THE PROGNOSIS OF THE NEGLECT SYNDROME IN ACUTE STROKE.

By SHELDON PAUL STONE B.Sc(Hons), M.B.B.S., M.R.C.P.

171 patients admitted to hospital with an acute stroke were examined after 3-4 years using a standardised battery of tests for neglect. Patients were re-examined at 10 days, 3 weeks, 6 weeks, 3 months and 6 months. Functional recovery was assessed in survivors at 3 and 6 months using the Barthel Index to determine outcome as independent, mildly, moderately or severely disabled.

The incidence and evaluating recovery rates for all components of the syndrome were identified. An overall neglect recovery index was developed. Logistic regression techniques were used to determine the predictors of functional recovery and the severity of visual neglect at 3 and 6 months.

Submitted for the MD thesis (University of London).
Section 1

INTRODUCTION
1.1 SUMMARY

The natural history of the neglect syndrome after acute stroke is not clear. The main reasons for this are that different studies have examined patients at different times post-stroke, using different clinical tests without adequate control data, and often without strict definitions of the various neglect phenomena. The prognostic features in the recovery of patients presenting with visual neglect has been examined in only one study. The design of this study may have lead to under-detection of visual neglect and may have exaggerated the association of neglect with a poor outcome. In addition, by grouping all dependent patients together, irrespective of the degree of dependency, the study may have failed to target the group in greatest need of therapeutic intervention. This thesis aims to re-examine the incidence and speed of recovery of the various features of the neglect syndrome in patients with acute stroke. In particular, it seeks to determine the predictors of the severity of visual neglect and of the level of independence in survivors at 3 months and at 6 months. These predictors may be helpful in selecting patients for trials of treatment of visual neglect.
1.2 THE NEGLECT SYNDROME

1.2.1 Definition

Heilman et al (1985) define the "Neglect syndrome" in patients with a cerebral lesion as failure to orientate, report or respond to behaviourally relevant stimuli on the side opposite their lesion. By definition the neglect syndrome cannot be considered present if the failure to respond can be attributed to primary sensory or motor loss. The neglect syndrome is classically associated with right hemisphere damage (Brain 1941; Haecn 1962) and the most common cause of this in clinical practice is a "stroke".

1.2.2 Symptomatology

Patients with the neglect syndrome due, for example, to a right hemisphere stroke, may not notice people approaching or addressing them from their left-hand side, may fail to wash or dress their left hand side and, when eating, may leave food on the left hand side of their plate. When reading text they may omit material from the left-hand side of the page (Fig 1.1) and, when writing, they may leave an unusually wide margin on the left of the page. In clinical tests such as Line cancellation (Albert 1973) or figure copying (Oxbury et al 1974) they fail to cancel lines on the left half of the page (Fig 1.2) and fail to reproduce details from the left half of their drawings (Fig 1.3). In short they act as though the left sided stimuli were not there (Leicester et al 1969) and seem to neglect the left half of space (Brain 1941). However, neglect is not an all or none phenomenon. It may be present in one clinical test or activity but not in another in individual patients (Leicester et al 1969; Ogden 1985; De Costello + Warrington...
1987; Friedland and Weinstein 1977; Mesulam 1981; Ogden 1985). It can be present in clinical tests but not in activities such as washing, dressing and eating (Battersby et al 1956). In other words, it is behaviourally inconsistent.

1.2.3 Main features of the syndrome: "Neglect phenomena"

The neglect syndrome consists of the following neglect phenomena: visual neglect (or hemi-spatial neglect), hemi-inattention, sensory extinction, allesthesia and hemi-akinesia (Heilman et al 1985).

Patients with visual neglect (or hemispatial neglect) tend to ignore relevant visual stimuli when carrying out tasks or activities on the side opposite their cerebral lesion. Hemi-inattention is similar to and often confused with visual neglect. Some authors refer to the failure to wash and dress the side opposite the cerebral lesion as visual (visuo-spatial or hemi-spatial) neglect (Heilman et al 1985) while others refer to this as (hemi-) inattention (Battersby et al 1956). For the purposes of this study, visual neglect is defined as the patients' failure to make a motor response to visual stimuli on a battery of clinical bedside tests (Stone et al 1987). Hemi-inattention, on the other hand, will be defined in terms of the patients' general spontaneous behaviour, irrespective of modality, in response to environmental stimuli (e.g. people approaching, noises or activity in the ward).

A patient with extinction is able to report a single lateralised sensory (e.g. light touch) or visual stimulus (e.g. confrontation testing of visual fields) but, when both sides are stimulated simultaneously, fails to report the
contralateral stimulus (Critchley 1949; Bender + Farlow 1945). Patients with allesthesia attribute stimulation of the limbs opposite the cerebral lesion to stimulation of those on the same side as the lesion. When requested to move the limb opposite their lesion they move those on the same side as the lesion (Jones 1907). Similarly, when addressed from the side opposite their lesion they turn their head away from the speaker, as if the latter were standing on the side of the lesion (Heilman et al 1985).

Patients with hemi-akinesia or "motor neglect" (Heilman et al 1985) fail to carry out an activity with the contralateral extremity, despite the presence of adequate strength and the absence of sufficient apraxia (Valenstein + Heilman 1981; Laplace + Degos 1983; Watson et al 1981). It should be noted that not all patients show all the neglect phenomena at any one time (Battersby et al 1956; Heilman et al 1985; Mesulam 1981).

1.2.4 Related disorders

Heilman et al (1985) also note that neglect phenomena are often accompanied by what they call "related disorders". These include anosognosia, anosodiaphoria, non-belonging, gaze paresis and visual field defects.

Anosognosia describes the clinical disorder whereby the patient denies or appears unaware of their motor deficit following their stroke. A patient with anosodiaphoria will appear indifferent to their weakness while patients with non-belonging feel that their weakened limb does not belong to them (Babinski 1914; Cutting 1978). A patient with a horizontal conjugate gaze paresis due to a unilateral hemispheric lesion is unable to follow a moving object such
as the examiner's finger as it moves horizontally away from
the side of the lesion.

1.2.5 Causes of neglect

Neglect is usually due to unilateral parietal lobe injury,
(Brain 1941; McFie et al 1950; Haecen 1962; Hier 1983;
Vallar + Perani 1986). The temporo-parieto-occipital junc-
tion is frequently involved, with the inferior parietal
lobule the commonest site of damage (Vallar + Perani 1986;
Bisiach et al 1981). However unilateral lesions at other
sites also cause contralateral neglect :- dorsolateral
frontal lobe (Heilman + Valenstein 1972; Damasio et al
1979; Stein + Volpe 1983; Vallar + Perani 1986); cingulate
cortex (Heilman + Valenstein 1972a; Damasio et al 1979);
thalamus (Watson + Heilman 1979; Watson et al 1981; Vallar
+ Perani 1986); caudate and putamen (Hier 1977; Damasio et
al 1979; Vallar + Perani 1986).

Neglect is classically associated with damage to the right
hemisphere (Brain 1941; McFie et al 1950). Haecen (1962)
found that it was rare in patients with a left hemisphere
lesion (four out of two hundred and six patients) compared
to fifty one out of one hundred and fifty one patients with
a right hemisphere lesion. Similarly, a study of one
hundred patients with an acute stroke reported neglect in
50% of those with right hemisphere damage but could not
find it in any patient with a left hemisphere stroke
(Cutting 1978). Other studies have confirmed the associa-
tion with right hemisphere stroke (Oxbury et al 1974; Denes
et al 1982; Fullerton et al 1986). Some studies have found
the incidence of contralateral neglect to be the same after
right or left brain damage (Albert 1973; Chain et al 1973;
Ogden 1985; Gainotti et al 1986) but that it is more severe after right brain damage (Albert 1973; Chain et al 1973; Ogden 1985). Some studies have suggested that there are qualitative differences in the type of neglect resulting from left or right hemisphere lesions (Leicester et al 1969; Gainotti + Tiacci 1972; Gainotti et al 1986).

1.2.6 What is the underlying mechanism of neglect?

There are two main theories which seek to explain neglect. These are (1) deficits in the "attention/arousal" or "intention/activation" systems (Watson et al 1973; 1974; 1981; Watson + Heilman 1979; Heilman + Valenstein 1980; Heilman + al 1985) (2) faulty internal spatial representation of events in the individual's environment or extrapersonal space (Bisiach + Luzzati 1978; Bisiach + al 1981). A detailed review of these theories is beyond the scope of this study but a general overview is presented.

(1) Deficits in Attention-Arousal and Intention-Activation

"Attention" is the conceptual mental process which enables an individual to attend to and focus on behaviourally relevant environmental stimuli and ignore distracting and irrelevant aspects (Mesulam 1983). Once the importance of a stimulus has been determined, the subject's response can be thought of as engaging an "intentional" component and an "activation" component necessary for the response (Watson et al 1981). It is proposed that deficits in either the system mediating attention to sensory stimuli or in the system controlling the "intentional" response may result in neglect.

