, 1953). However, with the recent availability of non-invasive neuroradiological techniques, such as C.A.T., M.R.I. and P.E.T. scans (Wilson, 1988), the original exclusiveness of this position has now become open to question. The current position suggests that

> "while the traditional associations have been by and large confirmed, clear evidence has also indicated various other locations including 'same side' on ipsilateral neglect". (Vallar and Perani, 1987).

One of the first papers which questioned the typical presentation of contralateral neglect was Welman's report in 1969. In this paper two cases of neglect were described which both demonstrated neglect on the same side as the lesion. The first case involved a 54 year old Dutch right handed factory labourer who sustained a cerebral infarction in the parieto - temporal region of the left hemisphere. Although normally oriented, co-operative and with no obvious visual field defecit, the patient nevertheless ignored all objects located in the left part of his visual space. The second patient presented with similar problems. Although as Welman subsequently points out, "these two [patients] represent a very rare state of affairs", Denny Brown had as far back as the early 1950's recognized that asomatognosia and anosognosia could occur ipsilaterally. As Welman's report predates the introduction of C.A.T. scans, and contains suggestions of crossed dominance (neither patient had major dysphasic symptoms) together with probable right hemisphere involvement, one might speculate that both patients suffered some form of bilateral damage. This suspicion is supported by the clinical experience of Mesulam (1985) who suggests that the most striking instances of right unilateral hemineglect that he has seen

> "... have occurred in patients with bilateral injury to the brain. Severe hemineglect for the right hemispace should therefore raise the possibility of bilateral lesions of the brain".

At present, the available evidence regarding the anatomical loci associated with visual neglect indicates a much wider range of right sided lesions, including both frontal, posterior cortex, together with subcortical structures. The implication is that the functional organization of the right hemisphere may be more diffuse and less localized than the left. (Kerterz and Dowbrowski, 1981). The range and size of lesions that can be involved are shown in Figure 2:1, which is taken from Hier et al., (1983).

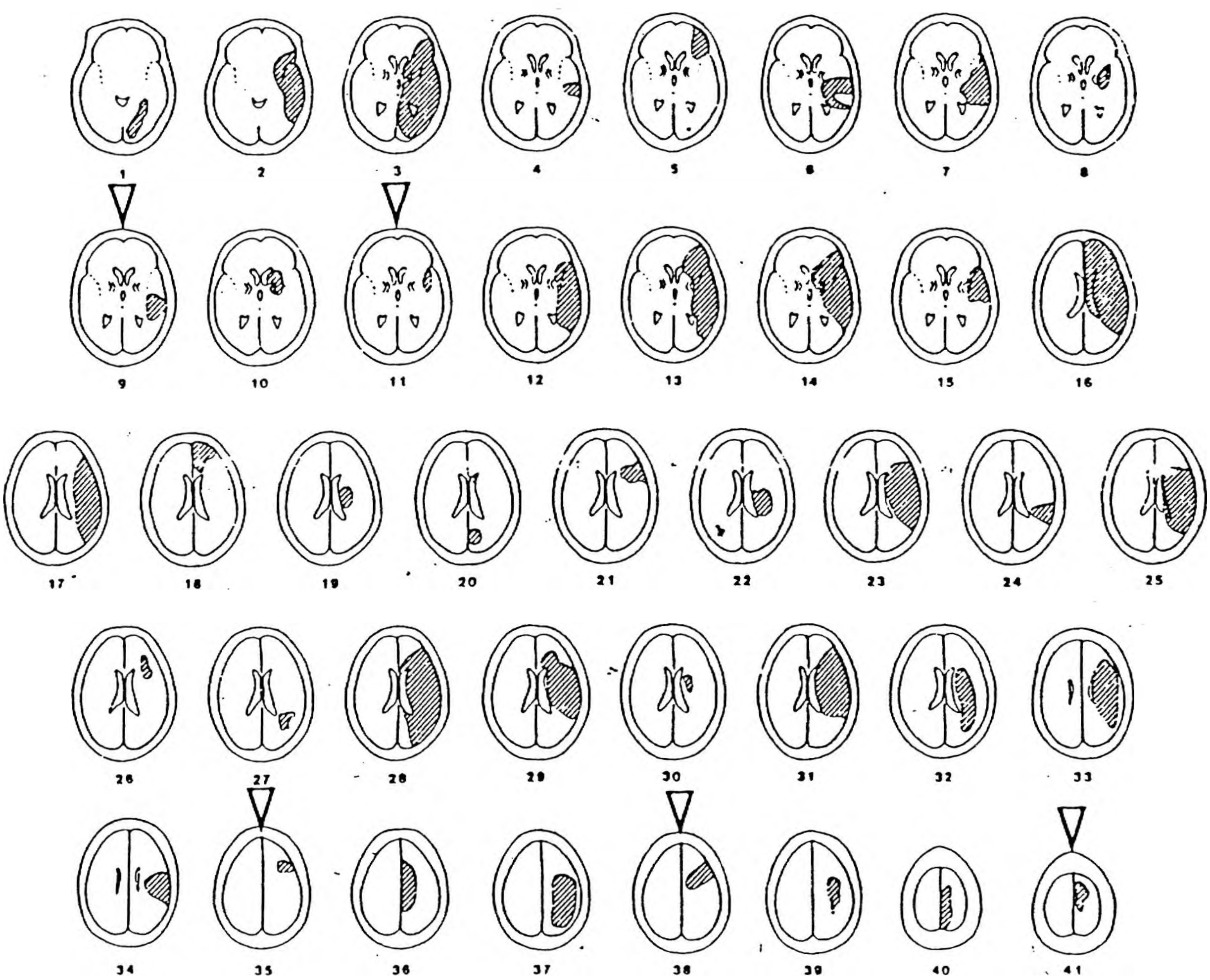


FIG.2.1 C.T. templates showing lesions at level of maximal extent for Hier's 41 right stroke patients. Patients 9,11,35;38,and 41 did not show neglect.

These anatomical loci clearly suggest the inadequacy of a "Master centre theory" (De Renzi, 1982; Vallar & Perani, 1986) and the need for any cogent theory of neglect to account for the diversity of neglect behaviours following a variety of both cortical and subcortical lesions. Table 2:5 lists some of the cortical/subcortical structures that have been implicated in human studies.

Table 2.5

Clinical and Experimental Studies : Anatomical location of Lesions

Cortical

1. Frontal eye Fields (Crowne, 1983)
2. Inferior parietal lobe (Valenstein, Heilman and Watson, 1982)
3. Inferior Area 6 (Rizzolatti, Matelli and Pavesi ,1983)
4. Superior parietal lobe (Posner, Walker, Friedrick & Rafal, 1984)
5. Medial Frontal Lobe (Cingulate Gyrus). Watson, Heilman, Cruthen and King, 1973)
6. Dorsolateral frontal lobe (Heilman and Valenstein 1972, Damasio et al., 1980)

Subcortical

1. Neostriatum (Hier et al., 1977; Healton et al., 1982)
2. Superior Colliculus (Heywood and Ratcliff, 1975)
3. Mesencephelic Reticular Formation (Watson, Heilman, Miller & King, 1974)
4. Substratia Nigra and Striatum (Dunnell & Inverson, 1982)
5. Posterior Internal Capsule (Ferro & Kertesz, 1984)

6. Thalamus (A) 'Syndrome of the Anterior Choroidal Artery' (Cambier et al., 1980)

(B) 'Syndrome of the posterior thalamic haemmorage'. (Hirose et al., 1986; Motomoro et al., 1986; Watson et al., 1979.)

Given the variety of lesion locations, a review of the clinical and experiential literature appears to favour such "Anatomorphysiological models" as Mesulam's (1981), "Multi-component cortical network for directed attention" or Heilman and Watsons' (1977) "hemispheric hypoarousal hypothesis" (resulting from a hypothetical dysfunction in a unilateral cortico-limibic reticular formation loop.)

However even such physiologically complex cortico-fugal circuitory cannot account for

(1) the multiplicity of brain centres, damage to which results in neglect behaviour.

(2) the anatomical independence of some of these centres which give rise to neglect.

A recent theoretical position which attempts to take account of these factors is that of Rizzollati et al, 1985). This model proposes a "constellation of centres", each of which can be assumed to control attention for different parts of space. The model conceives

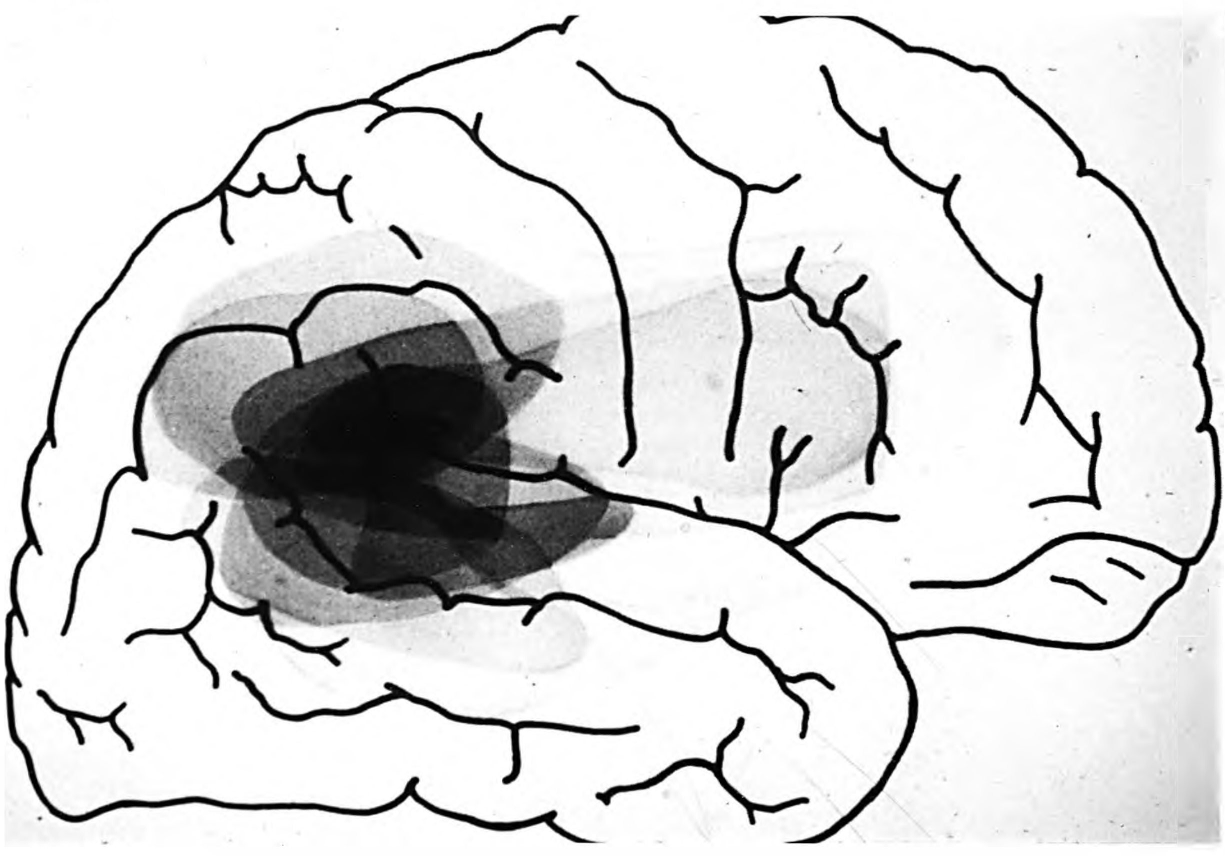
> "spatial attention not as a sub-ordinate function controlling the activity of the brain as a whole, but as a property intriniscally linked to the premotor activities and distributed among various cerebral centres".

Working with animals, Rizzollati has recently shown that neglect for "extrapersonal" space is typically associated with lesions of the frontal eye fields whereas damage to the post arcuate frontal cortex or the inferior parietal lobe resultes in an neglect which is confined to reaching movements within peripersonal space. (Rizzollati et al., 1983).

Despite the animal findings, for the most part

> "... the bulk of evidence from human studies points to the parietal lobe as the cortical area most commonly involved in patients suffering from neglect..."

This has been confirmed by Heilman and Watson in 1977 with radio nucleic brain scan,s and by Heilman, Watson, Valenstein and Damasio (1983) with C.T. scans. (Fig 2:2).



Lateral view of right hemisphere.Figure shows the superimposition of CT scans obtained from 10 neglect patients(p.478)

In conclusion, while it is possible that a number of different brain structures (cf. Rizzollati et al, 1987) may be involved in the complex process of orienting of spatial attention

> "the inferior parietal region (carrefour) appears to be a most important neural component even thought individual neglect patients with lesions confined to the pre-rolandic regions have been reported". (Vallar and Perani, 1987)

(6) Assessment Procedures

As already indicated, evidence of neglect can vary as a function of the task used and criteria employed. Probably the single most significant factor which has contributed to the variation found in previous studies reporting the prevalence of neglect centres on the range of different tasks that have been used to assess the condition. The absence of an operational definition has meant that many often diverse cross-modal assessment techniques have been used, apparently with the assumption that the same underlying deficit is being tapped.

For example, Hiers et al's study (1983) of right hemisphere damaged patient found a prevalence of 85% using omissions on the Rey Ostereith figure, in a group of 41 patients seen within 7 days post stroke. A similar study by Vallar and Perani (1986) with 110 right hemisphere damaged patients of similar aetiology found a prevalence of 43% using a simple "circle cancellation" task with patients seen within a mean internal post onset of 6.7 days. At the other end of the scale, Schenkenberg et al., (1980) showed how the relative prevalence of visual neglect could vary between 30-90% depending on the tasks choosen. At present, there is no single test used by all who investigate neglect. Some tests require the patient to search for or point to a visual stimulus on the contralateral side of space; some require representational drawing, while others require reading, or copying 2D drawings. The situation is further complicated by the fact that many clinicians use the bed side test of visual extinction as a test of neglect, with patients who otherwise shown intact visual fields. Recently, Ogden, (1985A) has shown a double dissociation between extinction as assessed by the confrontational technique of double simultaneous stimulation and a battery of 5 visuospatial tasks measuring visuospatial neglect.

The prevalence of neglect is also complicated by the issue of the criteria employed, and these have included;

(A) a failure to cancel targets on one side of a visual array. (Heilman & Watson, 1978).

(B) omission of details on one side when copying figures. (Gainotti, 1968)

(C) A greater response latency for visual targets to one side of a stimulus array.
(De Renzi, Faglioni & Scotti, 1970)

(D) A preference for targets to one side in a visually presented multiple choice task.
(Costa, Vaughan et al., 1969)

(E) Asymmetrical division of a horizontal line when instructed to bisect it. (Heilman & Valenstein, 1978)

As patients are often variable in the ways they manifest neglect, several authors have felt it necessary to use more than one test, as the chances are that in this way one is more likely to discover evidence of the condition than might be the case when only a single task is used.

The basis for this position originated from clinical and experiential studies such as Piercy et al (1960) which found that while 29% of patients in a right brain damaged group evidenced neglect on reading and counting visual stimuli, none of these showed neglect on copying or drawing. Furthermore, they also reported that 29% of the right brain damaged patients exhibited neglect on copying and drawing but not on any other test. More recently, Caplan (1987) has reported a similar dissociation between performance on a specially constructed reading task and two traditional tasks of neglect, the Ravens Coloured Progressive Matrices (R.C.P.M.) and Making Familiar Faces (M.F.F.). Caplan found that 11 (4 LBD and 7 RBD) patients who exhibited significant attentional bias on the R.C.P.M. and M.F.F. tests were able to perform the reading test without error. On the other hand, 10 (5 RBD and 5 LBD) while demonstrating clear cut omissions on the reading test, showed no significant position preference on either of the perceptual tests or on more general Occupational Therapy tasks.

2:8 The evidence for a "Neglect Syndrome"?

The detailed assessment of visual neglect only really began in the last twenty years. Up until the 1970's most of the large-scale studies reporting this neuropsychological sequalae of brain damage described the condition only in as much as it presented within a constellation of other visual, motor, somato-sensory and perceptual problems.

Hecaen's (1962) study provides an early illustration of some of the many features to be found in association with visual neglect in a large sample of retro-rolandic lesions. These include visual field deficits, constructional apraxia (defective visual control of manual activity) sensory loss, hemia-somatagnosia (unawareness of one half of the body), and dressing apraxia. However the basis for these relationships remains unknown.

Recently, however, Hier et al., (1983) has provided a detailed assessment of the relationship between 12 major behaviour sequalae commonly found after right hemisphere strokes. Details of these relationships are shown in Table 2.6

CORRELATION MATRIX - BEHAVIOURAL DEFICIT IN RIGHT HEMISPHERE STROKE PATIENTS

Table 2.6

DEFICIT	1	2	3	4	5	6	7	8	9	10	11
1. Hemianopia	-										
2. Arm weakness	08	-									
3. Leg weakness	38*	38*	-								
4. Extinction	23	10	31*	-							
5. Neglect	44*	21	23	50*	-						
6. Denial	27	36*	53*	46*	42*	-					
7. Impersistence	24	38*	52*	53*	48*	82*	-				
8. Face naming	38*	08	29	25	58*	46*	47*	-			
9. Rey figure	45*	44*	51*	23	26	42*	41*	36*	-		
10. Block design	32*	24	27	40*	49*	37*	38*	47*	79*	-	
11. USND	35*	26	17	12	33*	25	24	21	69*	63*	-
12. Dressing apraxia	47*	12	25	64*	62*	51*	56*	56*	56*	56*	40*

Adapted from Hier 1983 * P 0.05 N = 41

Subjecting this data to factor analysis revealed three major factors. The two main factors, entitled "inattention" and "visuospatial", accounted for over 52% of the total variance, and included visual neglect, constructional apraxia, extinction, and motor impersistence among its highest loadings. The emergence of these prominent "attentional and visuospatial features" is consistent with the traditional view of right hemisphere specializations for those tasks, requiring focused attention (Mesulam, 1981, 1985; Dimond, 1979; Heilman and Van Abel, 1980; Weintrab et al, 1987); and visuospatial processing (Joynt and Goldstein, 1975; De Renzi, 1982; Young, 1983). Table 2:7 may be taken as support for the position of those authors who propose a syndrome description with a common pathogenic mechanism and/or localization. (Heilman, Valenstein & Watson, 1985).

At a clinical level, Weinberg, Diller et al (1977), for example, have described visual neglect as "the primary defect underlying the problem of visual perception in R.B.D." (right brain damage). However, despite attempts to justify a unitary syndrome (Heilman & Watson, 1977; Heilman, Valenstein and Watson, 1985) the current situation remains uncertain. (Sunderland, 1984; Critchley, 1953; Schwartz et al, 1979). The main support for a unitary based condition rests on the assumption that several often contemporaneously presenting symptoms share the same behavioural description which may be characterized as the failure to notice objects located on the side opposite the lesioned hemisphere.

With regard to the modalities of sight and touch this claim may be open to question, given the limitations of normal clinical testing of functional motor or sensory deficits. (Heilman, Watson, Valenstein & Damasio 1983).

> "... Sensory loss may be the most common cause of a failure to report or response to a stimulus presented contralateral to the damaged hemisphere ... if the lesion site is unknown, one may not be able to distinguish hemianesthesia on hemianopia from severe inattention" (Heilman et al., 1985).

Despite this, Heilman and associates in particular have pursued the idea of a unitary hypothesis, preferring to consider the varieties of neglect, hemi-inattention (sensory neglect); extinction to simultaneous stimulation; hemiakensia - of the contralateral limbs, (Intentional or motor neglect); hemispatial neglect, (Visual spatial neglect on drawing/constructional tasks); and allesthesia (whereby a stimulation contralateral to the lesion is reported by the patient as ipsilateral) as part of the "sympton complex", of neglect. Heilman regards the syndrome approach as filling the gap left by other theorists who tend to confine themselves to selective features rather than to the fuller clinical presentation of the condition. Such a position regards the patients "neglect of their extremities, limb akensia, profound inattention, or allesthetic response, hemispatial neglect, head and eye deviation, and/or explicit denial of the illness", as constituting some of the features manifest in the acute stages of the syndrome. With recovery, patients progress along what appears to be a clinical continuum from florid neglect to extinction. Taken together with hemiakenesis and allesthesia, these phenomena are thought to represent a family of symptoms, whose clinical spectrum is determined by such factors as severity, location, and duration of the pathological process.

Many of these symptoms do not however necessarily co-occur. While most patients show hemi-inattention and hemispatial neglect, dissociated cases have been found (Ogden, 1985). Hemiakinesia and motor extinction can likewise occur without evidence of spatial neglect. (Valenstein & Heilman, 1981; Vallar & Perani, 1987). Furthermore, if we return to Hier et al's study (1983), which assessed 41 right brain damaged patients on 12 behavioural tests including hemi-inattention, extinction (tactile) and hemispatial neglect, there appears to be evidence that all three conditions (hemi-inattention, hemispatial neglect and extinction) are distinct disorders. The basis for this conclusion rests on the low inter-correlation observed between the three phenomena. Indeed this position receives some support from Heilman and Watson (1977) themselves who acknowledge that

> "sinic patients with neglect, allesthesia and extinction exhibit different behaviour, there can be little doubt that the pathophysiology underlying each of these behavioural aberrations is different".

Even within current hemispatial neglect research, there is now evidence to suggest the modality specificity of the condition. Villerditta, using a maze test of visual scanning to investigate the relationship between visual and tactile neglect found that right brain damage patients with visual neglect (line crossing and drawing tasks) preferred tactile scanning of the left visually neglected half of space. Villerditta concludes that

> "... this finding is not inconsistent with the view that there may be dissociable and modality - specific neglect phenomena with an intact modality able to compensate for the defective one".

This view is also consistent with the findings of Damasio and Geschwind, (1985) where cases of hemispatial neglect are reported in the absence of hemi-inattention, and at least 2 other studies (Bisiach, Cornacchia, Sterzi and Vallar, 1984; De Renzi, Gentilli and Pattacine, (1984), all of which failed to establish any significant coincidence between auditory extinction/neglect and visual neglect. In any event, these results fail to support a transmodal model of neglect and argue instead for the "disruption of discrete anatomical substrates specific for each modality". (De Renzi et al, 1984).

The limitations of a unitary syndrome approach include its lack of specificity, together with the fact that much of its support stems from animal studies. Furthermore, the heavy emphasis on animal studies which forms the basis for much of the unitary hypothesis (Heilman & Valenstein, 1979, Mesulam, 1981) has been itself the subject of discussion. (De Renzi, 1982). Recently, Halsband, Gruhn & Ettlinger (1985) have drawn attention to the fact that while damage to the posterior parietal lobe in man consistently gives rise to visual neglect it has never been observed as a consequence of parietal ablation in animal studies. The report by Heilman et al 1970, often cited as evidence of neglect in parietal monkeys, in reality describes extinction, which has "no lateralized predominance of one side over the other in cases of unimodal extinction". (Weinstein & Friedland 1977).

2:9 Conclusion

The resolution of whether neglect constitutes a syndrome or a group of relatively separate though temporarily and anatomically related symptoms has been hampered by the diversity of anecdotal and clinically based phenomena attributed to the condition, (Weinstein & Friedland, 1977); the variety of commonly unstandardized often cross-modal test procedures. (Heilman, Watson and Valenstein, 1985, Villerdita, 1987, Halsband, Gruhn & Ettlinger, 1985); the failure to establish the relationship between those tasks purporting to measure the condition (Keenan 1981); and the often over inclusive use of the term in cases where relevant sensory and motor deficits are concomitant factors. (Gianutsos and Matheson, 1987)

> "At this time, it is uncertain whether neglect can still be regarded as a unitary defect, or whether different processes are distributed in association with different forms of neglect". (Halsband, Gruhn and Ettlinger, 1985).

Note 1. Papangno, C. and Bisiach, E. Contributions on Neglect and Related Symptoms of the Neurologists between the end of the 1800 and the beginning of 1900. Unpublished Manuscript.

The Development of the Behavioural Test Battery

Chapter 3

3.1 Aim of the test

Having established that neglect is an important factor in rehabilitation, the question then at issue is how to assess the condition with a view to remediation. This study attempts to arrive at a representative assessment of visual neglect while at the same time providing the basis for a pragmatic assessment which might more readily permit generalization from the test results to adaptive functioning in the real world. The development of an objective behavioural test relevant to neglect should provide therapists with a more precise description of a patient's capabilities, and a more robust grounding for rehabilitation planning (cf. Chapter 1 and Chapter 2).

3.2 Behavioural Assessment

> "Coming to work in a rehabilitation centre can be a shock to the neuropsychologist accustomed to the academic setting where theory and scientific rigor are highly valued, or to acute care where assessment and diagnosis receive priority. In rehabilitation some form of treatment ... is the end and, in most cases, assessments and theory are regarded as little more than just a means to that end. One is therefore confronted at an early stage to justify one's work by showing its immediate practical significance". (Radcliff, 1987).

At present the challenge of neuropsychological rehabilitation is to develop appropriate concepts and instruments capable of demonstrating their validity and utility. (Diller, 1987). The traditional psychometric approach to assessment typically involves the systematic exclusion of confounding variables, ensuring the presentation and pacing of deliberately constructed often context-free materials in a suitably controlled environment.

Furthermore, many of the traditional tasks used in neuropsychology were designed to exploit individual differences and calibrated so as to facilitate the detection and locus of brain damage. As such, the majority of traditional tests do not mirror the typical demands of real life and do not readily inform us as to how the brain damaged patient will respond in situations close to everyday experiences.

> "Clinicans experienced with those patients are painfully aware that many of them function within normal limits on many formal neuropsychological tests and then show significant difficulties at work, in social situations, or at school". (Hart and Hayden, 1986).

Scores on a standardized neuropsychological battery can grossly overestimate a patient's ability to function in everyday situations. In many respects, traditional assessments stop short at the point of diagnosis and systematic description without having addressed the issue of remediation or rehabilitation (Diller and Weinberg, 1977).

Currently, there seems to be a general movement away from such purely diagnostic issues(Diller and Gordon 1981; Diller, 1987; Caplan, 1982; Costa, 1983; Heaton and Pendleton,1981) towards the position that recovery and success in rehabilitation are for the most part a function of the criteria choosen to measure it. (Barth & Boll, 1981).

With regard to visual neglect, traditional assessments have centred about useful, yet typically unstandardized tests of simple perceptual motor abilities. At present, there remains substantial disagreement among researchers in the field as to the relative incidence and extent of visual hemineglect following stroke in particular. What is required, is the development of a standardized multi-component battery, capable of answering both the theoretical questions of detection, type and extent, while at the same time going some way towards providing therapists and clinicans with a practical understanding of the patient's behavioural deficits and strengths.

The present chapter describes the development of such a battery of tests.

3.3 Design of Study

This study set out to achieve two major goals. First, the standardization of a battery of "conventional", pencil and paper tests capable of assessing visual neglect and at the same time establishing performance norms. Second, to assess the validity and reliability of a battery of behavioural tests. The validity of these behavioural tests as a measure of real world or everyday significance would be established by correlating the test performances with observations by therapists working directly with the patients.

3.4 Subjects

As the main aim of the thesis is to construct and validate a short test capable of evaluating visual neglect on a range of real world tasks, the primary requirement for selection within the patient group was that there should be a high incidence of the condition under study. This required the selection of a greater number of right hemisphere damaged patients.

A total of 130 patients with an initial diagnosis of unilateral brain damage secondary to cerebrovascular insult were recruited over an 18 month period. Given the expected neurological differences between patients (mode of onset, course, and associated symptoms) it was thought auspicious for the predictive strength of the test to collect data from patients with a similar aetiology. All patients save three were seen at Rivermead and were receiving ongoing rehabilitation. Rivermead is a 30 bed neuro-rehabilitation unit that caters for brain damaged adults within Oxfordshire. The majority of inpatients have suffered either a stroke or severe head injury. Each patient has his or her own timetable, which is reviewed weekly and consists where necessary, of sessional placements in physiotherapy, occupational therapy, speech therapy and psychology departments.

The criteria for inclusion in the study were:

(1) the absence of a prior history of stroke or major C.N.S. disorder.

(2) at least one week post onset at the time of testing.

(3) absence of any significant local impairment in visual or auditory modalities.

(4) no history of alcoholism, major psychiatric disturbance or evidence of generalized intellectual deterioration.

(5) that patients be sufficiently oriented, so as to be capable of responding to all the tasks administered.

(6) that all patients were right handed (writing hand and self report of hand preference were used as indicators of handedness.)

Of the 130 patients identified, 35 were excluded for reasons of bilateral cerebral involvement, severe visual impairment, general cognitive deterioration, and/or severe language/comprehension difficulties. Particular care was taken to include those aphasic patients who could understand the test instructions with prolonged explanation. 15 patients were excluded for reasons of insufficient or incomplete testing. Of the remaining 80 patients, 54 had right sided lesions, (RBD) and 26 left sided lesions (LBD). Table 3:1 lists some of the demographic details for the total sample of subjects tested.

Patients were allocated to one or other group according to the physical signs, but in most cases, the presence of a hemispheric lesion was supported by angiography and/or computer axial tomography. The average age of the RBD group was 57.7 with an age range of 33-74 years. The average age in the LBD group was 54.6, with an age range of 19-83. 50% of the RBD patients evidenced visual field deficits or extinction, while similar disorders within the LBD group constituted less than 30% of the total group. The majority of LBD patients (70%) evidenced some form of dysphasic disorder.

Neurological Examination

All subjects received a standard neurological examination upon admission, and these findings (which included clinical assessment of eyesight, visual fields, hearing, sensation, proprioception and motor co-ordination)

TABLE 3:1

SUBJECT CHARACTERISTICS

	L.B.D.	R.B.D.	Total	Controls
Number of subjects	26	54	80	50
Age	M. S.D. 54.6 (12.5)	M. S.D. 57.7 (8.4)	M. S.D. 56.2 (10.5)	M. S.D. 58.2 (13.5)
Range	19-83	33-74	19-83	22-82
Sex	M 17 (65%) F 9 (35%)	M 35 (65%) F 19 (35%)	M 52 (65%) F 28 (35%)	M 14 (28%) F 36 (72%)
IQ (NART)	M. 108.7 (9.8)SD	M. 108.6 (9.6)SD	M. 108.65 (9.7)SD	M. 115.1 (9.2) SD
Average	13 (62%)	26 (50%)	39 (53%)	15 (30%)
Above av'ge	5 (23%)	20 (40%)	25 (34%)	13 (26%)
Superior	3 (15%)	6 (10%)	9 (13%)	22 (44%)
Patients with Complete Data	(N=21)	(N=52)	(N=73)	(N=50)
VFD	7 (27%)	27 (50%)	34 (42.5%)	
Language Problems	18 (70%)	3 (5%)	21 (26%)	

VFD = Visual Field Deficit or Extinction
LBD = Left Brain Damaged Patients
RBD = Right Brain Damaged Patients
IQ (NART) = National Adult Reading Test
M. = Mean
S.D. = Standard Deviation

were taken into account when assessing the patient neuropsychologically. Visual field deficits were assessed principally by confrontation techniques and recorded as partial (upper or lower quadrantopia) or complete (homonymous hemianopia) when elicted with fixation by single stimulus presentation. Patients without such a deficit were subsequently tested for visual extinction using double simultaneous stimulation. Failure to report one of the two simultaneous stimuli presented bilaterally on full confrontation was classified as extinction. The presence or absence of a visual field deficit was often confirmed by perimetry. Gaze paresis and sensory extinction were also tested in most patients.

Controls

Fifty control subjects were seen in order to provide normative data for the test items. These were recruited from several sources and included hospital employees, members of the Oxford University subject panel, and volunteers from various community based groups. They were of a similar age to those of the patient group ($\bar{X}$ age 58.2). The main criteria for control subject selection was that they should have no history of brain damage, and ly within the age range of both brain damaged groups. They did not differ in mean age from the patient sample ($t = 0.69$; $df = 98$; N.S.).

3.5 Neuropsychological Evaluation

A battery of 15 tests were developed to assess the existence and extent of visual neglect. These tasks were constructed to be sufficiently demanding, so as to engage a high level of response on the part of the patient. Assessments were usually performed within the first week following admission to Rivermead. Each patient was tested on their own in a quite, distraction free room. The assessment often took an hour to complete, although many patients were capable of completing all tasks within 45 minutes. Table 3:2 lists the range of tests administered to each subject.

Table 3.2

Assessments

1 Clinical Neurological Examination

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

3 Galveston Orientation Test (Levin, O'Donnell and Grossman, 1979)

4 Psychometric Test Battery

(A) "Conventional Tests" of Visual Neglect

(1) Line Crossing

(2) Letter Cancellation

(3) Star Cancellation

(4) Copying Tasks

(5) Line Bisection

(6) Representation Drawing

(B) Behavioural Tests of Visual Neglect

(1) Picture Scanning

(2) Telephone Dialling

(3) Menu Reading

(4) Article Reading

(5) Time Reading/Setting

(6) Coin discrimination

(7) Address/Sentence Copying

(8) Map Navigation

(9) Card Sorting

5 Occupational Therapy Questionaire/Checklist

The assessment covered a wide range of abilities and yet was practical and simple to administer.

(A) The National Adult Reading Test or (N.A.R.T.) Nelson (1982) was administered to all patients (save 6) and control subjects, so as to provide an estimate of intellectual functioning. Formal testing of intelligence (eg WAIS-R) was considered inappropriate given, comprehension, practical and temporal constraints. Unlike other cognitive tests which claim to measure current levels of functioning and then infer discrepancies from pre-test performance, the N.A.R.T. by evaluating the patients competence to correctly pronounce phonetically irregular words, permits a more accurate and easily accessible prediction of premorbid functioning. (Nelson and O'Connell, 1978). The N.A.R.T. comprises 50 words printed in order of increasing difficulty. The subject reads aloud the list of words and the number of errors recorded. Using the appropriate regression formulae permits the prediction of a Verbal, Performance and/or Full Scale WAIS IQ. In some cases it was necessary to use a specially prepared set of cards with an enlarged set of letter types. This was used with patients with poor sight or obvious neglect. Five patients could not be assessed due to speech problems, and in one case, severe visual neglect made it impossible for the patient to read anything without missing off the left side of the word.

(B) Galveston Orientation Test; This was adapted from Levin, O'Donnell and Grossman (1979) and was completed by every patient so as to ensure that they were correctly oriented in time, place and current affairs. An arbitrary cut off was set at 90/100, below which the patient was excluded from further testing. (A copy of this test is provided in (Appendix I).

(C) The battery of visual neglect tests can be divided into two groups, "conventional" tests and everyday "behavioural" tasks.

The conventional or traditional pencil and paper tests have all been described in the clinical literature and have been referred to in earlier chapters. Although commonly employed in the clinical setting, most of those tests have not been standardized and for this reason studies reporting the incidence of neglect in brain damaged patients, have to be considered within the context of test used and the various criteria employed.

In order to validate the behavioural tasks, several tests were choosen from the literature and a standardized format was created for each. It was felt that these tests should be easy to administer, simple and relatively unambiguous to score, yet sufficiently wide ranging to detect less obvious signs of visual neglect. Given the evidence for the heterogeneity of the condition (Weinstein and Friedland, 1977, Ogden, 1985), a battery of 6 tests was constructed.

"... when a battery is used for the detection of neglect, individual cases may show dissociations; a particular patient may show extrapersonnel neglect on a visual task, yet have a normal performance on a tactile task, while another patient may show a reverse pattern.... Dissocation of this sort suggest that different tasks may involve different functional sub-components, which may be selectively impaired in individual cases". (Bisiach and Vallar, 1987).

Protocols for the administration and scoring of each test were drawn up. Following an initial pilot study carried out at Rivermead and reported in Wilson, Cockburn and Halligan (1987), a number of tests were removed or redesigned, so as to elicit more reliable evidence of visual neglect. All tests were given in the same order to subjects.

3.6 Conventional Tests

(1) Line Crossing. The original version of this test was designed by Albert (1973) and consisted of a modification of an earlier clinical test used by Denny Brown (1963). The patient is required to cross out, 40 (2.5 cm long) black lines drawn at various angles and arranged in an apparently random manner over an A4 page (209 x 297 mm). Albert's (1973) original standardization of this simple visual search task required the examiner to draw over the 40 lines on the test sheet with a red pencil so as to draw attention to them. The patient was then given a pencil and instructed to cross out all the lines, after the examiner had demonstrated the desired response by crossing out one of the 4 central lines.

The original version was standardized on 30 controls and 66 patients, who were 3 or more weeks after unilateral surgery. None of Albert's controls missed any of the lines, and hence the criterion choosen for neglect on this task by Albert was the presence of any uncrossed line. Albert's sample of neurosurgical patients did not differ significantly with regard to the lateralized frequency of omission, given the criteria employed, although patients with right sided lesions neglected almost 7 times as many lines as those of left sided lesions.

In restandardizing this test on a stroke population a number of changes were introduced.

(A) Although the same number of lines and their length were again used, their position and relative angulation differed from that of Albert. Furthermore the test page used was 209 x 297 mm (A4). (Cf. <u>Fig. 3:1</u>).

(B) The examiner did not draw attention to any of the lines by drawing over them with a red pencil. It was considered more desirable to observe the patients "uncued" performance, as might be the case in other daily activities engaged in by the patient. Albert's procedure might be expected to reduce the overall number of omissions.

(C) The examiner demonstrated the required response by crossing out <u>two</u> of the <u>four</u> lines located in the central column.

(D) The subject is then given the pen, and instructed to "cross out all the lines" they can see on the page. The test is concluded when the subject indicates that they have crossed out all the lines. The total number of lines crossed is then noted. The four central lines are not scored. Contralateral, ipsilateral and more diverse patterns of omission are noted on the score sheet provided.

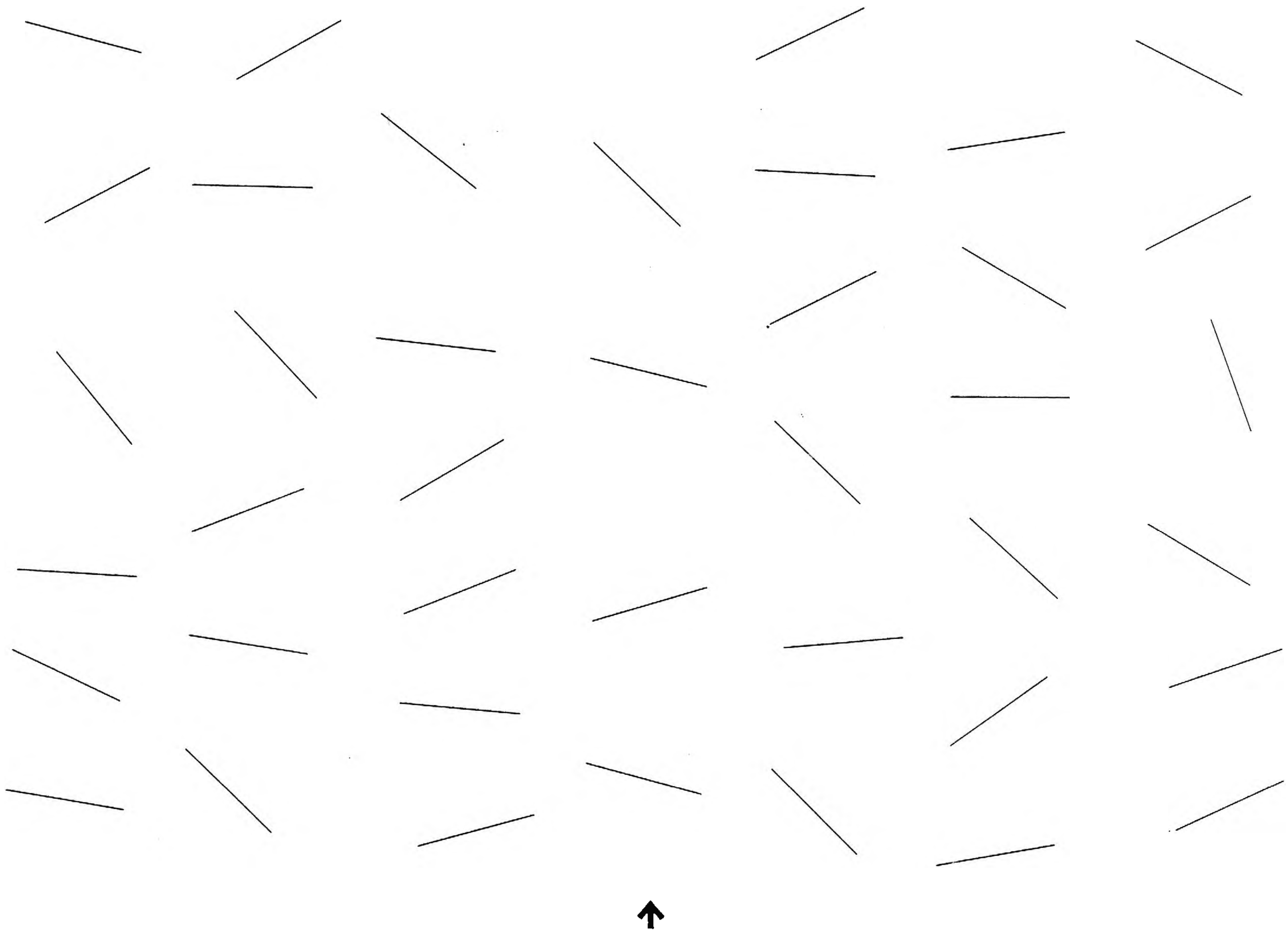


Fig.3.1 Line crossing test.

(2) Letter Cancellation

This paper and pencil test requires the patient to locate and cross out specific designated targets from a background of different non-targets. The test taps many functions including those of sustained attention, (vigilance), visual scanning, and the inhibition of rapid responses. The test has been shown to be a useful measure of both gross lateral neglect and more subtle visual inattention. (Lezak 1984). At the New York University Medical Centre, Diller and colleagues (1974, 1977, 1979) have experimented with this type of test using objects, letters, short words, pictures and small geometric shapes as target stimuli. An example of the later, has been recently developed by Mesulam (1985).

The basic form of the test consists of several rows of letters, randomly interspersed with designated target letters. Increasing the demands of the test can be easily achieved and produces a significant increase in omissions or completion time. e.g. In a "target only" condition (i.e. line crossing) the patient is simply required to cancel (cross out) all stimuli. A more demanding task requires the patient to discriminate targets from non-targets. Finally, the most difficult version "target-foil" requires the greatest amount of selective attention, scanning and identification skills so as to avoid crossing out foil targets from a background of targets and non-targets. Rapscak, Fleet and Heilman (1987) report significantly more omissions on this more difficult version of the task. Furthermore studies by Diller and Weinberg

(1977) has shown that the test can be made more difficult when target items are located closer to each other in the open display. Increasing the distance between the designated targets reduces the total number of omissions. The total number of non-target characters between targets has also been shown to contribute to the omission rate. Interestingly, the particular target stimuli, eg letters, numbers, shapes, words, pictures or geometric shapes do not appear to influence performance (Diller and Weinberg 1977). A recent study by Caplan (1985) confirms this, in that subjects who exhibited neglect, did so to a comparable degree on both verbal and non-verbal tasks.

The letter cancellation task developed for the present study consisted of 5 rows of 34 upper case letters presented on an A4 page (209 x 297 mm). The 40 arbitrally choosen targets (24%), letters "E" and "R", were placed so that an equal number appeared on each side of the page. The letters were each 6 mm high and were positioned close together (2 mm spacing). The density of the items in each row served to increase the information load of the task. Maximum score was 40, and a scoring template allowed the scorer to divide the total array into 4 columns of LL (left left), ML (middle left), MR (middle right), and RR (right right).

The examiner after pointing out the stimulus letter "E" and "R" located at the bottom of the stimulus sheet (cf. Fig. 3:2) instructed the patient to locate and cross out (cancel) all the target letters they could find on the page. On completion of the task, the total number of omitted target letters was computed and their locations noted.

AEIKNRUNPOEFBDHRSCOXRPGEAEIKNRUNPB
BDHEUWSTRFHEAFRTOLRJEMOEBDHEUWSTRT
NOSRVXTPEBDHPTSIJFLRFENOONOSRVXTPE
GLPTYTRIBEDMRGKEDLPQFZRXGLPTYTRIBS
HMEBGRDEINRSVLERFGOSEHCBRHMEBGRDEI

E & R

↑

Fig.3.2 Letter cancellation test.

3. Star Cancellation

Work by Mesulam (1985) has suggested that more targets are neglected when the array of target - non-targets is not structured. In the letter cancellation task, the patients scanning is facilitated by the linear row of stimuli. Less structured stimuli allowed a more sensitive measure of hemispatial neglect, even when other comparable tasks such as line crossing are performed within normal limits.