Evidence from clinical studies, animal experiments, single cell recording and neuroanatomical studies reviewed else-
where (Watson et al 1981; Heilman et al 1985; Mesulam 1983) suggests attention to contralateral sensory stimuli is controlled by the inferior parietal lobule (IPL). This is the site most commonly damaged in patients with neglect (see above). It receives highly integrated sensory information from association cortex and its function is regulated by input from cingulate cortex and the reticular formation (Fig 1.4). The main output from the IPL is to the Frontal Eye Field (FEF). This area appears to mediate intention to respond to contralateral stimuli. The IPL also directs its output to the corpus striatum and superior colliculi, areas which, together with the FEF, are important in visual scanning, orienting and exploratory behaviour of the head and eyes, and in reaching movements of the limbs. They thus constitute a motor mechanism for exploring contralateral space in response to significant stimuli. The function of the FEF is regulated by input from cingulate cortex, thalamus and reticular formation (Fig 1.4).

It is proposed that unilateral damage to the neuronal pathways subserving "attention" or "intention" results in contralateral neglect. The complexity of the neural pathways may explain why neglect can be caused by lesions in different areas. The exact clinical manifestations of neglect may depend on the precise areas or pathways damaged.

(2) Internal representation hypothesis

Bisiach and colleagues have shown that patients with neglect of left sided stimuli due to a right hemisphere lesion fail to describe the left half of recollected images (Bisiach + Luzzatti 1978; Bisiach et al 1981). Their pa-
Patients were required to describe from memory a well known scene (such as a square in their native city of Milan) viewed from two different perspectives, one facing the cathedral and the other facing away from the cathedral. Whatever their orientation, they omitted the left half of the scene in each view. It was suggested that this was because left space is represented in the right hemisphere and right space in the left hemisphere. In other words, there appears to be an "internal visual representation" of environmental space topographically split between the two hemispheres. This theory proposes that the association cortex of the parieto-temporal-occipital junction might be the locus of a "visuo-spatial scratch pad" on which this spatial information is represented (Bisiach et al 1981).

Mesulam (1981, 1983) has brought this theory together with that of deficits in the "attention arousal" and "intention-activation" systems. He suggests that the "scratch pad" or "internal sensory representation" might correspond to the IPL and the association cortex that connects to it. He also suggests that there is a similar "internal motor representation" of space topographically split between the hemispheres which corresponds to the FEF. In addition he proposes that there is an "internal motivational representation" of environmental space, in terms of interest and significance, split between the two hemispheres and which corresponds to the cingulate cortex. Each representation is thought to respond mainly to contralateral stimuli, although the right hemisphere is dominant (see above). The three representations are closely interrelated and interconnected and their function is partly regulated by input from the reticular formation (Fig 1.4).
1.2.7 Right hemispheric specialization

Neurophysiological studies suggest that the right hemisphere is dominant for "attention". It appears that each hemisphere has the capacity to attend to contralateral visual stimuli but that the right hemisphere is better able to attend to stimuli from both sides and is in fact dominant for this function (Heilman + Van Den Abell 1980; Kushner et al 1988). Further evidence suggests that the right hemisphere is also dominant for "intention" (Heilman + Van Den Abell 1979; Heilman + Valenstein 1985a; Howes + Boller 1975). This dominance of the right hemisphere for these two functions would explain why most studies find neglect is more common and severe in patients with a right hemisphere lesion. The hypothesis can be put forward that when the left hemisphere is damaged, the right "takes over" its attentional and intentional functions. When the right hemisphere is damaged however, the left is less able to "take over" these functions, because of the specialized role of the right hemisphere in the spatial distribution of sensory attention to environmental space.

1.3 WHY IS NEGLECT IMPORTANT IN STROKE?

1.3.1 Poor recovery

Neglect appears to be associated with a poor recovery from stroke. Early studies found that disorders of perception, including "motor neglect" (Adams + Hurvitz 1963), "spatial judgement" (Gregory + Aitken 1971), "unilateral spatial neglect" (Isaacs + Marks 1973) or "neglect" (Feigenson et al 1975) were associated with poor or slow recovery of independence in self-care. Recent studies have isolated
visual neglect as a major predictor of poor outcome (Kinsella + Ford 1980; Denes et al 1982; Fullerton et al 1986), although the influence of the other features of the neglect syndrome is unclear. It is therefore, on visual neglect that the current study concentrates.

Patients with visual neglect find it difficult to benefit from remedial therapy, despite months of conventional physiotherapy and occupational therapy. A study from one rehabilitation unit suggested that visual neglect interfered in particular with "the complex multifaceted activities of daily living" essential to independence in self-care e.g. dressing, cooking and washing (Kinsella + Ford 1980). Such patients have also been reported to be more prone to accidents in both the hospital and home (Diller + Weinburg 1970) and to experience difficulties reading and driving (Lorenze + Cancro 1962).

Visual neglect was confirmed as a poor predictor of outcome in another study from another rehabilitation centre (Denes et al 1982) which found that the presence of neglect was the only neurological or cognitive deficit that discriminated between patients making a good or bad recovery. Studies from rehabilitation units, though, concern a population which is unrepresentative of the whole stroke population. Units usually operate some sort of triage either selecting patients in the "middle-band" of disability (Garraway + Akhtar 1981) or including younger patients who are severely damaged but for whom a unit represents the only chance of a better functional recovery. Nonetheless, a large study of consecutive admissions to district general hospitals found that the presence and severity of visual
neglect was related both to survival and to the level of
dependence in self-care at six months post-stroke (Fuller­
ton et al 1986).

1.3.2 Treatment of visual neglect

Patients with visual neglect take up considerable rehabil­
itation time and resources. Intensive treatment of neglect,
focuses on teaching patients to become aware of their
perceptual problem and training them to scan towards the
neglected side (Diller + Weinburg 1977). Randomized con­
trolled trials of such treatment given for an average of an
hour a day for 4 to 7 weeks, showed that this helped reduce
visual neglect on a cancellation task and other tasks
similar to those performed in the scanning training (eg
reading, writing and doing arithmetical calculations
in self-care was no better however, in treated than in
control patients and the controls later made such sponta­
neous improvement in visual neglect that there was no
difference between the control and treated groups at a
later stage (Gordon et al 1985). Taken together all the
three studies suggest that specific task-related treatment
of visual neglect can lead to more rapid improvement in
those tasks. The theory was put forward that application
of the principles of visual scanning training to specific
activities of daily living disrupted by visual neglect
would lead to faster recovery of independence in self-care
(Weinburg et al 1979). Single case studies using computer
based visual scanning training support this suggestion but
a subsequent randomized controlled trial failed to show any
The relevance of these studies to the treatment of the acute stroke patient is not clear, for the following reasons. First, the patients in these trials were recruited from rehabilitation units and so are unrepresentative of the acute hospital-based stroke population. Second, patients were entered into the trials at a mean time post-stroke of 6 weeks (Weinburg et al. 1979), 10 weeks (Weinburg et al. 1977) and 14 weeks (Gordon et al. 1985) and were not matched for time post-stroke. In only one trial (Weinburg et al. 1977), was an attempt made to match patients for the severity of their perceptual deficit, but this was according to the presence or absence of a hemianopia rather than to the severity of neglect itself. A more recent trial (Robertson et al. 1990) matched for severity but included patients with head injury as well as those with stroke.

Clinical experience suggests that some stroke patients presenting with visual neglect make a good recovery without specialized treatment. If visual neglect is amenable to intensive treatment, it is essential to know which are the features that predict good or bad recovery of independence. Future trials can then randomize patients into treatment groups matched according to their prognosis. If such trials show the benefit of treatment, clinicians could then select patients for treatment as soon as possible after stroke. However, the prognosis of visual neglect and indeed the natural history of the neglect syndrome itself after stroke is not well studied.

1.4 WHY IS THE NATURAL HISTORY OF THE NEGLECT SYNDROME UNKNOWN?

Most work on the neglect syndrome in stroke has concentrated on visual neglect. The incidence and rate of resolu-
tion of the other neglect phenomena and related disorders has been little studied and patients with left hemishere stroke have been virtually excluded from consideration. Even for visual neglect, reports of its incidence vary widely, 33-85% for right hemisphere and 0-24% for left hemisphere stroke stroke (Oxbury et al 1974; Cutting 1978; Hier et al 1983; Fullerton et al 1986; Vallar + Perani 1986). Reports of its recovery vary even more widely. With regard to visual neglect such variation is due to three things. First, several studies use the various neglect phenomena interchangeably. Second, different studies examine patients at different times post-stroke. Third, different tests of visual neglect are used in separate studies, often without sufficient age matched control data.

1.4.1 Definitions of neglect phenomena

The interchangeable use of the terms "neglect", "inattention" and "extinction" throughout the literature is confusing for the clinician and research worker alike (Crithchley 1949; Heilman + Valenstein 1972; Halsband et al 1985; Wade et al 1988; Rout 1978; Weinburg et al 1977). These phenomena are by definition quite separate (Hier et al 1983; Schwartz et al 1979) and can dissociate clinically. Hier et al's study (1983) of patients with an acute right hemisphere stroke, however, shows that these three phenomena are often associated. The confusion due to lack of precision in using these terms is compounded by the use of additional names such as "visuo-spatial agnosia" (McFie et al 1950), "uni-lateral spatial agnosia" (Battersby et al 1956), "hemi-spatial agnosia" (Heilman + Valenstein 1972), "unilateral visual agnosia" (Isaacs + Marks 1973), "uni-
lateral spatial neglect" (Denes et al 1982; Halsband et al 1985; Gainotti et al 1986), "hemi-spatial neglect" (Heilman et al 1985), "visual hemi neglect " (Ogden 1985) and "perceptual neglect" (Fullerton et al 1986).

1.4.2 Different examination times post-stroke

Different studies have examined patients at different times post-stroke. Thus estimates of the incidence of visual neglect vary widely:-33-85% in right hemisphere and 0-24% in left hemisphere stroke (Section 1.4). Those studies which first examined patients at one or two months post-stroke (Denes et al 1982; Oxbury et al 1974) excluded patients whose visual neglect has resolved spontaneously. Studies based at rehabilitation centres (Denes et al 1982; Kinsella + Ford 1980) select patients who are unrepresentative of the acute hospital based stroke population (Section 1.3.1). Those studies which examined patients between two and seven days post-stroke (Cutting 1978; Fullerton et al 1986; Hier et al 1983; Vallar Perani 1986; Wade et al 1988) recruited patients more representative of the hospital-based stroke population. They report the incidence of visual neglect in patients with right hemisphere stroke to be 85% (Hier et al 1983), 50% (Cutting 1978), 49% (Fullerton et al 1986), and 43% (Vallar + Perani 1986). For patients with a left hemisphere stroke the incidence appears to be lower :- 25% (Fullerton et al 1986), and 0% (Cutting 1978).

Estimates of the speed of recovery of visual neglect in acute right hemisphere stroke also vary:- almost 100% at 10 weeks (Wade et al 1988), 50% at 2 months (Hier et al 1983a). However, the former study did not differentiate clearly between right and left hemisphere stroke and did
not give a clear figure for the overall incidence of visual neglect, owing to methodological problems. The second study concerned an atypical cross section of the hospital based acute stroke population for it excluded those with a lacunar infarct or a normal CT scan and those who were obtunded. Studies from rehabilitation units (Kinsella + Ford 1980; Denes et al 1982) or other centres which recruited patients a month post-stroke (Campbell + Oxbury 1976) exclude those patients whose visual neglect has resolved spontaneously by then and their figures on the rate of recovery have to be interpreted in that light: 0% at 4 months (Kinsella + Ford 1980), 0% at 6 months (Denes et al 1982) and 12.5% at 6 months (Campbell + Oxbury 1976) in right hemisphere stroke; 60% at 6 months in left hemisphere stroke (Denes et al 1982). No study has clearly examined the resolution of visual neglect in patients with an acute left hemisphere stroke.

1.4.3 Use of different tests of visual neglect

There is no single widely accepted standard test battery able to detect, measure and monitor visual neglect. There are over 50 bed-side tests of visual neglect available most of which comprise varieties of cancellation and drawing tasks. Only eight tests appear in more than 5 of over 60 papers in which patients have been assessed for visual neglect using a clinical bed-side test. The tests most commonly used by clinicians are probably line cancellation and a drawing task (Fullerton et al 1986; Cutting 1978; Andrews et al 1980).

All of these tests are assumed to measure the same neuro-
psychological variable. However, visual neglect may not be present in all tests at any one time (Leicester et al 1969). Of 45 patients with right brain damage, 8 (18%) of those examined showed visual neglect on filling in the numbers on a drawing of a clockface, 13 (29%) showed neglect on line cancellation and 17 (38%) on copying a cube (Ogden 1985). A recent study found dissociations between personal and extra-personal neglect and suggested that different tests assess different underlying mechanisms of neglect (Bisiach et al 1986). A similar conclusion was reached in another study that reported a patient, with tumour in both hemispheres, who consistently showed left visual neglect on reading and right visual neglect on line bisection (DeCastello + Warrington 1987). Visual neglect may therefore be "task specific" (De Castello + Warrington 1987). The current practice of clinicians and research workers of assessing visual neglect by one or two tests chosen often on the basis of their simplicity is therefore unsatisfactory and, as Ogden (1985) has pointed out, might lead to an under-estimate of the incidence of visual neglect. This may be especially true of visual neglect in left hemisphere stroke. Indeed, the presence of visual neglect may be masked by aphasia in patients with left hemisphere lesions (Brain 1945; Battersby et al 1956; Wade et al 1988) although others have not found this to be so (Albert 1973; Schenkenberg et al 1980; Ogden 1985; Wilson et al 1987).

Furthermore, although most studies consider that the presence of visual neglect on just one test is sufficient evidence (Ogden 1985; Halsband et al 1985), a few studies
consider that it must appear on at least two tests before it can be considered to be unequivocally present (Battersby et al 1956; Schenkenberg et al 1980). There is, similarly, no standard method of scoring visual neglect although various methods have been tried (Schenkenberg et al 1980; Ogden 1985; Fullerton et al 1986; Wade et al 1988; Bisiach et al 1981; Denes et al 1982; Gainotti et al 1986). Interpretation of the common drawing tasks may be subjective and rendered difficult by structural disorganization and other problems of perception or praxis (Mcfie et al 1950; Battersby et al 1956; Andrews et al 1980). The relevance of the more commonly used clinical tests to activities of daily living is uncertain (Battersby et al 1956 Weinburg et al 1977). Their predictive value with regard to recovery from stroke is unknown, except for line cancellation (Fullerton et al 1986).

A test battery, the **Behavioural Inattention Test (BIT)** consisting of tasks which simulate everyday activities (e.g. eating a meal, selecting coins, reading a paper) has recently been introduced (Wilson et al 1987;1987a). This was developed and validated with patients who were, on average, 2 months post-stroke. The BIT has been shortened and modified for use with patients a few days after their stroke (Stone et al 1987) but not yet fully validated. Its predictive value is unknown.

1.4.4 **Insufficient control data**

A further difficulty in standardizing assessment of visual neglect is that there is little in the way of age related control data (Wade et al 1988). Given that nearly half of all those suffering an acute stroke are over 75
years of age (Bamford et al 1988) and that age-related neurological (Howell 1949; Jenkyn et al 1985) and cognitive changes (Heron + Chown 1967; Schaiae et al 1983) are common, it is necessary to know how the normal elderly perform on tests of visual neglect in order to interpret correctly the findings observed in a stroke population of a similar age.

Few studies have adequately described visuo-spatial function in the elderly (Huppert 1987). A study of perceptual function in a community sample of elderly subjects found that tests commonly used to detect visuo-spatial neglect such as drawing a clockface or a human figure, and the Posting Box (Isaacs + Marks 1973) may be performed poorly or with difficulty in 47%, 18%, and 59% of elderly subjects respectively (Eccles 1988). However the relationship between such visuo-spatial impairments in normal elderly and the more florid examples of visual neglect in patients with stroke remains unclear.

Three studies of stroke patients with visual neglect have noted that elderly controls frequently made a small number of omissions on various neglect tests (Wilson et al 1987, Wade et al 1988, Stone et al 1987). These studies differed in the choice of control subjects, the method used to measure performance and the selection of cut-off points to distinguish between visuo-spatial impairment and visual neglect. Only one of these studies used active independent controls the same age as a typical stroke population (Wade et al 1988); the others used health professionals and relatives (Wilson et al 1987), or general medical in-patients (Stone et al 1987) whose performance may have been influenced by the general effects of unrecognized depres-
sion or recent ill-health.

The differences in examination times, patient populations, and definitions and tests used to detect visual neglect have combined to explain why the natural history of visual neglect in acute stroke patients continues to remain unclear.

1.5 THE PROGNOSIS OF VISUAL NEGLECT IN ACUTE STROKE

It is known from general studies of stroke that most deaths occur within the first 3-4 weeks (Aho et al 1980; Wade + Hewer 1985a) and that the majority of the remaining patients make most of their recovery within the first 3 months (Skilbeck et al 1983), with a relatively rapid phase of recovery in the first 10 days (Wade et al 1985a). Up to 30% may make considerable gains in specified areas of dysfunction between 3 and 6 months (Andrews et al 1981), although not all studies report this late improvement (Allen 1984).