The star cancellation task was developed to evaluate more subtle forms of visual neglect. The test consists of random arrays of both verbal and non-verbal stimuli (stars) as shown in Fig. 3.3 The stimuli, 52 large stars (14 mms), 13 randomly positioned letters, and 10 short (3-4 letters) words are interspersed with 56 smaller stars (8 mms) which comprised the target stimuli. Like all the tasks the A4 page with the stimulus array is presented directly in front of the patient. Again like the other tasks the patient is instructed to cancel all the small stars they can find. Two examples of the small stars are pointed out (along the mid-saggital axis) and cancellation is demonstrated (crossing out two central stars). The test sheet can be divided into 6 columns; 3 left (27) and 3 right (27). The two central "demonstration" stars are not included and therefore the maximum score is 54. Patients with left neglect (right sided lesions) typically begin on the right side and in extreme cases rarely approach even the centre of the test sheet. Because of its sensitivity the test has been shown to be a useful instrument for monitoring the recovery of neglect.

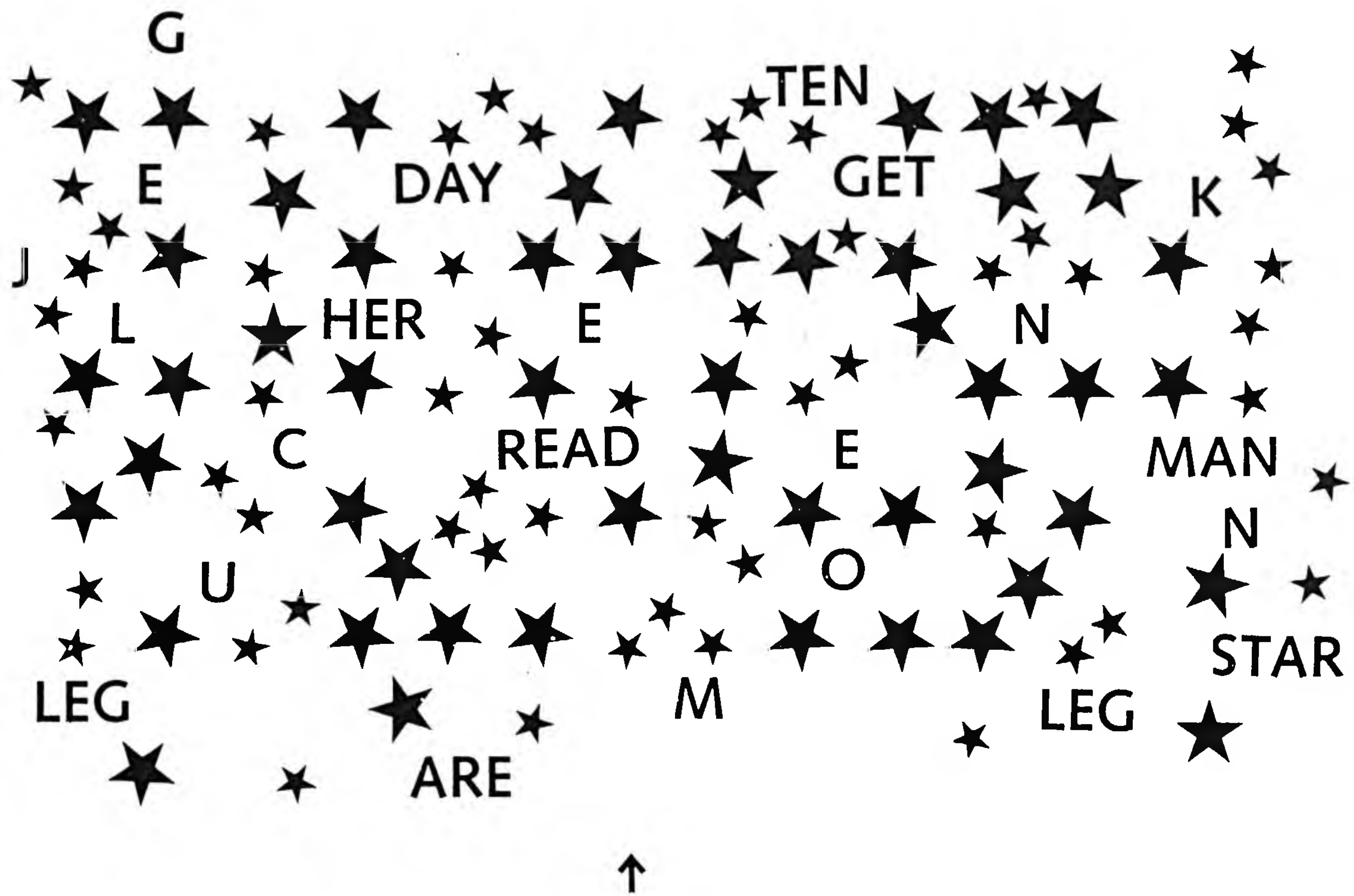


Fig.3.3 Star cancellation test.

(4) Figure and Shape Copying

This is probably the simplest and one of the most common clinical methods of eliciting visual neglect. Although potentially confounded by motor problems and other visual-motor difficulties secondary to brain damage the neglect patient's performance usually remains quite distinct. Most of the early researchers used copying of two dimensional objects as the preferred method of illustrating and assessing the condition. (Patterson and Zangwill, 1944; McFie, Piercy and Zangwill, 1950; Battersby et al, 1956; Lawson, 1963; Hier et al, 1983; Meienberg et al., 1986; Isaacs, 1971; Zarit and Kahn, 1974; Oxbury, Campbell and Oxbury, 1974; Kinsella & Ford, 1980; Gainotti et al. 1972; De Renzi, 1982.

In the present study the patient was instructed to copy three separate simple drawings from the left hand side of an A4 page cf. Fig 3.4. In cases where the patient has to use left hand, the copy of the stimulus sheet is put directly above the response sheet, so as to ensure that the patients left hand does not obscure the target stimulus while in the process of copying. The three drawings, a four pointed star, a cube, and a daisy flower are arranged vertically and are clearly indicated to the patient. The second part of this test requires the patient to copy a group of 3 geometric shapes presented on a separate A4 stimulus sheet (Fig. 3.5). This time the contents of the page are not explicitly pointed out to the patient.

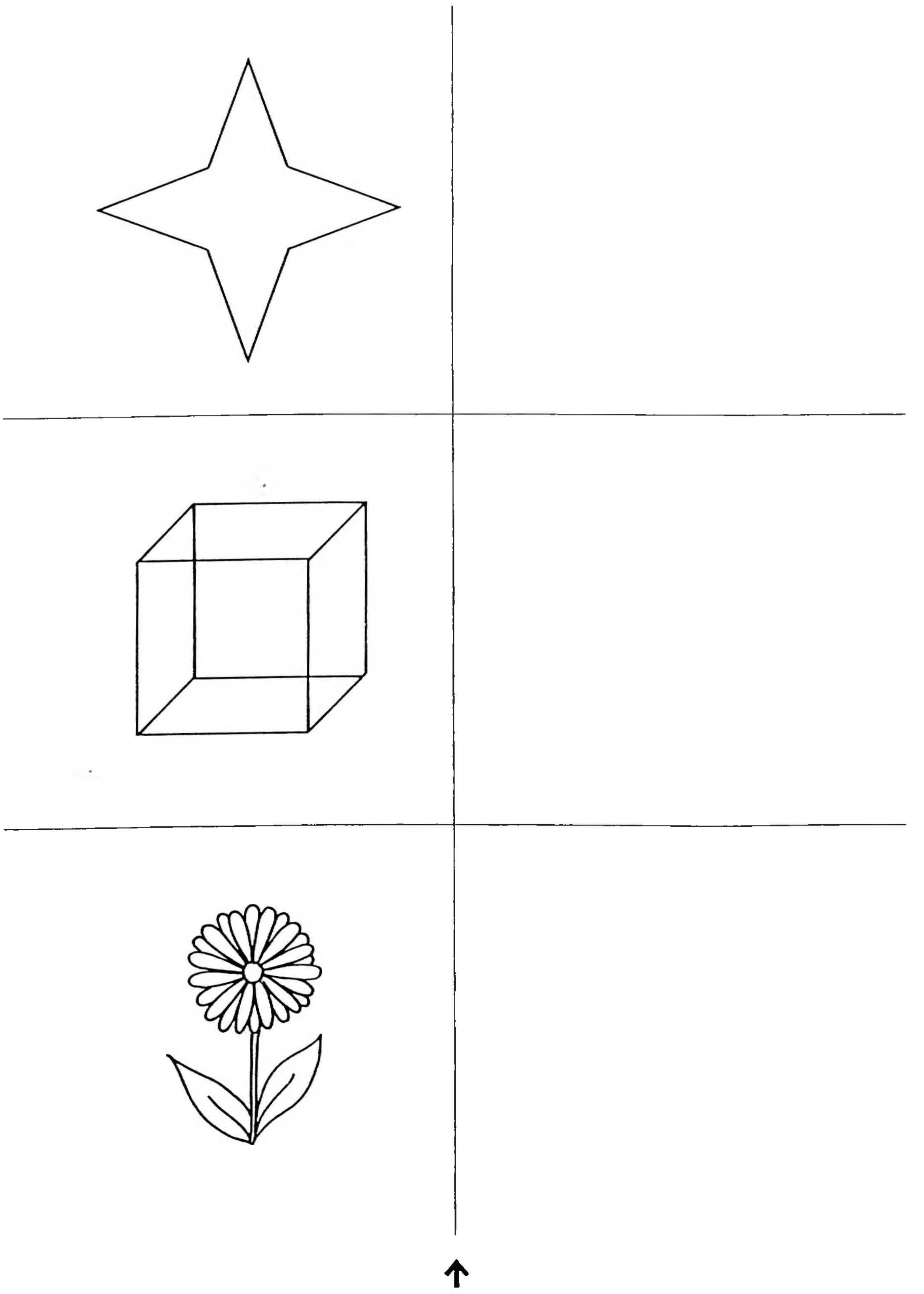


Fig.3.4 Figure and Shape copying test (1)

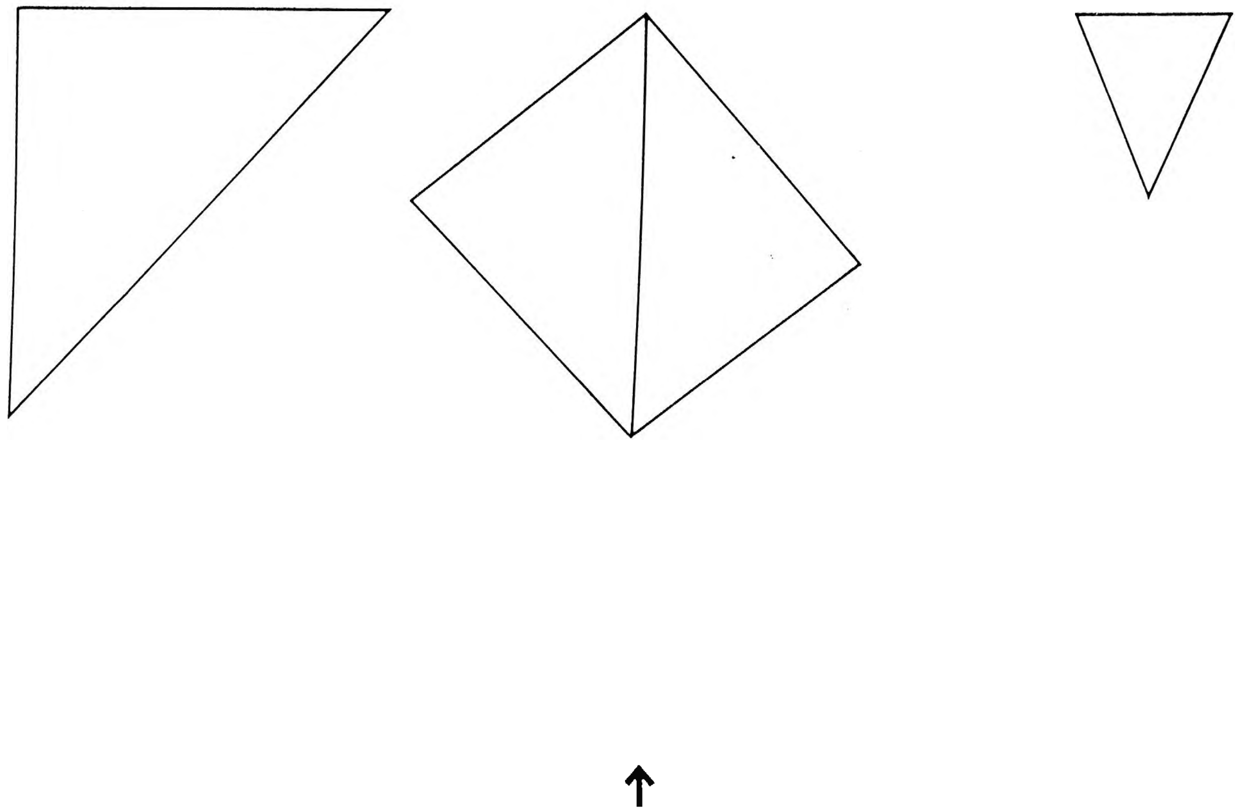


Fig.3.5 Figure and Shape copying test. (2)

The scoring of this sub-test was based on the completeness of the respective drawings. The presence of neglect was defined as an omission or gross distortion of any major lateralized component of the drawing. The first three drawings were scored out of a total of 3 points, (one point per complete drawing). The second drawing was scored as either complete or incomplete with the former achieving a score of one. The reason for the binary scoring system arose from experience with the pilot study which suggested that the continuum between complete and incomplete was fraught with difficulties of interpretation and ambiguity.

5. Line Bisection. This remains the most common bedside test used to obtain evidence of visuospatial neglect. (Gilroy and Meyers, 1969). The clinical procedure was originally taken from early German psychophysical studies (Kund, 1863) by Axenfeld (1894, 1915) who considered the test a useful method of "quantifying asymmetrical spatial behaviour" in patients with visual field deficits (Bisiach, Capitani, Columbo, and Spinnler (1976). Since then, numerous authors have used the test to investigate features of neglect. (Kleist, 1934; Patterson and Zangwill, 1944; Diller et al. 1974; Diller and Weinberg, 1977; Columbo et al. 1976; Weinberg et al. 1979; Zarit and Kahn, 1974; Rosenberger, 1974, Schenkenberg et al., Critchley, 1953; Heilman and Valenstein 1979; Bradshaw et al. 1985; Bisiach et al. 1983; Bowers & Heilman, 1980; Ishiai, Furukawa, and Tsukagoshi, 1987; Riddoch and Humphreys, 1983; Bisiach et. al, 1976).

Although the number and position of lines have varied between studies, the task basically requires the patient to estimate and mark the centre of a horizontal line.

"The expectation is that the patient will incorrectly estimate the centre of the line to the right of true centre, neglecting the left end of the line". (Schenkenberg et al., 1980).

Norms for control subjects have been described by Bisiach et al. (1976), Bradshaw et al. (1986) and Scarisbrick et al. (1987). All report, a tendency for normals to bisect lines to the left of centre using the preferred right hand. Bradshaw et al., (1986) calculated this left sided deviation from true centre to be about 2% ,"slightly more so with the left than with the right hand". Bowers and Heilman (1980) refer to this phenomenon as "pseudoneglect".

Using the line bisection task, two studies have addressed the question of the dissociable sensory and motor deficits involved in neglect, by assessing the relationship between effects of hemispace and overt cueing.

"Hemispace" is a complex term (Heilman, Bowers, Valenstein and Watson, 1987) and refers to an egocentric co-ordinate system by which the middle of the body/head serves as the plane which divides space into left and right sectors. Therefore left hemispace refers to the space that lies to the left of the body midline and right hemispace refers to that section of space to the right of the midline. Hemispace and visual field are not synonymous and are only aligned when the eyes are fixated on a midline visual stimulus. For assessment purposes, considerations of hemispace may involve the placing of the right or left edge of the stimulus sheet containing the horizontal line, 30 cm to the left or right of bodily midline. (Heilman, Bowers, and Watson 1984). Others such as Scarisbrick et al. (1987), Bradshaw et al. (1985) and Schenkenberg et al. (1980) have used centrally positioned stimulus sheets with lines commencing near the left or right margins.

Consistent with their hypokenetic hypothesis of neglect, Heilman and Valenstein (1979) reported that patients with right hemisphere lesions demonstrated more left sided neglect (i.e. right sided deviation) when the lines to be bisected were located in the left rather than the right hemispace. Cueing by way of letters, either at both ends or at one end respectively did not appear to effect the magnitude of neglect. A replication study, by Riddoch and Humphreys, 4 years later (1983) found that cues significantly influenced the extent of neglect, and so supported the attentional deficit theory (Riddoch and Humphreys, 1987). A left sided cue significantly decreased the magnitude of left sided neglect. Unlike the previous report by Heilman and Valenstein, they did not report a significant effect for hemispace position.

The line bisection task developed for the BIT used features described in earlier studies. The task consisted of 3 horizontal 8 inch (204 mm) black lines [(1 mm) thick] laid out in a staircase fashion across the page (Fig. 3.6). The extent of each line is pointed out to the patient who is then instructed to estimate the centre. The test is scored by measuring the deviation from the patients actual midpoint to that of the true midpoint. The maximum score for each line is 3. The total score of nine points (3 x 3) is achieved if the patients' mark in all three cases lies within 13 mm (1/2") of the true centre. Deviations from the true centre are scored by reference to deviations scores on scoring templates provided.

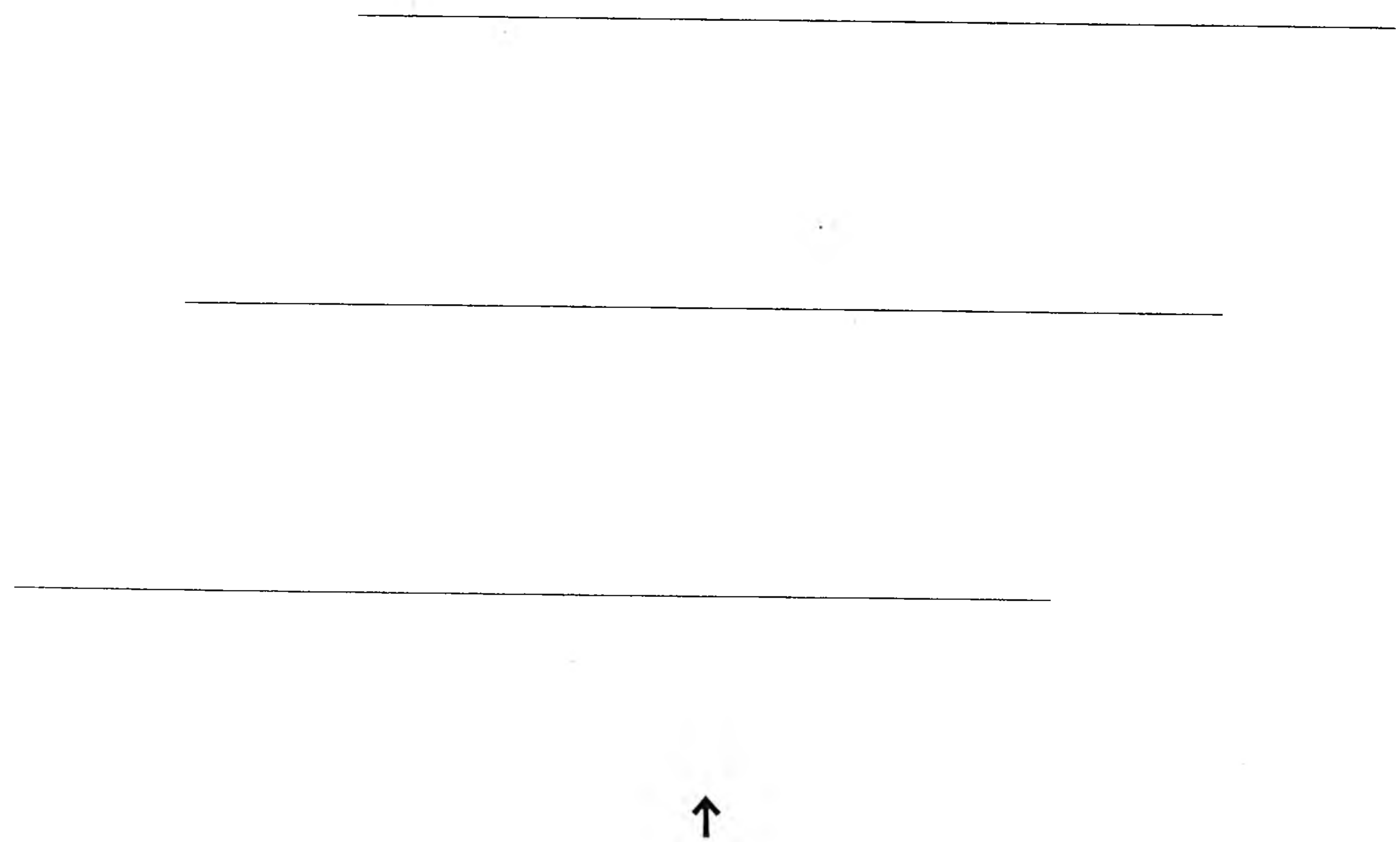


Fig.3.6 Line bisection test.

6. Representational Drawing

One of the most striking features of visual spatial neglect remains the incomplete drawings of patients who at least verbally appear to have a congruent symmetrical representation of an object. This test of representational drawing has been a popular method of demonstrating neglect (Patterson and Zangwill, 1974; Critchley, 1953; Lawson, 1962; Colombo et al. 1982; Piasetsky, 1982; Cutting, 1978; and Ogden, 1985). Examples of freehand drawings by such patients are demonstrated in Oxbury et al., 1974; Andrews et al., 1980; Riddoch and Humphreys 1983 and Chakravorty, 1980.

In the present case the patient is presented with 3 blank A4 sheets of paper, (one at a time) and is instructed to draw;

(A) a large clock face, all the numbers, and set a time

(B) a simple drawing of a man/woman

(C) a simple drawing of a butterfly

All task stimuli are easily conceptualized and in the case of (B) and (C) typically exhibit symmetrically similar halves. This task is designed to assess the patients premorbid visual representation of the stimulus in the absence of any direct or immediate sensory input relevant to the task item. Drawings of the human form together with those of symmetrical insects such as butterflies have shown themselves to be particularly sensitive stimuli in this regard.

One of the first references to the use of a clock face dates from Patterson and Zangwill in 1944. Since then several investigations have found it to be a sensitive measure. (Oxbury et al., 1974; Ogden, 1985; Bisiach et al, 1981). The scoring of representational drawing is similar to those of the copying task described earlier.

3.7 Behavioural Sub-tests

Studies that attempt to use neuropsychological test data to predict everyday functioning have reported some success (Heaton and Pendleton; 1981). However the relationship between such often diverse neuropsychological tests and their implications for daily therapeutic or functional tasks remain unclear.

> "For example, after a thoughtful discussion and investigation, Suzanne Corkin (1979) concludes 'The nature of the deficit revealed by the Hidden Figures Test remains a puzzle'. Such forthrightness is refreshing. The state of the art will advance only when we recognize that traditional tests are often complex and themselves require explanation. All too often they are used for clinical assessment and then offered as explanations". (Gianutsos et al. 1987).

In many cases the task demands are not readily apparent and as such do not readily facilitate clinical and prognostic judgements. There appears to be a discrepancy between the types of subjective experience described by the patient and the often indirect assessment of the underlying problem. (Hart and Hayden, 1986).

> "A part of the differences of opinion is linked to the fact that unilateral neglect has been examined and measured indirectly on the basis of results of tests which vary from one author to another (copying designs, tests by crossing out, asymmetric searching line in the course of visual exploration etc)." (Chedru, et al, 1973).

In order to construct a brief battery of tests capable of sampling some of the more 'real world' experiences of neglect patients in rehabilitation settings, information regarding their everyday difficulties were obtained from;

(1) Case reports described in the literature (Diller and Weinberg 1977, 1970; Lorenze and Cancro, 1962; Weinstein and Friedland, 1977; Critchley, 1953; Sunderland, 1984; Piasetsky, 1981; Smith, 1982; Piggott and Brickett, 1966).

(2) Informal observations of patients with neglect at Rivermead prior to formal data collection.

(3) Discussions with

(A) Occupational therapists

(B) Physiotherapists

(C) Clinical psychologists, geriatricans and neurologists, all of whom had experience with a number of patients suffering from left sided spatial neglect.

Numerous test items were reviewed. The practical selection of items was determined by the results of the pilot study together with considerations of time, duplication and item testability. Nine sub-tests comprised the behavioural battery.

(1) <u>Picture Scanning</u>

Scanning (i.e. the apprehension of successive samples of the visual environment) is central to visual information processing and underlies the ability to read (Gibson, 1970) detect and integrate complex stimulus arrays. This type of picture scanning has been used by Battersby et al,

Fig.3.7 Picture scanning test;copy of the three photographs.

(1956) - coloured magazine illustrations; Diller, (1974, 1980) - counting people in a photograph from a diplomatic conference, Young et al. (1983) - counting faces from a group picture of medical personnel.

In an effort to make the picture material more relevant, subject matter relating to the patient's everyday environment was used. 3 large photographs, each measuring 357 x 278 mm, are presented on a white background. The three large photographs were presented one at a time and depicted (1) a salad meal on a plate (2) a wash basin and toiletries, (3) and a large window flanked by various pieces of furniture and hospital aids. Each photograph has various items arranged about its' midline (Fig. 3:7). The patient is instructed on each occasion to name and/or point to the main items seen in each picture. The photographs are placed in front of the patient who is not allowed to move them. A score sheet is supplied and a note of all the items mentioned are kept. Only omissions are scored, errors of identification are not scored although noted. The scoring of this and all subsequent behavioural tests is out of a total of 9 and is based on the total number of omission recorded. Laterality or diversity of ommissions can be indicated on the score sheet (cf. Appendix II).

(2) Telephone Dialling

One of the areas that occupational therapists and patients with neglect agreed caused some difficulty was that of making phone calls. Several patients although knowing the number well (eg. their own home phone number)

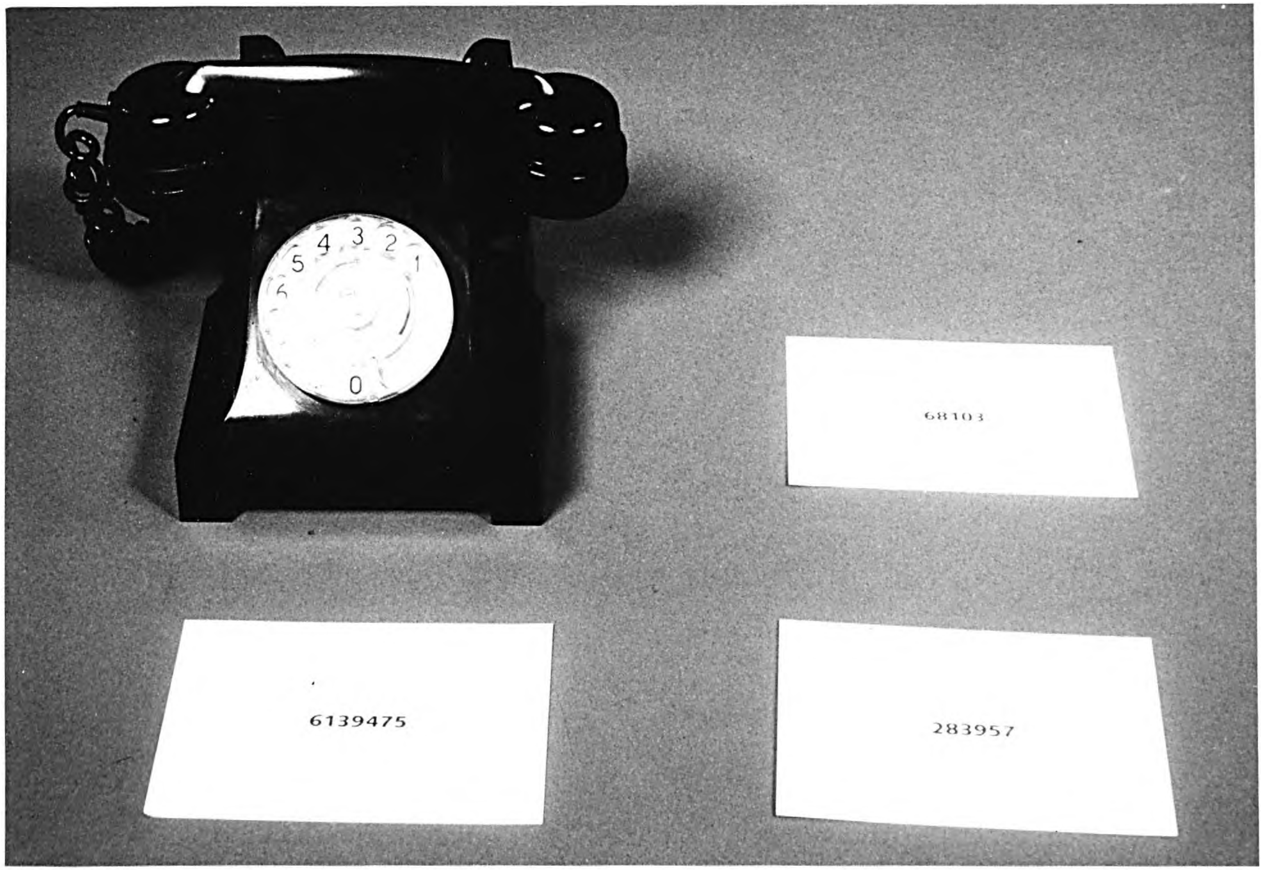


Fig.3.8 Telephone dialling test.

neglected some of the numbers while dialling. Other patients, and this was the most common problem, neglected the number as they read it from their list of telephone numbers. For the purposes of this test, a disconnected telephone with numbered dial on push button keyboard is presented. Three cards with telephone numbers printed in large numerals were presented, one at a time. Each number was placed directly in front of the telephone and the patient was then instructed to dial the number presented. The patients dialling sequence is recorded, together with the number and location of omissions. (Fig. 3:8).

(3) Menu Reading, consisted of an open-out page (420 x 297 mm) containing 18 common food items arranged in 4 adjoining columns. (2 on the left side and 2 on the right). The food items were printed in 6 mm high letters. A similar type of task was presented by Battersby et al (1956). In the present case the patient was presented with an unopened menu. On opening the menu, the patient is instructed to read out all the items she/he can see. The food items were choosen from a variety of hospital menus, and could as easily represent a shopping list or time schedule. Language impaired patients were permitted to point to all the words they saw. Each of the 18 items are scored as either correct, complete or partial omissions. The latter two are scored the same. In the case of language impaired patients only complete word omissions can be scored. (Fig 3.9).

4. Article Reading, remains a favourite test for many researchers working in the area of neglect. Several tests

Grapefruit	Tomato soup	Roast chicken	Tea
Ham & eggs	Pork chop	Lamb chop	Hamburger
Fried haddock	Shepherd's pie	Turkey	Salad
Cheese	Jam tart	Veal	Milk
Biscuits	Ice cream	Boiled eggs	Apple tart
Apple pie	Coffee	Melon	Sandwiches

Fig.3.9 Menu reading test.

have been used to evaluate this condition; Diller, 1980; Diller and Weinberg, 1977 and Young et al. (1983) used the Wide Range Achievement Test. (W.R.A.T. - reading subtest) from Jastak and Jastak (1965). This test consisted of a list of 74 words printed on 10 lines. Piggott and Brickett (1966), Issacs, (1971) and Diller and Weinberg (1977) have used newspaper headlines or text as test material. Unlike the W.R.A.T., this material was usually current and meaningful to the patient. Other tests used have included the Gray Oral Reading Test (Diller and Weinberg, 1977), Metropolitan Achievement Test (modified) (Gordon et al. 1985).

Caplan (1987) and Ellis, Flude and Young, (1987) have divided reading errors due to neglect into two basic types.

(1) There are those patients who omit or misread the first letters of particular words. Initial letters may be simply omitted especially where the residue forms a word meaningful in its own right. On the other hand the initial letters are often substituted by others eg. 'message' read as 'passage'.

(2) Secondly there are those patients who due to neglect have difficulty relocating their scanning from the end of one line (right) to the beginning of the next (left) and therefore fail to read the initial words. Such patients may begin each line of a passage in the centre, reading to the end of each line only to return to the centre. These two types are not mutually exclusive. Further details of "neglect-dyslexia" are described in Diller and Weinberg, 1977; Gilliat and Pratt, 1952;

HARSH TIME AHEAD

If Government plans for reform of the social security system go ahead in their present form, they could put the clock back to the harsh Poor Law.

'It appears to be deliberate Government policy to make it so difficult and humiliating for some people to claim state benefit, that many will go without rather than submit to the new indignities which the state will heap on them', said the Joint Consumer Council.

The committee, which represents all leading consumer groups, including the National Consumer Council, the Government's own consumer watchdog, welcomes reform of the social security system, but not in the way suggested.

The reform should be achieved by abolishing most means-tested benefits and making changes in tax allowances 'rather than imposing unacceptable hardship and complexity on needy people'.

'The Government has chosen the second path and with it a return to the concept of the deserving and undeserving poor.'

Fig.3.10 Article reading test.

Kinsbourne and Warrington, 1962; Hecaen and Marie, 1974; and Ellis, Flude and Young, 1987).

The article reading task developed for the behavioural test was adapted from an article in a local newspaper. It consists of 3 short columns of text. The scoring is based on the percentage of words omitted across all three columns. Word omissions, incomplete words, partial or whole substitutions are scored. The examiner used a photocopy of the original article to record the location and number of omissions made. (cf. Fig 3.10).

Telling and Setting the Time

Many patients who exhibit neglect demonstrate difficulties in orientation of time, and place. Severe neglect patients can often get lost and confused within their rehabilitation setting by taking only those right sided turns available to them. Similarily with regard to time, many of these patients appear to have difficulties telling the time.

This test is composed of three parts. The first part requires the subject to read the time from photographs of a digital clock. The second part requires the patient to read the time from an analogue clock face. Finally the third part requires the patient to set times on the analogue clock face called out by the examiner. (Fig. 3.11). All three formats are scored according to the number of omissions or substitutions made. The maximum score is 9.

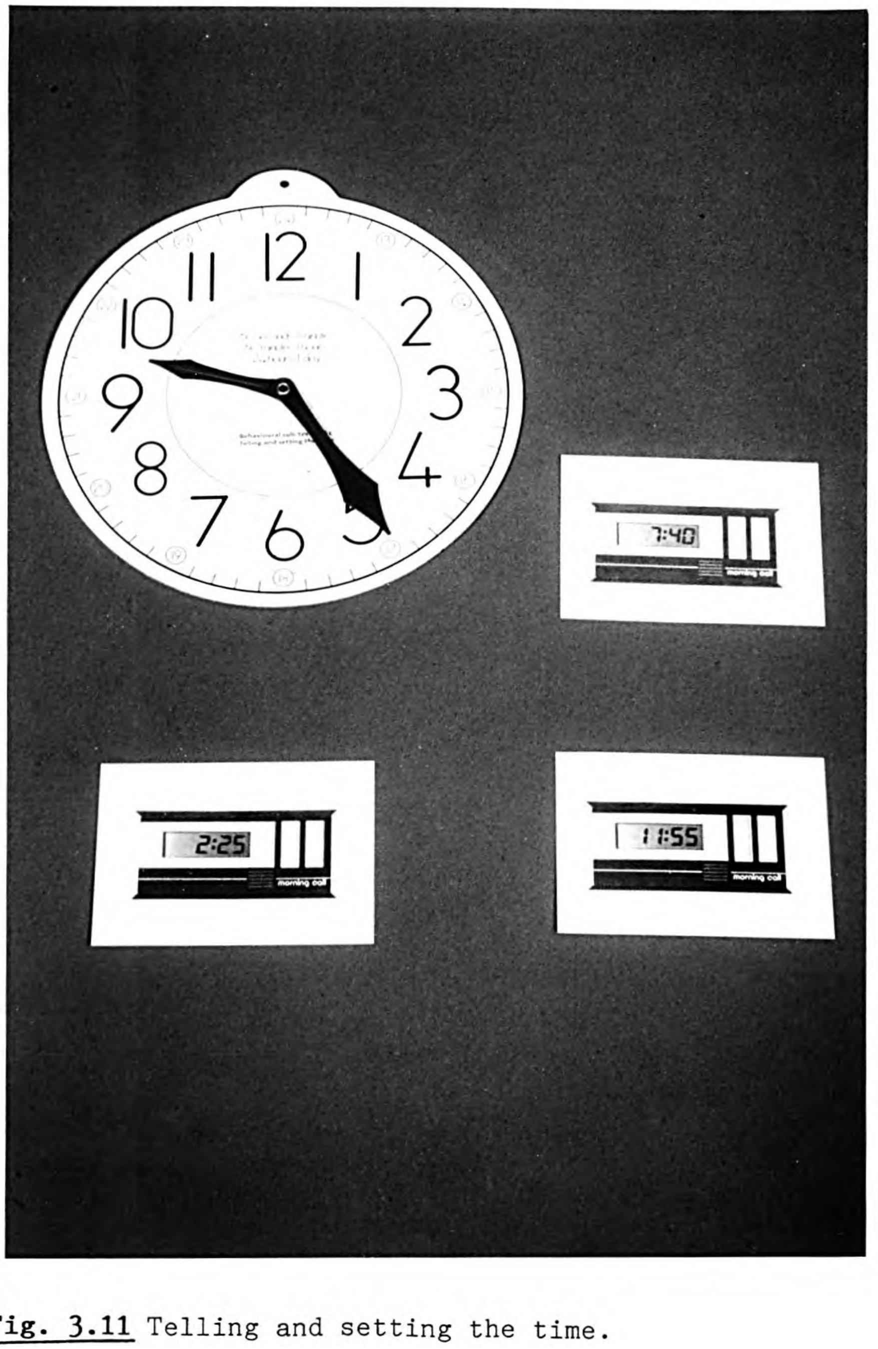


Fig. 3.11 Telling and setting the time.

(6) Coin Sorting

In this task, the subject is presented with an array of coins (6 denominations in all, three of each) and requested (according to a preset order) to indicate the location of the coins according to the demonstration called. Failure to pick up coins on the left side of a horizontal row of coins has been described by Weinstein and Friedland (1977) and has been used by Diller and co-workers at the New York Medical Centre to demonstrate to patients the significance of their spatial loss. The task requires selective scanning of all the coins in order not to miss a member of any denomination. The score for this test is based on the number of omissions. Location of these can be noted on the score sheet (Fig. 3:12).

(7) Address and Sentence Copying. Several investigations have used a version of this task. (Isaacs, 1971; Pigott and Brickett, 1966; Gordon et al, 1985; Young et al, 1983; Diller and Weinberg, 1977). In writing, the patient with left neglect, typically leaves wide margins on the left side, and when copying a sentence will omit the left end of the line. The present test requires the patient to copy an address and sentence on separate pages. (Figs. 3:13, 3:14) The total score is calculated from the number of letters omitted.

(8) Map Navigation describes a simple task which requires the patient to follow and locate spatial points (letters) positioned on a network of pathways, (cf. Fig 3:15) located on an A3 sheet in front of him. The ability to follow a sequence of spatially determined points may be disturbed

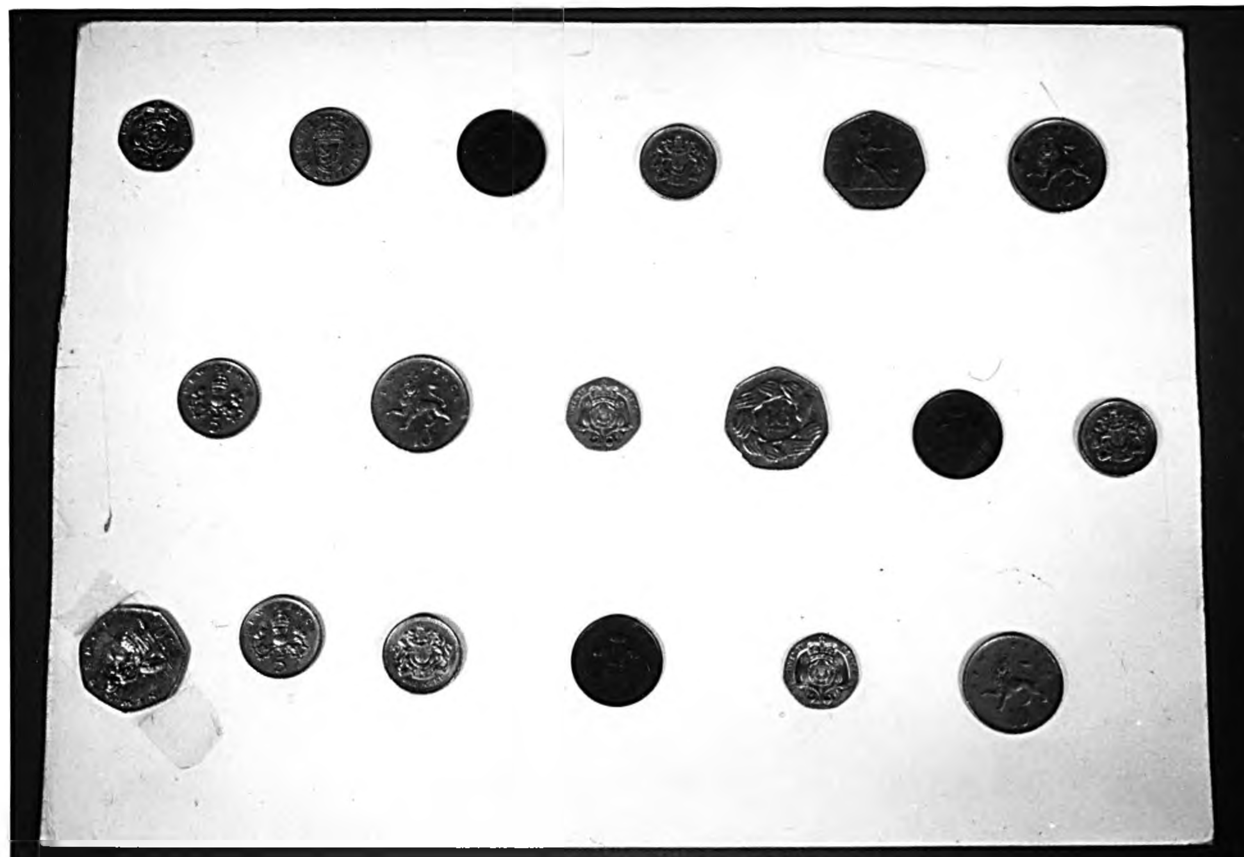


Fig. 3.12 Coin sorting task.

Mr and Mrs Alan Hamilton

1146 West Meadows Crescent

Cumbernauld Road

Glasgow

↑

Fig.3.13 Address copying.

The Shire Horse Society, founded in 1798, first held its annual show at St. Aldate's fair, Oxford in 1978.

Fig.3.14 Sentence copying. ↑

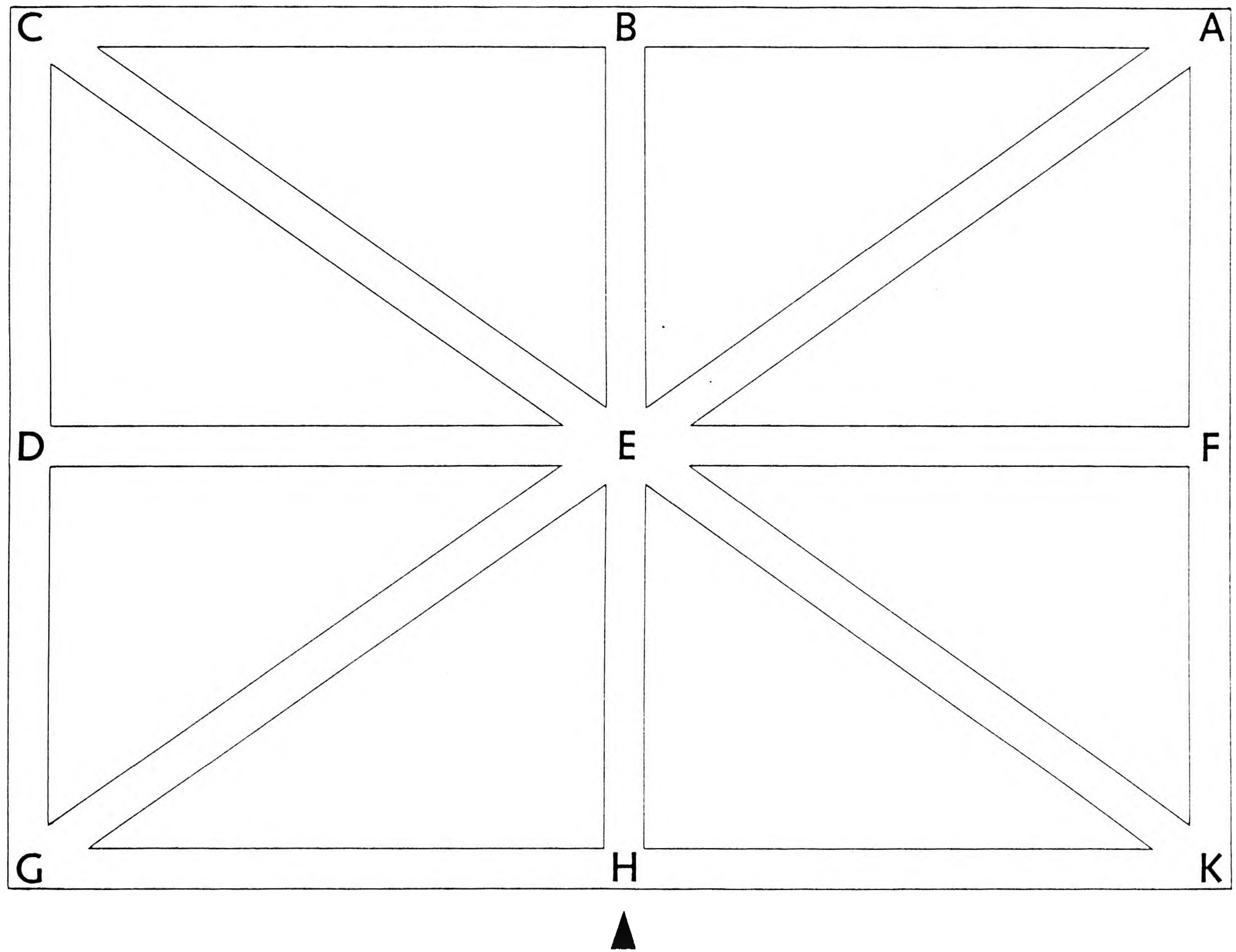
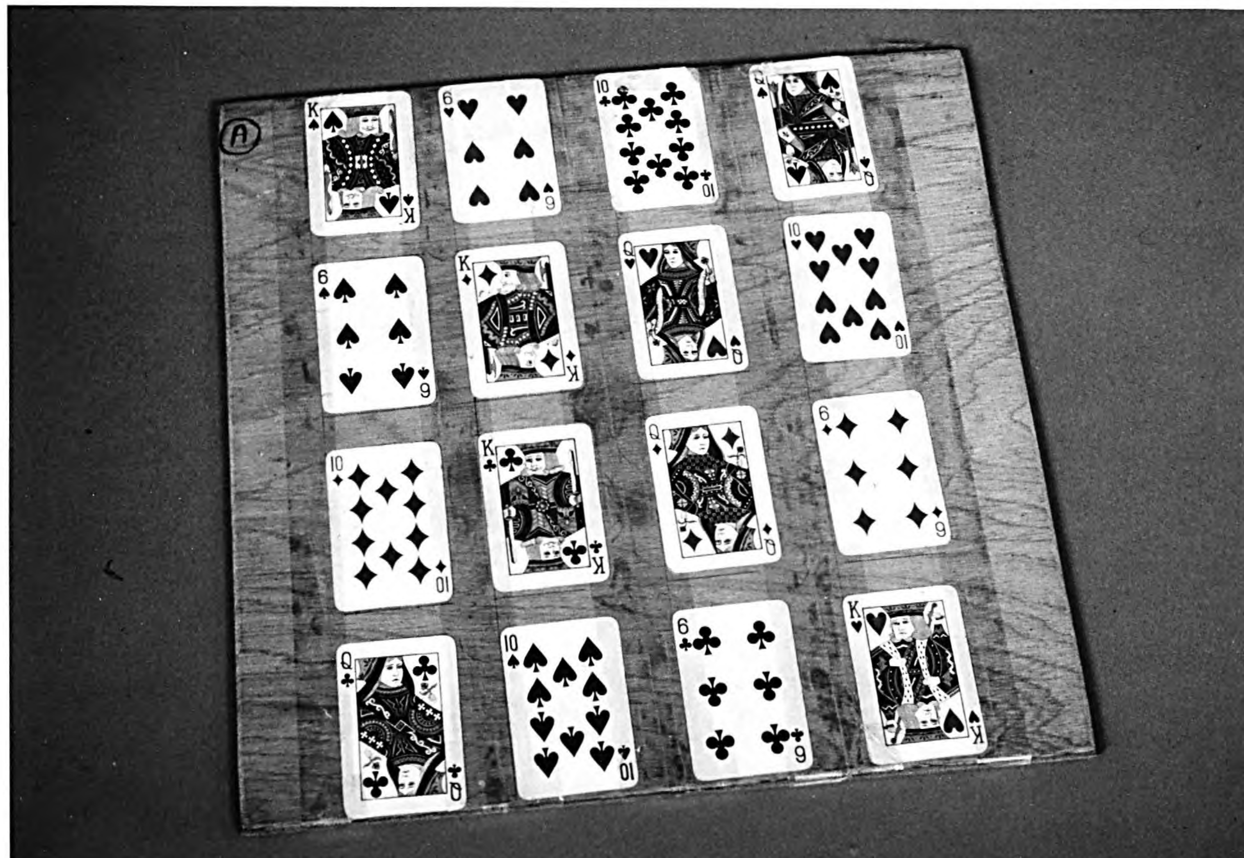


Fig.3.15 Map navigation test.

after right hemisphere damage. Such patients find it difficult to orient themselves in their home or local community. In this task the patients after being shown the junction of each pathway are instructed to use their finger to trace out each of the routes called out to them by the examiner. 3 points are scored for each correctly traced route. Failure to complete segments of the route sequence incurs a deduction of 1 point, down to a minimum of zero.

Card Sorting uses 16 playing cards familiar to the patient. The cards are laid out in front of the subject as indicated in Fig 3:16. The cards are separated by two inches and centred about the patient's midline. Unlike the coin task (No. 6) each card is pointed out to patients before they are asked to indicate each of 4 card types present. The position and number of omissions can be noted on the score sheet. In occupational therapy for stroke patients, therepists often use block construction, jigsaw puzzles, 2-dimensional group puzzles, mazes and sorting tasks. Other activities that have been found useful are table games, draughts, chess, educational and developmental games. These activities have been choosen because they incorporate several aspects of treatment (Wilcock 1986). Board games like chess, draughts or cards besides being generally known and socially acceptable games, facilitate concentration, social interaction, perseverance and logical sequencing. Reports of neglect effecting such visuospatial tasks have been described by Cherrington, (1974).



<u>Fig.3.16</u> Card sorting task.

3:8 Occupational Therapist Checklist

In all cases save three, the relevant occupational therapist completed a short checklist which was then used to validate the scored performance of the behavioural tests. The checklist, consisting of 11 items, asked each therapist to indicate whether the patient in their clinical opinion, exhibited specific neglect type behaviours. At Rivermead, the department of Occupational Therapy has a long tradition of working with and developing perceptual test batteries [cf. The Rivermead Perceptual Assessment Battery; Whiting, S., Lincoln, N., Bhavnani, G., & Cockburn, J, (1985)] and it was a fortunate convenience that therapists were familiar with the clinical expression of visual neglect.

Therapists were requested to score the checklist in terms of what they considered to be neglect responsible behaviours as opposed to poor performance that might be expected from concomitant disorders. The checklist was usually scored within two - three days of the patients formal assessment. The extent of neglect reported for the patient consisted of the number of checklist questions for which visuospatial difficulties were reported. Therapists were also requested to describe any other 'type' of neglect like behaviour not already covered on the checklist. Details of the checklist are provided in Table 3.3.

In addition scores from the Rivermead Activities of Daily Living Assessment were used (Whiting and Lincoln 1980). This A.D.L. measure can be divided into self care and household items. Due to incomplete data, only those items from the self care section were included in calculating the patients A.D.L. score. Although a less specific measure of the effects of neglect, it was considered appropriate as a reasonably comprehensive measure of functional outcome. (Kinsella & Ford, 1980).

Table 3.3

Checklist of Everyday Neglect Behaviours

(1) Does the patient have difficulties in dressing?

(2) Does the patient neglect the left/right side of personal space?

Does the patient show difficulties

(3) Talking or communicating with others?

(4) Reading?

(5) Negotiating their wheelchair between doors, kerbs, (etc.)?

(6) With self care skills, washing, bathing (etc)?

(7) On writing does the patient neglect one side of the page?

(8) Does the patient deny, minimize or realize the extent of their present condition?

(9) Does the patient neglect items of food located on one side of the plate?

(10) Does the patient display difficulties in their knowledge of the left and right side?

(11) Does the patient complain of having lost things? (personal belongings, etc).

3.9 Scoring and Classification of Neglect

Using the six conventional tests, errors of omission were calculated for each of the subtests. Errors of commission were noted but not formally scored. "Neglect" was defined as the score below that which is found in a normal group of subjects, similar in age to that of the stroke group. Norms for each of the subtests were calculated. The scores of the control group were used to establish the limits of normal performance and the cut off point for each of the tests. The presence of neglect on each of the six conventional subtests for the present study was defined as a score one point or more below the lowest control subject score. The total or aggregate score of the six conventional tests was used to diagnose the presence and extent of visual spatial neglect.

Operational definitions of visual neglect vary considerably and as discussed earlier in chapter 2, this results in a considerable range of reported incidence. This,

> "dilemma illustrates the need, as in the analysis of other cerebral syndromes (Oxbury 1975) to devise an adequate and widely accepted definition of unilateral spatial neglect". (Oxbury et al.1976)

Most of the criteria chosen are not norm-derived and although clinically useful remain essentially arbitrary. Ogden (1985) using 5 tests regarded patients as having neglect if they demonstrated omissions on any one of the five tests. Oxbury et al. (1974), despite using several visuospatial tests choose only omissions on drawing and copying as their criteria believing performance on other tests to be essentially equivalent. Albert (1973) found no errors on his line crossing task, using a hospitalized control group and therefore considered any omission on his test as evidence of neglect.

> "This highlights one of the problems that makes comparisons across human neglect studies so difficult in as it does not appear to be an all or nothing phenomena, at what point on the continium of deficits should we say one patient has neglect and another does not?" Ogden (1987).

As neglect is (1) not an all or none phenomena, and because (2) omissions (cf control data) can occur in the absence of obvious cerebral damage, and may be due (3) in part (within the patient sample) to concomitant sensory or motor difficulties; cut off scores representing performance inferior to that of the control population were determined from the actual distributions of control data for the 6 conventional and 9 behavioural measures. The scores of the control subjects were used to establish the limits of normal performance and the cut off points for each of the individual tests. The total or aggregate score for the 6 conventional tests was used to determine clinically and operationally the overall diagnostic and extent of visual spatial neglect.

Table 3.4 summarizes the respective conventional and behavioural scores for the three groups. Using the operational definition described above, the cut off score was found to be less than or equal to 129.

3.10 Preliminary Results

Thirty patients (37.5%) demonstrated visual neglect using

TABLE 3:4

Comparison of Mean Performance on Conventional and Behavioural Tests for LBD/RBD and Control Groups

	Max. Score	Controls	Range	Cut Off Score*	LBD	RBD	
Number of subjects		50			26	54	
Conventional Tests		(M) (SD)			(M) (SD)	(M) (SD)	
Line Crossing	36	35.96(0.19)	35-36	34	34.8(3.9)	32.6 (6.8)	
Letter Cancellation	40	38.12(1.98)	33-40	32	34.8(8.1)	30.2 (9.8)	
Star Cancellation	54	53.72(0.54)	52-54	51	50.5(7.3)	42.4 (14.4)	
Figure Copying	4	4.0 (0)	4	3	3.7(0.8)	3.0 (1.4)	
Line Bisection	9	8.9 (0.1)	8-9	7	8.6(1.1)	7.1 (2.8)	
Rep. Drawing	3	3.0 (0)	3	2	3.0(0)	2.6 (0.8)	
	146	143.8		129	135.4	117.9	
Behavioural Tests							
1. Picture Scanning	9	8.38(0.75)	6-9	5	8.0(1.45)	6.2 (2.9)	
2. Telephone Dialling	9	8.97(0.14)	8-9	7	8.8(0.69)	7.8 (2.2)	
3. Menu Reading	9	9.0 (-)	9	8	8.7(0.9)(25*)	7.4 (2.7)	
4. Article Reading	9	9.0 (-)	9	8	8.5(1.2)(12)	7.7 (2.6)	(39)
5. Time Reading	9	9.0 (-)	9	8	8.7(0.8)(24)	8.2 (1.6)	
6. Coin Sorting	9	9.0 (-)	9	8	8.5(1.2)	7.1 (2.7)	
7. Address/Sentence Copying	9	8.9 (0.1)	8-9	7	8.4(2.0)(23)	7.3 (2.8)	(52)
8. Map Navigation	9	9.0 (-)	9	8	8.4(1.4)(25)	8.1 (2.3)	
9. Card Sorting	9	9.0 (-)	9	8	8.9(0.6)(24)	7.6 (2.4)	(43)
	81	80.25		67	76.9	67.4	

M = Mean Score
SD = Standard Deviation
* = Number of patients with complete data

LBD = Left Brain Damaged
RBD = Right Brain Damaged

* = The cut-off score was derived by taking the worst performance by a control on each of the conventional tests. As such no single control subject actually scored this low on their aggregate score for the six conventional tests . The lowest score achieved by a control was 138/146.

the aggregate cut off score. 26 of these were right brain damaged as compared with only 4 left brain damaged. This incidence of visual neglect accords well with previous reports using clinical criteria; Albert, (1973) - 37%; Bisiach et al. (1986) - 36%; Oxbury et al. (1974) - 41%; Zarit and Kahn, (1974) - 43%; Vallar and Perani, (1986) - 43% despite the fact that all the tests were standardized on a stroke population admitted to a rehabilitation centre, on average two months post stroke.

A comparison of the data for the two patient groups revealed a statistically significant difference in performance from that of controls using the aggregate score obtained from the conventional tests. ($F = 17.63$; df 2:127; $p < .001$). Subsequent analysis revealed significant differences between all groups. [controls/RBD; $t = 5.86$; $df = 53$; $P < .001$; Controls/LBD; $t = 2.29$; $df = 23$; $P < .05$; RBD/LBD $t = -3.04$; $df = 76$; $P < .01$).

A more detailed test by test comparison between patients and controls is tabulated in Table 3.5. This preliminary analysis demonstrates that all the subtests are capable of distinguishing between normal controls and unilaterally brain damaged patients of a similar age.

Estimates of the relative incidence of neglect with regard to the side of lesion varied considerably as a function of the different tasks and criteria used. Table 3.6 summarizes the relative incidence of neglect on the 6 conventional tests and 9 behavioural tests. This relative frequency accords with the main findings in the literature (Cohn, 1961; Zarit and Kahn, 1974; McFie and Zangwill, 1960; Schenkenberg

TABLE 3:5

Comparison of Performance on Conventional and Behavioural Tests of LBD/RBD Patient Group with Controls

	Controls			Brain Damaged						
N	50			80						
	M	SD	Range	M	SD	Range	t	Df	P	N
Line Crossing	35.9	(0.2)	35-36	33.4	(6.1)	8-36	3.81	128	.001	130
Letter Cancellation	38.1	(2.0)	33-40	31.71	(9.5)	4-40	5.82	128	.001	130
Star Cancellation	53.7	(0.5)	52-54	45.1	(13.1)	8-54	5.91	128	.001	130
Fig Copy	4.0	(0.0)	4-4	3.2	(1.2)	0-4	5.58	128	.001	130
Line Bisection	8.96	(0.2)	8-9	7.63	(2.5)	0-9	4.74	128	.001	130
Rep Drawing	3.0	(0.0)	3-3	2.73	(0.74)	0-3	2.44	128	.01	130
Total	143.8	(2.12)	138-146	123.6	(29.45)	21-146	6.10	128	.001	130
Picture Scanning	8.4	(0.7)	6-9	6.8	(2.6)	0-9	4.91	128	.001	130
Phone Score	8.9	(0.14)	8-9	8.1	(1.89)	0-9	4.07	128	.001	130
Menu Reading	9.0	(0)	9-9	7.8	(2.34)	0-9*	4.47	127	.001	129
Article Reading	9.0	(0)	9-9	7.98	(2.35)	0-9*	3.13	100	.01	102
Time Telling	9.0	(0)	9-9	8.35	(1.47)	1-9*	3.91	126	.001	128
Coin Sorting	8.98	(0.14)	8-9	7.53	(2.37)	0-9	5.47	128	.001	130
Address/ Sentence	8.98	(0.14)	8-9	7.48	(2.72)	0-9*	4.78	124	.001	126
Map Navigation	9.00	(0)	9-9	8.20	(1.97)	0-9*	3.60	127	.001	129
Card Sorting	9.00	(0)	9-9	8.09	(1.95)	0-9*	3.64	110	.001	112
Total	80.32	(0.77)	78-81	69.05	(18.37)	0-81*	5.48	98	.001	100

M = Mean
* = Missing Values
df = Degrees of Freedom
SD = Standard Deviation

Table 3.6

Patient performance on each of the fifteen neglect tests

	LBD				RBD					
	A	B	C	D	A	B	C	D	E	F
Neglect criterion classification (Aggregate Score 6 Conventional Tests)	26		4	15%	54		26	48.0%	X^2 = 14.7	.001
Conventional Tests										
Line Crossing	26		3	11.5	54	3	14	31.5%	X^2 = 8.45	.01
Letter Cancellation	26	2	3	19.2	54		20	37.0%	X^2 = 7.84	.01
Star Cancellation	26	5	4	35.0	54	10	26	66.6%	X^2 = 15.02	.001
Fig/Shape Copying	26	2	4	23.0	54	7	18	46.3%	X^2 = 10.45	.001
Line Bisection	26	1	2	11.5	54	2	15	31.5%	X^2 = 8.45	.01
Rep. Drawing	26	0	0	0	54		11	20.4		
Behavioural Tests										
Picture Scanning	26		1	3.8%	54	2	15	31.5%	X^2 = 12.5	.001
Telephone Dialling	26		1	3.8%	54		15	27.7%	X^2 = 10.5	.01
Menu Reading	24	2	1	12.5	53	0	17	32.1%	X^2 = 8.45	.01
Article Reading	12	1	1	16.6	38	2	8	26.3%	X^2 = 4.08	.05
Telling/Setting Time	23	3	1	17.5	52	2	16	34.6%	X^2 = 7.68	.01
Coin Sorting	26	3	2	19.2	54	6	20	48.2%	X^2 = 12.90	.001
Address/Sentence	22		2	9.1	51	1	16	33.3%	X^2 = 10.32	.01
Map Navigation	25	2	3	20.0	54	-	12	22.2	X^2 = 2.12	N.S.
Card Sorting	19		1	5.3	43	2	12	27.9	X^2 = 9.60	.01

A = Number of patients tested

B = Number of patients who showed neglect on this test but who were not classified as showing neglect using the aggregate scoring system

C = Number of patients who showed neglect on this test and who were also classified as showing neglect using the aggregate scoring system

D = Overall percentage of patients showing visual neglect on this test

E = Chi-square (X^2) test result

F = Level of significance (P)

R.B.D. = Right brain damaged group

L.B.D. = Left brain damaged group

et al, 1980). In the present data, patients with right brain damage showed a frequency of neglect six times greater than that of left brain damage. Furthermore as every effort was made to retain those left brain damaged patients capable of understanding the tasks in order to avoid the 'caveat' pointed out by Brain, (1941); Battersby et al. (1956) and Zarit and Kahn, (1974) of sampling bias; it is interesting to note that the left brain damaged group (although half the size of the right brain damaged group) continued to show less neglect even as a percentage of the total number assessed (De Renzi, 1982).

Neglect v Non-neglect Patients

The group data can be further subdivided into those cases with and without visual neglect (as defined by the operational definition). A tabulation of all patient's scores together with comparative age control data clearly show the general poor performance of the neglect group on all measures despite their being no significant differences in age; ($t = 1.06$; $df = 78$; N.S.) IQ; ($t = 1.87$; $df = 72$; N.S.). or number of days post onsent of stroke ($t = 0.72$; $df = 78$; N.S.). The distribution of patient performance in terms of neglect is shown in Table 3.7. On the therapists questionnaire a higher score (unlike other measures) indicates the extent of observed or demonstrated neglect behaviour reported.

A one way analysis of variance (Anova) was performed on the conventional scores and this disclosed a highly significant difference, ($F = 105.8$; $df = 2,127$; $P < .001$) between all three groups. Individual comparisons sub-

TABLE 3:7

PATIENT PERFORMANCE ON VISUOSPATIAL NEGLECT-BATTERY

	Neglect (N +)	Non-Neglect (N-)	Controls
Number of subjects	30 (37.5%)	50 (62.5%)	50
Age Range	58.2 (8.3) (41-72)	55.8 (10.76) (19-83)	58.2 (13.5) (22-82)
Sex	M 16 (53%) F 14 (47%)	M 36 (72%) F 14 (28%)	M 14 (28%) F 36 (72%)
IQ (NART)	106.1 (7.8) N = (29)	110.2 (9.7) (45)	115.1 (9.2) (50)
Laterality of Lesion	RBD 26 (87%) LBD 4 (13%)	RBD 28 (56%) LBD 22 (44%)	-
Days Past Onset of Stroke	<150 > 150	<150 >150	
	N=25 $\bar{x}$56.7 SD (32.1) N=5 $\bar{x}$275.8 SD (92.1)	N=44 $\bar{x}$34.9 SD (34.9) N=6 $\bar{x}$208.5 SD (59.8)	
Conventional Tests Score	95.4 (31.8)	140.7 (4.3)	143.8 (2.1)
Behavioural Tests Score	6.1 (2.4)	8.7 (0.34)	8.9 (0.2)
OT Questionnaire Score	9.75 (5.1) N=(28)	4.6 (3.0) N=(49)	-
ADL Score	33.62 (8.14) N=(29)	39.66 (5.93) N=(47)	-

ADL = Activities of Daily Living

sequently showed that the control group could be clearly distinguished from both the neglect and non-neglect groups.

(1) Controls and non-neglect; $t = 4.58$, $P < .001$

(2) Controls and neglect; $t = 8.32$, $P < .001$

(3) Neglect and non neglect; $t = 7.74$, $P < .001$

In order to examine further the characteristics of the neglect group, a correlation between the relevant variables was performed and this is shown in Table 3.8.

This examination of the relationship between the measured variables revealed little or no association between test scores and age, IQ and the number of days post stroke onset. However significant relationships between the behavioural scores, the conventional scores and the occupational therapists checklist were clearly demonstrated. An examination of the presence of visual field deficits in the two samples is described in Table 3.9 Chi-square tests were used to compare presence or absence of visual field deficits (VFD) within the neglect group. There was no significant difference in this distribution. However, within the non-neglect group significantly fewer patients exhibited visual field loss than do not (x^2 = 9.68; df = 1; $P < 0.01$). In contrast patients with neglect are more likely to have VFDs than those without (x^2 = 10.42; df = 1; $P < 0.01$).

TABLE 3:8

Intercorrelations between measured variables within the Visual Neglect Group (N = 30).

	Behavioural Scores	Conventional Scores	O.T. Checklist	Age	No. of Days Post Onset
Conventional Score	.86 ***				
O.T. Checklist	.65 ***	.79 ***			
Age	.17 N.S.	.26 N.S.	.21 N.S.		
No. of Days Post Onset	.08 N.S.	.16 N.S.	.13 N.S.	.04 N.S.	
I.Q.	.17 N.S.	.07 N.S.	.03 N.S.	.08 N.S.	0.34 N.S.

*** = P < .001 N.S. = Not Significant

O.T. = Occupational Therapist

TABLE 3:9

A comparison of patients with and without visual neglect on the 6 conventional tests [excludes patients with extinction].

Visual Field Deficits	N+	N-
Absent	10	36
Present	17	14
	27	50

3.11 Reliability

Reliability in the context of test construction refers to the extent with which a test yields similar results when administered to subjects on different occasions. Reliability may be affected by variability in the patients performance and the examiners behaviour. A review of the literature showed that as yet no currently published test of visual neglect has taken into account factors of reliability. In assessing the reliability of the behavioural tests, three major aspects were considered; test-retest, parallel form, and inter-rater reliability.

Test - Retest Reliability was established by assessing 10 patients (7 RBD, 2 LBD) on two separate occasions with a mean interval of 15 days. The resulting co-efficient of stability was N = +0.89 ($P < .001$) for the conventional tests, and the administration of the behavioural tests also produced a highly significant co-efficient of +0.97 ($P < .001$). Both co-efficients indicate high stability for both sets of tests. A Pearson product moment correlation between the scores on the two occasions are displayed in Table 3.10.

TABLE 3:10

Test-retest Reliability of Convention and Behaviour Tests (N=10)

Conventional Tests	First Test	SD	Retest	SD	P
1. Line Crossing	35.0	2.5	35.0	2.3	.001
2. Letter Cancellation	34.3	5.0	35.5	4.9	.001
3. Star Cancellation	48.9	6.2	47.6	6.7	.001
4. Object and Figure Copy	3.3	1.1	3.9	0.3	.001
5. Line Bisection	8.3	1.3	8.3	1.1	.001
6. Rep. Drawing	2.8	0.4	3.0	-	N-Cal
Total	132.6	13.34	133.3	14.02	.001
Behavioural Tests					
1. Picture Scanning	6.3	1.8	7.2	1.5	.001
2. Telephone Dialling *	8.2	1.7	8.7	0.5	N.S.
3. Menu	7.2	3.04	7.6	2.2	.001
4. Article	7.2	2.7	7.2	3.1	.001
5. Time	8.9	0.3	8.4	0.7	.05
6. Coins	8.2	1.9	8.2	1.4	.01
7. Address/Sentence	7.1	3.4	7.5	2.4	.001
8. Map Navigation	9.0	-	9.0	-	N-Cal
9. Cards	8.1	2.0	8.7	0.9	.05
Total	70.20	14.46	72.90	10.14	.001

N-Cal = Correlation co-efficient could not be calculated.

N.S. = Non-Significant

* Telephone dialling was the only test not to reach statistical significance.

Parallel Form Reliability. In the clinical setting, it is often useful to monitor a patient's progress by administrating the test on more than one occasion. The recency effect, practice, and familiarity with test items are all features of basic learning and remain obvious considerations for the therapist concerned with evaluating the patient's condition. In order to provide for this, an alternative but equivalent form of the test was constructed. The two forms are said to be parallel or equivalent since they are constructed from the same type of items covered in the initial test. This form of reliability was calculated by administrating two alternative forms of the test to 10 patients (8 RBD, 2 LBD). Half of the patients were tested first, on Version A and the remainder with Version B. Using the Pearson correlation a highly significant co-efficient of equivalence was obtained $r = 0.91$, $df = 9$, $(P < .001)$ for the behavioural tests.

Inter-rater reliability describes the degree of agreement between testers scoring the test. This was established by having each subject scored separately but simultaneously by two raters. The battery was administered by one examiner, with each examiner scoring the patient's performance independently. This double scoring procedure was repeated for 13 patients. Using the double scoring procedure 195 pairs of scores were available. Correlation between the raw score aggregates for the two examiners was highly significant achieving $(r = .99 \quad P < .001)$ for both conventional and behavioural tests. This was not surprising as the scoring and administration of the test is simple and relatively unambiguous to score.

3.12 Validity

In developing the BIT the expectation is that brain damaged patients will score substantially worse than controls, and one albeit crude, index of validity can be derived by comparing the overall performance of the patient and control groups. The relevant data has already been presented (Table 4): and it is clear that neglect patients demonstrate considerably lower scores than the control group or a mixed brain damaged group (R/L hemiphere damaged).

An estimate of validity can be obtained in two ways. Performance on the BIT can be compared directly with that of performance on the six conventional tests for all 80 patients. If the BIT is a good measure of neglect, we would expect a reasonably high correlation. This method yielded a Pearson correlation co-efficient of .92, significant at the .001 level. Furthermore, a more detailed analysis of this relationship proved useful in ascertaining the extent to which conventional tests appear to be measuring the same underlying deficit. This intercorrelation of tests, shown in Table 3:11 indicates that most of the tests were closely related. The only test not to reach significance was representational drawing (although it was significantly related to the total score). This confirms the result of the pilot study (Wilson, Cockburn and Halligan, 1987) and suggests that drawing from memory is a

TABLE 3:11

Inter-correlation of Conventional Tests and Total Score on the BIT
(N = 50)

	Line Crossing	Letter Cancellation	Star Cancellation	Fig. Copy	Line Bisect.	Rep. Drawing
Line Crossing						
Letter Cancellation	.001					
Star Cancellation	.001	.001				
Figure Copying	.001	.001	.001			
Line Bisection	.001	.001	.001	.001		
Rep. Drawing	N.S.	N.S.	.001	.01	N.S.	
Conventional Total	.001	.001	.001	.001	.001	.05
B.I.T. Total	.001	.001	.001	.001	.001	.001

B.I.T. = Behavioural Inattention Test

relatively insensitive test when evaluating neglect after the acute stages of stroke.

A central feature in the construction of the BIT was that neuropsychological assessment performed within a hospital or rehabilitation setting should have predictive and instructive value with respect to daily functional tasks. In this regard we compared performance on the BIT with that of the checklist scores completed by the responsible therapist. This correlation proved to be significant $r = -0.67$ $P < .01$.

The correlation is negative because a high score on the checklist represents a greater manifestation of neglect whereas a high score on the test items indicates evidence of little neglect. A further comparison was made between the Activities of Daily Living Assessment (Whiting and Lincoln, 1980) used at Rivermead for stroke patients, and this again showed a significant relation for most subtests. The correlation coefficient for both measures and the conventional and behavioural subtests can be seen in <u>Table 3:12.</u>

TABLE 3:12

Correlation between external measures and visual neglect tests

N = 50	O.T. Checklist	A.D.L.
Line Crossing	- .59 (.001)	.40 (.01)
Letter Cancellation	- .60 (.001)	.53 (.001)
Star Cancellation	- .59 (.001)	.35 (.001)
Figure Copying	- .64 (.001)	.53 (.001)
Line Bisection	- .60 (.001)	.52 (.001)
Representational Drawing	- .23 (N.S.)	.04 (N.S.)
Total Score	- .71 (.001)	.51 (.001)
Picture Scoring	- .62 (.001)	.46 (.001)
Phone Dialling	- .56 (.001)	.34 (.05)
Menu Reading	- .42 (.01)	.14 (N.S.)
Article Reading	- .40 (.01)	.18 (N.S.)
Telling and Setting Time	- .46 (.001)	.32 (.05)
Coin Sorting	- .68 (.001)	.42 (.04)
Address and Sentence Copying	- .46 (.001)	.35 (.01)
Map Navigation	- .57 (.001)	.31 (.05)
Card Sorting	- .34 (.05)	.11 (N.S.)
Total Score	- .61 (.001)	.36 (.01)

O.T. = Occupational Therapist

A.D.L. = Activities of Daily Living

N.S. = Not Significant

The results of these comparisons demonstrate a strong relationship between therapists' observations and the scores obtained on formal testing. Furthermore, the significant differences observed between neglect and non-neglect patients $t = 3.46$; $df = 55$; $P < .001$ confirm the findings of Kinsella and Ford (1980) which indicate that visual neglect may be a particularly disruptive factor on a variety of tasks of daily living.

3:13 CONCLUSION

Progress towards the effective treatment of visual neglect has been hampered by the lack of consensus surrounding the criteria and measures used to assess it. The presence of neglect as defined by impaired performance levels on six conventional tests was found to be strongly related to performance on the B.I.T. The B.I.T. has shown itself to be a valid test of neglect and provides the therapist with the basis for a more precise description of patients' everyday problems. Furthermore, neglect on the new tasks, was found to be significantly related to occupational therapists judgements regarding neglect behaviour and general activities of daily living. The total test battery is reliable and capable of detecting less obvious signs of neglect; it fulfils the practical requirements of clinical testing by being short, easy to administer and score.

Factor and Discriminant Analysis of the B.I.T.

Chapter 4

Chapter 4

4:1 Introduction : Questions of Validity?

The validity of a test measures the extent to which scores can be seen to represent quantitatively what it is that the test claims to be measuring. Despite what appears to be a relatively simple definition the concept of test validity still suffers from ...

> "a confusing array of names ... ranging from face validity, validity by definition, intrinsic validity and logical validity, to empirical validity, and factorial validity" (Anastasi, 1986)

The process of test validation is not reserved for post hoc procedures, but may involve several multistage convergent processes including aspects of prior research, initial construct definition, operational definition and analysis of clinical observations.

Discussions of validity vary according to the context and nature of the specific question being asked (Ghiselli, Campbell and Zedeck, 1981). In this respect one can distinguish what Yates (1954) describes as two basic forms of validation, first, internal or higher order and secondly, external or lower order validity.

Internal validity typically involves the calculation of correlations between different tests, all of which are assumed to be measuring the same variable. Such an approach often uses factor analysis, to order, simplify, and illustrate the observed correlations between the related tests involved. Such an analysis is described in 4:3.

4:2 External or Lower Order Validity

Lower order validity describes the use of external criteria, by which the test under study can be evaluated. This approach considers the extent to which the test relates to an accepted or established "gold standard" in the area under research.

Throughout the history of clinical neuropsychology, these yardsticks or external criteria have changed considerably depending on the current emphasis within the field. At present, the direction of clinical neuropsychology favours a more qualitative, ipsative approach oriented towards practical clinical intervention and not merely with attempting to localize or establish the presence of brain damage per se.

However, the origins of modern neuropsychology (developed against a background of mental testing;Binet and Simon, 1905) emphasized the assessment of psychological dysfunction and the production of theoretical models which attempted to relate neuroanatomical damage to the resultant psychological deficits. The implicit assumption is that damage to neural tissue, the infrastructure for neurophysiological activity and hence psychological functions, would result in relatively consistent and predictable symptom patterns. This underlying assumption, that brain damage constituted a unitary phenomenon, characterized by a central behavioural deficit, persisted despite certain obvious and much more specific brain-behavioural correlates such as impairments of speech production following left sided frontal damage. As a result, the subsequent concern of clinical neuropsychology was one of improving the diagnostic hit-rate for tests of brain damage.

This proved to be problematic for a variety of reasons, not least that predictors of brain damage remained highly dependent upon the type of criterion chosen to establish the damage. (Klesges and Fisher, 1981). Furthermore the number of external criteria available remained very diverse. These included

> "anamnestic evidence, physical neurological findings and E.E.C. tracings. (Reed et al, 1975), a complete neurological exam, (Swercinsky and Warnock, 1977) and later encephlograms, angiograms, brain scans and computer axial tomography. (Klesges, Fisher, Boschee et al, 1984).

One comparative study by Spreen and Benton (1965), of over 38 tests used to assess brain damage revealed a hit-rate that varied between 33 and 90 per cent, depending on the degree of impairment, the groups of patients being compared, cut off scores adopted and criteria employed.

Dissatisfaction with this unidimensional model of "organicity" and criticism of the tests used to diagnose it, began to appear in the early 1950's. Yates (1954) for example, in a review of the validity of psychological tests of brain damage describes one of the main problems.

> "... if a random group of brain damaged patients is given a test, the results nearly always fall into an abnormal distribution ... From an anatomical and physiological standpoint, there is likewise no reason why all brain damaged patients should belong together."

Four years later in 1958, Meyers in a critical evaluation of the psychological assessment of brain damage questioned the whole basis of such tests in that

> "the concept of brain damage implying pathology of the brain as the sole factor in distinguishing brain damaged population from non-brain damaged is meaningless from both the practical and theoretical points of view ... one would not ask whether a person is brain damaged or not, but how much is he brain damaged?"

Meyer's question referring to the extent and nature of the patient's deficits, predated the eventual shift within neuropsychology towards considerations of cognitive psychology and the detailed functional analysis of psychological deficits. (Loring and Papanicolaou, 1987; Luria, 1980; Meier, Benton and Diller, 1987). The decline of interest in lesion location was precipitated by the advent of more sophisticated and reliable physical imagining techniques capable of demonstrating both structural and physiological brain dysfunction. (Beaumont, 1983).

At present, the direction of neuropsychological testing emphasizes the ability to make predictive statements concerning "the effective management and treatment of the psychological deficits following brain injury" (Hart and Hayden, 1986). While traditional diagnostic tests have proved helpful in sorting patients into pathologic categories, they were not designed to evaluate their results in terms of the patient's disabilities in the real world. In addition most of the traditional tests did not adequately sample the often complex pattern of deficits associated with brain disorders.

For example;

> "... a patient with right parietal damage secondary to a C.V.A., may receive a low score on a block design task, because he is unable to perceive and recreate the spatial relationships among the elements of the designs. A head injured patient could obtain the same low score because of more generalized difficulties in information processing including the interpretation and reproduction of spatial information under time pressure". (Hart and Hayden, 1986)

As many of these traditional tests (eg., W.A.I.S.) bore little resemblance to the tasks of everyday life, they "were often alien to patients and of questionable clinical relevance." (Crook and Larrabee, 1988)

Clinically, however, the impetus for neuropsychological assessment came from the need to clarify and substantiate a patients experienced or reported experience of specific psychological problems in daily life. As such, many measures of neuropsychological functioning today have been recalibrated in terms of those external criteria which deal with the quality of life, and for those activities of daily living (ADL), meaningful to the patient. Many A.D.L. scales have been developed for neurologically brain damaged patients (cf. Donaldson et al, 1973). However, in practice, most hospitals and rehabilitation centres adopt their own form of assessment. (Jay, 1976). A.D.L. scales, then, represent one of the few interdisciplinary measures that attempt to describe the patient's functioning in terms meaningful to therapist and family alike. As such they have been used to monitor recovery, set goals, and establish criteria for admission and discharge. (Diller, 1987; Wade et al, 1985).

With regard to the assessment of visual neglect, traditional methods have involved the use of simple tests which appeared intuitively to sample and demonstrate the presence of the condition. Like many other behavioural neurological disorders, there existed no single yardstick, or "gold standard" and the diagnosis of visual neglect remained firmly rooted in the clinical assessment and everyday observations of therapists and clinicans working with the patient. Part of this assessment typically involved the use of one or more paper and pencil tests, similiar to those described as "conventional tests" in the previous chapter. The development of these brief pencil and paper tests followed the need to objectify and monitor what had already been observed clinically.

In the present study, lower order validity was established by calculating the relationships between scores on the "Behavioural Tests" and scores on

(1) the 6 "conventional tests",

(2) the occupational therapist's checklist

(3) the patient's score obtained on the Rivermead A.D.L. assessment.

These will be discussed in 4:6.

4:3 Internal or Higher Order Validity

Although the process of factor analysis has particular relevance for construct validity, it still remains a comparatively new technique in the area of neuro-psychological research. (Franzen and Golden, 1984). The main aim of factor analysis is to minimize the number of variables under consideration while maximizing the information obtained. The basic process involves the examination of a correlation matrix to determine which variables appear to covary, and the combination of these variables into meaningful factors or traits. In this way, evidence for a hierarchical factor solution may be used to support the case for a relatively robust measure of the constructs involved.

Validity Implications

In the present study, "visual neglect" refers to a conceptual construct which describes the mechanisms thought to underly the visuo-spatial deficits observed in patients who fail to notice or orient to stimuli located on one side of space. As such, the Conventional and Behavioural tests represent measures which assess aspects of visuo-spatial functioning, that have been clinically shown to be impaired in patients diagnosed as manifesting hemi-neglect or visual inattention. A consistent or specific pattern of impairment across these tests would provide systematic evidence for the validity of the underlying construct.

Correlation between variables

Table 4:1 presents a correlation matrix between all the tests of neglect used in the test battery. Given the large number of comparisons being made, the significance level choosen was set at the .01 level. This group of correlations describes the performance of 50 stroke patients, as missing values on a variety of variables in some cases, resulted in patients being dropped from the analysis.

Table 4:1

Correlation matrix for test scores and variables in the stroke population N = 50

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
1	Days Post C.V.A.	-																				
2	Age	NS	-																			
3	IQ	NS	NS	-																		
4	Line Crossing	NS	NS	NS	-																	
5	Letter Cancellation	NS	NS	NS	54	-																
6	Star Cancellation	NS	NS	NS	56	62	-															Conventional Tests
7	Fig Copy	NS	NS	NS	58	62	65	-														
8	Line Bisection	NS	NS	NS	62	73	64	79	-													
9	Rep. Draw	NS	NS	NS	NS	NS	38	NS	NS	-												
	(M(L)	NS	NS	NS	-78	-82	-87	-74	-75	NS												
	(M(R)	NS	NS	NS	-54	-69	-82	-53	-63	NS												
	(M(L-R)	NS	NS	NS	-76	-84	-92	-72	-76	NS												
10	Summary Total	NS	NS	NS	76	84	91	76	81	NS												
11	Picture	NS	NS	NS	54	67	63	74	71	36	75	-	-	-	-							
12	Phone	NS	NS	NS	57	55	63	83	74	37	72	68	-	-								
13	Menu	NS	NS	NS	46	53	66	69	54	36	68	66	72	-								Behavioural Tests
14	Article	NS	NS	NS	40	67	65	52	69	NS	71	67	55	67	-							
15	Time	NS	NS	-47	49	50	55	56	62	NS	63	47	65	48	52	-						
16	Coins	NS	NS	NS	56	59	69	68	53	NS	74	70	63	74	59	54	-					
17	Address	NS	NS	NS	43	72	63	69	73	NS	73	67	69	75	83	49	63	-				
18	Map	NS	NS	NS	55	46	74	68	66	37	73	59	71	62	55	75	74	51	-			
19	Card	NS	NS	NS	NS	45	42	45	35	NS	47	48	51	61	54	39	70	63	43	-		
20	Total	NS	NS	NS	58	72	76	79	75	35	84	84	81	87	83	67	86	86	77	73	-	

NS = not significant

* 1% significant level (.346)

* Decimal point omitted

M (L) M (R) M (L-R) = missing/error scores on (L) left, (R) right and both sides of 3 visual search tests (L-R)

An initial examination of the correlations reveals that except for "Representational Drawing" all of the conventional tests are highly related (P<.001). An aggregate score of the lateralized errors produced on the first three visual search tasks (Line crossing, letter cancellation and star cancellation) were also included for comparison. The behavioural tests also reveal a pattern of significant associations (the vast majority of which are at the .001 level of significance), thus suggesting that all the tests used were in some manner, measuring features of the same phenomenon. Again, the only test which fails to reach significance when both "Conventional" and "Behavioural" tests are compared remains that of "Representational Drawing". This suggests that the test may not be a useful measure for assessing the condition in this population. The variable, days post stroke onset, and age of patients related to no other measure; I.Q. related only to "Time/Telling".

4:4 Factor Analysis

Having examined the correlational matrix, it is now appropriate to explore the factor structure of the battery of tests. Given the significant intercorrelations between tests, it might be expected that a single factor would be found to explain most of the observed performance. The identification of such a common factor would help substantiate the case for the internal validity of the test battery.

Using the B.M.D.P. computer package, a principal component factor analysis (P.C.A.) was performed which defined (for extraction of the initial factors,) the orthogonal linear combinations which accounted for the largest proportion of the total variance. In this way the first principal component or factor may be regarded as the single best summary of the linear relationships exhibited in the data. The second factor is defined as the second best linear combination of variables under the constraint that the first factor is orthogonal to the second. Following the identification of major factors the next question concerns the number of factors that can be meaningfully extracted. Typically, the theory underpinning the research analysis stipulates the number of factors that can be meaningfully extracted. The adequacy of these resultant factors can then be evaluated in terms of their interpretability, agreement with past research, and by examining the actual configuration of the factor loadings together with the proportion of variance explained. (Rummel, 1970). However, in the absence of a strong theory it is recommended in exploratory factor analysis to use more than one method in determining the number of factors to be extracted. (Franzen and Golden, 1984). For this purpose, the Kaiser-Guttman criterion, and Cattell's "scree test" were employed.