There has been no detailed study of the recovery of all components of the neglect syndrome in patients with right and left hemisphere stroke. In particular, no study has attempted to predict the severity of visual neglect at 3 months and at 6 months. Such a study might be useful in choosing comparable patients for trials of treatment of visual neglect.

Studies predicting the functional outcome of stroke have usually categorized it as "independent", "dependent" or "dead", sometimes amalgamating the latter two into one group (Prescott et al 1982; Allen 1984; Fullerton et al 1988). Statistical modelling techniques are then used to
relate the probability of membership of any one group at, say, 6 months, to the clinical variables observed at in individual patients at presentation.

Such categorization of outcome may have diminished the usefulness of these studies in that the cost of stroke relates mainly to the loss of independence in self-care (Henley et al 1985), rather than to mortality (which occurs early and predictors of which are well known) (Oxbury et al 1975). Moreover, grouping all dependent patients together ignores the implications that the degree of dependency has for service provision. Indeed, careful reading of the various assessments of dependency reveals, for example, that one study regards as "independent" those patients who need "supervision" in self-care (Prescott et al 1982). Another includes in the "independent" group those who require assistance in one of dressing, washing or continence (Andrews et al 1981). A third study defined as "independent" those who would be able to live at home "with the help of social services" (Allen 1984), a definition that may well depend as much on the strength and flexibility of local services, and the presence of a main carer as on the patient's level of dependence. A prognostic study that used a standardized assessment of independence in self-care and offered more than one category of dependency, thus enabling early identification of the more dependent survivors, might be more useful and open the way to development of new treatment to improve outcome.

1.5.1 Previous prognostic studies

An attempt has already been made to predict recovery of patients with visual neglect in acute stroke. Fullerton et al (1988) examined patients at 1–2 days post-stroke after
admission to hospital and showed that the initial severity of visual neglect was predictive of outcome. Outcome was categorized as "recovered", "independent", "dependent" or "dead". Equations were produced estimating the probability of independence. These could be used to allocate patients to trials of treatment. However, their study may have omitted a significant proportion of patients with visual neglect by only using one test of neglect (Ogden 1985). It may have exaggerated the association of visual neglect with a poor outcome by giving the mean neglect score to patients unassessable for visual neglect, who constituted a third of their population and of whom over 80% died. Moreover, the assessment of self-care used in the study was unstandardized and appeared to exclude washing and dressing.

1.6 THE AIMS OF THIS STUDY
The aims of this study are as follows.
(1) To standardize and validate a battery to assess visual neglect other neglect phenomena, and related disorders in acute stroke.
(2) To report the incidence of visual neglect, other neglect phenomena and related disorders in patients with an acute stroke.
(3) To report on the recovery of the same.
(4) To predict the severity of visual neglect and the degree of independence in self-care in surviving patients at 3 months and at 6 months post-stroke.
Driver killed, 30 hurt as packed train rams a loco

A Driver died trapped in his cab in a horror train smash last night.

Thirty others were hurt as a passenger train rammed two coupled locomotives on a track snaking across the Derbyshire Pennines.

The injured — three of them seriously — were rushed to hospital in a fleet of ambulances.

Last night emergency workers were trying to free the body of the driver from the passenger train which was derailed.

More than 100 people were on the four-coach diesel when it crashed near the village of Chinley near Buxton.

The alarm was raised by a young motor-cyclist who saw the crash and ran to a nearby school for help.

Two nurses on board the train

Figure 1.1 Neglect on reading (patient omits underlined text and starts on right hand side {arrow})

Figure 1.2 Neglect on line cancellation with right hand start (arrow).
Figure 1.3  Neglect on copying figures.
Figure 1.4 The "attention-arousal" and "intention-activation" systems. (modified from Mesulam 1983)
Section 2

METHODOLOGY
2.1 SUMMARY

The present study overcame some of the methodological problems of previous investigations in a number of ways. All patients were entered at 2-3 days post stroke; set definitions of neglect phenomena and related disorders were used; a battery of 7 tests, standardized with age matched control data, was used to increase the detection of patients with visual neglect; only outcome in survivors was assessed, using a standard measure of independence of self-care, and dependence was categorized according to severity; patients unassessable for visual neglect were not considered to have the mean amount of neglect.

One hundred and seventy one consecutive patients admitted to hospital with an acute hemispheric first stroke were entered in the study. Each received neurological and neglect-related assessments at 2-3 days post-stroke. Forty seven independent age-matched controls were also assessed and the findings used to standardize the assessment of neglect phenomena and related disorders.

The incidence of neglect phenomena and related disorders was recorded. Patients presenting with visual neglect at 2-3 days were followed up at 10 days, 3 weeks, 6 weeks, 3 months and 6 months post-stroke. The cumulative recovery rates of all neglect phenomena and related disorders were calculated for surviving patients.

A measure of severity of visual neglect was devised and used, together with the other clinical assessments, to predict the severity of visual neglect and 3 months and at 6 months, using stepwise regression analysis.

Independence in self-care in surviving patients at 3 months and at 6 months was categorized as "independent",

27
"mildly", "moderately" and "severely" dependent according to performance on the Barthel Index. Logistic regression analysis was then used to identify the important clinical variables observed at 2-3 days that predicted outcome in patients that could be assessed for visual neglect at 2-3 days post-stroke.
2.2 INTRODUCTION

In order to achieve the aims of the study, and to avoid the methodological problems outlined above, stroke patients were recruited at 2-3 days post-stroke, standard definitions of neglect phenomena and related disorders were adopted and outcome in survivors was defined using a standard assessment of independence in self-care. The study proceeded in six stages (Figure 2.1).

Stage A: A battery of tests for visual neglect and clinical assessments of neglect phenomena and related disorders were standardized on a group of acute stroke patients and age matched controls.

Stage B: These assessments were used to report the incidence of neglect phenomena and related disorders at 2-3 days post-stroke.

Stage C: Patients from this group, presenting with visual neglect were followed for up to six months to report the frequency and rate of resolution of neglect phenomena and related disorders.

Stage D: An overall measure of visual neglect was developed that expressed performance on the visual neglect battery as a single percentage figure.

Stage E: Statistical modelling techniques were used to determine which neglect phenomena and related disorders predicted the severity of visual neglect at 3 and at 6 months post-stroke.

Stage F: Similar statistical methods were used to determine which neurological features predicted the degree of independence at 3 months and at 6 months in surviving patients.
171 patients with an acute hemispheric stroke

Examined at 2-3 days

47 age match controls

Subsample first 44 patients with acute stroke

36 patients too ill to be assessed

A. Standardization of neglect battery

B. Incidence neglect phenomena and related disorders

98 patients with visual neglect at 2-3 days

Follow up at 10 days, 3 weeks, 6 weeks, 3 months, 6 months

Exclude deaths, 2nd stroke, refusals

37 patients with no visual neglect

68 patients with visual neglect alive at least 3 months

C. Recovery of neglect phenomena and related disorders

D. Development overall measure visual neglect

Assess independence self care at 3 months and 6 months

Stepwise regression analysis

E. Prediction severity visual neglect at 3 & 6 months (68 patients)

F. Prediction independence in self care at 3 & 6 months (89 patients)

Figure 2.1 Summary of research design: Stages A-F.

30
2.3 RECRUITMENT OF PATIENTS

2.3.1 Stroke patients

One hundred and seventy one consecutive patients (mean age 72.37 years, s.d. 12.11, range 28-100 years) admitted to St. Bartholomews and Homerton hospitals, in the City and Hackney Health District, with an acute hemispheric first stroke were recruited to the study. All patients were admitted as emergencies under general physicians, except for one admitted under the geriatricians, and two admitted under the neurosurgeons.

Patients were registered for the study by daily contact with the previous day's admitting medical team and were first assessed for the study at 2-3 days post-stroke. A stroke was defined as a focal neurological deficit lasting at least 24 hours and of vascular origin (modified World Health Organization definition, Aho et al 1980). Patten's criteria were used to define a hemispheric stroke (Patten 1978). Patients with subarachnoid haemorrhage were excluded from the study, as were patients whose stroke occurred more than 3 days prior to assessment.

Sixty nine of the patients (40%) had a right hemisphere and 102 (60%) had a left hemisphere stroke. Thirteen patients (8%) had lacunar strokes, as defined by Fisher's criteria (Fisher 1982), 11 of the pure motor hemiparesis variety and 2 of the sensorimotor type. Ninety one patients (53%) were female.

127 patients received a CT brain scan at 3-5 days, and 44 were assessed by the Guy's Hospital diagnostic score (Allen 1983) to determine whether the stroke was haemorrhagic (14 patients) or ischaemic (157 patients), according to stand-
ard cut-off points (Sandercock et al 1986). Of those who were scanned 48 (38%) had no visible lesion, 37 (29%) had cortical lesions, 20 (16%) had deep lesions and 22 (17%) had both. The 30 day case fatality rate was 27%.

2.3.2 Controls

Fourty seven controls (mean age 71.6 years, s.d. 12.77, range 34-93) were recruited. Each was resident in the City and Hackney Health District, had no history of neurological disease, and was independent in self-care. The sample was matched for age in 10 year cohorts with the first 160 patients in the acute stroke population (mean age 72.12 years, s.d. 12.61, range 28-100). Controls were recruited from amongst those patients in general good health admitted for elective procedures or investigations (e.g. joint replacements, cystoscopy, lithotripsy) to the urological and orthopaedic wards of St. Bartholemews hospital. Patients with a known neurological or psychiatric history or with a history of diseases known to have neurological manifestations (e.g. adenocarcinoma of the kidney, carcinoma of the bowel or lung) were excluded. Those at risk of small vessel disease due to diabetes or hypertension and were included as were those with cardiovascular disease for these were common disorders within the general and stroke populations.

2.4 DEFINITION AND ASSESSMENT OF NEGLECT PHENOMENA, RELATED DISORDERS

All neglect phenomena and related disorders were defined as in Sections 1.1.3-4. They were assessed using methods that were as closely related to standard clinical practice as possible. This way it was hoped that other clinicians
would be more likely to incorporate into their routine assessment of stroke patients any tests this study found to be of prognostic value. Although individual physicians can vary greatly in their standard neurological examination of patients, the difficulties involved in introducing new examination techniques has been amply demonstrated elsewhere (Garraway et al 1976). Simple and short assessments were preferred in order to avoid tiring the patients when acutely ill and in order to secure their co-operation with the frequent follow-up examinations.

2.4.1 Visual neglect

Visual neglect was assessed by the version of the Behavioral Inattention Test (Wilson et al 1987) that had been modified and shortened for use on patients within a few days of their stroke (Stone et al 1987). This consists of eight simple and sensitive tests. Four of the tests simulate everyday activities and are intended to help therapists select areas for treatment (eating a meal, reading a menu, reading a newspaper article and selecting coins). Three of the tests are paper and pencil tasks, two of which are used frequently by clinicians (line cancellation and figure copying). The other (star cancellation) was said to be particularly sensitive to visual neglect (P.Halligan--personal communication). The final test (Pointing to objects in a room) was included because, if found to have particular diagnostic or prognostic value, it would provide clinicians with a simple bedside test that requires no additional equipment.

All tests were presented in front of the subject's midline with the examiner seated directly opposite. No time limit was imposed. After a patient had completed a test
they were asked to check that they were finished. Some patients were unable to attempt tests due to language difficulties, the level of consciousness, fatigue, confusion, perseveration, poor eyesight, or paralysis of the dominant hand. The tests were administered in the following order.

(a) Pointing to objects located about the ward (Fig 2.2)

The patient was asked to point to and/or name all the objects that they could see on both sides scattered about their hospital room or ward (Patterson + Zangwill 1944). The examiner always stood directly behind the patient and made sure that there was an approximately equal distribution of objects located on the left and the right hand sides.

Using a photocopy of a closed semicircle, with the position of the patient's head marked at the centre of the base and with marks on the circumference at 45, 90 and 135 degrees, the examiner noted which objects were situated at 0, 45, 90, 135 and 180 degrees and used these as landmarks. When the patient pointed to or named objects in the room, the examiner marked their position relative to the landmarks. When the patient finished pointing, the examiner measured the approximate number of degrees omitted on the circumference of the semi-circle.

(b) Food on a plate (Wilson et al 1987) (Fig 2.3)

A life size colour photograph of a plate containing 8 items of food was placed in front of the patient who was asked to point or name each item of food. Where necessary the examiner demonstrated what was required. The total number of items omitted was recorded. Correct identifica-
tion of the food items was not required.

(c) Reading a menu (Wilson et al 1987) (Fig 2.4)

The patient was asked to open and read aloud from a menu that listed 12 items of food on the left page and 12 on the right. The number of words omitted on the left, right, and in total was recorded. Aphasics were allowed to point to words. If the patient did not begin reading in the first left hand column, this was noted as a sign of left visual neglect (Mesulam 1983; Holmes 1918) and referred to as a Right Hand Start (cf. arrow on Fig 2.4).

(d) Reading a newspaper article (adapted from Wilson et al 1987) (fig 2.5)

Patients were asked to read the "newspaper" extract aloud. The examiner marked any words omitted on a photocopy. Some patients were unable to read small print and in order to control for the effects of poor eyesight the number of words omitted from the Headlines (10 words in bold print), the Paragraph (5 words in smaller, finer capitals) and the Article (117 words in small newsprint) were recorded separately. If the patient began reading anywhere but at the top left hand corner a Right Hand Start was recorded. This test was not given to patients with a left hemisphere stroke because in the pilot study that modified the BIT (Stone et al 1987) it was found that few of these patients were able to read well enough to attempt this test and that few of those that could demonstrated neglect on this test.

(e) Line cancellation (adapted from Wilson et al 1987; Albert 1973) (Fig 2.6)

The patient was presented with a sheet of paper on which 40 one inch lines had been marked in 7 columns. The patient
was required to cross out all the lines on the page after the examiner had demonstrated what was required by crossing out the 4 lines in the centre of the page. The place where the patient started to cancel the lines was noted because initiation of tasks on the right hand side is a fundamental feature of patients with visual neglect due to a right hemisphere lesion (Chedru et al 1973; Weinburg et al 1977; Mesulam 1985). A **Right Hand Start** was considered present if the first lines to be cancelled were in the 6th or 7th column located on the right side of the page (cf. arrow in Fig 2.6). The number of lines omitted on the right, the left and in total was recorded. If the patient's dominant hand was too weak to cross out lines and they were unable to use the other hand, they were allowed to point to each line, which the examiner would then cross out.

(f) **Star cancellation** (Wilson et al 1987) (Fig 2.7)

The patient was presented with 56 small stars mixed up with many large stars and capital letters. They were instructed to cross out the small stars after the examiner had demonstrated this by crossing out two of the centrally positioned stars. The number of small stars omitted on the left, the right and in total was recorded. A **Right Hand Start** was considered present if the patient began cancelling stars in the 5th or 6th column located on the right side of the page. Where their hemiparesis made it difficult to cross out stars, they were again allowed to point to them.

(g) **Coin selection** (Wilson et al 1987) (Fig 2.8)

A large card (32x21cm) with three coins of each of the following values (2p, 5p, 10p, 20p, 50p, £1) was presented
to the patient with the three five pence coins on the side opposite their cerebral lesion. The patient was asked to point to each of the coins called out in turn. The examiner marked the results on a photocopy of the test card. The number of omissions on the left, right and in total was recorded. Occasionally the examiner would place a loose coin of the value required in front of the patient in order to help an aphasic patient understand which coin they were being asked to find. An alternative strategy was to write the value of the coin requested on a piece of paper.

(h) Figure copying from the left (Wilson et al 1987) (Fig 2.9)

The patient was presented with a piece of paper divided into six squares. In the 3 squares on the left were figures of a four pointed star (Oxbury et al 1974), a cube (Gainotti et al 1972) and a daisy (Gregory + Aitken 1971). These were to be copied into the empty 3 spaces on the right side. The number of major omissions (e.g. half a cube) and the number of minor omissions (e.g. a leaf) was recorded for each object. Each major omission was given an arbitrary score of 2 and each minor omission a score of 1 (Ogden 1985). Other difficulties in spatial exploration on construction e.g. closing figures in a rough undifferentiated manner, were not regarded as a sign of visual neglect (Gainotti + al 1972).

This test was not given to those patients with a right hemisphere stroke as the pilot study that modified the BIT (Stone et al 1987) indicated that this test was less sensitive to neglect than many other tests in the battery. However it was found to be useful for those patients with LH stroke. Those patients with neglect often ignored the
empty right spaces and "crowded" their copies into the left hand side of the page. This crowding had also been observed in patients with a right hemisphere lesion when they were presented with figures on the right to be copied into spaces on the left.

2.4.2 Operational definition of visual neglect

Control results for these tests were used to establish a normal range of performance for each test. Visual neglect was considered to be present in a stroke patient if they made more omissions on any one test than the independent age-matched controls.

2.4.3 Scoring the tests

The total number of omissions made on Lines, Stars, Meal, Menu and Coins were expressed as a percentage of the total number of items in each test (Fullerton et al 1986). The number of degrees omitted on Pointing was expressed as a percentage of 180 degrees. The number of words omitted in Headlines was expressed as a percentage out of 10, the number omitted on Paragraph as a percentage of 5, and the number in the Article was expressed as a percentage of 117. The score for Figure Copying was converted into a percentage (of a maximum score of 6).

The percentage score on each test was then graded as follows: Grade 0: no neglect; Grade 1: up to 20% of items omitted on the test; Grade 2: 21-40% items omitted; Grade 3: 41-60%; Grade 4: 61-80%; Grade 5: 81-100%.