A factor analysis was performed using data from the patient group on the 15 tests (6 conventional, 9 behavioural) and five other variables (IQ, Age, days post-onset, ADL and OTQ). In order to enhance clarity of the factor solution, rotational methods are commonly employed. For present purposes, the varimax rotation is the rotation of choice, as it maximizes the variance within factors. The varimax solution involves locating a new position for the reference axis which helps reduce the amount of ambiguity found in the unrotated solution. Mathematically, the rotated solution remains the same since it involves the linear transformation of the original solution. The P.C.A. program on the B.M.D.P. package, with orthogonal rotation, produced five relevant factors. The five factors extracted accounted for over 76% of the total variance and included all of the 15 tests in the analysis. Although, as is common in other tests of neuropsychological functioning, the distribution of scores obtained from the continuous test variables was not normal, the procedure of factor analysis is relatively robust. However, as a guard against the extraction of erroneous factors a non-parametric correlation matrix was prepared from the data and subsequently entered into the factor analysis program. No discernible differences were observed between this analysis and the linear analysis.

Criteria for selecting the number of factors extracted

Use of The Kaiser-Guttman criterion involves adopting only those factors having latent roots or eigen values above unity. Another empirical method suggested by Cattell (1966) involves plotting the derived eigen values for all the factors extracted. This is known as the 'scree test' where factors are extracted in decreasing order of size. The first few factors are likely to account for most of the information, and the point at which the plot curve appears to change from a gradually decreasing line to a generally horizontal line is the point at which the factor extraction should be halted. In the present analysis both methods indicated that 5 major factors were present. Fig 4:1 shows the plot of eigen values against the number of factors. Not all factors are represented since the remaining 9 factors accounted for less than 5% of the total variance.

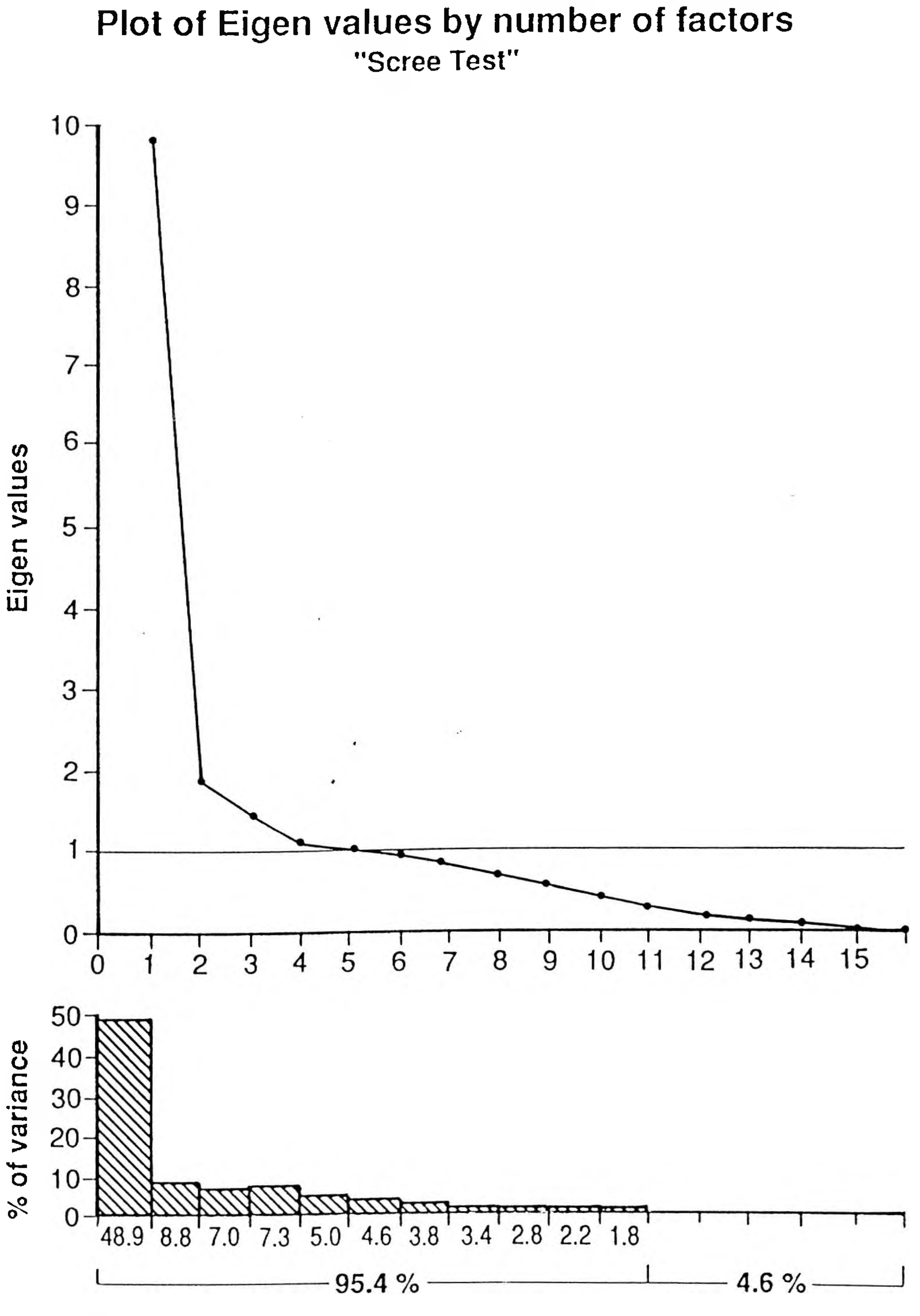


Fig. 4.1.

Criteria for the significance of factor loadings

In order to decide which factor loadings to consider in the interpretation, the Burt and Banks formula was employed. (Child, 1970). In the present case the standard errors for a sample size of 50 at the 1% level of significance were .346, .354, .364, 375, .386 respectively for the first five factors. As further P.C.A.'s of the data involved fewer than 50 subjects it was decided to adopt this stringent cut off. Therefore, items that loaded .40 or higher on a given factor and less than this value on all other factors have been underlined and considered for further analysis. The results of the factor analysis are presented in Table 4:2.

Table 4:2

(N = 50)

Varimax Rotated Factor Matrix

No.	Test/Variable	I	II	III	IV	V	Communalties
1	Post C.V.A. (Days)	-09	-69	02	-01	-10	0.50
2	Age	-04	06	00	-02	89	0.79
3	IQ	13	06	04	93	-01	0.89
4	Line Score	76	06	-26	-12	-13	0.68
5	Letter Score	83	03	02	-04	15	0.71
6	Stars Score	73	22	31	-06	-11	0.70
7	Figure Copying Score	84	14	24	02	-13	0.79
8	Bisection Score	88	03	09	-04	19	0.82
9	Rep. Drawing Score	17	01	94	-02	02	0.91
10	Picture Score	80	15	24	02	-01	0.73
11	Phone Score	75	28	29	09	03	0.74
12	Menu Score	62	59	28	-04	-06	0.81
13	Article Score	66	42	17	-06	24	0.71
14	Time Score	61	12	19	-70	03	0.92
15	Coin Score	74	41	15	-01	19	0.78
16	Address Score	75	43	06	03	22	0.81
17	Map Nav. Score	69	23	34	-21	-18	0.73
18	Cards	47	66	-01	01	-10	0.66
19	A.D.L.	71	-42	-14	02	-01	0.71
20	O.T.Q.	-81	10	-06	-07	19	0.71
	Eigen Value	9.79	1.76	1.40	1.45	1.00	15.35
	Percentage of Variance	48.95	8.80	7.0	7.25	5.0	76.75

Decimal point removed in the)
case of the factors loading)

Results of the General Factor Analysis

Factor I. The first factor (with major loadings from "Line score", Letter score", "Stars score", "Figure copying score", "Line bisection score", "Picture score", "Phone score", "Menu score", "Article score", "Coin score", "Address score", "Map navigation score", "ADL", and "OTQ" appears to represent the dimension of "visuospatial imperception". Importantly for validation purposes, all but one of the conventional tests (Rep. Drawing) and two of the behavioural tests (time telling, and cards) failed to achieve their highest item loading on this factor, although "Time telling" does obtain a significant secondary loading (0.61). This first factor explains more than 64% of the total variance explained by the five factors and indicates that the majority of the tests under consideration appear to be measuring aspects of the same component. The bipolar factor "OTQ" (-.81) results from the fact that a low score on this factor represent less neglect in the patient's observed performance.

Factor II The second factor has major loadings from "card score" and "number of days post CVA" and minor secondary loadings from "coins", "address", "article reading" and "menu scores". This factor contains two significant loadings, one positive (card sorting) and one negative (Days post C.V.A.). This can be seen as representing significant variables located at opposite poles on the same factor. The factor in question probably relates to the extent of recovery although why this should single out one of the visual search tasks is not immediately obvious.

Factor III The third factor has only one major loading from "Rep. Drawing" scores. This factor represents a central constructional problem that may relate more specifically to imaginal than to sensory based perceptual representations.

Factor IV The fourth factor has two main loadings from "IQ" and "Time Reading" scores. This bipolar factor (I.Q., .94; Time telling, .-70) appears to represent a more general dimension of verbal memory, intelligence, and temporal orientation. As such, the two factor items may be conceptualized as existing on a continuum from one pole to the other.

Factor V The fifth factor has only one major loading, that of patient's "age". It is important in that patient's age appears unrelated to scores that load heavily on the visuospatial neglect factor.

Validity implications

The results of the P.C.A. provide evidence for a general set of relatively robust visual-spatial deficits assessed by the battery of conventional and behavioural tests. Interestingly, these deficits appear to be independent of age, I.Q. and extent of recovery after stroke. A summary of the factors and their respective significant loadings is provided in Table 4:3. This table suggests that all the tests except "Rep. Drawing" and "Time Telling" provide a reliable assessment of visuospatial functioning. In addition, the test measures appear to be significantly related to rehabilitation measures of observed daily functioning (-.81, .71). Thus generalization from test performance to performance in a more natural setting would appear to be less hazardous than might be the case with some unstandardized tests. The behavioural tests also lessen test anxiety and as a result greatly increase their acceptability for repeated clinical use.

The initial factor analysis, then, provides evidence for the validity of the construct under consideration: performance on the set of visuospatial tasks clearly indicates that the tests appear to be measuring features of a specific construct, clinically described as visual neglect. This factor analysis, however was based on the performance of 50 patients, not all of which (as already pointed out in Chapter 3) demonstrated what was operationally defined as visual neglect. Indeed only a minority (37.5%) of the total stroke population screened were so classified. The reason for including so many members of the total stroke population in the general analysis stems from the fact that, clinically, visual neglect is not an all or none phenomenon (Riddoch and Humphreys, 1983). Therefore, while some of the stroke patients scored as well as controls, the majority (while not demonstrating clinical neglect) did show several omissions on various test items. Although florid examples of visual neglect typically (but not necessarily) follow specific right hemisphere damage (eg: inferior parietal lobe lesions); manifestations of inattention have been reported to follow both generalized left and right brain damage, and other loci not commonly associated with the florid clinical condition (Rizzolati et al, 1987). As a result, evidence of a depressed performance on some of the visuospatial tasks would not be surprising following a unilateral cerebrovascular accident.

Table 4:3

A Summary of the Sorted Factor Loadings in the General Analysis

Percentage of Variance	49%	9%	7%	7%	5.0
	I	II	III	IV	V
1. Bisection score	88	-	-	-	-
2. Fig. score	84	-	-	-	-
3. Letter score	83	-	-	-	-
4. Pict. score	80	-	-	-	-
5. Line crossing	76	-	-	-	-
6. Address	75	-	-	-	-
7. Phone	75	-	-	-	-
8. Coins	74	-	-	-	-
9. Stars	73	-	-	-	-
10. Map Nav.	69	-	-	-	-
11. Article	66	-	-	-	-
12. Menu	62	-	-	-	-
13. Card	47	-	-	-	-
14. Rep. Drawing	-	-	94	-	-
15. Time Reading	-	-	-	-69	-
16. OTSQ	-81	-	-	-	-
17. ADL	71	-	-	-	-
18. Age	-	-	-	-	89
19. IQ	-	-	-	93	-
20. Post CVA	-	-70	-	-	-

(Decimal point removed)

4:5 Further Analysis of Factors Extracted

In order to further analyse the specific contribution of "neglect" it was decided to run a second P.C.A. which would incorporate only those patients who had already demonstrated neglect on the specified criteria. Table 4:4 presents the five factors extracted, together with their respective loadings. The same criteria for factor selection and loading significance were adopted.

As in the general analysis, Factor I (the "Visuospatial imperception" dimension) accounted for most of the variance (45.4%) and had heavy loadings from "Line", "Stars", "Fig. Copy", "Line Bisection", "Picture Scanning", "Phone", "Time", "Map Navigation", "A.D.L." and "O.T.Q.". Contrasting with the general analysis, Factor I lost "Letter Score" to Factor IV, and "Menu", "Article", "Coins", "Address" and cards to Factor II. Factor II in the general analysis described the dimension of recovery; its main loadings originated from the "number of days post stroke" onset. As we can see, the two reading tasks "Menu" and "article"; the two manipulo-visuospatial tasks, "coins", and "cards"; and the "address/sentence copying" tasks load heavily onto this factor. This second factor with its highly significant yet negative loading of "days post C.V.A." suggests that recovery may well play a part in patients' performance on this factor. That is, the greater the number of days post stroke the lower the omissions on the five tests; the fewer the number of days, the greater the omissions. It is not surprising that such a factor has been extracted, given the range of days post-onset within this variable.

Table 4:4

Varimax Rotated Factor Matrix

Using "Neglect" Patients Only. (N = 19)

Test variables	I	II	III	IV	V	Communalities	
Post C.V.A.	-04	-88	-02	00	22	0.82	
Age	-05	-06	-11	73	-23	0.60	
I.Q.	-01	-09	-12	-12	88	0.80	
Line Score	82	15	-30	-01	-02	0.78	
Letter Score	46	16	14	62	18	0.67	Conventional Tests
Stars Score	62	31	44	-03	-31	0.76	
Figure Score	67	39	37	02	35	0.85	
L. Bisection	68	19	24	48	36	0.90	
Rep. Drawing	08	06	91	03	-11	0.85	
Picture	55	39	42	24	24	0.75	
Phone	57	48	35	16	13	0.72	
Menu	29	82	30	-001	-01	0.85	
Article	22	58	28	56	-07	0.78	Behavioural Tests
Time	72	37	26	23	-04	0.77	
Coins	59	64	15	-07	-12	0.79	
Address	25	67	16	50	26	0.85	
Map	72	36	34	-08	-0.0	0.77	
Cards	05	84	-08	08	04	0.72	
ADL	75	-30	04	21	35	0.81	
OTQ	-88	-04	-07	-19	17	0.85	
Eigen Value	9.08	2.58	1.54	1.36	1.20	15.76	
Percentage of Variance	45.4	12.9	7.7	6.8	6.0	78.8%	

*Decimal point removed for factors

Factor III does not change from its characterization in the general analysis and retains "Rep. Drawing" as its only significant loading.

Factor IV has two significant loadings ("age" and "letter score") and may represent a selective age-related fall-off in visuospatial search tasks employing verbal stimuli and foils. This hypothesis is supported by the cut-off score employed on this test and obtained from the control population sample. Unlike "Star" cancellation, which used a cut-off score of just below ceiling, "Letter" cancellation had to employ a cut off score of 7, more than 3 times that of the "Stars" test despite the fact that the 'Letters' test employed 25% less targets overall.

Factor V remains the same as in the general analysis and shows only one main loading from verbal I.Q.

Theoretical Implications

Thus it would appear that the examination of a relatively "pure" sample of neglect patients following stroke revealed a clear cut "visuospatial imperception" factor, independent of variables such as age and intelligence. Unlike the general analysis, which incorporated both "neglect" (N = 19) and non-neglect patients (N = 31), the analysis of the former group indicated the effects of recovery on at least 5 of the main visuospatial tests employed, together with the possible influence of age on visual-verbal search tasks. The five factors extracted accounted for more than 78% of the total variance.

Hemispheric Differences

The consistent finding of a lateralized, and therefore asymmetrical, presentation of visual neglect in the literature has been taken to support the hypothesis of hemispheric differentiation of function. This hypothesis suggests that the right hemisphere is in the majority of cases, specialized for visuospatial functioning. Thus, the possibility exists (given the sensitivity of the tasks employed) that L.B.D. patients might demonstrate a pattern of performance that would be qualitatively distinct from their R.B.D. counterparts (Heilman et al, 1978; De Lacy Costello, and Warrington 1987; Caplan, 1985). Two approaches were employed in order to examine the question of the possible role of hemispheric differences on performance of the visuospatial tasks employed.

(A.) A further P.C.A. analysis was performed on the battery of tests using the total number of cases of observations for each respective hemispheric group.

(B.) Using the total number of left and right brain damaged patients with complete data, those test variables which clearly did not contribute to the 'visuospatial imperception' or neglect factor were systematically removed. In other words, this analysis used a series of steps that extracted only 'pure neglect' variables. Having isolated what may now be described as a set of 'pure neglect' variables, it was possible to re-examine the respective contributions of left and right brain damaged groups.

(A) The results of these further P.C.A.'s are shown in Table 4:5. Three factors were found for the R.B.D. group and this accounted for over 77% of the total variance. The L.B.D. group analysis extracted 4 factors, accounting for 71% of the variance. Although obviously difficult to interpret, given the small number of L.B.D. patients, a comparison of the significant loadings per factor revealed considerable differences between L.B.D. and R.B.D. groups. Only 3 test variables ("Lines", "Figure Copy" and "Line Bisection") shared similar significant loadings on factor I. In the absence of representational loadings on "Phone", "Coins", and "Cards", within the L.B.D., it would appear that the R.B.D. patients were selectively sensitive to 7 tests, four of which were not particularily sensitive for the L.B.D. group. Seven of the 8 "sensitive" tests within the R.B.D. group also comprised the main loadings within factor I of the "neglect group", of which 79% were R.B.D. patients to begin with.

Table 4:5

L.B.D. / R.B.D. Patients

LBD N = 11
RBD N = 36

Varimax Rotated Factor Analysis

Factors

Tests	I		II		III		IV	Communalities	
	LBD	RBD	LBD	RBD	LBD	RBD	LBD	LBD	RBD
Line	99	86						0.98	0.78
Letter			79			48		0.98	0.59
Stars		62			68			0.82	0.80
Fig Copy	75	59.4						0.58	0.81
L. Bisection	91	68						0.90	0.78
Rep. Draw	-99					92		0.98	0.86
Picture						58	59	0.79	0.75
Phone		67							0.76
Menu				69			93	0.89	0.75
Article	99			67				0.98	0.71
Time		79	94					0.93	0.83
Coins				67					0.77
Address	99			74				0.98	0.82
Map		80			92			0.90	0.77
Cards				89					0.81
Eigen Values	6.08	9.39	1.79	1.13	1.72	1.08	1.12	10.7	11.6
% of variance	40.5	62.6	11.9	7.53	11.5	7.2	7.5	71.4	77.3

(Decimal point removed from the factor loadings)

(B) The second method of looking at hemispheric differences involved extracting the test variables which best characterized the "visuospatial imperception" or "neglect features" under consideration. This involved several stages of analysis and test variables were removed until a P.C.A. could be arrived at which (using the total sample) extracted a single factor capable of representing visual neglect. This is shown in Table 4:6. Using this set of "pure neglect variables", two subsequent analyses were performed, using the respective L.B.D. and R.B.D. groups with complete data, on the test variables in question.

Table 4:6

Factor analysis using

"Pure Neglect Variables"

L.B.D. / R.B.D. (N = 59)

Tests	Factor 1	Communalities
1 Line) Cancellation	74	0.55
2 Letter) Cancellation	82	0.68
3 Star) Cancellation	79	0.62
4 Figure Copy	83	0.68
5 L. Bisection	75	0.57
6 Rep. Drawing	67	0.44
7 Picture Scanning	77	0.60
8 Phone	86	0.74
9 Menu	84	0.70
10 Address	79	0.62
11 Map	67	0.45
12 Cards	64	0.41
Eigen Value	7.08	-
% of variance	59.0%	-

(Decimal point removed from the factor loadings)

The results for the R.B.D. group (N = 42) are shown in Table 4:7. This shows that, when non-contributing test variables are removed from the total sample, a single factor is capable of characterizing the performance of the total R.B.D. group. The analysis accounted for over 61% of the total variance.

Table 4:7

Factor analysis using

"Pure Neglect Variables"

R.B.D. (N = 42)

Tests	Factor I	Communalities
1 Line) Cancellation	71	0.50
2 Letter) Cancellation	83	0.68
3 Star) Cancellation	83	0.69
4 Figure Copy	84	0.71
5 L. Bisection	81	0.66
6 Rep. Drawing	76	0.58
7 Picture Scanning	80	0.64
8 Phone	85	0.73
9 Menu	89	0.79
10 Address	77	0.60
11 Map	66	0.44
12 Cards	62	0.38
Eigen Value	7.41	
% of variance	61.8%	

(Decimal point removed from the factor loadings)

Table 4:8

Factor analysis using

Pure Neglect Variables

L.B.D. (N = 16)

Test	Factor I	Factor II	Factor III	Communalities
Line) Cancellation	91	-04	-25	0.89
Letter) Cancellation	79	.03	03	0.62
Star) Cancellation	71	28	-26	0.65
Figure Copy	81	08	-32	0.76
Line Bisection	43	-71	13	0.71
Rep. Drawing	-29	69	61	0.93
Picture Scaning	67	-29	13	0.56
Phone	86	40	08	0.90
Menu	41	-33	76	0.85
Address	91	-16	10	0.86
Map	82	23	38	0.86
Card	59	32	-19	0.48
Eigen Value	6.09	1.61	1.40	9.1
% of variance	50.8	13.4	11.7	75.9%

(Decimal point removed from factor loading)

The results of the L.B.D. group (N = 16) are shown in Table 4:8. Here it can be seen that "neglect performance" can only be accommodated by the extraction of two further independent factors. The orthogonality of the factors means that each of the factors may be found in isolation from the others or in any combination within the population of stroke patients. This suggests that while the presentation of neglect performance in R.B.D. patients is relatively homogenous, the picture in the case of L.B.D. is more complex; 25% of the total variance fails to be captured by the neglect factor I.

Summary

The current series of P.C.A.s provide evidence in favour of the hypothesis that the behavioural and the conventional tests are sensitive measures of the clinical disturbance of visuospatial functioning known as visual neglect. The behavioural tests were intended to cover several different aspects of functioning in daily life reported by clinicans and therapists to be affected by neglect. The series of P.C.A.s have achieved this goal in that they have repeatedly singled out one factor which explains the largest percentage of variance found. Finally, a more detailed examination of the possible role of hemispheric differentiation indicated a constant pattern of performance in right brain damaged patients, while left brain damage performance suggested the involvement of other features (cf. Gianutsos, Glosser, Elbaum, and Vroman, 1983).

4:6 Lower Order Validity

Lower order validity may be established by comparing the performance of the nine behavioural tests with those of the six conventional tests. If the behavioural tests represent a good measure of the construct under consideration, we would expect a reasonably high degree of association. Using the aggregate scores on all tests, this method yielded a Pearson correlation co-efficient of 0.84 using scores from 50 stroke patients. This value is significant at the .001 level. A similar comparison using only those patients diagnosed as manifesting neglect (N = 30) on the conventional battery yielded an equally significant coefficient of 0.86 ($P < .001$).

A more detailed analysis of the relationships between the individual tests is provided in Table 4:9. This inter-correlation matrix demonstrates that the majority of tests comprising the behavioural test battery were significantly related to those on the conventional battery. Card sorting was the only test that failed to reach significance. Representational Drawing as already seen in the factor analysis) does not appear to be related to many of the conventional or behavioural tests, although it does reach significance with a few tests.

Table 4:9

Behavioural/Conventional Test Correlation Matrix

	Line Crossing	Letter Can.	Star Can.	Fig Copy	Line Bisection	Rep. Draw	Total
(1) Picture	.54 .001	.67 .001	.63 .001	.74 .001	.71 .001	.35 .01	.75 .001
(2) Phone	.57 .001	.54 .001	.62 .001	.83 .001	.74 .001	.37 .01	.72 .001
(3) Menu	.46 .001	.53 .001	.66 .001	.69 .001	.54 .001	.36 .01	.68 .001
(4) Article	.40 .01	.60 .001	.64 .001	.52 .001	.69 .001	.28 NS	.71 .001
(5) Time	.49 .001	.50 .001	.55 .001	.56 .001	.62 .001	.29 NS	.62 .001
(6) Coins	.56 .001	.60 .001	.69 .001	.68 .001	.53 .001	.29 NS	.74 .001
(7) Address	.43 .01	.72 .001	.63 .001	.69 .001	.73 .001	.19 NS	.73 .001
(8) Map	.55 .001	.46 .001	.74 .001	.68 .001	.66 .001	.37 .01	.73 .001
(9) Cards	.31 NS	.45 .01	.42 .01	.46 .01	.35 .01	.13 NS	.47 .001
(10) Total	.58 .001	.72 .001	.75 .001	.79 .001	.75 .001	.35 .01	.84 .001

(N = 50)

A central intention behind the construction of the behavioural tests was that neuropsychological assessment performed in a hospital or rehabilitation centre should have predictive and instructive value with respect to the daily activities of the patient. In this regard we compared performance on the behavioural tests with those of the checklist scores completed by the responsible therapist. For the total test battery this correlation proved to be highly significant $r = -0.61$ ($P < .001$). The correlation is negative since high scores on the therapist's checklist represents a greater degree of neglect, whereas a high score on the behavioural or conventional tests indicates little evidence of visual neglect. Details of how the respective subtests compared with the checklist scores are shown in Table 4:10. Like the behavioural tests, all the conventional tests except "Representational Drawing" correlated significantly with the professional ratings of the therapists.

TABLE 4:10

Correlations between Conventional and Behavioural Test Scores and Therapists measures of Visual Neglect and Daily Living

N = 50	O.T. Checklist	A.D.L.
Line Crossing	- .59 (.001)	.40 (.01)
Letter Cancellation	- .60 (.001)	.53 (.001)
Star Cancellation	- .59 (.001)	.35 (.001)
Figure Copying	- .64 (.001)	.53 (.001)
Line Bisection	- .60 (.001)	.52 (.001)
Representational Drawing	- .23 (N.S.)	.04 (N.S.)
Total Score	- .71 (.001)	.51 (.001)
Picture Scoring	- .62 (.001)	.46 (.001)
Phone Dialling	- .56 (.001)	.34 (.05)
Menu Reading	- .42 (.01)	.14 (N.S.)
Article Reading	- .40 (.01)	.18 (N.S.)
Telling and Setting Time	- .46 (.001)	.32 (.05)
Coin Sorting	- .68 (.001)	.42 (.04)
Address and Sentence Copying	- .46 (.001)	.35 (.01)
Map Navigation	- .57 (.001)	.31 (.05)
Card Sorting	- .34 (.05)	.11 (N.S.)
Total Score	- .61 (.001)	.36 (.01)

O.T. = Occupational Therapist

A.D.L. = Activities of Daily Living

N.S. = Not Significant

Finally, a further comparison was made with a standardized measure of daily living, - "The Activities of Daily Living Assessment (Whiting and Lincoln, 1980) - used and developed for stroke patients at Rivermead. This A.D.L. assessment claims to provide a comprehensive index of daily living activities. As such, the index is a measure of disability, the nature and extent of which may depend on a number of factors, in addition to purely motor-associated dysfunctions. In other words, the index does not claim to discriminate between the various intellectual, perceptual, sensory or motor aspects involved in daily living.

The Rivermead A.D.L. index is divided into two sections, "Self Care" and "Household" items. The later more complex sections were not included in the current analysis as complete data for each patient in this section was not always available. Each of the 16 items of the 'self care' section was scored on a 3 point scale.

A score of 1 represents dependence; a score of 2 represents partial independence but requiring an aid/or supervision, and a score of 3 represents independence for that item. The scale items are scored as actually completed and do not require the therapist to speculate as to the patient's potential abilities. The assessment is carried out in a standardized fashion. Inter-rater, and test-retest reliability results indicated that the assessment index is a reliable measure (Whiting and Lincoln, 1980). The Self-care section of the index includes 16 different functional areas which were measured at the time of admission, during rehabilitation, and at discharge. For the purposes of this study, the assessment closest to the time of testing was always choosen. The sixteen items of the self care section included (1) drinking a full cup of a hot liquid; (2) cleaning one's teeth; (3) combing/brushing one's hair. (4) washing one's face and hands; (5) putting on make-up or shaving; (6) eating skills; (7) the ability to undress; (8) ability to move from one room to another; (9) ability to move from bed to chair; (10) lavatory skills; (11) ability to cover a distance of 50 metres; (12) ability to dress; (13) ability to wash in a bath; (14) move in and out of the bath; (15) ability to wash oneself overall; (16) ability to transfer from the floor to a chair.

The correlation co-efficients for both Conventional and Behavioural tests and the A.D.L. index are shown in Table 4:10. Aggregate scores for both the Behavioural and Conventional tests were significantly correlated with the A.D.L. score. Three of the behavioural tests (Menu Reading, Article Reading, and Card Sorting) and one of the Conventional Tests (Representational Drawing) failed to reach significance, but as already pointed out, this was to be expected given the heterogenous nature of the measures employed and the limited scoring system employed in the A.D.L. index.

4:7 Multivariate Analysis : Discriminant Analysis

In developing the behavioural inattention test battery, we aim to quantify in detail how brain damaged patients with visual neglect score significantly worse than both controls and other brain damaged patients without neglect. However, as it would be both time consuming and impractical to test all stroke patients on the full battery (25-35 min), it would be clinically useful to establish a simple bedside screening method capable of predicting the diagnosis accurately. One method used by several investigations to achieve this result is that of discriminant function analysis(Delgen et al, 1981 and Allen, 1983, 1984).

Discriminant Function Analysis (D.F.A.) describes a form of multiple regression which permits the researcher to distinguish statistically between two or more groups. Such analysis permits the expression of the diagnosis in terms of formal statistical probability rather than subjective clinical judgement. Once a set of variables is found which provides satisfactory discrimination for cases with known group membership, then a set of classification functions or equations can be constructed which allow for the prediction of new cases with unknown membership. The solved classificatory function or equation, together with weighted co-efficients, is called the "linear discriminant function". The information which the solved equation gives describes the changes in the criterion score one can expect as a result of changes in the predictor scores. Typically, the original set of subjects scores are entered into the discriminative analysis in order to see how many of the original cases are correctly classified by the variables employed.

In order to avoid the extraction of redundant discriminators most researchers employ a stepwise methodology (Frazen and Golden, 1985). In stepwise D.F.A., a number of predictions are entered into the predictive equation, but only those predictors which contribute to the overall predictive accuracy are retained. In this way a reduced set of variables can be found which predict almost as well as the full set of variables.

Practical Implications

In the current study, it would be advantageous to obtain a discriminant equation which could distinguish between those subjects with and without visual neglect. The use of a D.F.A. solution would facilitate the clinical diagnosis of visual neglect and provide for the early planning of rehabilitation programs.

Results

Statistical analysis was performed using the B.M.D.P. statistical package. The B.M.D.P. P7M program solves the linear discriminant function for maximizing differences between group means, determines the cut off points, and gives the percentage of correctly classified subjects on the basis of the predictors choosen. Only those variables which made a difference to the separation of the control and stroke groups at a significance level of $P < .001$ were retained. These are shown in Table 4:11. As a result of the criterion of significance choosen to maximize the difference between the two groups, "Article" and "Rep. Score" were removed.

Table 4:11

Comparison of Control and Stroke Patients Mean Performance

on the 6 Conventional and 9 Behavioural Tests

	Variables	Controls			Stroke			t	df	p
		MEAN	SD	N	MEAN	SD	N			
	Conventional Tests									
1	Line Crossing	35.96	0.19	50	33.36	6.09	80	3.81	128	.0003
2	Letter Cancellation	38.12	2.03	50	31.71	9.51	80	5.82	128	.0001
3	Star Cancellation	53.72	0.54	50	45.07	13.06	80	5.91	128	.0001
4	Figure Copying	4.0	0.0	50	3.23	1.24	80	5.58	128	.0001
5	Line Bisection	8.96	0.19	50	7.63	2.51	80	4.74	128	.0001
6	Rep Drawing	3.00	0.0	50	2.74	0.74	80	2.44	128	.02
	Total	143.78	2.12	50	123.61	29.45	80	6.10	128	.0001
	Behavioural Tests									
1	Picture	8.38	0.73	50	6.85	2.63	80	4.91	128	.0001
2	Phone	8.98	0.14	50	8.11	1.89	80	4.07	128	.0001
3	Menu	9.00	0	50	7.82	2.34	79	4.47	127	.0001
4	Article	9.00	0	50	7.98	2.34	52	3.13	100	.003
5	Time	9.00	0	50	8.35	1.47	78	3.91	126	.0002
6	Coins	8.98	0.14	50	7.53	2.37	80	5.47	128	.0001
7	Address	8.98	0.14	50	7.48	2.71	76	4.78	124	.0001
8	Map	9.00	0	50	8.20	1.97	79	3.60	127	.0006
9	Card	7.00	0	50	8.09	1.95	62	3.64	110	.0006

(1) A first D.F.A. was performed to compare all those stroke patients without missing values (N = 59) with the total control group (N = 50). This analysis extracted 2 test variables, shown in Table 4:12.

Table 4:12

First D.F.A.

Variable Predictor	F to Enter	Wilk's Lambda	F-Statistic	Df	P
1. Letter Score	24.09	0.81	24.08	1:107	.001
2. Star Score	4.78	0.78	14.86	2:106	.001

"F to enter" is a measure of the discrimination offered by a potential predictor. The larger the "F to enter" the better the discrimination produced by that predictor. Another method of examining the separation or discrimination between criterion groups is to compute "Wilks Lambda". This represents a measure of the distance between groups and is computed as the ratio between the within group sums of squares and cross products and the total sums of squares and cross products (Frazen and Golden, 1985). This measure is sensitive both to the difference between groups and the homogeneity within groups. Thus the larger lambda is, the less discrimination power remains in the unused variables. In this case, both variables were found to be significant discriminators at the .001 level. On the basis of the D.F.A. the best linear expression for control subjects was;

0.71 x letter score + 0.54 x star score - 28.66

and for stroke patients;

0.61 x letter score + 0.46 x star score - 21.35

Using these solutions predicted the following table of classification.

Table 4:13 **Table of Classifactions for First D.F.A.**

Classification Groups	No. of cases classified Controls	Strokes	% Correct
Controls	49	1	98.0%
Stroke Patients	29	30	50.8%
	78	31	72.5% Total

Using this two step discrimination variable equation and assuming a classification criterion of 50% probability for group membership, the resultant classification allocated 98% of the controls to the control group. However, stroke patient prediction appeared to be at chance level. In other words, the linear equation clearly distinguishes control subjects from stroke subjects, but misclassifies 49.2% of stroke patients as controls. This latter classification rate is clearly not very helpful, but an examination of the variable predictors and patient groups involved provides an alternative explanation for the results.

The predictor variables (letter and star scores) are concerned with predicting overall performance on a set of visuospatial tasks demonstrated to be sensitive to visual neglect. From Chapter 3, we already know that only a minority of the total stroke group (N = 30/80) actually demonstrated neglect according to a strict operational definition. Therefore what the predictor variables and the linear equation have produced is a discrimination between those subjects (irrespective of original classification) who performed either poorly or well on the set of visuospatial tasks concerned. In this case, of the 59 stroke patients, 29 scored within or very close to the range of scores obtained by the control group. Therefore it is not surprising that, on the basis of the linear equation those patients with scores within the range of control scores should be classified as lying within that group of controls. That is the total number of individuals classified, as controls is the total number of actual controls plus those patients whose visuo-spatial scores did not differ significantly from the same controls. On the other hand, 23 of the stroke patients had scores below the cut-off criterion employed earlier to diagnose neglect. All of these patients were subsequently placed by the D.F.A. in the stroke group, together with 7 other stroke patients whose aggregate score was above the cut off criteria for neglect, but not high enough to be classified into the control group.

In order to follow up this extrapolation, a second D.F.A. was performed which this time compared the 50 control subjects scores with those of patients who were not classified as showing neglect. This procedure selectively eliminated the 23 neglect patients and focused on the remaining 36 non-neglect (N-) patients. This analysis extracted 3 test variables, and is shown in Table 4:14.

Table 4:14

Second D.F.A.

Variable	F to Enter	Wilk's Lambda	F-Statistic	Df	P
Predictors					
1. Star Score	17.36	0.83	17.36	1:84	.001
2. Picture Score	9.54	0.74	14.33	2:83	.001
3. Line Bisection Score	6.48	0.69	12.35	3:82	.001

The computation of Wilk's Lambda and the F-Statistic indicated that all variables were significant ($P < .001$) discriminators between the two groups. These solutions predicted the following classifications.

Table 4:15

Table of classificationsfor Second D.F.A.

Classification Groups	No. of Cases Control	Classified Stroke	% Correct
Control (50)	45	5	90%
Stroke (36) (non-neglect)	13	23	64%
	58	28	79%

The second D.F.A. indicated that the discriminant function was capable of classifying 90% of the controls. The equation misclassified 5 control subjects. On the other hand, the classification of stroke improved from the first D.F.A. in that now 64% of patients were correctly identified. However, despite this rise in classification accuracy, 13 stroke patients (36%) were incorrectly classified as controls. This however is again not surprising since at the upper band of the 29 stroke patients mis-classified in the first D.F.A., several have scores very similar to that of the average control. Therefore, given that almost 1 out of every 2 stroke patients without neglect (on the basis of this study) was misclassified, it would seem together with the findings of the first D.F.A. that the best approach would be to consider an analysis whereby all three groups, controls, stroke and neglect groups could be discriminated.

Therefore, a third D.F.A. was performed which compared the control (N = 50) stroke (N^- = 36) and neglect groups (N^+ = 23). This analysis produced 2 test variables shown in Table 4:16.

Third D.F.A.

Variable Predictors	F to Enter	Wilk's Lambda	F-Statistic	Df	P
1. Letter Score	81.39	0.39	81.4	2/106	.001
2. Star Score	13.63	0.31	41.3	4/210	.001

These were the same two test variables identified in the first D.F.A. Although the Wilks Lambda is somewhat low, the F-statistic suggests that the two variables were capable of discriminating significantly between the three groups. A discriminant function equation for the three groups expressed in terms of classification coefficients can be derived for each subject by

Ci = cilVl + Ci2 V2 + ... cip Vp + Cio

where Ci = the classification group score for i

Cip = the classification co-efficients

Cio = the constant

V = the raw score for that discriminating variable

The resultant classification co-efficients were as follows

(1) Controls = 1.98 x letter score + 1.15 x star score - 69.69

(2) Non neglecting strokes = 1.93 x letter score + 1.11 x star score - 65.7

(3) Neglecting strokes = 1.32 x letter score + 0.81 x star score - 33.24

Using these solutions produced the following table of classifications:

Table 4:17

Table of Classification for Third D.F.A.

Classification Group	No. of cases classified Control	Stroke	Neglect	% Correct
Control (50)	38	12	0	76%
Stroke (36)(N^-)	15	21	0	58%
Stroke (23)(N^+)	0	6	17	74%
	53	39	17	69.7

The control group is considered first. It is not surprising in the light of the results of the second D.F.A. that some of the controls (N = 12) should be classified as stroke given the operational definition chosen. This is balanced by having 15 of the stroke group classified as controls. However, using this equation none of the controls were classified as demonstrating neglect; hence in terms of distinguishing between controls and stroke patients with neglect, the percentage of correct classifications is perfect.

The stroke group (N^- = 36) is now considered. It has already been shown that some of these patients have scores which clearly overlap with those of controls. Again, if one distinguishes those stroke patients with 'normal' like performances from the remaining group (classified as stroke patients,) then the percentage of correct classifications remains perfect. That is, none of the stroke patients (N^- = 36) without neglect were misclassified as showing neglect.

The last group, the neglect patient sample ($N^+ = 23$) achieves a respectable 74% classification accuracy, loosing only 6 patients to the stroke group. This is considerably better than one might expect on the basis of chance assignment alone (Chi-square = 23.04 with $P < 0.001$).

Since the aim of the discriminant analysis was to distinguish from normals those patients whose performance on a sample of visuospatial tasks was significantly impaired then the table of classifications may be reconstructed in terms of the presence or absence of neglect. This is shown in Table 4:18.

In terms of the operational definition of neglect used, the extracted test variables were capable of distinguishing 74% of those subjects with neglect from those subjects (both control, and stroke patients performing within control limits) without neglect. Furthermore, none of the controls or stroke patients without neglect were misclassified. Thus, whereas the sensitivity of the classificatory co-efficients (i.e. the proportion of subjects in whom neglect was correctly identified) is 93%, specificity (the proportion of identified subjects without neglect) is 100%. This results in a high predictive value of 87% for all subjects classified. The discriminant function equation which best characterized the performance of the non-neglecting stroke patients is

1.93 x letter score + 1.11 x star score - 65.70.

Table 4:18

Diagnostic Table

Neglect	Classificatory Co-efficient Groups: Neglecter	Non-neglecters	Total
Present +	17 (A)	6 (B)	23
Absent -	0 (C)	86 (D)	86
	17	92	109

Sensitivity = A/A + C = 17/17 = 100%

Specificity = D/B + D = 86/92 = 93%

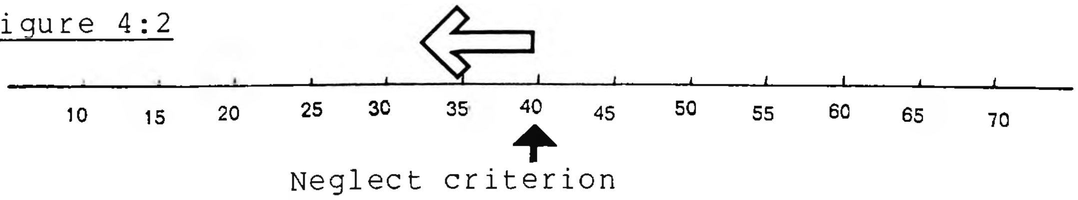
Positive Predictive Value = A/A + B = 17/23 = 74%

Negative Predictive Value = D/C + D = 86/86 = 100%

Accuracy = A + D/A + B + C + D = $\frac{103}{109}$ = 94.5%

Using the data from the original standardization sample the parameters for the diagnosis of neglect can be computed. These are displayed in Figure 4:2.

Figure 4:2



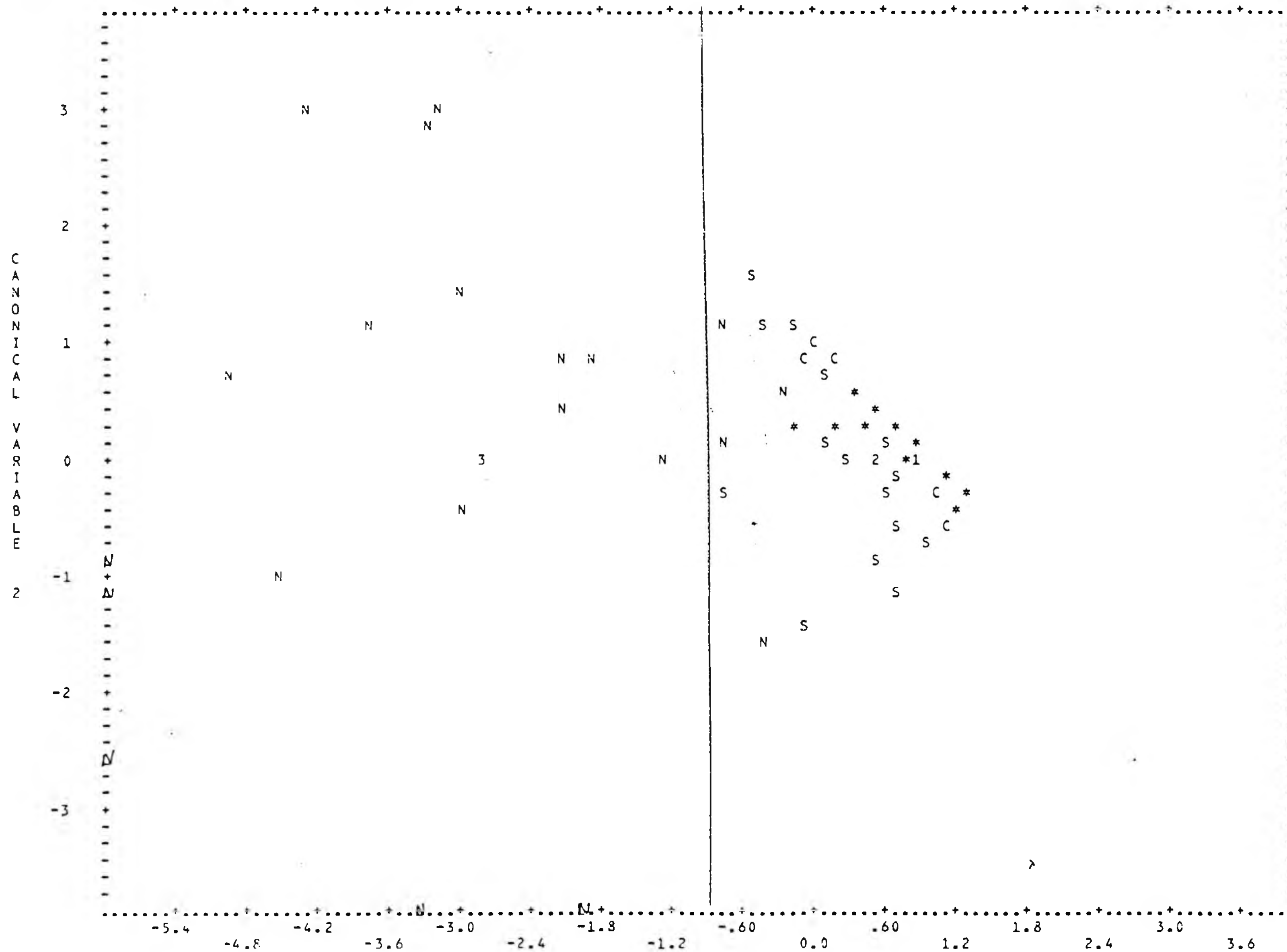
For the practical purposes of using the discriminant function equation to screen potential stroke patients, who may require further investigation on treatment, a diagnostic score of less than 40 should be used.