Right Hand Start and crowding were both considered to be qualitative rather than quantitative measures of neglect and were therefore noted but not scored.
2.4.4 Hemi-inattention

There is no standard method of assessing hemi-inattention (hemi-inattention) given in standard textbooks of clinical or neurological examination (Swash + Mason 1984; Weatherall et al 1987; Pappworth 1984). The literature however gives several clinical accounts of hemi-inattention and these were used as the basis for its assessment.

Hemi-inattention was regarded as present if the subject's general spontaneous behaviour during examination suggested an inability to orientate or respond correctly to environmental stimuli on one side (e.g. people approaching, noises or activity in the ward) (Battersby et al 1956; Hier et al 1983; Heilman et al 1985). It was also regarded as present if the subject had failed to shave or to position their glasses properly on the contralesional side of their face (Gordon et al 1985), if they consistently bumped into obstacles or doorways on one side when mobile (Weinstein + Friedland 1977; Weinburg et al 1977; Battersby et al 1956), or if the subject appeared unaware of their contralateral limbs and let them remain in uncomfortable or unnatural positions (Heilman et al 1985).

2.4.5 Sensory Extinction

Sensory extinction to light touch was assessed by the technique of double simultaneous stimulation (DSS) (Critchley 1949; Swash + Mason 1984) using a modification similar to that used in other studies (Denes et al 1982; Bisiach et al 1986a). Subjects were asked to close their eyes and report whether they were being touched on their left hand, right hand or on both. Care was taken to touch the subject at the same spot on each hand. A regular alternating rhythm
was established which, at selected intervals, was interrupted by bilateral stimulation. If a subject reported unilateral stimulation instead of bilateral, the side that was ignored was noted. Bilateral stimuli were given a total of five times and the number of correct responses out of five was recorded. The cut-off point, below which score the patient was considered to have sensory extinction in that limb, was set in accordance with the age matched control data. The test was then repeated on the subject's feet.

This method differs from standard clinical practice (Swash + Mason 1984) only in that it attempts to quantify the severity of extinction which, in other studies, has been shown not to be an all or none phenomena (Schwartz et al 1977, 1979). It is simpler than methods which require the use of several different objects and textures (Schwartz et al 1977). There is no standard procedure for testing patients with aphasia. When this made testing difficult, patients were asked to keep their eyes open and report stimuli verbally or by gesture or by movement response. The response mode, once established, was noted and if the patient was able to identify all 5 double simultaneous stimuli with their eyes open, the test was repeated with eyes closed and the score was noted.

2.4.6 Visual Extinction

"Visual extinction" was also assessed by double simultaneous stimulation on full confrontation testing (Bender + Farlow 1945), subjects being asked to report movement of the examiner's fingers. This is standard clinical practice (Swash + Mason 1984) and has been used in previous studies of patients with stroke (Denes et al 1982; Bisiach et al 1986a). Scoring and strategies for dealing with aphasia
were as for sensory extinction.

2.4.7 Allesthesia

"Allesthesia" was regarded as present if subjects consistently attributed sensory stimulation of one side to stimulation of the other or if they consistently moved the limbs on one side when requested to move the limbs on the other (Jones 1907; Heilman et al 1985). The number of times that this happened during examination for sensorimotor deficits was noted.

Evidence of motor neglect (hemi-akinesia) was sought i.e. a spontaneous failure to use the contralateral limbs which could not be attributed to power loss or apraxia (Heilman et al 1985; Laplace + Degos 1983). This, however was observed very infrequently because hemiparesis was so common. It was therefore included as a sign of hemi-inattention in order to avoid an unnecessary increases in the number of variables to be analysed.

2.4.8 Anosognosia

A modified version of the "anosognosia questionnaire" from a detailed study of anosognosia (Cutting 1978) was used to record the presence of anosognosia and of the commoner anosognosic phenomena. Anosognosia was regarded as present if, on direct questioning, a patient denied that the major deficit in their paralysed limb was weakness. This recording of explicit denial or lack of consciousness of hemiplegia is standard clinical practice (Swash + Mason 1984), has been used in other studies of stroke patients (Denes et al 1982; Hier et al 1983; Fullerton et al 1988) and is equivalent to the "severe" and "moderate" grades of anosognosia reported in a more detailed neuropsycholog-
2.4.9 **Anosodiaphoria**

This was recorded as present if the patient's response to the questions "does it bother you? is it a nuisance?" was "no" (Cutting 1978).

2.4.10 **Non-belonging**

This was regarded as present if, on direct questioning, the patient felt that their limb did not belong to them (Cutting 1978).

2.4.11 **Gaze Paresis**

Gaze paresis was assessed by the ability of the subject to track a moving object (the examiner's finger) from right to left and back again. Loss of active following movements beyond the midline was regarded as a grade 1 paresis, forced lateral deviation of the eyes to one side as a Grade 2 paresis (adapted from DeRenzi et al 1982). If there was no frank gaze paresis but, on observation, the subject appeared to have lost spontaneous scanning movements to one side in response to environmental stimuli, they were considered to have a "gaze preference" (Watson + Heilman 1979) which was considered as a sign of hemi-inattention (hemi-inattention) (Chedru et al 1973).

2.4.12 **Visual field defect**

Assessment was by the standard clinical method on confrontation asking patients when they first detected the examiner's moving fingers (Swash + Mason 1984). Defects were recorded as a hemianopia or quadrantanopia. Where aphasia or impaired consciousness intervened, the presence or absence of the blink response to threat was noted (Swash + Mason 1984).
2.5 OTHER NEUROLOGICAL ASSESSMENTS

Other neurological and general features shown to have prognostic value in previous studies of the outcome of stroke were assessed.

2.5.1 Level of consciousness

Many studies have found the level of consciousness to be predictive of outcome (Marquardsen 1969; Oxbury et al 1975; Allen 1984; Wade + Hewer 1985; Fullerton et al 1988). This was recorded as alert, drowsy, or comatose (Allen 1984), a classification used, in practice, by many general physicians and which is prognostically useful (Allen 1984). This was preferred to the motor section of the Glasgow Coma Scale (Jagger et al 1983) which has been successfully used in previous prognostic studies (Wade + Hewer 1985) but which is not commonly used by general physicians and which has recently been shown to be subject to considerable interobserver variation (Rowley + Fielding 1991). Moreover, a pilot study found that many patients who were clinically drowsy or semi-comatose had a normal motor score and this method was therefore discarded.

2.5.2 Weakness

The severity of weakness has been found to affect outcome after stroke in several studies (Marquardsen 1969; Wade et al 1983; Allen 1984; Henley et al 1985; Wade and Hewer 1987). It was assessed in the current study by the motricity index (Demaurisse et al 1982) because it is simple, directly related to the M.R.C. grading used in clinical practice, has been used in several recent studies of stroke (Wade 1984; Wade et al 1985a; Wade + Hewer 1985) and has some prognostic value (Wade et al 1983; Wade and Hewer 1987). It correlates well with independence in self-care
The motricity index was developed by recording the power, which was expressed in MRC grades, of many different muscle groups in 100 patients with an acute stroke who were reassessed at two monthly intervals for six months. Mathematical techniques showed that the power of any one muscle group acting at a particular joint was representative of the power of the other muscle groups acting at that joint. Any change in power of that group could be taken as representative of the general trend in all groups acting at that joint. In order to give some meaning to the MRC grades, the difficulty experienced by individual patients in progressing, in any one movement, from one grade to the next, over a two month period, was compared with the total difficulty experienced in progressing in that movement from the bottom grade 0 to the top grade 5 over that period. This relative difficulty was expressed as a percentage, so that for example, change from grade 2 to grade 3 in shoulder abduction is equivalent to progressing from 42% to 56% of total motor recovery of that movement. This removes the arbitrariness of the grades so that measurements at different joints are equivalent and can be summed, to give an overall score that expressed power as a percentage of total motor recovery. A total arm score is therefore given by adding and averaging the motricity percentage scores for individual movements at, for example, the shoulder, elbow, and fingers. A total leg score is similarly derived and the two are summed and averaged to give an overall score suitable for further statistical analysis.

Other studies have based their assessment of power on the
M.R.C. grades and have assessed "movement of the limb as a whole" (Prescott et al 1982; Hier et al 1983; Fullerton et al 1988). Another study classified power loss, without prior definition, as "slight", "moderate", "severe", and "total" (Cutting 1978). Other studies have graded the ability of the patient to hold their limb in a constant position (Denes et al 1982; Bisiach et al 1986a), a method that is neither standard nor validated. One study used the MRC grading system and aggregated the grades of individual movements to give a total limb score (Andrews et al 1981). However the grades have no intrinsic value and could just as well be represented by letters as by numbers. Furthermore, the grades are not equivalent in that the force exerted on knee extension is not the same as that exerted on finger extension even if they are both given an MRC grade of 3. They therefore they cannot be summated to give a total limb score that has any real mathematical value.

The most complete and valid assessments of motor function in stroke patients, which take account of tone and of the quality of movement (Ashburn 1982; Fugl-Meyer et al 1975; Henley et al 1985) take too long to perform and do not give an aggregate score suitable for statistical analysis.

2.5.3 Proprioception

Proprioceptive loss has been shown, in three studies, to relate to outcome (Prescott et al 1982; Allen 1984; Wade et al 1985a). Proprioception was measured, in the current study, by a method similar to that described by Mayne et al 1965. A series of five movements in the vertical plane (two gross and three fine) were carried out at the wrist, distal interphalangeal joint of the index finger, ankle and inter-phalangeal joint of the great toe. Subjects were
asked to keep their eyes closed and to tell the examiner whether the joint were being moved up or down. The number of correct responses (maximum=10 for each limb was record-ed). Strategies for testing in the presence of aphasia were the same as for extinction (see above).

This method is closely related to routine clinical prac-tice (Swash + Mason 1984) and enables severity of loss to be guaged. It was preferred to the method of finding the thumb with the normal hand (Prescott et al 1982). Although the latter method is simple, prognostically useful, and associated with the recovery of independence in self-care (Smith et al 1983), it does not assess the lower limb, and does not appear to have any advantage over routine clinical examination, which also yields prognostically useful infor-mation (Allen 1984). Furthermore it may reflect neglect as well as proprioception (Smith et al 1983).

Other forms of sensory loss were not recorded. Although recent studies have suggested that light touch may predict in recovery (Henley et al 1985; Fullerton et al 1988), neither this nor loss of two-point discrimination or pin-prick have been found to be of special prognostic signifi-cance in large studies using adequate statistical analysis (Feigenson et al 1977a; Wade et al 1983; Allen 1984). The only study to claim that this was an important predictor of outcome used a mechanical, rather than a clinical, method of assessment, which had neither been validated nor tested on controls. The population was too small to allow for proper statistical analysis and was unrepresenta-tive of the whole stroke population, consisting of late entry patients to rehabilitation units (Stern et al 1971).
The patient's age was recorded as previous studies have found that this influences outcome (Marquardsen 1969; Wade et al 1983; Allen 1984; Henley et al 1985). The side of the cerebral lesion, the patient's handedness, sex and any aphasia were noted. The presence of any pre-existing disability or disease, and of any intercurrent illness unrelated to stroke all of which might affect independence in self-care, were recorded. Each patient received a CT brain scan at 3-5 days, when an infarct is most likely to be visible without contrast (Skriver + Olsen 1982), or was assessed by the Guy's Hospital diagnostic Score (Allen 1983; Sandercock et al 1986) to determine whether their stroke were haemorrhagic or ischaemic. There is some evidence to suggest that although a patient with a haemorrhage is more likely to die during the acute phase (Allen 1984a), if they survive, the recovery of residual impairments, may be quicker than if they had had an infarct (Hier 1983a).

2.6 OUTCOMES

The level of dependence in survivors was determined at 3 months and at 6 months by assessing the ability to carry out basic self-care activities using Wade et al's (1985) modification of the Barthel Index. This is a check-list of ten items: continence of urine and faeces, grooming, toileting, bathing, feeding, transfers, walking, stairs and dressing. To each of these is allotted an arbitrary score. The individual scores are summated to give the Barthel score, out of a maximum of 20. The Barthel score has recently been used to define levels of dependence in self-care "Independent" 20 ; "Mildly dependent" 15-19 ; "Moder-
ately dependent" 10-14; "Severely dependent" 0-9 (Wade et al 1987). These categories of dependency were adopted to assess outcome in the current study.

The Barthel Index is simple, reliable and valid (Wade et al 1985). There is good agreement between the score given for an individual patient by nurses, relatives and therapists (Collin et al 1988). Its routine use has been recommended with all patients after stroke (Wade 1986). It has been used extensively in recent studies (Dejong + Branch 1982; Wade et al 1983; Wade + Hewer 1987; Skilbeck et al 1983). The initial score has prognostic value (Wade et al 1983; Wade + Hewer 1987) and the discharge score is a major determinant of the place of discharge (Dejong + Branch 1982).

The disadvantage of using the above categories is that there is a great difference, for example, between the services needed by people with scores of 19 and 15. Nevertheless consideration of the individual activities of daily living by use of the Barthel Index is a practical way of deciding how dependent a patient is. Although some studies have used statistical modelling techniques to predict the Barthel score, or similar, at 6 months post-stroke (Wade et al 1983; 1985a; Wade + Hewer 1987), it should be remembered that scores allotted to individual activities are arbitrary and categorical, with no real mathematical value. Therefore the summed score cannot be treated as continuous data in statistical manipulation. For this reason the current study used the Barthel to categorize outcome into those groups previously defined by Wade + Hewer (1987) and used statistical modelling techniques to predict which group individu-
al patients might belong to.

It has recently been proposed that the modified Rankin scale (Dennis + Warlow 1987) should be used as a standard measure of dependency. However, this does not differentiate clearly between dependence in self care and inability to lead an unrestricted lifestyle although these outcomes have quite different implications for the level of provision of services post-discharge. Other studies have place of discharge or length of stay (Henley et al 1985; Sheikh et al 1981) as outcomes but these are likely to be strongly influenced by social factors (Lehmann et al 1975; Dejong + Branch 1982) so was not assessed in the present study, although they too are affected by the degree of neurological impairment (Labi et al 1980; Sheikh et al 1981). For these reasons, outcome was categorized according to independence in self care, using the Barthel Index as a standardized assessment.

The Barthel suffers from the problem that the summed score does not reveal in which activities the patient is disabled. There are two assessments in which activities are arranged in order of difficulty so that the overall score indicates which activities the patient cannot do. However one of them (Lincoln + Whiting 1980) is too long and detailed for rapid assessment, especially by non-therapists. The other (Ebrahim et al 1985), although simple, had not yet been widely used at the time of planning the present study. The Barthel has been shown to have its own intrinsic hierarchy of difficulty (Wade et al 1987). The main alternative to the Barthel at the time of planning the present study was the Northwick Park Index (Sheikh et al 1979). This, however includes cooking, cleaning and shop-
ping, the relevance of which is likely to depend on sex, marital status and pre-morbid ability. Disability in these activities is less likely to prevent discharge home than disability in basic self-care. The Barthel was thus preferred.

The number of deaths was also recorded and categorized as being due either to the acute stroke, or to the consequences of immobility (e.g. pneumonia, pulmonary emboli, pressure sores) or to other diseases (e.g. myocardial infarction, renal failure).

2.7 STAGES OF THE STUDY

The clinical assessments and the outcomes categories were used to study the natural history and prognosis of the neglect syndrome in the six stages outlined in Section 2.2 and Figure 2.1. The methodology of each of these stages is described below.

2.7A STANDARDIZATION OF THE VISUAL NEGLECT TEST BATTERY

Patients

Forty-four consecutive patients (a subsample of the 171 stroke patients entered in the study [section 2.3.1]), with a mean age 71.2 years (s.d. 12.8), admitted to hospital with an acute hemispheric stroke were examined. Eighteen had signs of a right hemispheric stroke, 26 had signs of a left hemispheric stroke. The diagnosis was confirmed clinically and the test battery was administered at 3 days. Patients were re-examined at 3 months because after this interval most neurological deficits make most of their recovery (Section 1.5). All patients underwent a non-contrast CT brain scan at 3-5 days. Two patients had a
haemorrhage, the rest had an infarct.

The battery was also administered to 47 independent age matched controls whose characteristics have already been described (Section 2.3.2).

In 21 patients the findings on examination were validated against an occupational therapist's assessment of "hemi-inattention" in activities of daily living. Inter-observer reliability was also established using 12 of the stroke patients. The sensitivity of the battery to change over time was assessed.

Each control was also assessed for depression and cognitive impairment, using quick and easy screening tests that have been developed and validated for elderly people: the Geriatric Depression Scale "GDS" (Yesavage et al 1983, 1986), Hodkinson's Mental Test Score "MTS" (Hodkinson 1972) and Kendrick's Object Learning Test "KOLT" (Kendrick et al 1979).

The GDS is a depression scale that has been specifically developed for elderly people, taking into account the different presentation in this age group. The MTS is a gross assessment of memory, concentration and orientation that has become a standard part of the clinical assessment of elderly people (Iredale 1986). It was derived from the Blessed score, which correlates with histopathological (Blessed et al 1968) and neurochemical (Perry et al 1978) abnormalities in the brain. The KOLT is a test of recall of pictures of everyday objects after a brief viewing period. Its sensitivity to diffuse brain pathology irrespective of age, its value as a measure of severity of cognitive impairment and its correlation with other commonly used cognitive assessments have all recently been reviewed.
(Kendrick 1987; Roth et al 1986).