A scatter-plot of D.F.A.(3) demonstrating the distribution of the three groups defined by functions 1, and 2 is shown in Fig. 4:3.

BMDP7M NEGLECT POPULATION DATA

Fig.4.3 Scatter-plot of D.F.A. (3).

OVERLAP OF DIFFERENT GROUPS IS INDICATED BY *



Letters on the plot represent patients belonging to the indicated groups. (C = controls, S = stroke (N^-) and; N = neglect (N^+). An asterisk (*) indicates areas of overlap between the different groups. The abscissa (Horizontal axis) describes Discriminant Function I (Letter Score) whereas the ordinate (vertical axis) describes discriminate function 2. The line drawn down the middle of the plot represents the broad classification described in Table 4:18. The numbers 1, 2 and 3 correspond to the mean of the control, stroke, and neglect groups, respectively.

The two tests extracted by the discriminant analysis have clearly been shown to load significantly on to Factor I in the general analysis. This factor which represents the construct under consideration, "impairment of visuospational functioning" or neglect may be predicted using these two conventional tests.

The diagnostic score is not intended to be a substitute for clinical judgment or more exhaustive investigations, but may aid the clinican or therapist by providing them with a practical, reliable, time-saving bedside evaluation when more lengthy testing may not be possible or practical. The practical use of the discriminant function for clinical diagnosis therefore remains with the individual clinican given the classification hit-rate described. An inherent limitation of D.F.A. is that the classification achieved is most accurate for the group of patients which comprized the original data for the analysis.

4:8 Summary

This chapter has been concerned with considerations of validity and predictivity for the full test. The predictivity of the shortened version of the test and its ability to classify neglect patients correctly was also discussed.

The main results of the factor analysis, for both the total stroke and specific neglect sub-groups, clearly support the claims of the test battery to be a valid measure of the construct underlying visuospatial neglect. In addition validity was confirmed by significant correlations with both conventional tests scores and independent therapists ratings of the patient's condition. The later measures, together with the overall significant relationships with the index of everyday functioning, supports the claim that the test is sensitive to the problems experienced by stroke patients in daily activities.

Re-appraisel of visual neglect : Single Cases

Chapter 5

5:1 Introduction

5:2 Line bisection : Overview

5:3 Line bisection : Group study

5:4 Line bisection : Single case studies

5:5 Line length and visual neglect

5:6 Investigations of "Altitudinal" neglect

5:7 What is neglected in visual neglect?

Chapter 5

5:1 Introduction

The results presented in Chapters 3 and 4 dealt with the development, standardization and analysis of the group data obtained from administering the test battery to 130 subjects. In the course of gathering this information, several patients were singled out for more detailed investigation and these provide the basis for the single case and group studies described in the present chapter.

These studies address aspects of visual neglect, such as the effect of line length and hemispatial position on line bisection performance. They also consider whether the classical picture of spatial neglect should be revised to incorporate vertical dimensions of the condition. Finally, Chapter 5:7 provides evidence which indicates that what is "neglected" in visual neglect may still influence the patient's judgement and subsequent behaviour.

All of the studies reported in this chapter involve the use of the original conventional tests, and in particular the line bisection task. The latter tasks' simplicity and potential for experimentation provides the researcher with a easily quantifiable yet sensitive measure of spatial neglect.

5:2 Line Bisection : Overview

The apparently simple task of line bisection requires the subject to estimate and mark the centre of a line positioned on a stimulus sheet. This technique has long been favoured as a clinical measure for determining the presence and extent of left sided neglect in patients with right hemisphere brain damage. The expectation is that the patient will underestimate the magnitude of the line to the left, placing the subjective bisection point too far to the right. Before discussing pathological performance and some of the major theories of neglect that have attempted to explain neglect using this task, it is appropriate to consider the performance of normal control subjects.

Line Bisection by Normal Subjects

Few clinical reports of visual neglect have specifically examined the performance of normals on the visual line bisection task, presumably (as suggested by Bruyer, 1984) because it was assumed that normal subjects would either perform flawlessly or produce errors randomly distributed about the objective midline. However, as far back as 1884, Hall and Hartwell had already noted that for normals,

> "a line at right angles to the medium plane seems a little longer to the left than to the right of it, if the observer is right handed".

From this early observation of Hart and Hartwell, one might infer that right handed subjects should transect lines slightly to the left of centre. This indeed was the result obtained by Bisiach, Capitani, Columbo and Spinnler (1976) almost a century later on a sample of 50 controls. The same group did not however show a systematic error with their left hand. This leftward displacement using the right hand has also been reported by Bradshaw, Nettleton, Nathan and Wilson (1985) and Ramos-Brieva, Olivan, Palomares and Vela, (1984). A similar significant left sided displacement, for the left hand has also been reported by Scarisbrick, Tweedy and Kuslanski (1987) and Schenkenberg et al, (1980). Bowers and Heilman (1980), using a tactile bisection task with a group of right handers, found that subjects deviated to the left regardless of the hand used. These authors describe the condition as "pseudoneglect" since control errors were opposite in direction to those made by patients with visual neglect. Bradshaw et al, (1987) on the other hand describes this phenomenon as "left side underestimation" or L.S.U. This description appears somewhat strange since presumably patients with left sided neglect are thought to perceptually represent the left extent of the line as shorter than it is, so as to explain the deviation to the right (Nichelli, Rinaldi and Cubelli, 1989). However, the explanation for the use of the term "L.S.U." in normals can be found in Bradshaw et al, (1987).

> "It is as if such subjects see the extent of the left of centre as larger than it really is, possibly because of the greater visuospatial processing power of the right hemisphere ... and so in compensation make the left side slightly smaller to seem equal to the right".

This "L.S.U." has been calculated by Bradshaw et al, (1985), (1986), to be in the region of 1.6% of the true half length under conditions of visual line bisection; the bisection of space between two dots; and in tasks requiring the subject to adjust a rod about its central point.

Brain Damaged Patients

Within a neuropathological context, the task of line bisection was first deployed by Axenfeld (1894, 1915) to study asymmetries of spatial perception in patients with hemianopia. The principal conclusion of these early studies (as reviewed by De Renzi, (1982) was that the subjective midpoint was frequently displaced towards the "good" field. In the absence of a meaningful conceptual framework, spatial disorders such as neglect, tended to be explained in terms of more obvious concomitant sensory disorders.

The effect of right sided deviations cannot be in all instances however a direct consequent of hemianopia, since not all patients with neglect have visual field deficits; and several patients within the present B.I.T. standardization with homonous hemianopia but not neglect, performed within the normal range on the line bisection task. Thus it is generally accepted that visual neglect, although exacerbated by visual field deficits (Ogden, 1985), is not a sensory disorder per se, but rather reflects some underlying deficit of higher level perception or selective attention. (Bisiach, Luzzatti and Perani, 1979; Posner, Walker, Friedland and Rafal, 1984). Other suggestions include that of Heilman and Valenstein (1979), who speculate that patients (in this study, 6 neglect patients, 4 of which had no hemianopia) may have sustained a hemispatial memory defect such that despite initially seeing the full (leftward) extent of the line, could not form "a stable trace" of it.

The line bisection test has been used by several investigators to study the neuropsychological mechanisms though to underly visual neglect. On the one hand, supporters of the theory that neglect represents a spatial disturbance of selective attention (Kinsbourne 1987, Posner, Cohen and Rafal, (1982) and Mesulam (1985) predict that neglect performance will be affected by the existence of "attentional cues" situated on the normally neglected side of the line. This theoretical position has found support in the work of Riddoch and Humphreys (1983) whose results showed that cueing has significant effect on the magnitude of right sided deviation.

Supporters of the "hypokenetic" or "intentional" theory of neglect as described by Heilman and Valenstein, (1979) claim that neglect is the result of a unilateral reduction of cerebral arousal, and that this gives rise to a reduced or delayed preparedness for motor responses towards and within the contralateral field. According to this position, moving the line's relative position with regard to the patient's mid-line should have a significant effect on the extent of neglect. Such a theory would also predict no effect for cueing strategies which ensure that patients processed the neglected end of the line.

Finally, the "representational theory", championed by Bisiach et al, (1987) claims that neglect results from a cognitive disorder which has its source in the breakdown of the egocentric reconstruction of representational space. This position predicts that despite the representational loss, patients with neglect

> "should deduce the total stimulus length from its right extremity, independently of how much of the line they see ... consequently, attentional and spatial cues should not be effective..."
> (Nichelli, Rinaldi and Cubelli, 1989).

In the following series of experiments, on line bisection, all three theoretical positions will be considered and discussed.

5:3 Group Line Bisection : Variability Within and Between Normal Controls and Patients with Left and Right Hemisphere Damage

This experiment set out to investigate and quantify the effects of spatial position on the extent and direction of line bisection performance in a group of controls; right and left brain damaged patients, and a sub group of neglect patients. In previous reports it has been shown that left neglect may be reduced by placing the stimulus in right space, and conversely left sided neglect is worsened by placing the stimulus line in left space (Bowers and Heilman, 1980; Schenkenberg et al, 1980). The effect of spatial positioning was also found in controls, who tended to transect the line to the right of the true midpoint when the stimulus line was presented in left hemispace, and to the left when it was presented in right hemispace. That is, control subjects tend to displace the subjective midpoint toward their mid-saggital plane (Nichelli, Rinaldi and Cubelli, 1989).

Materials and Method

Subjects. Forty normal controls, of similar age to the main stroke population already described were employed. All were right handed (10 male and 30 female). Each performed the line bisection task described in Chapter 3 once, with their right and once with their left hand.

The patient group consisted of 93 stroke subjects (13 more than the standardization sample), all of whom had sustained a unilateral cerebrovascular lesion within 6 months of testing. All subjects were right handed and were inpatients at the Rivermead Rehabilitation Centre. Twenty five patients (17 male, 8 female, mean age = 54.1 years S.D. = 12.4) had suffered left sided stroke; 68 patients, (42 male, 26 female, mean age = 58.1, S.D. 8.6) had suffered right sided stroke.

Unlike previous investigations (Heilman and Valenstein, 1979; Riddoch and Humphreys, 1983) this investigation used an operational definition of neglect (and severity thereof) which was derived independently of the patient's performance on the line bisection task itself. On the basis of the aggregate score obtained on five tests (Line Crossing, Letter and Star Cancellation, Figure and Shape Copying; and Representational Drawing), patients were assigned to one of three groups:-

(A) No discernible neglect (N^-)

(B) Mild neglect (N^+)

(C) Moderate to severe neglect (N^{++})

These assignments were derived from the normative data reported in Chapter 3. Patients scoring within the normal range on these five tests (121-137) were classified as N^-; patients who achieved scores between 110-120 points (i.e. below the worst control) were classified as N^+; and finally patients who scored less than or equal to 100 were classified as N^{++}.

Stimuli and Procedure

More details about the line bisection procedure and stimuli can be found in Chapter 3. Briefly, the stimulus sheet presented to each subject contained 3 horizontal lines drawn in black ink. Each line was 203 mm long and 1/2 mm wide. The lines were arranged from top right to bottom left, such that the top line (centred in right hemispace) began 8 mm from the right edge of the sheet; the middle line began 48 mm from the right edge; and the bottom line (centred in left hemispace) 87 mm from the right edge. The vertical spacing between lines was 55 mms. Subjects were instructed to bisect each line as accurately as they could. Control subjects responded first with their preferred hand, and then with their non-preferred hand. Patients responded with the hand ipsilateral to the damaged hemisphere. Each subject performed the task in free vision with no constraint on eye or head movements. Moving the stimulus sheet was not permitted.

Results

Errors in line bisection performance for each subject were measured to the nearest millimeter. The mean numerical errors (with S.D. and ranges) to the left, or right of the objective midpoint, together with the absolute means are given in Table 5:1 (A.B.C.) for all groups and line positions. Only 3 patients with left hemisphere damage manifested neglect on the operational definition employed, and these have been treated as one group irrespective of severity, (2 mild and one severe). Deviation to the right of objective centre is reported as a positive value (+); to the left as a negative value (-).

Table 5:1 (A)

Line Bisection

Results of Group Study : (Controls)

	Left Line		Middle Line		Right Line	
Controls	N = 40		N = 40		N = 40	
R. Hand	Sg	Ab	Sg	Ab	Sg	Ab
Mean	- 0.73	3.87	- 2.03	3.07	- 2.85	4.90
SD	4.93	3.06	3.04	1.94	5.45	3.66
Range	- 13 → + 8	21	- 7 → + 5	12	- 16 → + 6	22
Median	0		- 2.0		- 2.5	
Variance	23.65		9.02		28.93	
Skewness	- 0.48		0.41		- 0.32	
Kurtosis	2.57		2.26		2.27	
Controls						
L. Hand	Sg	Ab	Sg	Ab	Sg	Ab
Mean	- 0.30	3.75	- 2.85	3.85	- 5.23	5.53
SD	4.67	2.74	3.95	2.9	4.13	3.70
Range	- 9 → + 10	19	- 12 → + 5	17	- 15 → + 3	18
Median	- 0.50		- 2.00		- 5.0	
Variance	21.31		15.23		16.62	
Skewness	0.43		- 0.10		- 0.23	
Kurtosis	2.58		2.62		2.59	

R./L. Hand = Right hand/Left hand

Sg = Signed Mean Deviation

Ab = Absolute Mean Deviation

S.D. = Standard Deviation

Table 5:1 (B)

(LBD)

Results of Group Study

	Left Line		Middle Line		Right Line	
LBDN⁻	N = 22		N = 22		N = 22	
	Sg	Ab	Sg	Ab	Sg	Ab
Mean	1.59	3.95	- 2.91	6.4	- 4.3	6.2
SD	7.0	5.9	9.8	7.9	6.6	4.7
Range	- 10 → + 22	32	- 38 → + 14	5.2	- 20 → + 11	31
Median	0		- 3.0		- 5.00	
Variance	47.33		92.81		41.11	
Stewness	1.76		- 1.82		0.04	
Kurtosis	6.28		8.66		3.60	
LBNN⁺	N = 3		N = 3		N = 3	
	Sg	Ab	Sg	Ab	Sg	Ab
Mean	-2.66	13.3	-6.0	8.0	-9.6	9.6
SD	16.2	2.31	8.2	5.0	11.9	11.9
Range	-12 → + 16	28	- 13 → + 3	16	-23 → 0	23

Sg = Signed Mean Deviation

Ab = Absolute Mean Deviation

Table 5:1 (C)

(RBD)

Results of Group Line Bisection

	Left Line		Middle Line		Right Line	
RHN$^-$	N = 33		N = 33		N = 33	
	Sg	Ab	Sg	Ab	Sg	Ab
Mean	3.45	7.88	3.03	6.91	0.91	6.55
SD	10.3	7.3	8.04	4.99	8.78	5.81
Range	- 16 → + 35	51	-14 → + 23	37	-27 → +18	45
Median	2.00		4.00		2.00	
Variance	102.25		62.76		74.81	
Skewness	0.69		0.05		- 0.56	
Kurtosis	4.22		3.05		4.68	
RHN$^+$	N = 17		N = 17		N = 17	
	Sg	Ab	Sg	Ab	Sg	Ab
Mean	16.6	18.8	9.24	11.47	0.35	10.0
SD	22.6	20.5	19.96	18.69	18.6	15.0
Range	-15 → + 85	100	- 7 → +81	88	- 24 → +65	89
Median	10		3.0		- 1.0	
Variance	479.99		375.12		327.52	
Skewness	1.604		2.89		2.46	
Kurtosis	6.04		11.17		9.85	
RHN^{++}	N = 18		N = 18		B = 18	
	Sg	Ab	Sg	Ab	Sg	Ab
Mean	41.4	45.9	32.0	33.8	12.6	18.6
SD	31.2	23.5	27.4	24.9	22.2	17.2
Range	- 21 → + 81	102	- 13 → +78	91	- 13 → + 56	69
Median	48.5		36.50		7.00	
Variance	919.79		710.33		465.90	
Skewness	- 0.64		- 0.004		0.69	
Kurtosis	2.39		1.76		2.23	

Sg = Signed Mean Deviation   Ab = Absolute Mean Deviation

The results are also shown graphically in Fig. 5:1. Here the data are presented separately for each of the three spatial positions, together with the mean error and range.

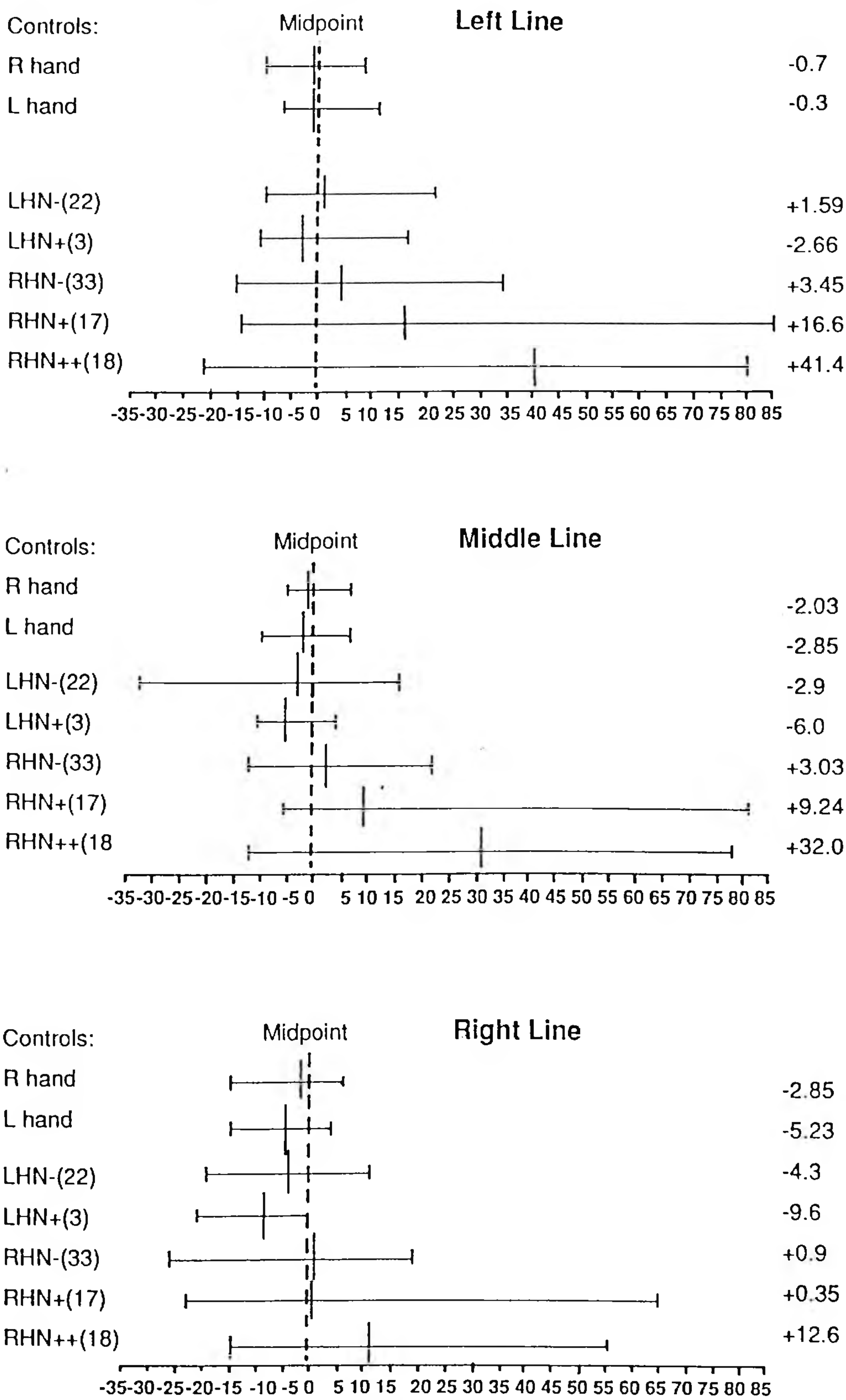
The data are remarkably regular. Midline presentation shows a small left sided bias in controls, an effect that is marginally increased in left hemisphere patients without neglect. Left handed performance by control subjects did not appear to differ greatly from that of right hand performance. Right hemisphere patients without neglect (as defined by the battery of five visuospatial tasks) show a small rightwards bias, an effect that increases threefold in patients with mild neglect, and almost ten-fold in patients with moderate to severe neglect. Overall, presentation centred in left hemispace shifts the majority of these effects rightwards, and presentation centred in right hemispace shifts them all leftwards.

Controls. A repeated measure analysis of variance (Anova) was performed on the line bisection data for the control group, with hand used (Left/Right) and hemispace (left, centre and right) as within subject factors. The results of the Anova revealed no significant main effect for hand used. [F = 1.37; df = 1,39; N.S.] or its interaction with spatial position [F = 2.67; df = 2,78; N.S.]. However, statistically significant main effects were found for the spatial position of bisection. [F = 19.06; df = 2,78; P < .0001]. Consequently, data from the Left and Right handed line bisections were pooled and compared using t-tests. This revealed that (A); line bisection was more accurate when performed in left hemispace than at centre (left = -1.02 mm,

Fig. 5.1

Line Bisection Tasks: Group Study 93 Patients 40 Controls

Mean Deviation and Range From Midpoint



L/R hand= left/righthand

LHN- =Left hemisphere damaged group without neglect
LHN+ =Left hemisphere damaged group with neglect
RHN- =Right hemisphere damaged group without neglect
RHN+ =Right hemisphere damaged group with mild neglect
RHN++=Right hemisphere damaged group with moderate to severe neglect

centre = -4.87 mm, t = 3.24, df = 72, P < .01) or in right hemispace (left = -1.02 mm, right = -8.07 mm, t = 4.94, df = 76, P < .001) and (B) that centre position was more accurate than bisection in right hemispace (centre = -4.87 mm, right = -8.07, t = 2.49, df = 68, P < .02). The mean deviation for central presentation (-2.4%) is similar to that reported by Bradshaw, Nettleton, Nathan et al, (1985).

To assess the extent to which bisection performance in each spatial condition differed significantly from the actual midpoint, t-tests were performed. These indicated that bisection in left hemispace was the only occasion when irrespective of hand used control scores did not differ significantly from the actual midpoint (Right hand, left hemispace t = -0.93, df = 39, N.S.; Right hand, centre position, t = -4.2, df = 39, P < .001; Right hand, right hemispace, t = -3.31, df = 39, P < .01; Left hand, left hemispace, t = -0.41, df = 39, N.S.; Left hand, centre position, t = -4.56, df = 39, P < .001; Left hand, right hemispace, t = -8.0, df = 39, P < .001).

Patients

Within the left hemisphere group (N=25) the analysis of variance revealed a significant difference between spatial positions. [F = 3.41; df = 2,72; P < .05]. Subsequent t-tests showed that line bisection for this group was more accurate when it was performed in left hemispace than at midline. (left = 1.08 mm, centre = -3.28 mm, t = 1.73, df = 46, N.S.) or right hemispace (left = -1.08 mm, right = -4.92 mm, t = 2.74, df = 47, P < .01).

In the right hemisphere patient groups, those with mild neglect and those without neglect did not show any significant difference with regard to spatial position ($F = 0.74$; $df = 2,96$; N.S.), ($F = 2.7$; $df = 2,48$; N.S.).

The only group to show an effect for hemispace was the moderate to severe right hemisphere neglect group [$F = 5.24$; $df = 2,51$; $P < .01$]. Again post-hoc comparisons revealed that right sided line bisection was more accurate than left sided, (right = 12.6 mm, left = 41.4 mm, $t = 3.19$, $df = 30$, $P < .01$) and central positions, (right = 12.6 mm, centre = 32.0 mm, $t = -2.33$, $df = 32$, $P < .01$) for this group.

Discussion

With midline presentation, the control group shows a significant leftwards bias of approximately 2.4% to the left. The existence of this right sided "overestimation" or left sided "underestimation" confirms the findings of Bisiach et al, 1976; Bowers and Heilman, 1980; Ramos-Brevia et al, 1984; and Bradshaw et al, 1985).

Unlike Bisiach et al's (1976) study which found no systematic deviation for left handed bisection, the present study confirms the findings of Scarisbrick et al (1987) and Schenkenberg et al., (1980) where left handed bisection resulted in a significant right sided overestimation. One possible explanation for this discrepancy involves the number of lines used per stimulus page, together with the various lengths and spatial locations of these lines on the page. For example the study by Bisiach et al (1976) used single lines centred about the bodily midline on different sheets of paper. On the other hand, hemispace position contributed significantly to bisection performance as can be seen from Figure 5:1. Hemispace describes the egocentric co-ordinate system in which both the midline of the body or head, serve as the plane for dividing space into left and right sectors. The operational definition used by Heilman, Bowers and Watson (1984) involved placing the stimulus sheet such that the right/left edge of the page was located 30 cm to the left or right of bodily midline. Control presentation required the positioning of the stimulus page directly in front of the patient's midsaggital plane.

However, not all studies have used this format. Nichelli et al (1989) using A3 (420 x 258 mm) sheets of paper positioned the respective line lengths either centrally or 70 mm to the left or right of the centre of the page. Several studies have tended to use smaller overall stimulus sheets, locating the respective lines to be bisected on the left or right sides of the page, e.g. Schenkenberg et al, (1980) and Ramos-Brevia et al, (1984).

Despite the use of these relatively small spatial positionings, both studies reported an effect on performance of the relative positions of the lines on the page. In the present experiment, despite using a small stimulus page (208 x 298 mm) and only one line per spatial position, these findings were replicated. The results of spatial position for the control and patient groups are shown in Figure 5:2.

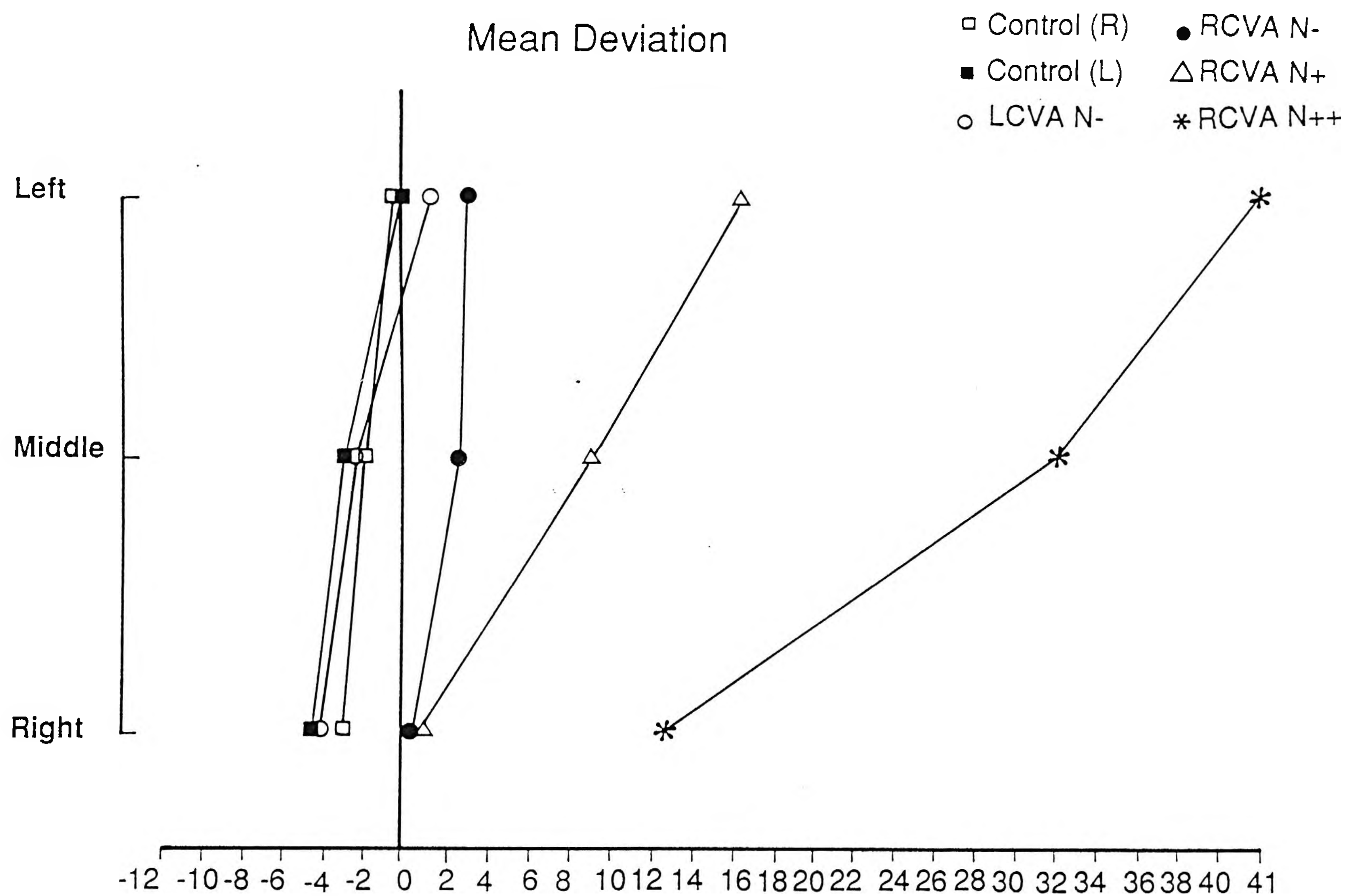


Fig.5.2 Mean results of spatial position for control and patient groups.

LCVA N- =left brain damaged group without neglect

RCVA N- =right brain damaged group without neglect

RCVA N+/RCVA++ =right brain damaged group with mild / moderate to severe neglect

The general effects of spatial position can be described as follows (A) control subjects tended to bisect central lines significantly to the left of centre. (B) lines presented in right space were bisected by controls further to the left. This deviation direction was also observed for all other patient groups. (C) presented with left sided lines, controls (and patients) tended to deviate towards the right. Our findings are in agreement with those of Nichelli et al., (1989), where control subjects bisected lines towards their bodily midline. Curiously, two previous studies, again using small stimulus sheets (Schenkenberg et al, 1980; Ramos-Brevia et al, (1984) describe deviation patterns which (while similar to one another) are markedly different from the description just given. In these studies, control subjects bisected right sided lines towards the right of the mean left bisection point, and left sided lines to the left of the mean right sided bisection point. One explanation for the aforementioned discrepancy may relate to the number and proximity of different line lengths used on a single stimulus sheet.

Within the patient groups; left hemisphere patients (LH) without neglect (as established on the pretests) behave like the control group on line bisection. The left hemisphere damaged patients with neglect (3/25) showed "right neglect" on line bisection, and this leftwards deviation was approximately three times that of controls.

By contrast, patients with right hemisphere damage (RH) who were not diagnosed as manifesting neglect on the pretests nonetheless showed abnormal performance on line bisection. Their rightwards deviation was greater than the leftwards deviation of normal controls. This right-wards deviation increased six fold (over controls) in the right hemisphere patients with mild neglect, and sixteen fold in patients with moderate to severe neglect. The percentage of right hemisphere patients with neglect was 35/68 (51%) dramatically greater than the percentage of left hemisphere patients with neglect [2/25 (12%)]. The overall severity of neglect (as assessed by both line bisection and the pretests) was greater in the R.H. than the L.H. groups, thus confirming neglect studies reviewed by De Renzi (1982); Ogden, (1985) and Albert, (1973). The pretest assignment to severity subgroups within the R.H. group was consistent with performance on line bisection; i.e. the moderate to severe (RH) group showed a larger right deviation than the milder group.

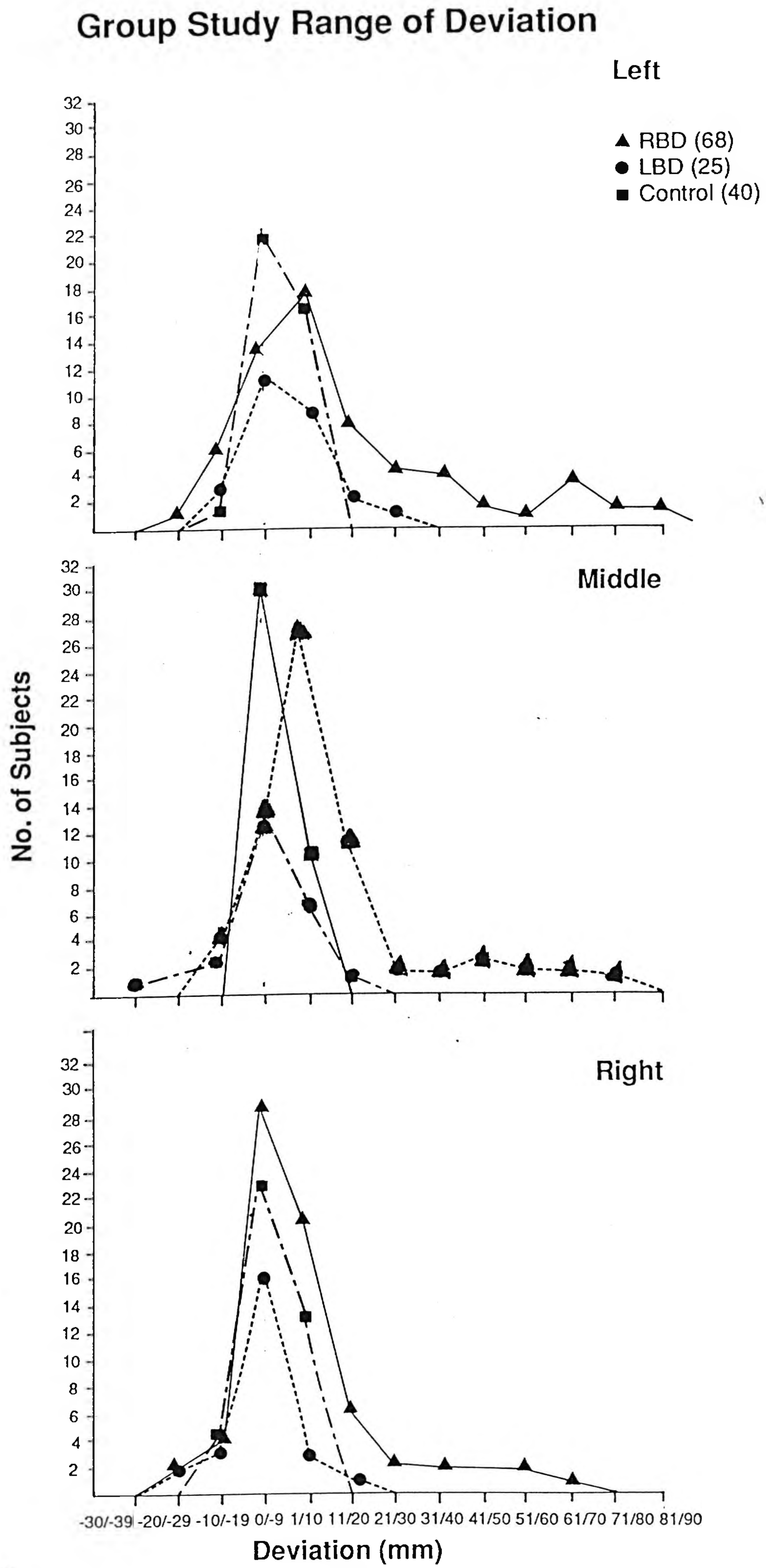
Presentation with the true midpoint centred in right hemispace moved the mean displacement to the left. In control subjects, the effect was very slight, but the L.H. group without neglect showed a displacement which is almost double that of controls. In the three L.H. patients with neglect the shift was four fold over that of controls. On these data, the line bisection tasks appeared to be a sensitive indicator of right neglect. For the R.H. groups, right hemispace presentation reduced the magnitude of left sided neglect, but still left a rightward bias, which was very substantial for the subgroup with moderate - to severe neglect.

Presentation with the midpoint in left hemispace, moved all save one of the mean displacements to the right.

Controls and L.H. patients without neglect crossed the midline and showed (slight) "left" neglect. The L.H. patients with neglect still bisected to the left of true midpoint, but the effect was reduced over that shown with midline presentation. R.H. patients as a group continued to show left neglect on bisection, and for those patients diagnosed as manifesting neglect in the pretests, the affect is substantially increased over that of midline presentation.

Although the means of the group data show very regular and consistent effects, they do hide considerable variability within the various subgroups. Perhaps the most striking feature of the results is the very large differences in accuracy of performance within each group, including controls (cf. the ranges reported in Table 5:1). In order to examine this variability, data from the three largest groups is graphically displayed in Figure 5:3.

This illustrates the number of subjects/patients within a set of accuracy ranges for all three spatial positions. This aspect of the bisection performance is rarely discussed in previous studies of neglect. Yet, Figure 5:3 clearly shows that a small tail of right neglect can be found in L.H. patients, extending beyond the range of normality. Even more striking is the performance of the R.H. patients. Here the mode is shifted to the right of the normal controls, and a large 'tail' extends beyond the limits of normality. Theoretical interpretations of neglect must (eventually) take account of such variability. A particularly clear illustration of the problem can be seen in the performance of R.H. patients with mild neglect, (cf Table 5:1) in right hemi-



Group Study Range of Deviation
Left
RBD (68)
LBD (25)
Control (40)
Middle
Right
No. of Subjects
-30/-39 -20/-29 -10/-19 0/-9 1/10 11/20 21/30 31/40 41/50 51/60 61/70 71/80 81/90
Deviation (mm)

Fig 5.3

space. The group mean is remarkably close to the objective midpoint (+0.35), yet this figure has to be qualified by attention to individual patients whose performance range between a displacement of -24 mm and +65 mm, a total extent of 90 mm. Hence it is important to include a description of the absolute deviation within studies which describe neglect displacement in terms of (+) right, and (-) left (cf. Table 5:1).

If we examine the range of deviations across groups, it is possible to discern some of the contributing factors which accounts for this variability.

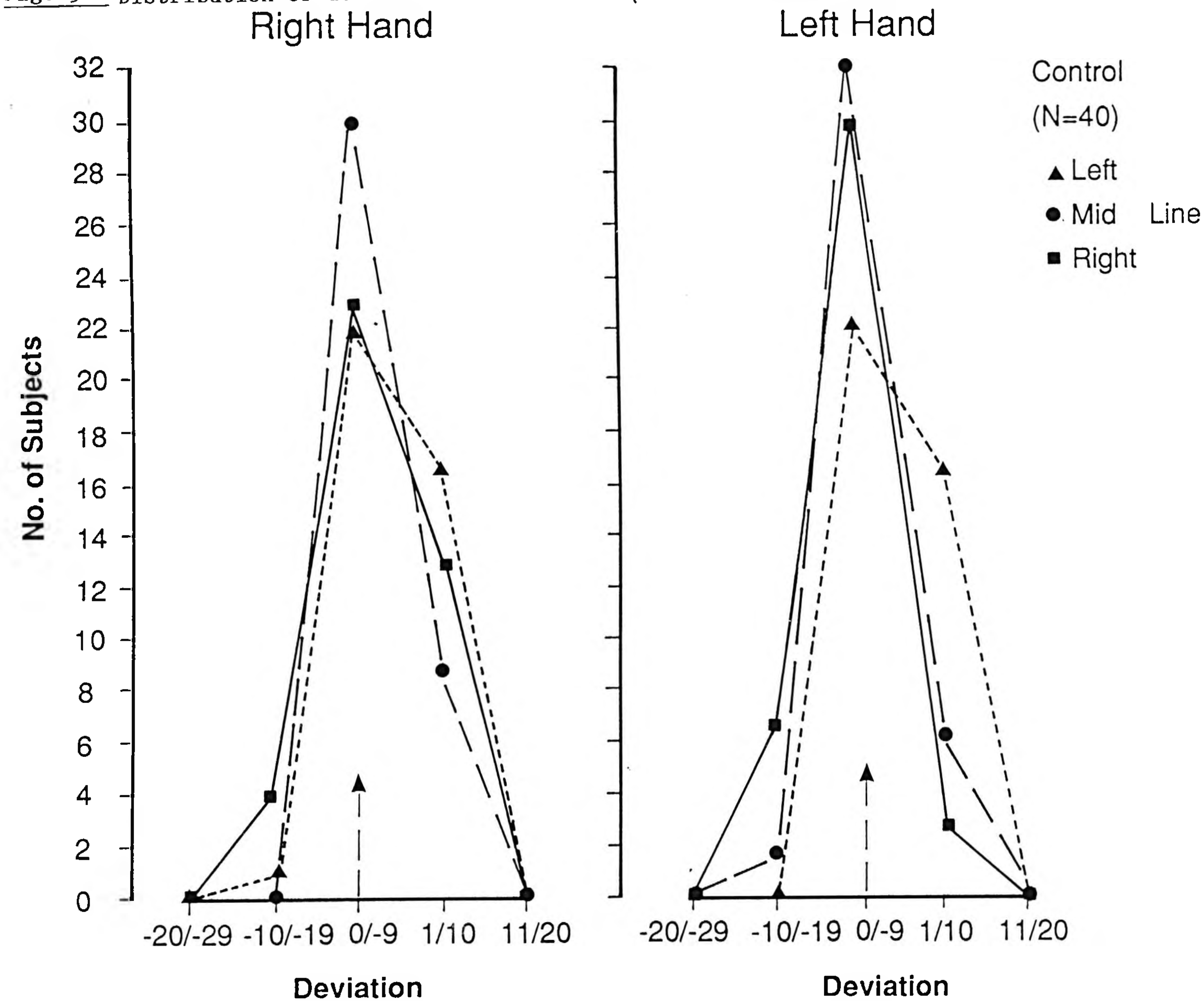
When plotted graphically control performance shows a tall triangular shaped distribution covering a relatively small base area. Figure 5:4 illustrates the dispersion of deviations scores for the 40 right handed controls using both left and right hands.

Although there is evidence of inter-hand spatial differences, both left and right hands cover roughly similar ranges (Left hand; -15 → + 10; Right hand; -16 → +8).

In a similar plot of the RH groups (N^-) and N^+ and N^{++} two main factors can be seen to be at work. (Figure 5:5).

First, there is the gradual enlargement of the triangular distribution base of deviations as one moves from RH (N^-) to RH (N^{++}). This has the result of changing the peakedness or kurtosis of the distribution. As one moves from the normal controls (in Figure 5:4) where there is a small range of deviations about the mean, the distribution changes from being leptokurtic to mesokurtic (R.H.N^-) to

Fig. 5.4 Distribution of deviations for Controls (left and right hand.)



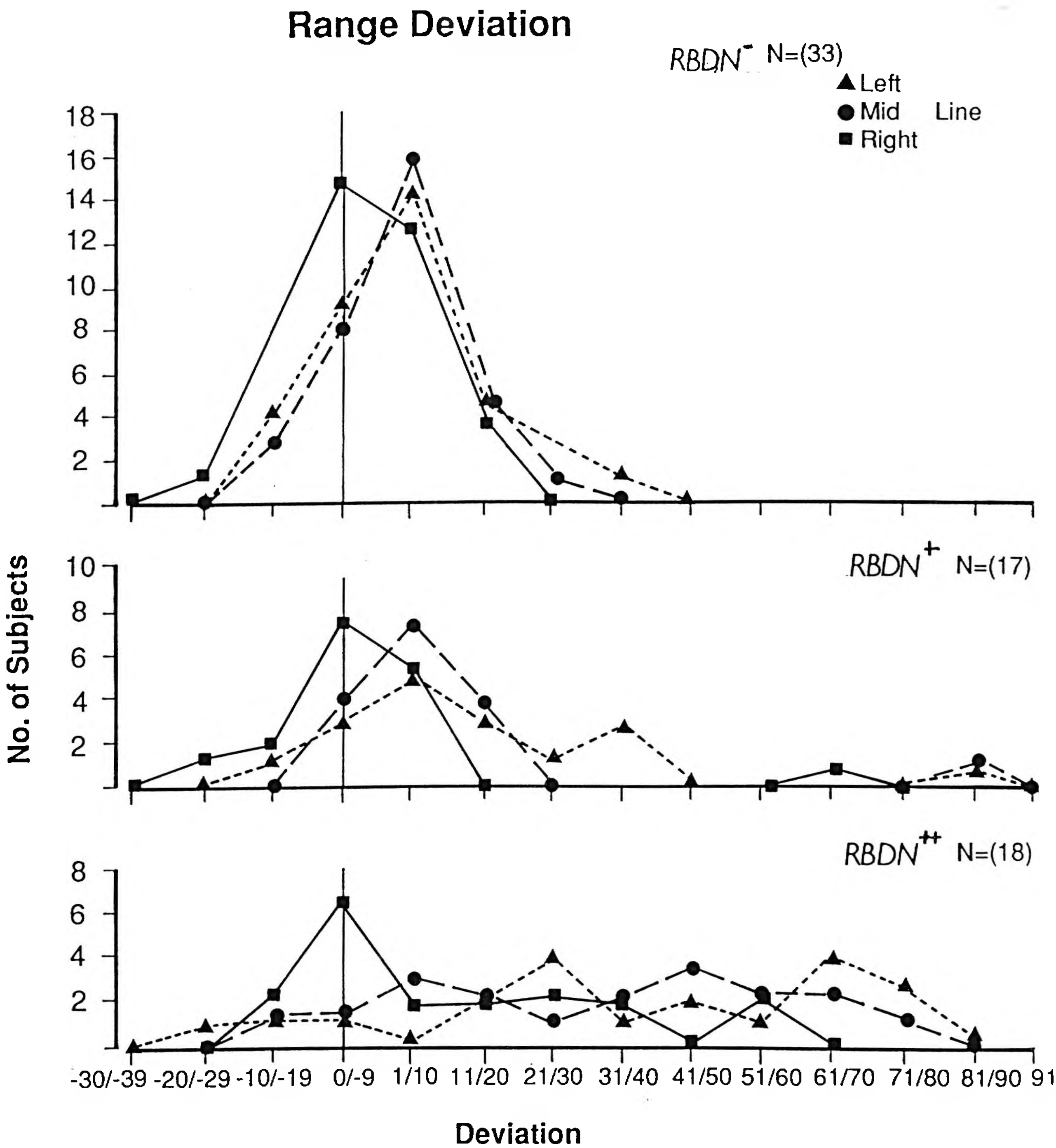


Fig.5.5 Range of deviation for the three right brain damaged groups
RBDN- =right brain damaged group without neglect
RBDN+ =right brain damaged group with mild neglect
RBDN++=right brain damaged group with moderate to severe neglect

platykurtic (R.H.N^{+}, R.H.N^{++}). This gradual expansion of the distribution base as one moves towards greater neglect performance (as assessed on the operational definition) can be demonstrated more clearly by charting the respective groups standard deviations in Figure 5:6.

Although it was not always possible to obtain computer axial tomography scan evidence of the extent of damage for every patient, two recent studies (Levine, Warach, Benowitz and Calvino, 1986; Hier et al, 1983) have shown that severe and persistent neglect typically results from large lesions involving injury to frontal, parietal and subcortical structures. Hence the kurtosis factor observed may reflect a general effect of the extent of brain damage suffered by the patient.

A second factor that can be clearly seen to influence the distribution pattern as it progresses from controls to R.H. N^{++} group is the apparent shift or skewness of the deviation distribution. The non-neglecting RH patients (N^{-}) distribution of bisection performance clearly indicates a movement towards the right side of the graph. This shift develops into a very significant right sided tail when influenced by the kurtosis factor already described. This rightwards skewedness represents the "directionally specific" effects of visual neglect. The L.B.D. group (not shown) revealed a slight left sided tail, in marked contrast to that of the R.H. groups.

One possible criticism of the findings presented so far, is that they represent the performance of groups on the basis of a single administration of the test. The variability

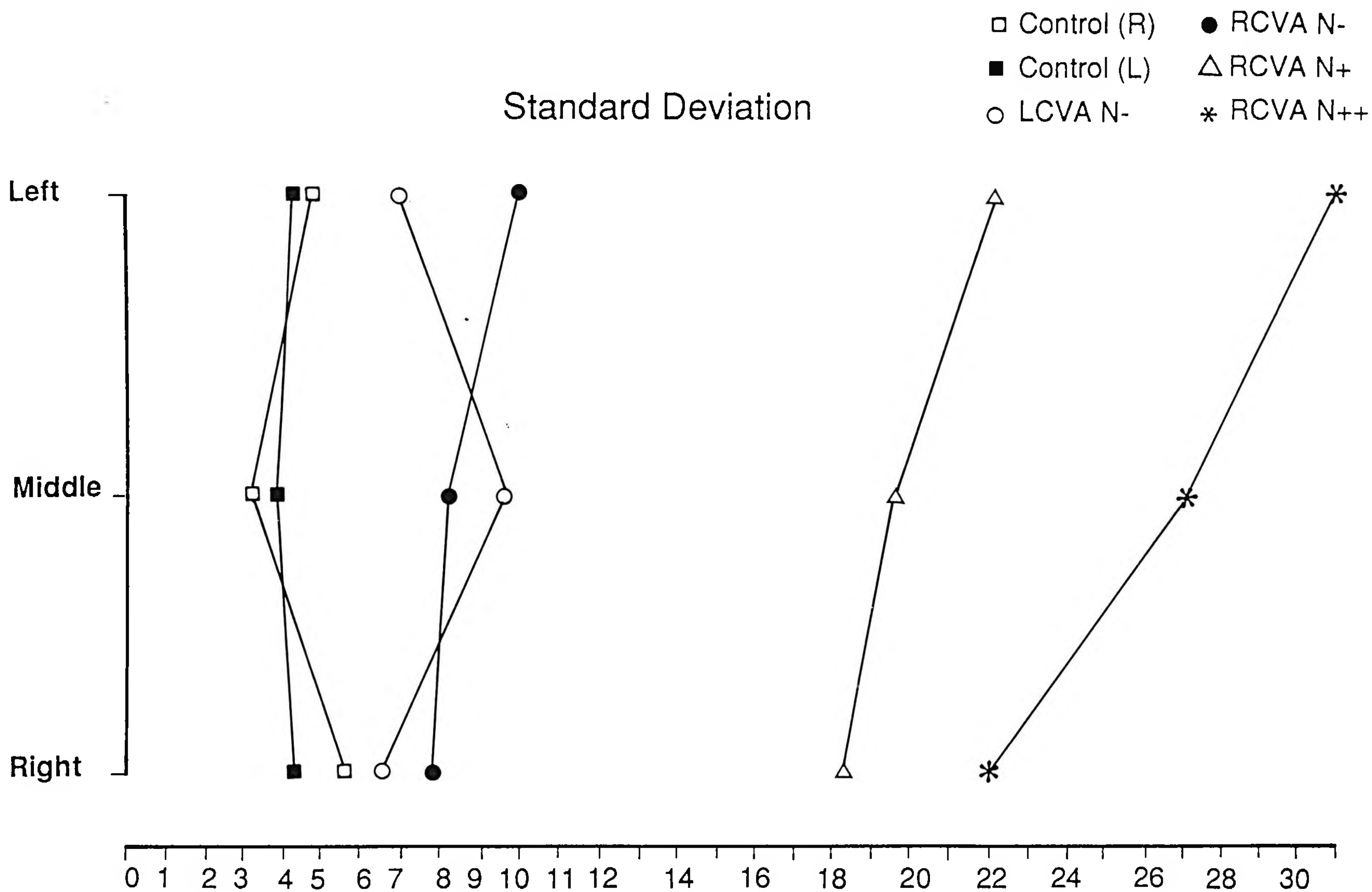


Fig 5.6 Group standard deviations. (legend as for Fig .5.2)

evident throughout the group study indicates the need to complement such studies, with single cases designed to investigate the range of performance of controls and patients on successive trials. In order to examine this, a second study was performed which investigated the performance of two controls and 3 patients, two of whom demonstrated persistent and florid visual neglect.

5:4 Line Bisection : Repeated Measures with Single Cases

The methodology and procedures are the same as those already described in the group study 5:2.

Subjects

Two control subjects were recruited. The first was a female, (J.M.) (aged 25) the second was a male (I.N.) (aged 60). Both were right handed.

Three patients were also seen. The first G.W. was a 47 year old man who had suffered a right sided sub-arachnoid haemorrhage, 4 months prior to testing. Examined on the B.I.T., G.W. obtained a score of 140/146, which was well within normal performance.

P.P. was a 59 year old woman who had suffered a stroke leading to hemiplegia on the 15th October, 1987. Admitted to Rivermead on the 1st February, 1988 she demonstrated motor and perceptual problems including profound left sided neglect. Assessed on the B.I.T. at this time she obtained a score of 65/146.

B.B. was a 59 year old woman who had suffered at right C.V.A. in November 1987. Examined on the B.I.T. test battery she achieved a score of 81/146 and clearly demonstrated visual neglect in many activities of daily living.

All subjects/patients were administered the line bisection tasks, 40 times in a single session. No knowledge of results was provided. Bisection performance was scored as in the group study 5:2.

Results

The results were analysed in the same way as the group study in 5:2. Table 5:2 (a,b,c) shows the mean signed and absolute deviations across subjects as a function of spatial position.

Again, deviations to the right of objective centre are reported with a positive value (+) to the left as a negative value (-).

Controls

(1) The performance of J.M. is similar to that of the group study reported in 5:2. Midline presentation demonstrates a small left sided shift, which is increased on right sided lines. Bisection performance in left space, as with the control group demonstrates a significant rightward shift of deviation. A repeated analysis of variance of J.M.'s performance revealed a significant effect for spatial position [$F = 115.6$; $df = 2,78$; $P < .001$] and its interaction with hand used [$F = 39.08$; $df = 2,78$, $P < .001$]. There was no main effect for hand used [$F = 0.31$; $df = 1,39$; N.S.). Using her Right hand, J.M.'s line bisection was most accurate when performed at central rather than at either left or right

Table 5:2 (A) Control J.M.

LINE BISECTION PERFORMANCE

Controls	Left Line		Middle Line		Right Line	
J.M.	N = 40		N = 40		N = 40	
R. Hand	Sg	Ab	Sg	Ab	Sg	Ab
Mean	3.10	3.3	- 0.67	1.93	- 4.97	4.97
Sg	2.35	2.05	2.54	1.77	1.9	1.9
Range	- 1 -> +9	10	- 10 -> +6	16	- 10 -> -2	8
Median	3.0		- 1.00		- 5.00	
Variance	5.39		6.32		3.52	
Skewness	- 0.001		- 0.72		- 0.83	
Kurtosis	2.76		6.46		3.73	
L. Hand	Sg	Ab	Sg	Ab	Sg	Ab
Mean	0.85	1.60	0.57	2.12	- 2.25	2.55
SD	2.08	1.56	2.77	1.84	2.16	1.77
Range	-5 -> +5	10	- 5 -> +9	14	- 7 -> +2	9
Median	0		- 1.00		- 2.0	
Variance	4.23		7.49		4.54	
Stewness	- 0.14		0.96		0.048	
Kurtosis	3.32		4.99		2.38	

Sg = Signed Mean Deviation

Ab = Absolute Mean Deviaton

Table 5 : 2 (B) Control I.N.

Controls I.N.	Left Line		Middle Line		Right Line	
	N = 40		N = 40		N = 40	
R. Hand	Sg	Ab	Sg	Ab	Sg	Ab
Mean	2.8	6.9	3.3	5.4	3.03	5.18
SD	7.44	3.8	5.38	3.19	5.96	4.17
Range	- 16 → +14	30	- 9 → +12	21	- 10 → +18	28
Median	5.00		4.00		3.50	
Variance	53.91		28.21		34.63	
Skewness	- 0.79		- 0.63		0.23	
Kurtosis	2.81		2.69		3.38	
L. Hand	Sg	Ab	Sg	Ab	Sg	Ab
Mean	- 6.1	6.6	- 4.65	5.45	- 2.45	3.1
S.D.	4.97	4.27	5.76	4.98	2.82	2.06
Range	- 18 → +5	23	- 19 → +5	24	- 8 → +4	12
Median	- 6.00		- 3.50		- 2.50	
Variance	24.14		32.33		7.75	
Skewness	- 0.076		- 0.58		0.16	
Kurtosis	2.90		2.66		2.47	

Sg = Signed Mean Deviation

Ab = Absolute Mean Deviation

LINE BISECTION PERFORMANCE

Table 5:2 (C) Patients

	Left Line		Middle Line		Right Line	
G.W. (N^-)	N = 40		N = 40		N = 40	
1	Sg	Ab	Sg	Ab	Sg	Ab
Mean	- 3.47	4.87	- 2.85	3.37	- 5.85	6.15
SD	4.69	3.17	3.65	3.19	4.2	3.59
Range	- 13 → +6	19	- 11 → +2	13	- 13 → +1	14
Median	- 4.00		-2.0		-5.50	
Variance	21.49		13.34		15.05	
Skewness	0.19		- 0.51		- 0.010	
Kurtosis	2.56		2.26		2.35	
PP(N^{++})	Sg	Ab	Sg	Ab	Sg	Ab
Mean	35.8	36.05	23.62	24.3	7.00	12.35
Sd	21.42	20.32	21.47	20.65	16.3	12.66
Range	- 13 → +80	93	-6 → 72	78	-28 → +55	83
Median	29.00		16.00		5.00	
Variance	447.34		449.48		259.45	
Skewness	0.45		0.78		0.82	
Kurtosis	2.57		2.55		3.99	
BB(N^{++})	Sg	Ab	Sg	Ab	Sg	Ab
Mean	37.1	37.1	20.5	20.5	- 2.75	5.9
SD	6.6	6.6	5.9	5.9	6.98	4.56
Range	+ 25 → +51	26	+ 7 → +35	28	- 20 → +12	32
Median	38.0		21.50		- 3.0	
Variance	42.77		33.45		47.49	
Skewness	- 0.05		0.076		- 0.25	
Kurtosis	2.06		2.97		3.12	

Sg = Signed Mean Deviation

Ab = Absolute Mean Deviation

N^- = No Neglect

N^+ = Mild Neglect

N^{++} = Moderate to Severe Neglect

sided space. (centre = -0.67 mm, left = 3.10 mm, t = 6.89, df = 77, P < .001 ; Centre = -0.67 mm, right = -4.97, t = 8.56, df = 72, P < .001) and in left hemispace compared to the right (left = 3.10 mm; right = -4.97 mm, t = 16.9, df = 74, P < .001). The mean deviation for central presentation with either hand was approximately 0.3% to the left. Further t-tests were carried out to determine whether performance by either hand was significantly different from the actual midpoint. This yielded the following conclusions; (1) central presentation with either hand did not differ significantly from the actual midpoint (2) left or right sided presentation with either hand resulted in a significant deviation to the right and left respectively (right space; Left hand = -2.25 mm, t = -6.59, df = 39, P < .001; Right hand = -4.97, t = 16.55, df = 39, P < .001) (left space; Left hand = 0.85, t = 2.58, df = 39, P < .02; right hand = 3.10, t = 8.34, df = 39, P < .001). Therefore like the control group, left spatial position resulted in a right sided deviation, while a right spatial position resulted in a further leftward deviation over midline position.

(2) The performance of I.N. was subjected to a similar analysis. A 2 x 3 repeated Anova revealed a significant main effect for hand used. [F = 88.52; df = 1,39; P < .001], spatial position [F = 3.48; df = 2,78; P < .01] and the interaction between them [F = 3.01; df 2,78; P < .01]. Subsequent analysis showed that the significant effect for spatial condition occurred only when the left hand was used. [F = 8.12; df = 2,78; P < .001].

Midline presentation showed a marked right sided deviation which was significantly different from the actual midpoint, (Centre = 3.30, t = 3;88, df = 39, P < .001) and from left hand performance; (left centre = -4.65 mm, right centre, = 3.30 mm, t = 6.38, df = 77, P < .001). This was in turn significantly left of midpoint. (Centre = -4.65 mm, t = -5.10, df = 39, P < .001).

Bisection in left space again revealed a significant difference between the left and right hands. (Left hand/ left space = -6.1 mm; Right hand / left space = 2.80 mm; t = 6.29, df = 68, P < .001) and from the actual midpoints. (Left hand/left space = -6.01 mm, t = -7.75, df = 39, P < .001; Right hand/left space = 2.80 mm, t = 5.25; df = 39; P < .001).

Bisection in right space also revealed a significant difference between left and right hands. (Left hand/right space = -2.45 mm; Right hand/right space = 3.03 mm; t = 5.25, df = 55, P < .001) and from actual midpoints (Left hand/right space = -2.45 mm, t = -5.49, df = 39, P < .001; Right hand/right space = 3.03; t = 3.21, df = 39, P < .01). Thus the performance of I.N. (the 60 year old control) was different in direction from both J.M. and the mean of the control group (mean age = 57.0 years). Unlike the controls and J.M., right handed performance for the midline position deviated to the right. This effect was reduced slightly with left sided lines which is the opposite effect to that shown by the control J.M. Right sided bisection with the right hand again deviates to the right, away from the direction of the control group. This unlike the controls, I.N.'s right handed line bisections were not significantly affected by hemispace.

Left hand performance was influenced by hemispace, however this again produced a different pattern to that of the group controls. In right space the expectation is that bisection performance will deviate towards the left. I.N.'s performance moves further right than the mean central or left sided bisection points. The expectation with left sided bisections is that the deviations will swing towards the right. I.N.'s performance moves in the opposite direction to this expectation and remains further left than either the mean central or right sided bisection point.

(C) G.W., the non-neglecting right hemisphere damaged patient showed a significant main effect for hemispatial position using his right hand [$F = 26.6$; $df = 2,78$; $P < .001$) Throughout all the bisections, G.W.'s performance remains consistently negative (i.e. to the left of the actual mid-point), and does not follow the pattern of spatially induced deviations found in controls or in a similar group of non-neglecting right hemisphere damaged patients. All performances were significantly different from actual midpoint. (left space = -3.47 mm, $t = 4.68$, $df = 39$, $P < .01$; centre space = -2.85 mm, $df = 39$, $t = 4.83$, $P < .001$; right space = -5.85 mm $t = -9.58$, $df = 39$, $P < .001$).

(D) The neglect patient P.P. revealed a very significant effect for hemispatial position [$F = 90.58$; $df = 2,78$; $P < .001$]. However her spatially induced deviation follows that of the controls and other right hemisphere group subjects. Again all her bisections were significantly different from the objective midpoint.

(E) Again, B.B., the second neglect patient, showed a significant main effect for hemispatial position [F = 21.08, df = 2,70; P < .001]. She also demonstrated a similar spatially induced deviation performance from that of controls and the other right hemisphere groups and was significantly different from objective midpoint on all occasions.

The results of all the single cases are graphically illustrated in Figure 5.7. An analysis of the distributions of the deviations for three of the single cases described (J.M., B.B., and P.P.) using their right hand is illustrated in Figure 5.8.

Here again, patients with neglect show a wide base of deviations which is shifted left or right depending on the spatial location of the line to be bisected. It is important to note the different types of distribution patterns that the two neglect patients present within the central or middle position. The greater proportion of B.B.'s performance clearly lies between 1/10 mm and 31/40 mm, whereas patient P.P.'s performance peaks at 1/10 only to tail off to the right up to 71/80 mm. Left and right sided spatial line bisection has the effect of reducing this distribution pattern and producing a more peaked distribution.

Analyses of these distribution patterns in neglect patients may well provide researchers and clinicians with the basis to classify sub-types within the same condition. The identification of different factors underlying these sub-types may in turn suggest a different kind of rehabilitative strategy (Gianutsos et al, 1983).

Line Bisection Tasks: Single Cases 3 Patients 2 Controls

Mean Deviation and Range From Midpoint

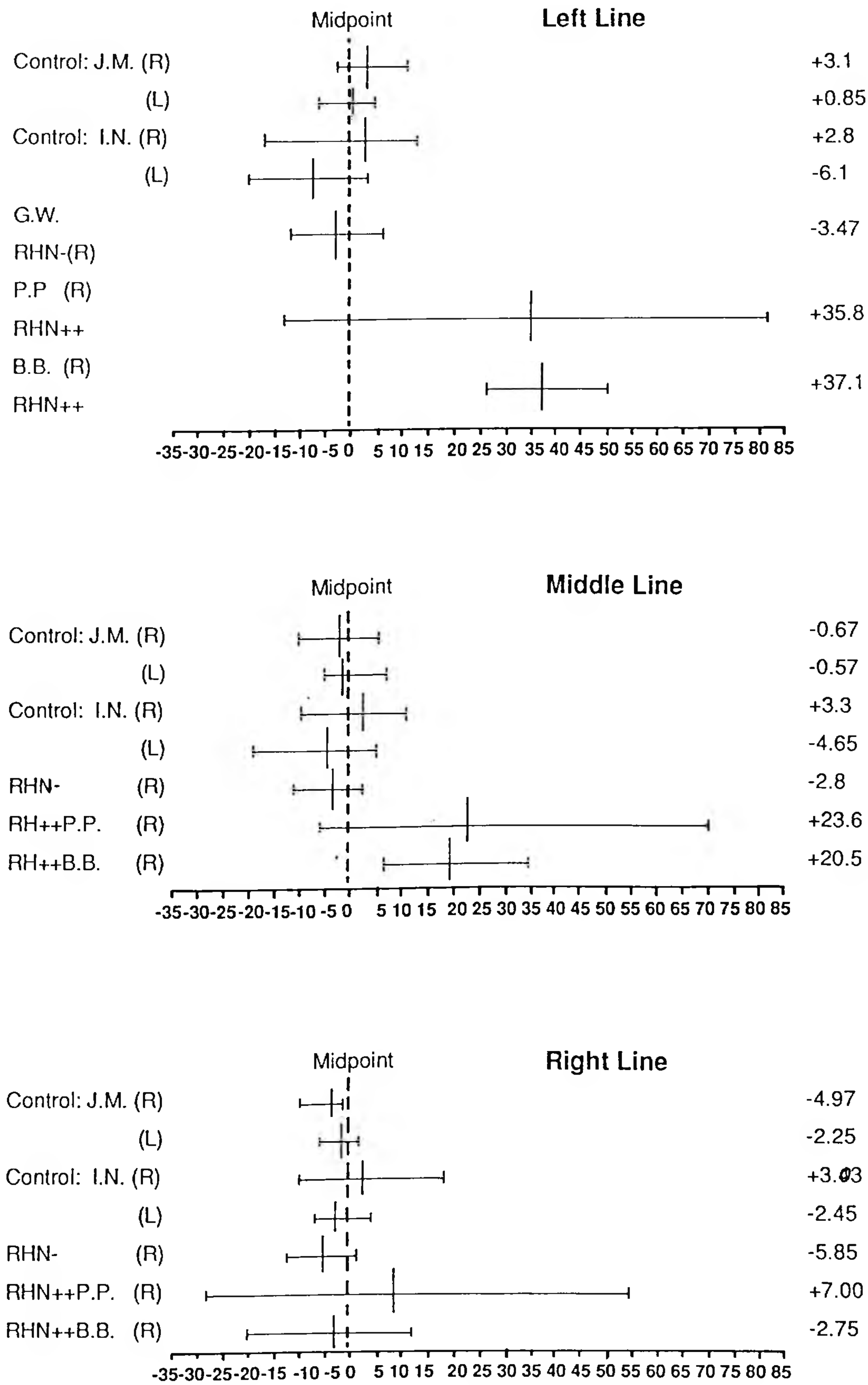


Fig. 5.7 J.M.(R/L) =Female control;left and right hands
I.N.(R/L) =Male control;left and right hands

G.W. =Right brain damaged patient without neglect
P.P. =Right brain damaged patient with severe neglect
B.B. =Right brain damaged patient with severe neglect

Single Case Study Range of Deviation

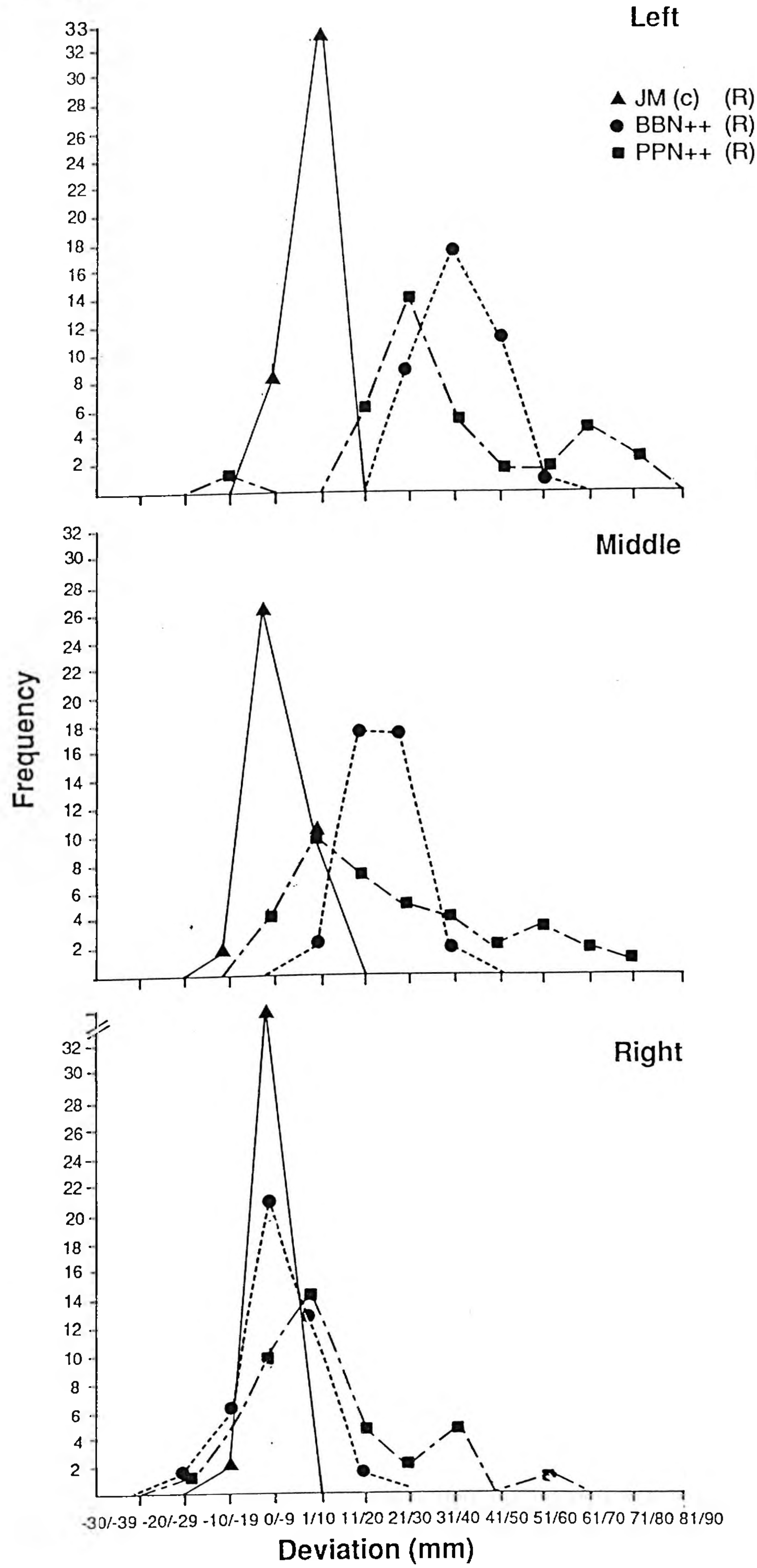


Fig.5.8

5:5 The effect of line length on right sided deviation in visual neglect

In both experiments 5:2 and 5:3 line length remained constant although spatial position was varied. Several investigators, however, have also varied line length. (Heilman, Bowers and Watson, (1984); Bradshaw et al, (1985); Heilman and Valenstein, (1979); Riddoch and Humphreys, (1983); Bisiach et al, (1976); Scarisbrick et al, (1987); Ferro and Kertesz, (1984); Schenkenberg et al, (1980); Diller (1980); and Nichelli et al, 1989). Most of these studies have not specifically drawn attention to any effect of length. Exceptions include the findings of Riddoch and Humphreys and of Bisiach, Bulgarelli, Sterze and Vallar both published in 1983.

Riddoch and Humphreys (1983) studied five patients with left neglect. They confirmed that, for their patients, there was a constant linear increase in the extent of neglect as a function of increases in line length from 80 mm through 100, 120, 140, up to 160 mm. No patient in their sample failed to show this linear relationship although no information about the differing rates of increase from patient to patient was provided. Some of the patients reported by Bisiach et al, (1983) showed a similar right displacement which appeared to be related to line length. This was one of the first studies to systematically investigate the relationship between line length and magnitude of deviation from objective centre. They found that the proportional rate of increase differed (sometimes substantially) from patient to patient. In two patients (T.Z. and C.C.) the right sided displacement appeared to be roughly constant across line lengths.

The possibility exists, however that all patients with visual neglect will show linear increases in displacement of the subjective centre as a function of line length, but that in some patients the magnitude of the effect may be very small (Halligan and Marshall, 1988).

Central to Bisiach's interpretation of this finding was the notion of "representation" of the objective line. For Bisiach, the left side of a represented object is neglected because the patient is unable to adequately represent the left half of space independently of current external stimulation. In other words, the patient with neglect has an adequate representation only of the right extremity of an objective horizontal line centred about the sagittal mid-plane of his body. However, despite the "representational amputation" of left sided space, the patient can deduce the left extremity of the represented line from the right end part and the subjective midpoint chosen.

> "Following this rationale, it becomes clear that the deduced left endpoint of the represented line, rather than the directly observable subjective midpoint, is the informative dependent variable in an experiment on line bisection".

One clear example of the extent to which "the representational scotoma" may be penetrated by cognitive processes can be seen in the case of R.G. Bisiach et al's 10th patient. In this case, if one extrapolates his tested performance (on only 3 lengths, 600, 400 and 200 mm lines) to even smaller lines (not tested) it would appear that the patient's subjective midpoint would cross-over from a right-

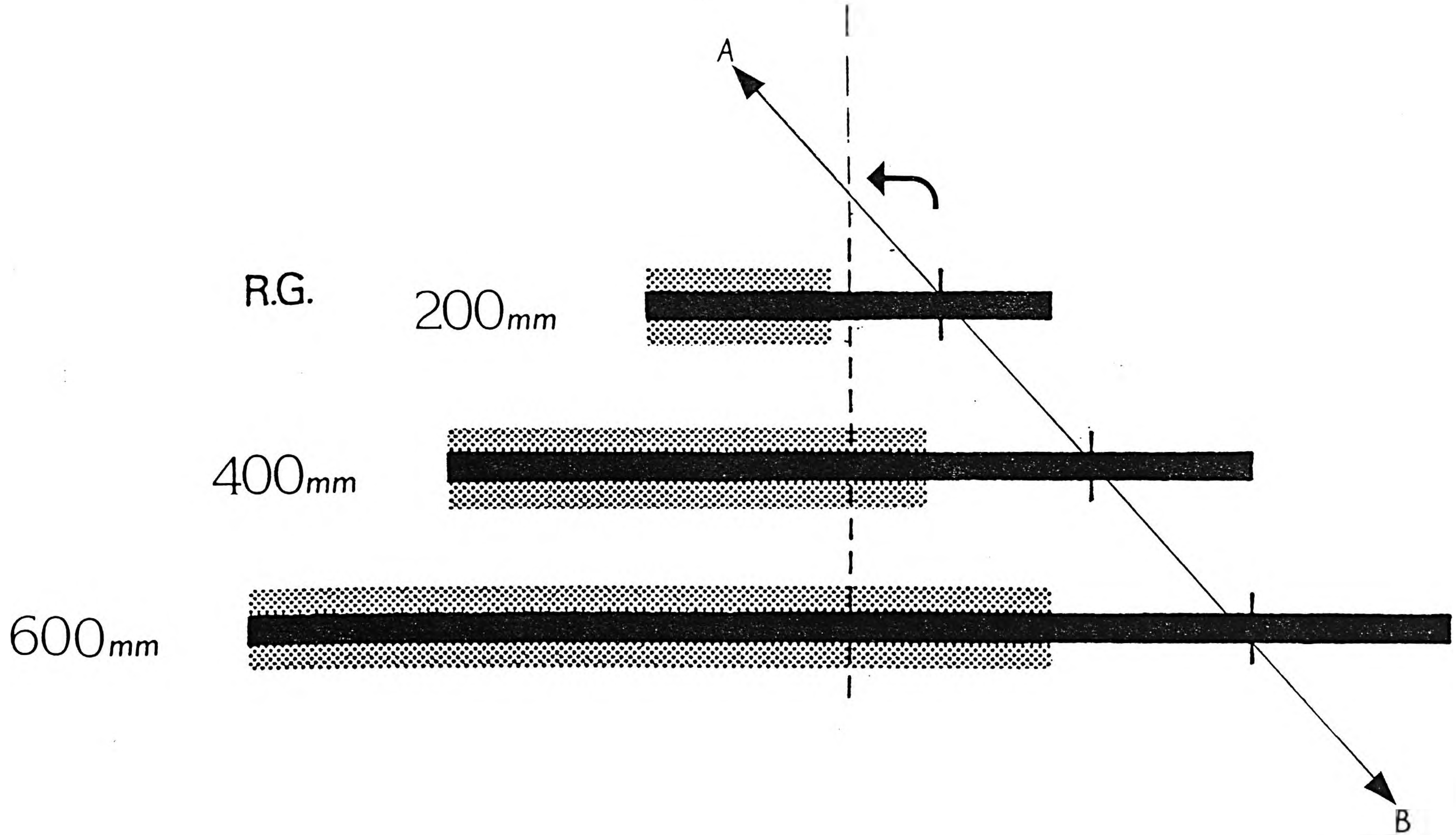


Fig. 5.9

Linear extrapolation from the performance of R.G. a neglect patient from Bisiach et al's 1983 study of line bisection.

wards to a leftwards displacement. That is, R.G. would be relatively accurate on lines of circa 100 mm but will then show significant "right sided neglect" rather than left on lines smaller than 50 mm. This argument does of course depend upon performing a linear extrapolation from Bisiach et al's data. (Figure 5:9).

Using Bisiach et al's experimental design, it is possible to investigate the counter-intuitive hypotheses that a patient with left neglect and right displacement on long lines will demonstrate "right neglect" and left displacement on shorter lines. In an attempt to confirm this "counter-intuitive" hypotheses the performance of P.B., a R.B.D. patient with visual neglect was investigated in detail. In this case the patient's bisection performance was evaluated on line lengths which varied between 279 mm (11") and 25 mm (1").

Subject P.B., was a 54 year old right handed retail manager who was admitted to the Radcliffe Infirmary in February, 1986 following the gradual onset of left sided weakness. On admission, neurological examination revealed a homonymous hemianopia with left neglect, sluggish pupils and complete left sided hemiplegia. A C.T. scan performed on admission showed a widespread infarction of the right middle cerebral artery territory, with moderate compression of the right lateral ventricle and some shift of the midline. Admitted to Rivermead at the end of April 1986, P.B. was found to be fully alert, well oriented, and co-operative. Speech was fluent and highly articulate. IQ was estimated as within the high average range. Besides his hemiplegia, PB's main problem at this time, was florid neglect of the left side. P.B. was assessed on the 6 conventional tests of the B.I.T. and achieved a score of 77/146. On a tactile search task that involved taking pegs out of holes, the blind-folded patient showed no evidence of hemihypokinesia. As normal controls, ten staff members of Rivermead were recruited. Their mean age was 41.6 years with a standard deviation of 8.4.

Stimuli and Procedure

Eleven horizontal black lines were individually drawn on sheets of white paper (208 x 298 mm). Each line was approximately 1 mm wide. The lines varied in length from 1" (25 mm) to 11" (279 mm) in steps of 1". Each line was presented on a separate sheet in pseudo-random order, and positioned on the desk so that the objective midpoint lay in the saggital mid-plane of the subject's trunk. The subjects were instructed to mark the midpoint of each line with a pencil, using the preferred hand. The entire set of lines was repeated at least 8 times for P.B., though on some occasions, particular lines were repeated randomly within a trial. Controls performed the task once each.

Results

The distance to the right of each transection was measured to the nearest millimetre and subtracted from the distance to the right of the objective midpoint. The resultant difference represents the extent to which there was a leftward bias if the sign is negative, or a rightwards bias with a positive sign. The data for P.B., and the normal controls are shown in Table 5:3.

Table 5:3

Line bisection performance for P.B. and Controls.

Line Length		Mean Displacement (+SD)	Range		N
279mm/11"	P.B.	+62.0 (19.5)	+38	+ 100	9
	Controls	-1.0 (4.5)	-8	+6	10
254mm/10"	P.B.	+50.5 (13.6)	+31	+73	11
	Controls	-0.9 (4.3)	-7	+5	10
228mm/9"	P.B.	+54.0 (17.4)	+23	+74	11
	Controls	-0.6 (33.5)	-6	4	10
203mm/8"	P.B.	+45.2 (10.2)	+34	+67	11
	Controls	+0.5 (3.5)	-4	+5	10
178mm/7"	P.B.	+36.3 (12.4)	+22	+51	11
	Controls	0 (3.2)	-5	+5	10
152mm/6"	P.B.	+27.0 (8.4)	+17	+39	11
	Controls	+1.9 (4.0)	-2	+10	10
127mm/5"	P.B.	+16.3 (11.7)	0	+31	8
	Controls	-0.8 (2.1)	-5	+1	10
102mm/4"	P.B.	+11.6 (9.04)	-2	+24	8
	Controls	+0.4 (2.9)	-4	+7	10
77mm/3"	P.B.	+4.0 (11.7)	-21	+16	9
	Controls	+0.5 (1.8)	-2	+4	10
51mm/2"	P.B.	+0.2 (5.5)	-11	+7	10
	Controls	-0.3 (0.9)	-1	+2	10
25mm/1"	P.B.	-4.4 (5.6)	-18	0	12
	Controls	+0.1 (0.6)	-1	+1	10

As can be clearly seen, P.B. shows an approximately linear increase of the rightward displacement of the subjective midpoint as a function of line length. This is precisely the result that Bisiach et al (1983) found for their patient R.G. The corollary for the present study however, is that for lines shorter than those used by Bisiach et al, P.B. is more accurate with lines of 2" (51 mm) and does in fact show "right neglect", (i.e. a consistent leftward displacement of the subjective midpoint) at line length 1" (25 mm). This is exactly the anomalous result predicted from the earlier extrapolation from the original data of Bisiach et al's patient R.G.

Discussion

The results of P.B. appear to have confirmed the counter-intuitive prediction derived from the earlier study by Bisiach et al (1983), that a patient with classical left sided neglect can show "right neglect" on a bisection task when the lines are sufficiently small. That P.B.'s performance with smaller lines is more accurate than with longer ones confirms standard clinical wisdom that large lines should be employed when testing for the presence of neglect. Before considering the implications of the result for current theories of neglect, it is necessary to investigate other explanations and evaluate how robust the phenomena is across other patients.

Does the presence of a hemianopia explain the pattern of results? Although as already pointed out in section 5:2, hemianopia accompanies many cases of neglect, it is by no means a necessary nor a sufficient condition for the presentation of neglect behaviour. Furthermore, a sensory loss would not predict such a cross over effect. Perhaps P.B.'s performance on the 1" lines are in fact normal? Although as we saw in 5:2 normal subjects tend to transect the midline consistently to the left of centre; the average magnitude of normal left displacement from the true midpoint found by Bradshaw et al (1985) was -1.02 mm (1.6%). For the 1" (25 mm) lines, P.B. showed a mean left displacement of 4.4 mm. The individual figures for the 12 trials can be ranked as follows, -18, -14, -4, -4, -4, -3, -2, -2, -1, -1, 0, 0. Eight of these 12 readings show larger left displacements than the mean reported by Bradshaw et al. (1985). Six of the readings are beyond the mean absolute displacements of the control group with a lines of 8", reported in 5:2. Therefore even if the direction of P.B.'s displacement at line length 1" (25 mm) is normal, the magnitude of the displacement is four-fold over that of Bradshaw's et al.'s normal subjects.

One further possibility is that P.B.'s left displacement is normal in direction but exaggerated by problems of visuo-motor co-ordination or dyspraxia.

This objection can be ruled out with some confidence since the figures just quoted for P.B.'s 12 trials on the 1" line does not show random swings around a displaced subjective centre. Rather the transections are systematically displaced to the left. Further evidence against a visuo-motor co-ordination hypothesis comes from P.B.'s performance on the earlier described cancellation tasks. When crossing out stars or individual letters (whose horizontal and vertical extention was approximately 6 mm). P.B. never motorically missed any stimulus he was cancelling. Yet on two occasions, when performing the 1" (25 mm) line bisection task, P.B.'s displacement was such as to place the "perceived" midpoint further left than the left endpoint of the actual line.

One possible explanation for P.B.'s performance can be seen if his displacements are charted. (Figure 5.10). From Figure 5:10 one can see that the left most points of P.B.'s "subjective" line (using Bisiach et al's calculation of the distance between P.B.'s transection and the right most point of the objective line x 2) remains approximately constant. For the eleven line lengths the mean distance to the subjective end point is 21.1 mm with a standard deviation of 8.0 mm. This point could be envisaged as a boundary beyond which P.B. cannot further direct attention leftwards. As a result, the perceived line is that which lies to the right of this boundary, and it is this line that the patient bisects. Up to the point of cross over this explanation suffices to account for the majority of the data. Following the work of Warrington (1962) and Bisiach and Vallar (1984) the "cross over" could be interpreted as an example of "pathological completion" provoked by the conditions of testing. For all lines except the 1" line, the objective stimulus does indeed extend to the "attentional" boundary. Performance on the 1" line may be interpreted as a dramatic completion of the line to that boundary and hence on occasion into empty space. This hypothesis of completion is consistent with P.B.'s completion on other tasks in free vision. For example, when presented with chimerics of human

Line bisection performance of patient P.B.

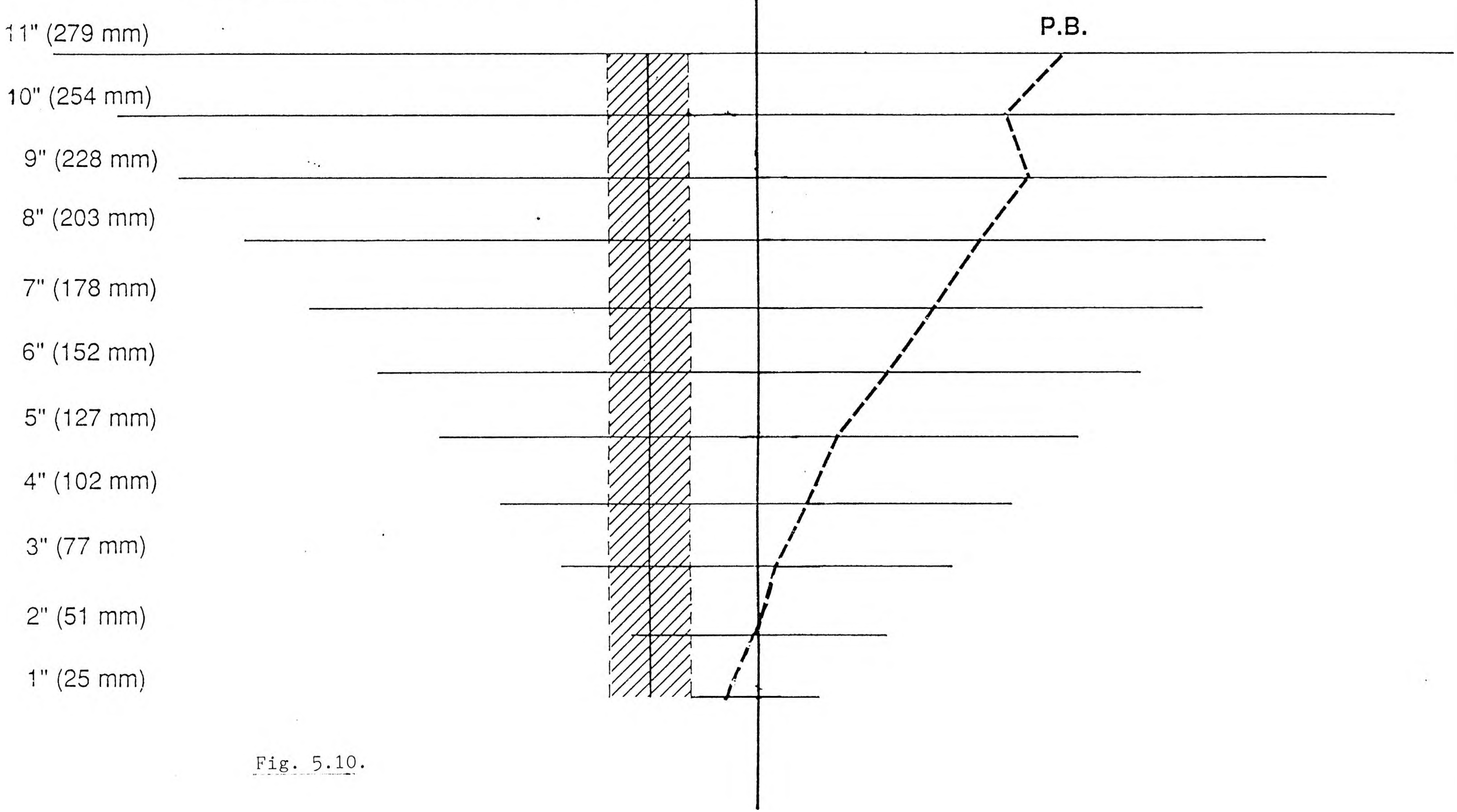


Fig. 5.10.

faces, (i.e. one side female, the other male), P.B. consistently named the right side, even after intensive questioning. Thus in the case of line bisection with 1" lines, completion must in some sense be perceptual completion to the hypothesized boundary. In other words P.B. has incorporated the space to the attentional boundary into his representation of the 1" line. He thus bisects (on at least some trials) a space that is devoid of sensory information.

5:6 The effects of visual neglect on the vertical meridium; Is visual neglect only lateralized?

Although there exists considerable disagreement about the psychological mechanisms responsible for visual neglect, (Baynes et al, 1986) there is a general consensus of agreement regarding the clinical presentation of the condition. In particular, the clinical literature has emphasized that hemispatial neglect is both more frequent and severe after right sided posterior cerebral lesions. Furthermore, the condition is almost invariably described as a disorder of lateral space (hence the term 'unilateral neglect') where laterality is defined by reference to the saggital midplane of the trunk, head and line of sight. (Heilman, Bowers, Valenstein and Watson, 1987). Why neglect should invariably present along a horizontal meridian rather than that of/or together with a vertical disorder has not been addressed in any detail.

One explanation why cases of vertical neglect have not been reported extensively may stem from the lack of quantifiable measures used and/or the existence of a much milder form of neglect compared with that of the typical lateralized presentation. Since the introduction of Albert's line crossing test in 1973, however, several examples of performance that suggest that more items are missed on the lower half of the stimulus sheet have been published, without comment by the respective authors; Hecaen and Albert, 1978 (P.218); Joanette and Brouchon, 1984, (P.157) and Heilman, Watson and Valenstein, 1985 (P.247). Thus it appears to be a pertinent line of enquiry to investigate more systematically the distribution of upper/lower omissions on the line crossing task developed for the Behavioural Inattention Test (B.I.T.).

Method & Procedure

The stimuli used are as described in Chapter 3. Briefly, this consisted of an array of variously oriented one inch black lines scattered across a stimulus sheet. This stimulus sheet was placed on the desk in front of each subject, centred about the saggital midplane of their trunk. Crossing out was demonstrated by the examiner, using two of the four central lines; these central lines were not included in the scoring of the test. Head and eye movements were in no way restricted, and no time limit was imposed.

Subjects

Eighty six patients with unilateral stroke were tested in total. Sixty of the patients had suffered right hemisphere stroke (mean age = 58.6 $\pm$ 39 years) and twenty six had suffered left sided stroke (mean age 54.6 $\pm$ 26 years). Forty six normal controls (mean age 58.6 $\pm$ 36 years) were also tested. All control subjects and patients were right handed. Controls responded with their right hand, patients with the hand ipsilateral to the lesion.

Results

Of the 46 controls subjects, 44 made no errors, and two made one error each. A cut off of two or more uncrossed lines irrespective of location was chosen as a diagnosis for neglect on this task. Within the sixty right hemisphere damaged patients, 23 (38.3%) met this criterion for neglect. Among the twenty six left hemisphere brain damaged patients only 3 (11.5%) met the criterion.

The responses for this test are normally scored with respect to the number of lines missed in left or right hemispace. However, the test lends itself equally to a vertical/analysis with respect to top and bottom omissions. Table 5.4 shows the distribution of errors in the four quadrants of the stimulus field, for right and left hemisphere damaged patients with neglect.

A. Patients with right hemisphere damage (n=23)

	Left:	Right:
Top:	103 (39%)	14 (5%)
Bottom:	127 (48%)	21 (8%)

B. Patients with left hemisphere damage (n=3)

	Left:	Right:
Top:	1 (3.3%)	13 (43.4%)
Bottom:	1 (3.3%)	15 (50%)

Table 5:4 Distribution of omissions by quadrant on a modified version of Albert's line cancellation task by patients with right and left hemisphere damage.

Statistical analysis (Chi-square tests) showed that the distribution of omissions in the four cells differed from chance ($P < 0.001$). Further analysis of upper versus lower errors showed that there were significantly more errors in the lower half, (Wilcoxon rank sum test, $P < 0.005$). Of the 23 left sided neglectors, two produced more errors in the top half, three made the same number of errors in each half, and eighteen produced more errors in the bottom half. This "altitudinal effect" was most pronounced in the impaired lateral hemispace. Data for the left hemisphere damaged patients with neglect, although too small to permit meaningful analysis, were similar to that of the larger right hemispere damaged group (except reversed with respect to the lateral side of impairment).

In addition, it is also possible to analyse the results as an ordered series of six columns (not including the unscored central column). These "horizontal" results are shown in Fig. 5:11. This figure suggests that errors of omission fall off continuously from right to left (after right brain damage) and from left to right (after left brain damage). However, this impression is misleading since the actual data are characterized by both floor and ceiling effects (i.e. 0% and 100%) omissions in some cases and by large "jumps" in detection from column to column in other cases. Therefore while as a group study Fig. 5:11 describes the distribution of omissions, taken as single cases the impression of a more or less linear decrement over spatial positions is only true in a minority of cases. (cf. Marshall and Halligan (in press).

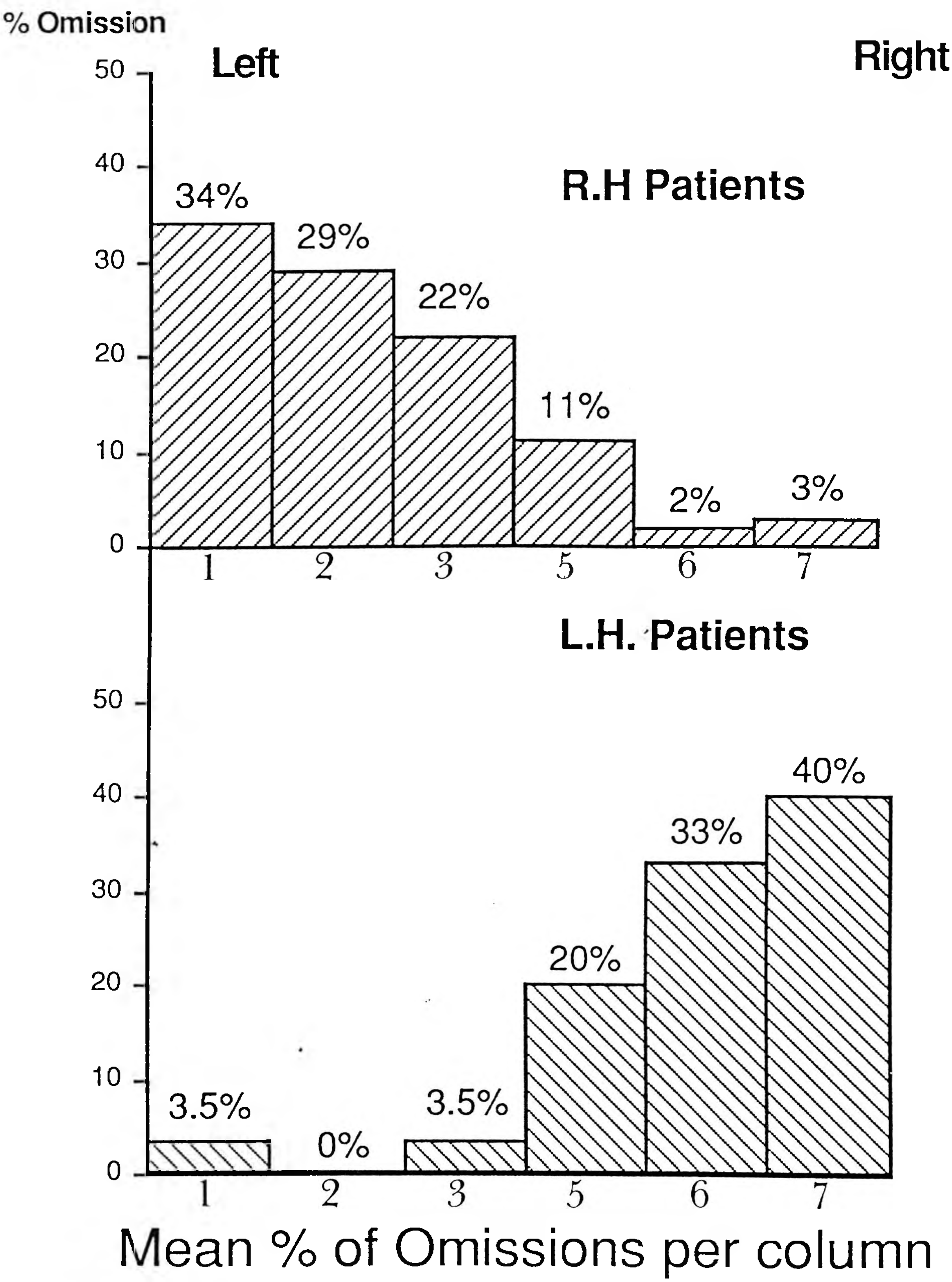


Fig.5.11 Distribution of omissions on line crossing for right and left brain damaged neglect patients.

Discussion

The full data from the 23 patients with left sided neglect are shown in Table 5:5.

This table includes age, sex, time-post-onset when tested, and performance on clinical testing for visual field deficits. Of the 8 patients assessed as free from any field deficit, 7 showed evidence of the "bottom" neglect, characteristic of the group as a whole. In so far as the anatomical locus of the lesion is predicable from the presence or absence of field deficits, "altitudinal neglect" was found irrespective of whether or not the lesion involved the geniculocortical opticradiations. Furthermore, of the original sixty patients with right sided strokes, 37 did not manifest neglect according to the criterion employed. Within this subset, there were 14 patients, with visual field deficits who nevertheless obtained perfect scores (36/36) on the line crossing task. Hence it is clearly not the case that visual field deficits per se gave rise to the phenomenon, although some interaction between those with neglect and field deficit cannot be ruled out.

One of the first studies that drew attention to what has been called "altitudinal neglect" was published by Bender and Teuber in 1948. In both their cases, the patients had sustained shrapnel wounds involving the right parietal area, and when presented with vertical lines, they positioned the subjective midpoint systematically above the actual midpoint. In a more directly comparable study, Morris, Mickel, Brooks, Swavely and Heilman (1985) found that "a number of patients showed a pattern which suggested that the lower left quadrant

Table 5:5

Patient Characteristics and Score on Cancellation Task

No.	Age	Sex	Days post-onset	Left hemianopsia	Score Left Top	Score Left Bottom	Score Right Top	Score Right Bottom	Total Score
1	53	M	114	+	0	0	6	6	12
2	65	F	355	+	0	0	9	9	18
3	64	F	366	+	8	7	7	9	31
4	72	M	72	+	0	0	6	2	8
5	64	F	86	Extinction	7	3	9	9	28
6	57	F	125	-	0	0	9	8	17
7	57	F	42	-	0	0	9	8	17
8	56	M	26	-	9	7	9	9	34
9	57	M	68	+	8	6	9	9	32
10	64	F	63	+	7	6	9	9	31
11	56	F	75	-	7	3	9	9	28
12	65	F	16	-	8	6	7	8	29
13	63	M	162	+	9	7	9	9	34
14	60	M	27	-	0	0	9	8	17
15	64	M	13	+	9	7	9	9	34
16	59	M	12	+	8	6	8	9	31
17	59	M	52	-	9	9	7	9	34
18	65	M	35	+	0	0	8	6	14
19	69	F	68	+	6	5	9	9	29
20	78	F	30	+	0	0	9	6	15
21	59	F	196	-	9	6	9	9	33
22	67	M	245	+	3	0	9	8	20
23	59	F	111	+	0	0	9	9	18

of a stimulus page was the last to recover" in neglect. This finding does not necessarily result from fatique consequent upon the serial order in which the patient cancels the lines. Mark and Heilman (1988) have shown that for 3 out of their 5 patients with neglect of the lower quadrant space, the effect held up despite patients being "requested to perform a series of cancellations tasks bottom half first". More recently, Rapcsak, Cimino and Heilman (1988) reported a patient with "Balint's Syndrome" who showed lower altitudinal neglect when requested to perform visual and tactile bisections of vertical rods.

These findings together with the results of the line crossing test suggest that right hemisphere damage may also cause deficits along dimensions of extrapersonal space other than the horizontal. The relative sparing of attention functions in the upper parts of extrapersonal space (lower hemi-retinal field) and the mild yet consisted impairment of lower field (upper hemi-retinal field) attentional function indicates different cerebral localization or perhaps evidence for a vertically asymmetrical allocation of attention comparable to that of the horizontal findings. Several studies support the later conclusion. Data on critical flicker, constrast-sensitivity and evoked potentials all demonstrate the functional superiority of the upper-hemi-retinal field.

Furthermore, this hemifield has more rods and cones than its lower counterparts (Osterberg, 1935) and consequently visual acuity is better (Millodot and Lamont, 1974) and motor reaction times to light stimulation are faster (Payne, 1965).

Finally, Rapcsak et al (1988) suggest that the bias in vertical attention allocation may have occurred for evolutionary reasons, whereby a more powerful upper hemi-retinal system would be advantageous given that both predators and prey are more likely to occur in the lower part of extra-personal space.

These observations suggest that future studies should investigate the distribution of attention across all dimensions of space.

5:7 What is neglected in visual Neglect?

Although explanations of visual neglect have included a variety of theories, including both sensory and representational features, the current consensus strongly favours a position which regards neglect as a spatial disorder of selective attention (Mesulam, 1985, Jeannerod, 1987). Selective attention can be described as the process by which subjects attend focally to a section of the environment while ignoring other portions simultaneously impinging upon them. (Posner, 1975, 1980).

Recent psychological models of selective attention have typically proposed a dual stage selection process involving two functionally independent processing levels (Neisser, 1967; Broadbent, 1970, Kahneman, 1973, Schneider and Shiffrin, 1977, Triesman and Gelade, 1980). The first stage involves a largely automatic, pre-attentive, non-conscious, multi-level stimulus - analysis system responsible for encoding all environmental stimuli. Pre-attentive processes are generally assumed to be fast, spatially parallel, and unlimited - capacity operations that create base representations from which more detailed representations can be constructed. (Folk and Egeth, 1989). Theories of information processing differ however with regard to the extent of processing involved at this stage, but ...

> "Whatever the case, it is generally thought that a conscious representation of an integrated stimulus is only made available at a second level of processing". (Riddoch & Humphreys,1987).

This second stage desribes a more limited capacity process, which requires focal attention to be directed serially across the spatial field. This level involves the selection of perceptual products for final translation into conscious awareness and has been compared to a mental spotlight that scans the visual spatial field, sometimes independently of eye movements

> "... Although spatial attention can be directed away from the fovea and assume various shapes, it can do so only at a considerable sacrifice in processing acuity. Processing is most efficient when attention is aligned with the centre of the fovea and directed to consolidated regions of space". (Johnston & Dark, 1986).

The ability to direct attention towards behaviourally relevant sensory stimuli within extrapersonal space is modulated by a complex cerebral network which includes both cortical and subcortical components (Rizzolati et al, 1987). Visual neglect, the failure to act on visual input on the side of space contralateral to the lesion side has been interpreted as a deficit in "attending locally to information made available by early (pre-attentive) visual processes". (Riddoch and Humphreys, 1987).

If this theoretical explanation is accepted, then the possibility arises that "neglected " material may be able to influence the judgements or decision making process of the patient.

Evidence on this possibility from normal visual perception processing is currently divided. Some theorists (Schneider and Schiffrin, 1977; Duncan, 1980; Marcel, 1983; Humphreys, 1985) propose that perceptual encoding of pre-attentive material runs the full course of analysis, producing an integrated description of the object/s. Others have argued that only primitive features of objects, such as colour, orientation, size and brightness are processed at the pre-attentive stage. (Broadbent 1982, Triesman, 1982).

Clinical evidence consistent with the possibility that what is "neglected" in visual neglect, (although not directly available to conscious awareness,) may in fact enter into the determination of voluntary behaviour, will now be reviewed.

The suggestion that there exists an implicit awareness of neglected stimuli in some patients is consistent with recent evidence for dissociations between explicit and implicit knowledge in several other neuropsychological conditions. Examples of these dissociations include,

(1) Prosopagnosia. This condition describes the inability to recognize visually the faces of familiar persons who continue to be recognized normally through other sensory channels. Recently both psychophysiological and behavioural

studies (Bauer, 1984; De Haan, Young and Newcombe 1987) have revealed that some of these patients possess implicit knowledge of faces which they cannot recognize explicitly. These results indicate that despite their explicit inability to experience familiarity with the visual stimulus, some patients appear to be able to carry out many of the steps in the recognition process.

(2) Amnesia. Within the area of memory loss, several studies have reported intact motor skill learning despite devastating explicit everyday memory loss (Corkin, 1965; Eslinger and Damasio, 1985; Warrington and Weiskrantz, 1978). One of the best known examples remains that of H.M., the amnesic patient who showed excellent learning and retention on tasks such as pursuit motor and mirror tracing despite failing on each trial to recollect explicitly his previous experience with the tasks.

(3) "Blindsight" refers to the ability to make certain classes of responses, in the absence of explicit perceptual awareness, to stimuli presented in the blind visual field. The investigation of "blindsight" or "residual vision" in humans was prompted by research on primates which suggested that complete ablation of primary visual cortex does not necessarily result in permanent blindness. (Weiskrantz, 1986). This is not surprising since, as in the case of patients, only part of the complex visual system is actually altered by the lesion. Other pathways originating in the retina, but terminating in areas other than the visual cortex remain anatomically intact (Sergent, 1984). The

evidence from blindsight suggests that the mechanisms for location specific selection and the subsequent recruitment of visual attention may be preserved in residual vision following damage to the visual cortex. Furthermore, the importance of the 'blindsight' phenomena lies in the fact that it indicated the need to consider the nature of the patient's response during assessment. If the task had required the patient to make an explicit verbal response based on subjective experience, then no (correct) response vis-a-vis the stimulus would have been obtained. However, using a forced choice or visuomotor response enabled the researchers to tap the patient's implicit awareness of not only spatial location but also of more complex properties like shape and size.

Other examples of this dissociation have been found in cases of dyslexia and aphasia and have been reviewed by Schacter, McAndrews and Moscovitch, (1988). In the case of neglect, however the evidence for such a dissociation has until recently been sparse and anecdotal. Nevertheless, a few studies can be found whose results lend support to the position.

(1) The work of Bisiach and Luzzatti (1978); Bisiach, Capitani, Luzzatti and Perani (1981); Joanette and Brouchon (1984) have described cases where neglect patients sometimes report the existence of stimuli from the neglected side, although they mistakenly attribute them to the intact side.

(2) Informal observations of neglect behaviour have also indicted that the patient may have available more informa-

tion than they exhibit on explicit tasks such as drawing. In the case of drawing itself, given a sheet of paper the

> "... patient will confine his drawing to the right of an imaginary line, which will shift, sometimes dramatically, as the width of the piece of paper changes. It is the size and symmetry of the target object that determines, in part, what is neglected and what is attended". (Schacter et al, 1988).

An illustration of the latter can be seen in the examples of the butterfly. (Fig. 5.12: I, II, III). Here the patient was asked to copy the stimulus object.

(A) Full butterfly with both wings.

(B) the same butterfly with the left wing missing.

(C) the same butterfly with the right wing missing.

The performance of the neglect patient P.B. is shown in Fig. 5.13 (I, II, III).

When asked to copy the simple full winged butterfly (5:12(1)) P.B. not surprisingly neglected the left wing. He drew only the abdomen, right wing and, interestingly, both the left and right sided antenna (5:13(1)). This is odd since the left wing was consistently omitted irrespective of the relative spatial positioning of the target butterfly (5:12(1)). When subsequently presented with the same butterfly but with the left wing missing (5:12(II)), P.B. copied much the same (5:13(II) as he did for (5:13(1)), the full butterfly, and failed to notice any differences. Finally, upon being presented with (5:12(III), the butterfly with the right wing missing, the patient on several occasions copied only the abdomen and left and right antenna (5:13(III) commenting that one of the wings was missing. Questioned as

1

2

3

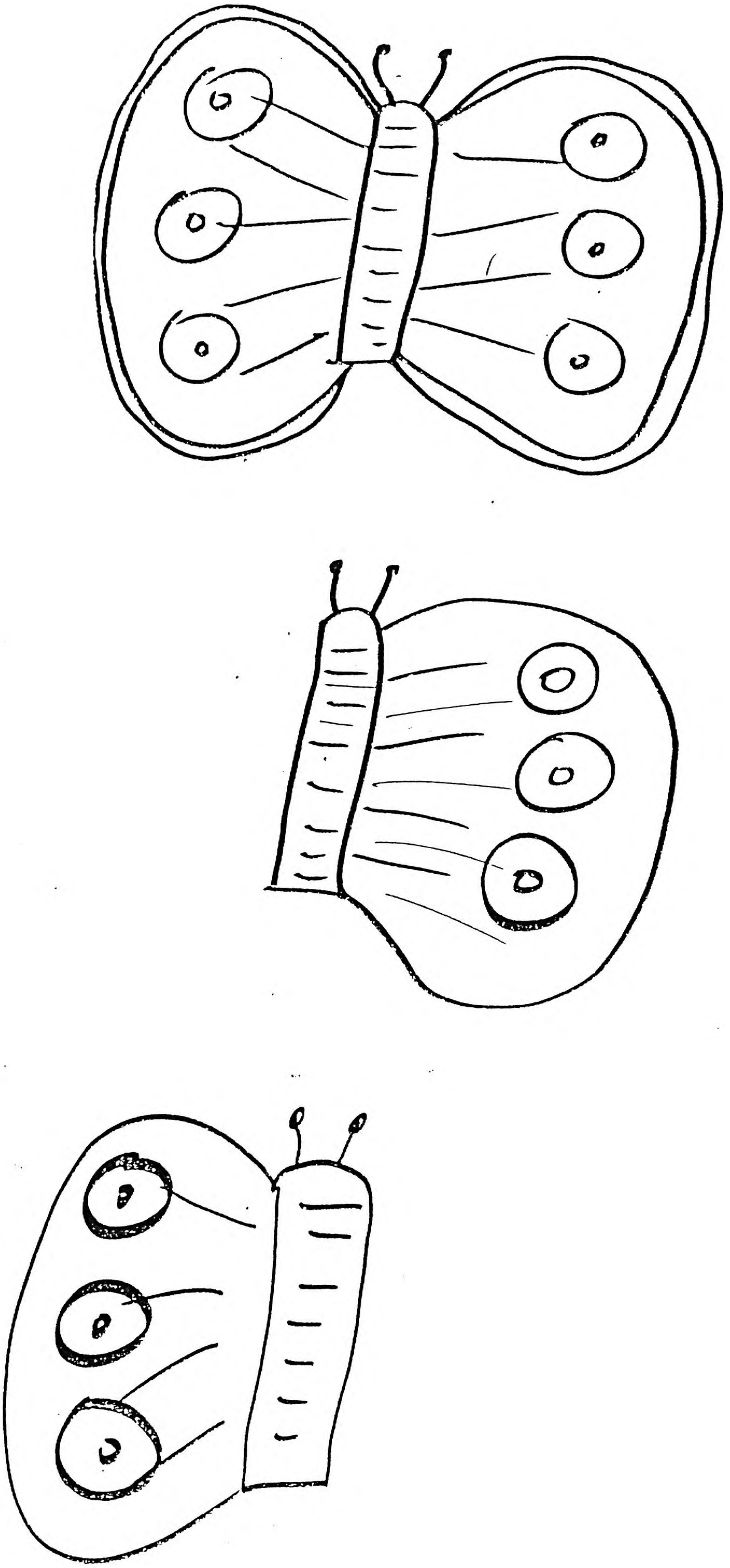


Fig. 5.12 Stimulus copies of (1) Full butterfly
(2) Butterfly with left wing missing
(3) Butterfly with right wing missing

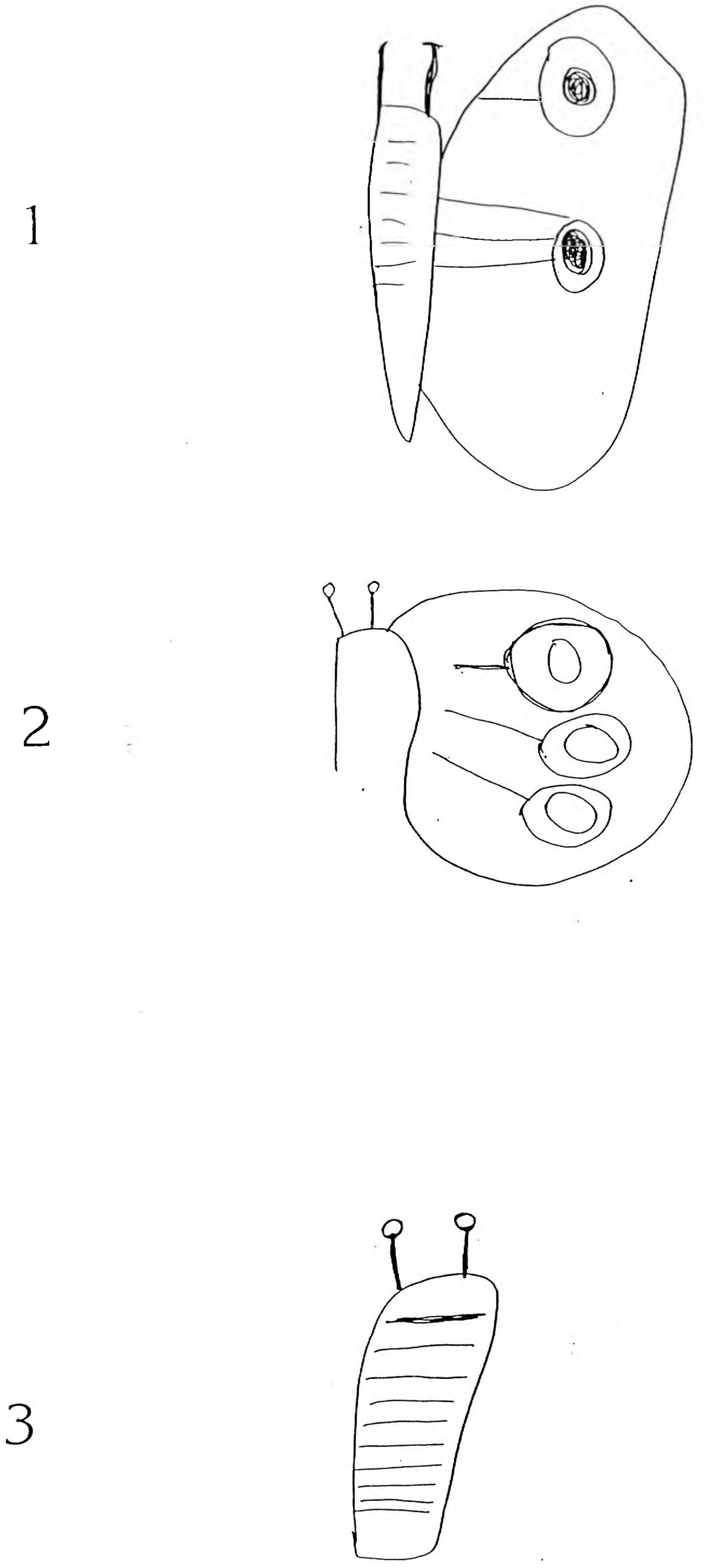


Fig. 5.13 Patients copy of (1) Full butterfly
(2) Butterfly with left wing missing
(3) Butterfly with right wing missing

to which wing, P.B. indicated that the right wing was missing. This sequence of performance was found on several occasions during P.B.'s stay at Rivermead.

The performance of P.B. raises the question as to what actually constitutes the left side of space for symmetrical/ asymmetrical stimuli. In other words what is neglect left of in these cases? Presumably in order to neglect that which is considered to be the left side of a roughly symmetrical stimulus (the butterfly), the patient must have access to information of what constitutes the whole object. In the case of P.B., this appears to have involved the left wing but not the left antenna. Furthermore, asked to bisect each of the original stimulus figures (5:12(I)(II)(III)) upon completion of his copying performance (5:13(I)(II)(III) P.B. consistently divided the butterflies down the "conventional centre" and not as one might expect from his copying performances.

This point regarding the influence of the patient's implicit awareness and the need to adopt the conventional midline while still claiming half drawings to be complete, is perhaps best illustrated by a further example of P.B.'s work. Asked to copy a lateral view of a dog, or front view of a man, P.B. again consistently omitted the left side. However asked to copy his own original performance of both again; and again, P.B.'s performance did not indicate an endless regressive reduction based on sheer object "left sidedness". Rather, the copies continued (with minor variations) to preserve the right side of a complete dog or man.

(3) The results of P.B.'s, performance on the line bisection task described earlier, indicate that information about the neglected part of the line influenced his estimate of the subjective midpoint and hence the line's overall length.

(4) In the related condition of visual extinction, Volpe, Le Doux and Gazzaniga (1979) reported data which supports a dissociation between processing of the 'extinguished' stimuli and the ability to use the processed information for identification purposes. Despite failing to report the left field stimulus when two different stimuli were simultaneously presented, the patients in this study responded at a level significantly above chance when asked to judge whether the two stimuli were in fact the same or different. In other words, the stimulus comparison task appeared

> "to have been carried out at a post-perceptual preverbal level, with only the resultant comparison entering consciousness".

(5) In Chapter 2, reference was made to the finding that in some cases of neglect, verbal material may be relatively uneffected in patients who clearly display visual neglect on drawing/copying or cancellation tasks (Caplan, 1987, Costello and Warrington, 1987). Evidence of this sparing of verbal material was also found in the case of the patient P.B. Asked to copy Fig 5:14 which consisted of an outline drawing of a cow with 13 letters superimposed across the cow's body; P.B. put all the letters in (including an extra two letters) on his copy yet neglected to draw the cows head and front legs although both were spatially further right that the left extent of the sequence of letters. Figure 5:15.

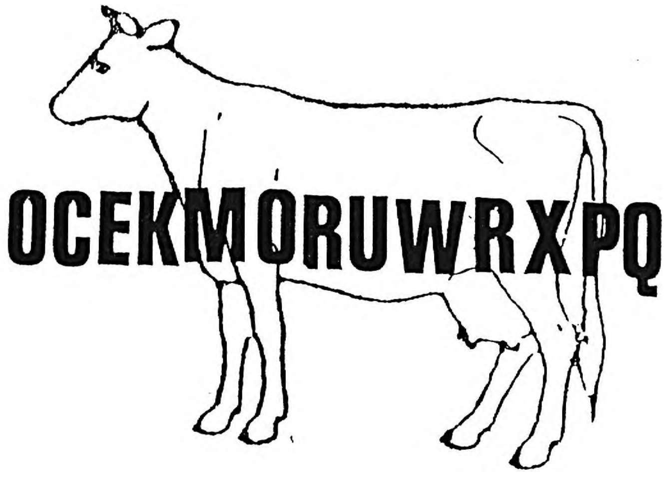


Fig. 5.14. Outline drawing of cow and letters superimposed.

Fig.5.15 Patients copy.

(6) One of the first formal investigations of implicit awareness in neglect was described by Karnath and Hartze in 1986. A 56 year old right handed patient demonstrated neglect on drawing, copying and reading tasks. The C.T. scan revealed a large hypo-dense lesion including the right lentiform nucleus. However, perimetric examination of his visual fields revealed no discernible field deficit. The investigation of this patient involved two stages.

The first, required the patient to name individual stimuli presented (tachistoscopically) in either the left or right visual field. On this task the patient performed at the 100% correct level for both unilateral L/R visual field identifications.

The second part of the test involved the bilateral presentation of simple object drawings to both fields. On some occasions the stimuli were identical, and on others they were different. With central fixation, the two objects, presented for 180 ms, 3^{o} - 5^{o} to the left and right of fixation, could be reliably judged as the same or different. However, on trials, where the judgment "different" was correctly elicited, the left visual field stimulus could only be identified on about 50% of the presentations. Thus, not unlike the findings of Volpe et al, 1979 with extinction, the ability to perform, "Same/different" interfield comparisons with bilateral presentation in this case of neglect could be tentatively explained as due to pre-attentive processing which is not disturbed by selective attention for right visual field information.

(7) In a recent review, Riddoch and Humphreys (1987) have shown in three patients with visual neglect, how pre-attentive feature processing remained relatively intact despite impairment of serial (controlled) processing.

In their experiment, patients were given a visual search task, and were requested to search for a target set against a background of distractor stimuli. The targets appeared either on the right or left of the stimulus card, and the number of distractor elements were varied. The results of this study indicated that all three patients with neglect had relatively intact pre-attentive processing for colour features, e.g. a red circle situated within an assortment of green circles and located on the left side of the stimulus card, was less likely to be neglected than a corresponding inverted T situated within a background of upright Ts. (Riddoch and Humphreys, 1986)).

However, these authors point out that despite evidence of intact pre-attentive processing

> "discriminatory responses can not be formulated directly from the pre-attentive information otherwise the patient would presumably attend to the (neglected side)".

Thus they regard neglect as resulting from the breakdown in the sequentially later "attentional capture process" that is controlled by a "limited capacity selective processing system".

Therefore, although the neglect patient's explicit behaviour suggests an impairment of attention to one side of space, several studies have demonstrated cases where "pre-attentive" visual processes normally not directly available to conscious awareness, have acted to determine patient's behavioural responses.

In all the formal studies reviewed, this consisted in the patient being able to make a discriminate judgment on the basis of a visual stimulus they explicitly failed to report. All of these studies required fixation of gaze and used tachistoscopic presentation. In this the final section of Chapter 5, evidence from two patients (both seen at Rivermead in the course of the test battery development) will be presented, which lend support to, and extend the findings already described. Both experiments have the advantage of having been carried out in free-vision.

(8)(A) The first patient was P.B. who has already been referred to in 5:5. P.B. was presented with the outline drawing depicted in Figure 5:16 and asked to copy it. The stimulus drawing consisted of an outline drawing of a potted plant, with a main stem which then bifurcates into two smaller stems with flowers and leaves attached to both. P.B. was then asked to copy Fig. 5:17, a stimulus drawing identical to the first drawing stimulus (5:16) except that the lower half (pot and common stem) was now missing. Both figures were presented on two separate occasions several months apart. His performance on both occasions are shown in Figures 5:18 (A), (B) and Figure 5:19 (A) and (B).

When the complete plant (Figure 5:16) was presented, P.B. selectively neglected the left sided branch and drew only the right branch and flower. On one occasion (5:18B)

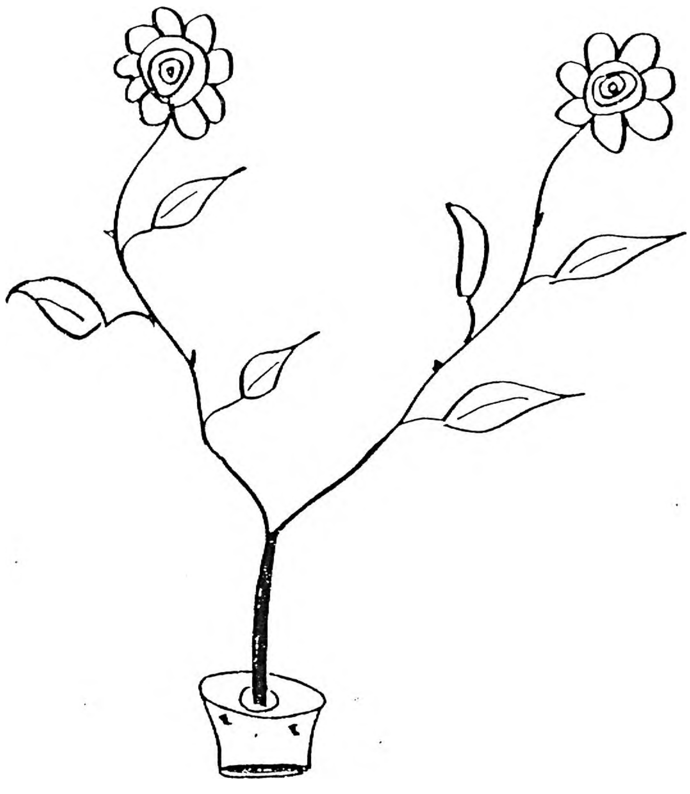


Fig. 5.16 Drawing of two flower plant in pot.

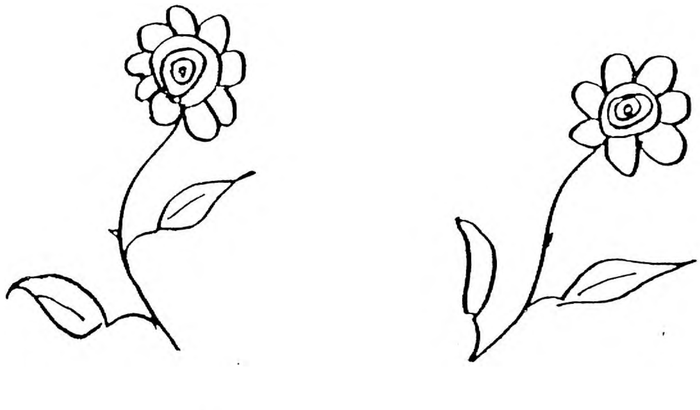
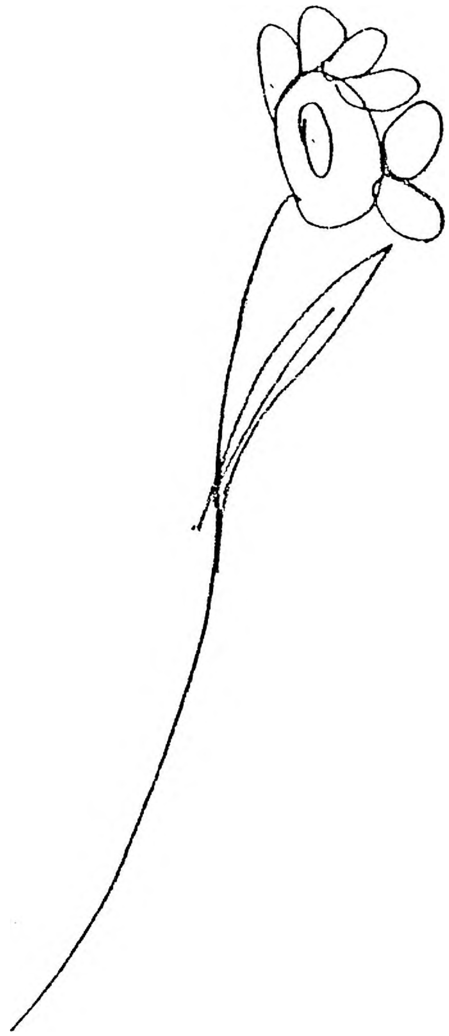
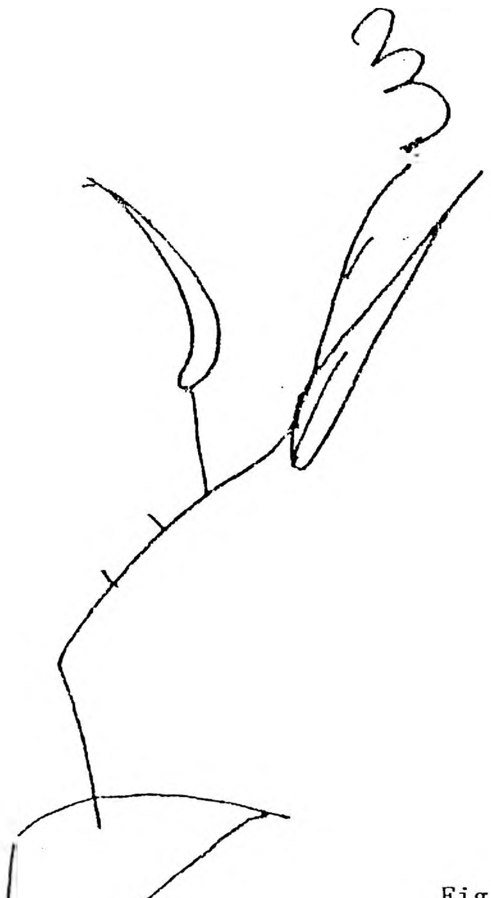


Fig. 5.17 Drawing of two flowers.

A



B



<u>Fig. 5.18</u> Patients copy of Fig.5.16. on two occasions.

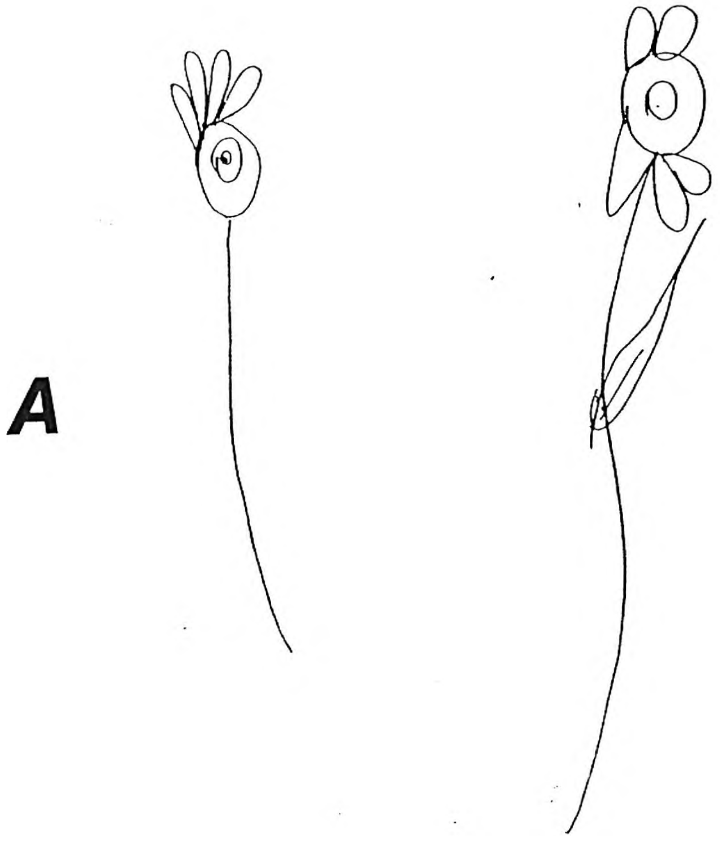
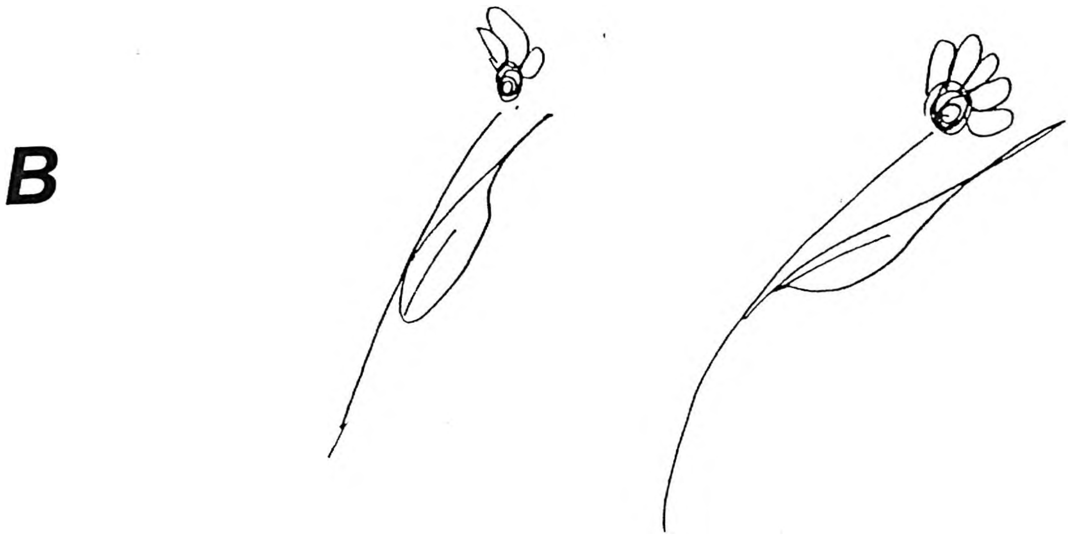


Fig.5.19 Patients copy of Fig. 5.17. on two seperate occasions.



he included the pot in which the flower was embedded. He has also neglected the left side of the right branches that he copied.

Asked to copy the second stimulus (Fig 5:17), P.B. always drew both branches this time, although he again neglected the left sides of each of them.

The critical difference between the two stimuli which had to be copied, lay in their classification as either a single plant with two branches or as two separate plants whose base could not be seen. Regarded as a single object with discernible left/right halves, it would appear that P.B. neglected the left side of the object. However, given roughly the same stimulus with similar spatial dimensions and extension (Figure 5:19) P.B. apparently notices the left side (previously neglected) since now the stimulus to be copied is composed of two relatively independent objects, one located on the left and one located on the right.

This it would appear from the copying performances of P.B. that his initial judgment of the complete plant (Fig. 5:18) probably contained indications of convert awareness of the explicitly neglected left side.

8(B)

The patient P.S. was a forty nine year old lady with no previous history of neurological disorder. She was admitted to Northampton General Hospital on the 1st May, 1988 following the sudden onset of severe headache. The onset of headache was followed by a loss of consciousness for 5 minutes. A C.T. scan performed at this time showed sub-arachnoid blood with mild hydrocephalus. Transferred to the Radcliffe Infirmary on the 11th of May, P.S. had no focal signs, and was alert and oriented despite menigeal irritation. Angiography performed on the same day revealed a 1 cm aneurysm at the bifurcation of the basiliar artery. On the following day a right fronto-temporal craniotomy was performed with clipping of the neck of the basiliar artery. Post operatively, the patient was drowsy and disoriented with a left hemiparesis and no movement of the left arm. Repeat C.T., several days later revealed a little intracrainal air and blood but no focal pathology. P.S. was discharged from the Infirmary and admitted to Rivermead on the 27th of May. On neuropsychological examination, the only finding of note was florid left sided neglect. Like the previous drawing task with P.B., the experiments with P.S. were an attempt to demonstrate pre-attentive processing with central presentation, free vision, and unlimited viewing time.

Procedure

The stimuli used consisted of 4 line drawings of a house, in two of which bright red flames could be seen emerging from the respective left and right sides of the house Figure 5:20A,B Each of the stimulus cards measured 138 mm x 130 mm. The experiment proceeded in 6 steps. Each step was carried out in free vision, with presentation centred about the patients mid-saggital plane. Viewing distance was approximately 16 inchs (408 mm). Head or trunk movements were in no way constrained.

Step I. P.S. was shown individually, two otherwise matched cards (5:20A), one of which had flames on the left and one

A

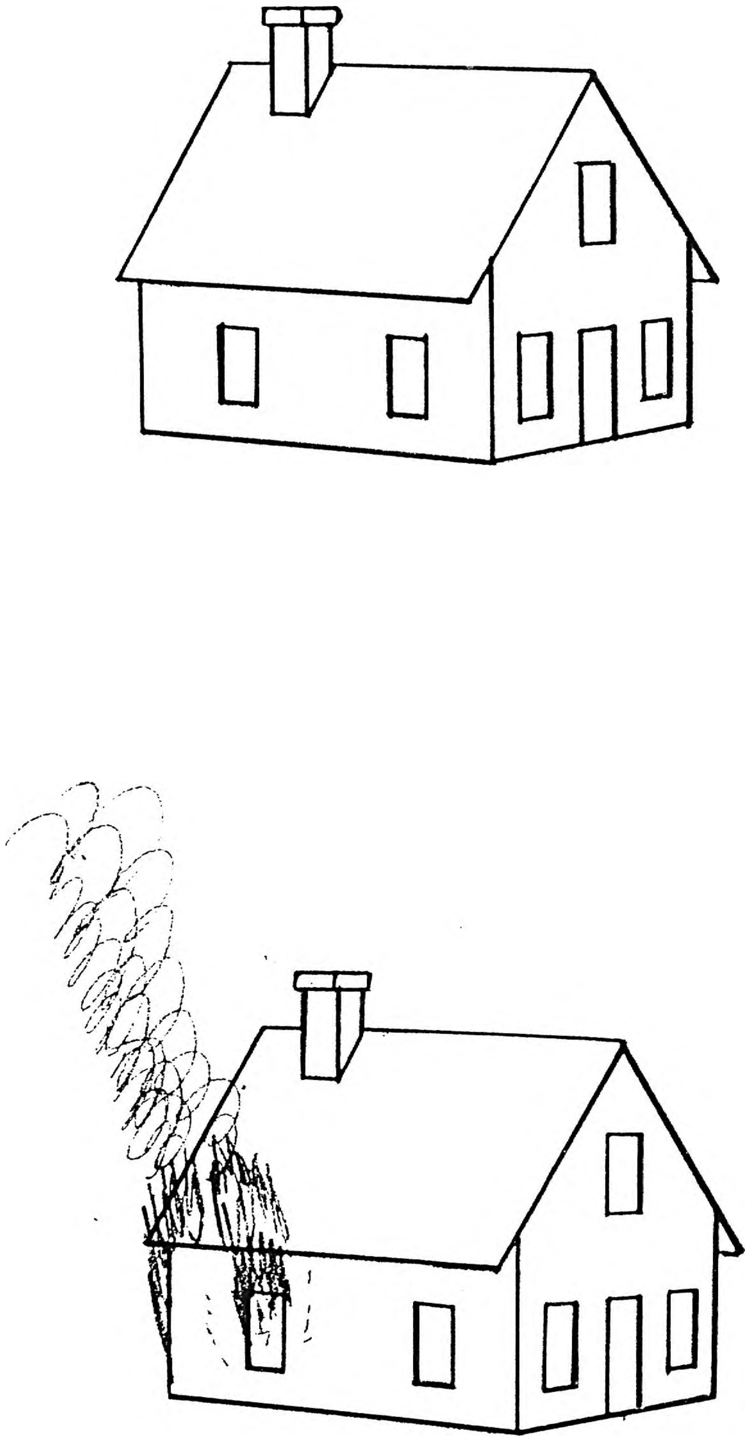


Fig.5.20 Drawings of the houses with the fire on the left side.

B

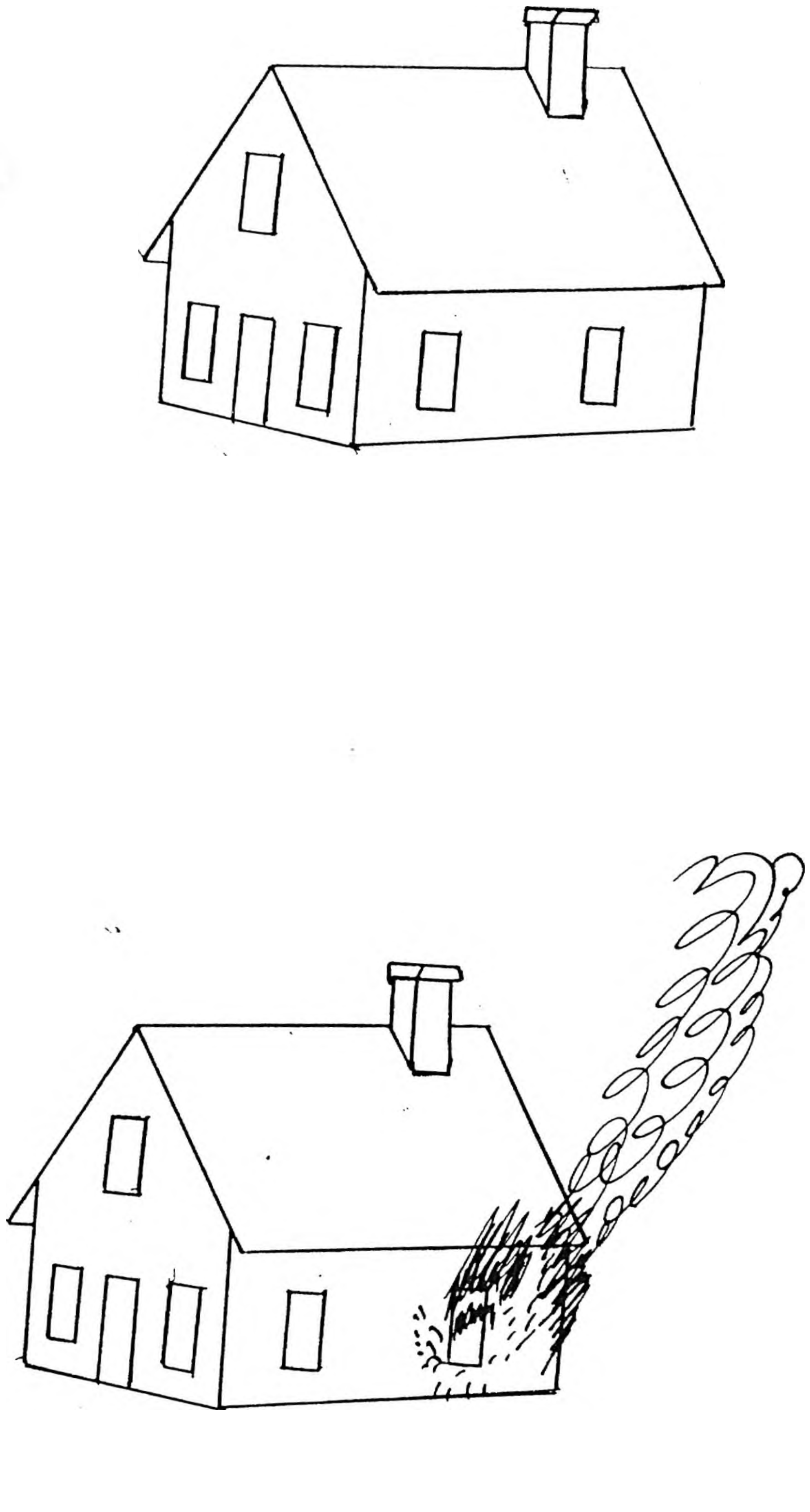


Fig.5.20 Drawings of the two houses with the fire on the right side.

which did not. She was shown the cards twice in sequence and each time was asked to describe the drawing. On each occasion, she described each of the cards as a drawing of a house.

Step 2. The next step involved the presentation of the same cards vertically aligned in front of the patient while asking her if both houses were the "same or different". She described them both as the same. She was then asked if there was anything wrong with either card. She replied that there was nothing wrong and that both houses appeared to be the same.

Step 3. The stimulus cards were again presented in the same way (vertical alignment), but this time P.S. was asked which house she would prefer to live in. She thought that this was "silly" as she felt they were clearly both the same. However, when forced to make a decision, she chose the non-burning house on 9 out of the 11 trials using alternative vertical order presentation. This was significant on the binomial test at 0.03 level.

Step 4. The cards were again presented one above the other for a further 6 trials. After each trial, P.S. was first requested whether the two stimuli were the same or different, and secondly which house she would prefer to live in. Again she failed to notice the flames, and on 5/6 occasions she again chose the non-burning house. If the preferences from step 3 are summed, the probability associated with the null hypothesis of no reliable preference arises to 0.006.

Step 5. This step involved two new cards, (5:20b) one with flames on the right side of the house, and one normal house. Again they were presented in a similar manner to those described already. P.S. was asked on all 6 trials whether the cards were the same or different and which house she preferred; she immediately noticed the flames on all of the 6 trials, and consequently chose the non-burning house.

Step 6. This final step reverted back to the original cards with the left sided flames. On the first four trials P.S. again maintained that both stimuli were identical and on 3/4 occasions preferred the non-burning house. On trial 5, however, (no doubt primed by the effects of step 5), P.S. achieved insight into the task, exclaiming with some surprise that one of the houses was in fact on fire.

If the preferences shown by P.S., from step 3, 4, and 6 are pooled, then one can reject the null hypothesis at $P < 0.004$.

The results of this experiment clearly suggest that the neglected stimuli on the left may in some circumstances exert a covert influence on cognitive judgments, but not to the extent that they ensure translation to explicit conscious awareness. P.S. could report both members of a pair that differed on a critical feature, but nonetheless judged them identical. Yet her preference judgment clearly indicated covert awareness of this feature. In other words, the failure to explicitly identify neglect stimuli should not of itself be taken to imply the absence of perceptual processing in such patients.

General Conclusions and Implications

Chapter 6

6:1 Introduction

6:2 Clinical Pratice

6:3 Theoretical Implications

6:4 Final Assessment

Chapter 6

General Conclusions and Implications

6:1 Introduction

The aim of this chapter is to review some of the conclusions described in the earlier chapters and offer a synoptic overview of the findings with implications for theory, clinical practice and future research.

6:2 Clinical Practice

The patient who has suffered a stroke typically has to overcome a variety of complex, behavioural disturbances that affect many areas of daily life. Helping such patients requires recognition not only of the more common physical problems but also of less obvious cognitive, perceptual and affective disorders.

The identification of visuospatial disorders such as neglect did not emerge until the late 1960's (Delis, Robertson and Balliet, 1985; De Renzi, 1982) when clinical studies showed that they could adversely affect the recovery and rehabilitation progress of stroke patients. However, despite the growing awareness that functional performance could be adversely influenced by spatial disorders, the rehabilitation of stroke patients has until recently continued to emphasize the treatment of motor and language deficits. As a result, visuospatial deficits such as neglect have usually gone undetected and untreated. One survey by Haslett et al, (1976) of 153 stroke patient's notes revealed that 93% failed to make any reference to visuospatial performance.

Up until recently the clinical assessment of spatial disorders has relied upon therapists' own subjective evaluations (Ottenbacher, 1980) assisted by several non-standard clinical measures such as copying or drawing (Siev et al, 1976).

Several factors conspired to delay the investigation of visual neglect. Unlike language disorders, damage to visuospatial processes are difficult to characterize and in the absence of a coherent theory of spatial processing have to be inferred from the patients' comments and behaviour. Furthermore, the diversity of phenomena reported, the striking lack of awareness in many patients, and the fact that neglect rarely presents as an all-or-none phenomenon has rendered it difficult to define or evaluate the condition satisfactorily.

Investigations of the condition throughout the 1970's led to the gradual characterization of neglect phenomena (and in particular visual or hemineglect) as a spatial disturbance of selective attention. (Mesulam, 1985). In addition, clinical reports indicate that neglect is a serious rehabilitation problem which affects reading, writing and the performance of many basic self care activities. Recently, Fullerton et al., (1988) have shown that performance on a simple neglect test (Alberts' line crossing test) isthe single most powerful predictor of long term recovery in a large sample of acute strokes.

Despite ample clinical documentation and experimental investigations, progress towards the effective treatment of neglect has been hampered by problems of definition and assessment. This has resulted in considerable confusion regarding the relative incidence, and natural history of the condition as well as the pattern of recovery from it.

In marked contrast to other clinical neurological assessments (eg. confrontation for visual field testing), the absence of a single widely accepted operational definition of visual neglect has resulted in the development of over 50 tests and a similar number of descriptive labels. Tests range from the simple bedside drawing tests, to sophisticated research tools involving divided visual field and computerized presentations, many of which cannot be routinely and reliably used to assess hospital inpatients. In addition, although various authors have used more than one index of neglect, few studies have addressed the question of the extent to which these tests all measure the same underlying construct.

One of the major limitations of clinical tests currently used to evaluate neglect, is that they fail to consider the patient's performance in their everyday enviroment. As the functional consequences of visual neglect are varied and differ from patient to patient, routine clinical and neurological assessments are unlikely to reveal those characteristic features of the condition in a format useful for the planning of rehabilitation. Despite the obvious importance of delineating the patients' behavioural strengths and deficits in a manner readily understandable to those involved in rehabilitation, this has hitherto been largely ignored in favour of diagnostic issues.

Central to the aim of the present thesis, was the recognition of the applied shift within current neuro-psychology towards consideration of more pragmatic components of patient behaviour. A qualitatively different approach to patient assessment is required as many of the "traditional measures that are most objective, dependable, precise and readily quantifiable are also likeable to be the least relevant to the patient" (Tallis, 1987). Only a minority of neglect studies have attempted to relate results to the intervention of therapists or the functional rehabilitation of the patient.

With these considerations in mind, the object of the study described in the present thesis was to develop a standardized procedure for the assessment of visual neglect, which also permits generalization from test results to adaptive functioning in the real world. Rehabilitation prospects of stroke patients are enhanced by considering their behavioural strengths and weaknesses within a functional framework. Behavioural dependent measures provide a useful tool for evaluating a patients' performance irrespective of the theoretical orientation adopted. By clearly indicating potentially disruptive aspects of patient functioning, resources can be directed more efficiently and effectively to functionally relevant areas. Such a characterization of neglect performance is a necessary pre-requisite for therapists to predict those patients who will benefit from different treatments. A similar approach; the Rivermead Behavioural Memory Test has been successfully developed to measure everyday memory problems. (Wilson, Cockburn and Baddeley, 1985).

In addition, an objective standardized battery of tests capable of assessing the effects of visual neglect on daily functions would contribute towards alleviate the confusion that currently surrounds the question of definition and assessment.

The Behavioural Inattention Test (B.I.T.) was standardized using 80 patients drawn from a stroke population admitted to Rivermead Rehabilitation Centre. Of the 80 stroke patients seen, 54 (67%) had right sided lesions, and 25 (33%) had left sided lesions. A control group of 50 non brain damaged subjects was also seen in order to provide normative comparisons for test items. A battery of 15 tests were developed and administered to each patient. As the testing of visual neglect is most often carried out by clinicians and therapists, the practical selection of the behavioural tests was determined by their suitability for testing with adults, ease of administration and relevance to aspects of daily life. The battery consisted of 6 conventional and 9 behavioural tests. The aggregate score of the 6 conventional tests for the control subjects was used to calculate the cut off point below which patients were considered to show neglect.

Using this cut off, 30 patients (37.5%) were found to fall into the neglect category. These results confirm previous clinical findings that neglect is both more common and severe following right rather than left sided lesions. The present study also demonstrated the differential sensitivity of the various tests to the presence of visual neglect. Visual field deficits were only present in

63% of patients with neglect, thus in-keeping with other studies, they were neither a necessary nor sufficient condition for the present of neglect behaviours.

Central to any assessment of psychological impairments is the question of validity. The validity of a test describes the extent to which the test scores meaningfully represent what it is that the test claims to be measuring. The simplest way to calculate the validity of a test is to compare the patient's test result with those of their observed performance on some other acceptable criterion.

The validity of the behavioural tests was ascertained by calculating the correlation co-efficient between scores on the behavioural and conventional tests ($r = 0.92$, $df = 50$, $P < .001$) and comparing scores on the behavioural tests with those obtained directly from scores obtained by the patients on a standardized measure of Activities of Daily Living (ADL; $r = 0.36$, $df = 50$, $P < .01$) and a checklist administered to each occupational therapist ($r = -0.67$, $df = 77$, $P < .001$).

Another indicator of test validity can be found by calculating the extent to which all tests are measures of the same underlying construct. Using factor analysis, the process involves an examination of the correlations between tests, so as to determine which variables appear to co-vary. The subsequent combination of these variables and their examination provides for the meaningful extraction of common factors or traits underlying the test scores. Using this procedure, evidence for a hierarchical factor solution can be used to support the case for the existence of a relatively robust measure of the construct under consideration. Using data obtained from the administration of the test battery, factor analysis revealed the existence of a single factor or trait that accounted for almost 50% of the variance and had significant loadings from 12 of the 15 tests used in the battery. Thus factor analysis confirmed that 80% of the tests employed were measuring aspects of the same construct. A more detailed examination of the role of hemispheric differences indicated that while right hemisphere patients performance could be explained by a single factor, left brain damaged patient performance was more heterogenous, requiring 3 separate factors to explain the variance among the tests of neglect.

Another important feature of test construction concerns the reliability or consistency of patient performance. The main sources of variability include interobserver, and test-retest variation. Several measures of stability or reliability were calculated for the B.I.T.

(1) Inter-rater reliability; reliability between different raters or observers. This was established by having thirteen subjects scored separately but simultaneously by two raters. Correlations between the raw scores for both conventional and behavioural tests for two independent examiners yielded a highly significant co-efficient of $r = 0.99$, $P < .001$.

(2) Test-retest reliability; the consistency of the tests scores on two separate occasions. Ten patients were given the same group of tests on two separate occasions, on average 3 weeks apart. The correlation for the behavioural tests was $r = 0.97$ $P < .001$.

In conclusion, the B.I.T. is capable of predicting those brain damaged patients most likely to experience everyday problems arising from unilateral neglect. Thus generalization from test performance to activities in a natural setting would appear to be less hazardous than might be the case with some conventional paper and pencil tests. In addition this feature of the battery appears to lessen test anxiety and greatly increase the acceptability of tests.

The test has been shown to be both reliable and valid. It has the further advantage that it offers an ecologically valid approach to the assessment of neglect, while also fulfilling the practical requirements of a psychological test by being short, easy to understand and interpret. The test was published in November 1987, and is currently undergoing standardization at the New York University Medical Centre to enable it to be used with an American population.

Further research with the behavioural test battery would involve extending the assessment to other clinical populations eg, traumatic head injury, where reports of a low incidence suggests the need for more sensitive test measures. Future research would also benefit from more precise details regarding the exact locus and extent of lesions. It would be desirable to administer the test battery to patients in the acute stages after stroke, as right sided neglect following left brain damage is frequently reported to be more common at this stage. Recently, the test battery has been modified for use with an acute hemispheric stroke population. (Stone, Halligan and Greenwood, submitted). It is also intended to use the modified form to monitor recovery over several months and evaluate the effects of aging on test performance in a group of older, age matched controls (Stone, Halligan and Greenwood; in preparation).

6:3 Theoretical Implications

The first task of a scientific discipline is to establish a body of knowledge that describes the salient features and empirical relationships within its subject matter. Theoretical accounts of neglect presuppose a data base that accurately represents the basic patterns of impaired and preserved performance with and between individuals; however despite considerable interest no large scale data base currently exists.

The results of the B.I.T. and in particular the differential performance of patients on the conventional tests, provides the potential researcher with a robust starting point from which to consider some of the theoretical constructs underlying neglect.

It is unlikely that visual neglect is a unitary phenomenon and that all its manifestations can be entirely explained at the level of sensory or motor deficits. The sensory deficit hypothesis was explicitly suggested by Battersby et al (1956) who claimed that neglect was due to an interaction between sensory deficits and general mental deterioration. Although sensory loss in the form of hemianopia may exacerbate symptoms of visual neglect, several patients in the B.I.T. sample, without visual field deficits exhibited florid neglect, while others with hemianopia did not neglect their blind field when free to move their eyes and head. This same argument holds for the defective exploration hypothesis proposed by Schott, Jeannerod and Zahin (1966) and more recently by Rubens (1985). This theory suggests that neglect behaviour arises predominantly as a consequence of an oculomotor disorder which prevents the patient from fully exploring the left side of space. However, not unlike several other studies Bisiach, Luzzatti and Perani, 1979) it is well established clinically that florid manifestations of neglect can be found in the absence of clinically detectable oculomotor impairments.

Furthermore, neglect can be demonstrated on tasks which require neither an analysis of sensory information nor an active scanning of the external world. Thus Bisiach and Luzzatti (1978) have shown that patients may describe from memory only the right side of a familiar scene - the view from the steps of Milan Cathedral and when asked (in their imagination) to go to the other end of the Piazza, and now describe the scene when facing the Cathedral, only reported again the right side, the contents of which were previously neglected on the first prespective. Similar examples have been reported by Messerli (1984) - the Place Neuve in Geneva; and by Lhermitte, Cambier and Elghozi (1981) - Place de la Concorde in Paris. This representational hypothesis argues that the inner representation of outside reality is topologically structured across the two hemispheres and that unilateral spatial neglect results from a disruption of one half of this internal map. The importance of the representation hypothesis is that it sets the discussion of visual neglect firmly within spatial rather than retinopic parameters. This can be clearly seen in the performance of the neglect patient who on star cancellation typically begins at the right upper most targets. They then proceed leftwards until they finally stop cancelling (usually) somewhere around the central third of the stimulus sheet. At this point, they would appear to be actively neglecting targets located within the same retinal space but which during foveatation of the earlier right sided targets were always detected.

Failures of the representational theory include several cases where patients who demonstrate neglect on copying (visuomotor tasks) fail to show neglect on tasks requiring them to draw objects from memory. The representation hypothesis also fails to explain how some patients despite florid and persistent neglect on star cancellation are capable of performing adequately on writing or reading tasks. Furthermore since neglect has been shown to be significantly reduced by overt cueing (Riddoch and Humphreys, 1983) the implication for the representational theory is that the internal map is not lost, but fails to be activated due to a disruption of internal scanning mechanisms. The latter qualification suggests an attentional disorder, and more readily explains the findings of the residual processing in the neglected field described in chapter five. These findings suggested that at least for some patients with neglect, the failure to describe or utilize left side stimuli should not of itself be taken to imply the failure or absence of perceptual processing.

Over the last decade there has been a growing consensus that visual neglect is primarily due to a disturbance of spatially distributed attention. However there is less agreement as to the precise attentional mechanisms involved. Several theories have been formulated. These can be divided into two basic types, those concerned with "Anatomo-physiological models" of directed attention and those interested in elucidating the neuropsychological components of attention.

The first approach originates from the work of Heilman and associates in the early 1970's. They proposed a theory of neglect which explains both the hemispheric asymmetry and the constellation of behaviours observed, in terms of damage to the right hemispheres cortico - limbic reticular system, which they claim is dominant for bilateral arousal. Unilateral lesions produce hypoarousal of the right hemisphere which results in a neglect of stimuli processed by that hemisphere and a hypokinesis of all movements in the hemispace contralateral to the damage hemisphere.

A similar approach by Mesulam proposes a more specific neural network model, damage to components of which result in the different types of neglect behaviour. However, both Heilman's and Mesulams' models fail to accommodate the now extensive number of reported lesions sites giving rise to neglect behaviours, and the anatomical independence of some of these structures. As a result a further model has recently been proposed by Rizzolatti. This model suggests that attention is not a supraordinate function controlling the whole brain, rather it is distributed among several relatively independent cerebral neural circuits. The major disadvantage of such physiologically based models is that they fail to account for the main anatomical and psychological aspects of the condition in a format that may be empirically investigated. (Gainotti, D'Erme and De Bonis, 1989).

The second approach provides a more analytical investigation of neglect in terms of its neuropsychological components. According to Posner and associates who have analysed visual attention in normal subjects, visual attention can be covertly oriented to an internal mental image or overtly by shifting ocular gaze. This orientation to visual stimuli may come about automatically or intentionally and consists of at least three successive mental operations, (1) disengagement of attention from previous target focus, (2) movement of the attentional "spotlight" towards the non-target and (3) the subsequent engagement of the new target. Posner et al. (1984) working with right parietal patients on a detection task, showed that while they could voluntarily shift their attention in response to a cue, they demonstrated a selective deficit in the automatic step of disengaging attention from a previously focused right sided target. In other words, patients with neglect were strongly attracted or severely impaired at disengaging from stimuli occupying non-neglected (right) hemispace.

In an attempt to test this hypothesis clinically, Mark, Koosistra and Heilman (1988) presented patients with two versions of a cancellation task. In the first, they cancelled lines by drawing over them, in the second they simply erased the lines they detected. The results indicated that patients made more omissions in the drawing over task than on the erasing task, this confirming Posner's hypothesis that the presence of stimuli in the non-neglected hemispace act to influence the detection of stimuli in the neglected hemispace. These findings suggest that it is pertinent to consider all aspects of the test characteristics being used to elicit neglect.

Another aspect of attention referred to in Chapter five concerns the notion of attentional capacity. Since the pool of available attentional resources remains limited, the ability to perform numerous tasks together is constrained. Capacity requirements may be expected to vary according to the nature and difficulty of the tasks employed. Reference was made in Chapter 5 to two main types of information processing, - automatic and controlled. Automatic or preattentive processing describes the seemingly effortless process whereby conspicuous local features and their spatial location are detected. This process requires minimal allocation of resources and covers a large visual field.

On the other hand, detailed visual analysis of stimuli requires controlled or focused attention and is largely subject regulated. This type of serial processing is described as effortful and involves stimulus by stimulus sequential scanning by a 'spotlight' of focal or selective attention. This selective property of attention determines what information will be consciously processed. Studies by Schneider, Dumas and Shiffrin (1984) have shown that serial or controlled processes are limited by attentional capacity whereas automatic or preattentive processing in parallel have no such limitations. The prediction is that serial search performance in right hemisphere damaged patients will be worsened by any increase in the number of distractions or by using distractors which are difficult to discriminate from the intended targets, whereas preattentive processing will remain intact. Evidence for the later, has been described in Chapter 5. Evidence for the former can be found in several sources. Riddoch and Humphreys (1987) have shown that pre-attentive processing was intact in three subjects with visual neglect, while performance on tasks requiring controlled processing was impaired. Pillon (1981) has also shown that left sided omissions increased as a function of the complexity of the geometric design being copied by the neglect patient.

Since the number of distractors and targets to be cancelled on the three visual search tasks used in the B.I.T. (line crossing, letter cancellation and star cancellation) increased from one to the next, it can be predicted that patient performance will be differentiality affected. All three conventional visual search tasks can be viewed as requiring differential amounts of selective scanning depending on the number of targets and foils present. Line crossing requires patients to cancel all the targets (n = 36) they could see. Since it contains no foils it may be described as a "target only" condition. Letter cancellation is more complex, and requires the detection and discrimination of two targets from a serial array of non-targets and similar looking targets. Finally star cancellation requires the patient to detect and discriminate 54 targets from a non-serial array of both larger stars, letters and small words. Although, the tests were not spatially comparable, the results of these three tests reported in Table 3:6 for right brain damaged patients support the position that neglect of left hemispace was more common in star cancellation (n = 36) than in either letter cancellation (n = 22) or line crossing (n = 17). Similar results using specially designed and balanced test stimuli have been recently reported by Rapscack, Verfaellie, Fleet and Heilman, (1989).

Another factor that has been shown to influence performance on neglect tasks is that of spatial position. Heilman and Valenstein (1979) demonstrated that patients with neglect following right hemisphere lesions performed worse on line bisection tasks, when the lines were positioned in left rather than right hemispace. Using the task of line bisection in the present B.I.T., confirmed the significant effect on spatial positioning for both controls and patients. Not all patients however showed this effect. Right hemisphere damaged patients without neglect (n = 33) and those with mild neglect (n = 17) failed to show a significant effect for spatial positioning.

Control subjects furthermore transected centrally positioned lines significantly to the left of objective centre. This finding supports the work of Bradshaw et al. (1987) and others who have all reported a significant deviation to the left. Asked to bisect left and right sided lines, controls always tended to bisect towards their own bodily midline, i.e. right lines well bisected towards the left, and left lines towards the right. Although proportionally different, the same trend was observed in all brain damaged groups.

An examination of the distribution of accuracy ranges on line bisection for the four main patients groups (left brain damaged without neglect, right brain damaged without neglect, right brain damaged with mild, and those with moderate to severe neglect) reveals an interaction of two separate factors. The first factor, describes the effect of the extent of brain damaged suffered i.e. severity of impaired performance on the 5 independent tests of neglect was associated with an enlargement of the range of deviations observed.

Secondly, the distribution pattern of deviations for the non-neglecting to severely neglecting right brain damaged patients, is significantly skewed to the right. This rightward skewedness can be seen to represent the directionally specific effect of visual neglect on performance. Individual case studies of both control and patient subjects furthermore indicate a need to qualify the results of group studies given the variation observed, and the need to obtain several readings from each subject.

One feature of line bisection that has itself being neglected is that of the effect of line length. Although most studies that have investigated neglect have varied line length, few if any directly refer to the effect on neglect performance. One exception includes the work of Bisiach et al. (1983) who demonstrated that for most neglect patients an increase in line length resulted in an increase of right sided displacement. Although Bisiach et al's (1983) report only used 3 line lengths it was possible to extrapolate the counter intuitive hypothesis that patients with left neglect and right displacement on long lines would demonstrate right neglect on shorter lines. Using a single case study this implication was confirmed. Excluding sensory and visuomotor deficits the results were interpreted in terms of (1) an "attentional boundary; placed slightly to the left of objective midline and (2) "representational completion" that extended to the attentional boundary.

Discussions of visual neglect have typically considered only lateralized deficits. Using the data from 23 stroke patients with visual neglect on a modified version of Alberts' line choosing test, indicates that there is an affect of stimulus position in the vertical dimension. A vertical analysis of the data revealed that there was significantly more errors in the lower half. This study emphasizes the need to study the distribution of attention along all spatial dimensions in the assessment of visual neglect.

6:4 Final Assessment and Future Research

Since unilateral visual neglect was first documented in the late 19th century, many clinical neurologists and psychologists have speculated as to the processes involved. Until recently, these accounts had little impact on mainstream cognitive psychology, and have tended to fall within the traditions of clinical neurology rather than neuropsychology. As a result, little attention has been directed towards the systematic analysis of the behaviour of patients with neglect. From a neuropsychological perspective the objective measurement and description of the behaviours associated with visual neglect will provide both clinicans and therapists with a more robust profile of the those potentially disruptive symptoms in the brain injured patients' behaviour. The B.I.T. will provide future researchers with a practical yardstick with which to compare and discuss patient results.

The significance of visual neglect for theories of spatial cognition have been indicated by a number of authors (Kinsbourne, 1988; Bisiach and Berti, 1987; Schacter, McAndrews and Moscovitch, 1988; Bisiach and Vallar, 1988). A summary of these, suggest that studies of visual neglect have relevance for the ongoing investigation of theories of mental representation, anosognosia, attention, conscious awareness and implicit knowledge.

The results of chapter five demonstrate the wealth of information that can result from a series of simple investigations of neglect. For too long the subject has been clouded by confusing terminology and anecdotal descriptions. With the development of cognitive neuropsychology there currently exists a conceptual framework to investigate, explain and characterize the condition in a way that is both meaningful and helpful to rehabilitation considerations. For example, recent research using the B.I.T. subtests has shown that, contrary to popular description, the spatial position of the neglect boundary in most patients is not intrinsically linked to their midsaggital plain; (Marshall and Halligan, 1989); that laterality of motor response has a significant effect on visual neglect; (Halligan and Marshall, 1989) and finally that stimulus response incompatability on a computerized version of line bisection precipitates only minimal qualitative or quantitative changes, (Halligan and Marshall, 1989).

APPENDIX 1

Cognitive Awareness Test (A modification of the Galveston Orientation and Amnesia Test (Levin, O'Donnell and Grossman, 1979) Adapted by Keenan E.E. (1980)

Name

Address

Age

D.O.B.

Diagnosis &
Type of Lesion

Marital Status

PENALTY SCORE

(-10) 1. What is your name?

(-1) 2. What age are you?

(-5) 3. Where do you live?

(-4) 4. Where are you now?

(-3) 5. Which town are we in now?

(-1) 6. What day of the week is it now?

(-3) 7. What year is now now?

(-2) 8. What month are we in now?

(-1=±7) 9. What is today's date?

(-5) 10. What is your date of birth?

(-5) 11 What do you normally do during the day?

(-8) 12 Are you single or married?

(-3) 13 Who is the prime minister of England at the moment?

(-4) 14. Who is on the throne of England at the moment?

CAT Score -(Error Points from 100)

Behavioural inattention test scoring sheet

APPENDIX 2

Section A Subject's details

Number

Name

Age

Date of birth

Sex

Occupation

Marital status

Years of education

Estimated IQ

Hand preference Left Right Ambidexterous

Location status Inpatient Outpatient

Present diagnosis

Date of onset

Date of admission

Medication

Previous significant illnesses

Head injury

Operations

Encephalitis

Hypertension

Diabetes

Cardiac disease

Other (specify)

Observations

Language deficits

Sensory deficits

Motor deficits

Visual field deficits

Eye movements

ADL score

Aetiology of lesion

Stroke

Head injury

Neoplasm

Other (specify)

Section B Details of test

Date

Name of examiner

Assessment First Second

Version A B

Comments

Results of test

Conventional score 146

Behavioural score 81

Section C

Conventional sub-test scores

	Scores (maximum indicated in each box)						Total score
1 Line crossing Score the total number of lines crossed in each column (do not include the central column)	6	6	6	6	6	6	36
2 Letter cancellation Score the total number of E's and R's cancelled in each column		10	10	10	10		40
3 Star cancellation Score the total number of small stars cancelled in each column (do not include the two small) stars immediately above the centralising arrow.	8	8	11	11	8	8	54
4 Figure and shape copying (a) Figure copying Score one for each figure drawn complete	Star	1	Cube	1	Daisy	1	3
(b) Shape copying Score one if all the shapes are drawn complete							1
5 Line bisection Score each line according to the amount of deviation shown on the scoring template	Left line	3	Centre line	3	Right line	3	9
6 Representational drawing Score one for each drawing completed	Clock face	1	Man/ woman	1	Butter-fly	1	3

Total conventional test score 146

Section D Behavioural sub-test scores

1 Picture scanning

Scoring is based on the number of omissions per picture according to the table on the right

	Number of omissions in each case			
	0	**1**	**2**	**≥ 3**
Score	3	2	1	0

	Response (tick as each item is identified)				**Number of omissions**	**Score**
Picture one (Meal)	**Version A**					
		Tomato	Cheese	Carrots		
		Celery	Potatoes	Parsley		3
		Lettuce		Sausages		
	Version B					
		Sausages	Potatoes	Lettuce		
		Parsley	Cheese	Celery		
		Carrots		Tomato		
Picture two (Wash basin)	**Version A**					
		Shampoo	Soap	Razor		
		Foam	Overflow	Toothbrush & paste		3
		Tap	Plughole	Tap		
	Version B					
		Soap	Foam	Shampoo		
		Toothpaste	Overflow	Tap & toothbrush		
		Tap	Plughole	Razor		
Picture three (Room)	**Version A**					
		Cabinet	Window	Curtain		
		Curtain	Table	Switch		3
		Locker	Chair	Flowers		
		Flowers		Locker		
		Wheelchair		Stool		
		Basket		Walking frame		
	Version B					
		Cabinet	Window	Curtain		
		Curtain	Table	Switch		
		Locker	Chair	Flowers		
		Flowers		Locker		
		Walking frame		Stool		
		Basket		Wheelchair		
						Total score
						9

2 Telephone dialling

Scoring is based on the number of omissions or errors made in the dialling sequence according to the table on the right

		Number of omissions			
		0	**1**	**2**	**≥ 3**
Score	Telephone number one	3	1	0	0
	Telephone number two	3	2	1	0
	Telephone number three	3	2	1	0

	Response (record the sequence of numbers dialled)	**Number of omissions**	**Score**
Telephone number one			3
Telephone number two			3
Telephone number three			3
			Total score
			9

3 Menu reading

Scoring is based on the number of omissions or incorrectly read items according to the table on the right

	Number of omissions or incorrectly read items					
	0	**1–2**	**3–4**	**5–8**	**9–13**	**≥ 14**
Score	9	7	5	3	1	0

Response (record items as they are identified)	**Number of omissions etc**	**Score**
		9
		Total score
		9

4 Article reading

Scoring is based on the percentage of words omitted wholly or in part in the article according to the table on the right

	Percentage of words omitted					
	0–2%	**3–7%**	**8–15%**	**16–20%**	**21–29%**	**⩾ 30%**
Score	9	7	5	3	1	0

Response (record the total number of words omitted in each column, and the laterality of the errors)

	Column one		Column two		Column three		**Totals and score**	
Version	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**
Number of words	55	53	48	48	48	46	151	147
Number of words read incorrectly								
Percentage of words read incorrectly		%		%		%		%
Laterality of errors	L	R	L	R	L	R		

Total score

9

5 Telling and setting the time

Scoring is based on the number of omissions/substitutions made when telling or setting the time according to the table on the right. In setting the time a misplacement of greater than 4 minutes on either hand of the clock is considered an error.

	Number of omissions in each case			
	0	**1**	**2**	**⩾ 3**
Score	3	2	1	0

Response (record the subject's responses)

	One		Two		Three		**Number of omissions**	**Score**
(a) Digital time telling	**A** 2.25	**B** 3.35	**A** 7.40	**B** 8.40	**A** 11.55	**B** 12.50		3
(b) Analogue time telling	**A** ¼ to 11	**B** ¼ past 11	**A** 10 past 7	**B** 20 past 2	**A** 20 past 1	**B** ¼ to 8		3
(c) Setting the time	**A** 10 past 4	**B** 20 past 7	**A** 10 to 7	**B** 10 past 4	**A** 20 to 3	**B** 10 to 8		3

Total score

9

6 Coin sorting

Scoring is based on the number of omissions or incorrectly identified coins according to the table on the right

	Number of omissions or incorrectly identified coins					
	0	**1–2**	**3–4**	**5–6**	**7–9**	**≥ 10**
Score	9	7	5	3	1	0

Response (tick as each coin is identified)						**Number of incorrect responses**	**Score**
Version A (sequence: 2p, 10p, 50p, 20p, £1, 5p)							
20p	5p	2p	£1	50p	10p		
5p	10p	20p	50p	2p	£1		9
50p	5p	£1	2p	20p	10p		
Version B (sequence: £1, 20p, 50p, 10p, 5p, 2p)							
10p	20p	2p	£1	5p	50p		
£1	2p	50p	20p	10p	5p		
10p	50p	£1	2p	5p	20p		

(£1–Foreign coin, 50p–Half dollar, 20p–Quarter, 10p–Dime, 5p–Nickle, 2p–Penny)

Total score

9

7 Address and sentence copying

Scoring is based on the number of letters omitted from the address or sentence according to the table on the right

	Number of omissions			
	0–1	**2–3**	**4–5**	**≥ 6**
(a) Address score	4	3	2	0
(b) Sentence score	5	4	2	0

Response (record the number of letters omitted)	**Score**
(a) Address	4
A 65 **B** 66	
(b) Sentence	5
A 82 **B** 86	

Total score

9

8 Map navigation

Scoring is based on the number of incorrectly traced segments of each route sequence according to the table on the right

Score	Number of errors: 0	1	2	≥ 3
Route one	3	1	0	0
Route two	3	2	1	0
Route three	3	2	1	0

Response (record the sequence of segments travelled)								Number of errors	Score
Route one									3
Version A	B→C	C→E	E→A	A→B					
Version B	H→G	G→E	E→K	K→H					
Route two									3
Version A	B→E	E→G	G→H	H→E	E→A	A→B			
Version B	H→E	E→A	A→B	B→E	E→G	G→H			
Route three									3
Version A	B→C	C→G	G→H	H→E	E→F	F→A	A→B		
Version B	H→K	K→A	A→B	B→E	E→D	D→G	G→H		
								Total score	9

9 Card sorting

Scoring is based on the number of cards incorrectly identified according to the table on the right

	Number of cards incorrectly identified: 0	1–2	3–4	5–7	≥ 8
Score	9	6	3	1	0

Response (tick as each card is identified)				Number of errors	Score
Version A (sequence: Kings, 6's, Queens, 10's)					
King	6	10	Queen		
6	King	Queen	10		9
10	King	Queen	6		
Queen	10	6	King		
Version B (sequence: Queens, 10's, Kings, 6's)					
Queen	10	6	King		
10	Queen	King	6		
6	Queen	King	10		
King	6	10	Queen		
				Total score	9

Summary of test scores

Summary of conventional test scores

1 Line crossing	36
2 Letter cancellation	40
3 Star cancellation	54
4 Figure and shape copying	4
5 Line bisection	9
6 Representational drawing	3
Total	146

Summary of behavioural test scores

1 Picture scanning	9
2 Telephone dialling	9
3 Menu reading	9
4 Article reading	9
5 Telling and setting the time	9
6 Coin sorting	9
7 Address and sentence copying	9
8 Map navigation	9
9 Card sorting	9
Total	81

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