The controls were also examined for the other neglect phenomena and related disorders in order to establish a normal range of performance.
2.7B INCIDENCE OF VISUAL NEGLECT, NEGLECT PHENOMENA AND RELATED DISORDERS

Patients

Having standardized the assessment of neglect phenomena and related disorders in a sub-sample of the study population, all 171 patients with an acute hemispheric first stroke (see Section 2.2.1 for their characteristics) were examined at 2-3 days post-stroke, using the assessments described above.

The incidence of visual neglect, neglect phenomena and related disorders was recorded. Where aphasia or impaired consciousness prevented assessment, this was noted.

The association of neglect phenomena and related disorders with right or left hemisphere damage was examined using 95% confidence intervals for the difference between proportions.
2.7C RECOVERY OF NEGLECT PHENOMENA AND RELATED DISORDERS

(1) Patients

50 patients with visual neglect due to a RH stroke and 48 with visual neglect due to a LH stroke were identified in the preceding stage of the study at 2-3 days post-stroke. The presence of other neglect phenomena and related disorders in these patients was recorded. They were re-examined at 10 days, 3 weeks, 6 weeks, and 3 months until follow-up revealed no visual neglect or until they died. Excluding those patients who died as a consequence of their stroke (10 patients), those who refused follow-up (2 patients) and those in whom other disease, such as renal failure, myocardial infarction, aortic aneurysm and carcinoma of the pancreas, intervened (13 patients), and those who had a second stroke (5 patients), there were 34 right hemisphere and 34 left hemisphere patients who could be followed for up to 3 months.

(2) Method

The incidence of neglect phenomena and related disorders in these patients was documented together with their cumulative recovery rates.

Where possible, these patients were seen again at 6 months post stroke but 6 patients were lost to further follow up, 1 died of other disease, 1 died from the late complications of stroke related immobility and 1 suffered a second stroke. This left 28 right hemisphere and 31 left hemisphere patients in whom the 6 month cumulative recovery rates of neglect phenomena and related disorders could be determined.
(3) Choice of follow-up times

The first examination was performed at 2-3 days post-stroke because it would be most helpful for clinicians if the prognostic factors for independence in self-care were to be based on early clinical findings (Allen 1984; Fullerton et al 1988). Patients were examined at 10 days because cerebral oedema will have resolved or will be diminishing (Spatz 1939; Skriver + Olsen 1981). The third examination was at 3 weeks, because the most rapid period of recovery will have finished (Skilbeck et al 1983) and the majority of deaths will have occurred (Aho et al 1980; Wade Hewer 1985a). The six week examination was included because this is the average length of stay for patients in district stroke units according to estimated planning figures (Stevens + Isaacs 1984). The three and six month examinations were chosen as most recovery occurs in the first three months but may continue for six months (Section 1.5). Patients were not assessed after 6 months, for recovery beyond this stage occurs in very few (Andrews et al 1981; Skilbeck et al 1983; Katz et al 1966), although arm function may be an exception to this trend (Bard + Hirschberg 1965; Skilbeck et al 1983).
2.7D DEVELOPMENT OF AN OVERALL MEASURE OF VISUAL NEGLECT

The 0-5 grading system used to express performance on the visual neglect battery (Section 2.4.3), gives a profile of scores on the individual tests and is able to show change in neglect over time but is not as useful as a single overall score. Such a score would make it easier for therapists and physicians to communicate the severity of visual neglect to each other and to monitor change.

The simplest solution would appear to be to summate and average the graded scores on the entire battery. However, this cannot be done for two reasons. First, these grades are in arbitrary units of no real value, so cannot be treated as continuous variables. Secondly, it cannot be assumed that each test is measuring the same neuropsychological variable (Del Castello + Warrington 1987; Bisiach et al 1986) and that grade 3 neglect on one test is equivalent to grade 3 neglect on another.

The problem is similar to that encountered in trying to express the power loss after stroke as an overall score, instead of describing the power of individual muscle movements in the arbitrary 0-5 grades of the MRC scale. Demaurisse and al (1982) overcame this problem in their development of the Motricity Index (Section 2.5.2).

It is possible to apply the principles underlying the development of the motricity index to create an overall measure of neglect recovery, using the graded performance of patients on the individual tests in the neglect test battery. This measure was named the "Visual Neglect Recovery Index" (VNRI).

Each patient's graded score on each test of the battery at
3 days and at 3 months was recorded in the 68 surviving patients that presented with visual neglect and whose subsequent course over the next 3 months was unaffected by other disease or a second stroke. In order to facilitate comparison of patients with right hemisphere and left hemisphere strokes, only those tests administered to both groups of patients were considered i.e. Pointing to objects, Photograph of a meal, Reading a menu, Line and Star cancellation, and Coin selection. If neglect had resolved in a patient at, say, 3 weeks it was assumed that no neglect would have been present at 3 months. Three months was chosen as the end point because most patients make the majority of their recovery at 3 months in, for example, arm function, mobility, (Andrews et al 1981; Skilbeck et al 1983) and, it is thought, visual neglect (Wade et al 1988).

For each test a double entry table was constructed, such as that for Reading the menu (Table 2.1). The first vertical column refers to the number of patients who had grade 0, 1, 2, 3, 4, or 5 neglect on the Menu at 3 days post-stroke who, at 3 months had grade 0 neglect on that test. The second vertical column gives the number of patients whose initial grade was 0, 1, 2, 3, 4 or 5 and whose final grade at 3 months was grade 1. The third vertical column gives the number of patients with grade 0, 1, 2, 3, 4 or 5 neglect at 3 days whose final grade at 3 months was grade 2 etc.
TABLE 2.1

Double entry table for Reading a Menu

<table>
<thead>
<tr>
<th>Grade neglect at 3 days</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade neglect at 3 days</td>
<td>8</td>
<td>1</td>
<td>0</td>
<td>3</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>12</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>7</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

From this table it follows that there were 8 patients who initially had grade 5 neglect on this test. Seven of these (3+0+0+2+2) improved over 3 months. The percentage (X) of those who recovered from grade 5 to grade 4 at some stage over the 3 months is 7/8 x 100% i.e. 87.5%. Similarly, the number of patients whose initial grade at 3 days was grade 4 or who had recovered from grade 5 to 4 at some stage over the 3 months is 7+1+2+1+0+3+0+0+2+2=18. Sixteen of these (7+1+2+1+3+0+0+2) recovered from grade 4 to 3 at some time over the 3 months. The percentage (X) who recovered from grade 4 to 3 is, therefore, 16/18 x 100% (88.9%). There were 13 patients (12+1+0+0) whose initial grade was 3, and 11 patients (7+1+2+1) who had at some stage recovered from grade 4 to 3, and 5 patients (3+0+0+2) who had progressed from grade 5 to 3, giving a total of 29 patients. Twenty-six of these (12+1+0+7+1+2+3+0+0) recovered to grade 2 at some stage over the 3 months. The percentage (X) recovering from grade 3 to 2 is therefore...
26/29 \times 100\% \ (i.e.89.66\%). Similarly the percentage \( X \) recovering from grade 2 to 1 is 28/30 \times 100\% \ (i.e.93.33\%).

The percentage \( X \) recovering from grade 1 to 0 neglect at some stage over 3 months is 26/29 \times 100\% \ (i.e.89.65\%).

If every patient had had grade 5 neglect at 3 days the percentage of those who would have recovered from grade 5 to 0 over 3 months would be

\[
\begin{array}{cccccc}
1 & 2 & 3 & 4 & 5 \\
X & X & X & X & X \\
100 & 100 & 100 & 100 & 100 \\
\end{array}
\times 100\% = \frac{X}{10} = 58\% \\

The percentage of patients who did not recover from grade 5 to 4 is 100-\( X \) from grade 4 to 3 is 100-\( X \); from grade 3 to 2: 100-\( X \); from grade 2 to 1: 100-\( X \); from grade 1 to 0: 100-\( X \). The percentage who would not have recovered from grade 5 to 0 can be given by

\[
\begin{array}{cccccc}
1 & 2 & 3 & 4 & 5 \\
100 - X & .X & .X & .X & .X \\
8 & 10 \\
\end{array}
\]

The coefficients \( D \), \( D \), \( D \), \( D \), \( D \), comparing the relative difficulty in recovering from grade 5 to 4, grade 4 to 3 etc., with that of total recovery of neglect from grade 5 to 0 over three months are derived as follows:
The relative value of stage 1 of recovery, i.e. recovery from grade 5 to 4, expressed as a percentage is given by the relative difficulty of recovery from grade 5 to 4 divided by the total difficulty of recovery from grade 5 to 0 i.e. 

\[
100-X \\
\hline
1 100-X
\hline
10 1 2 3 4 5
\hline
8
10
\]

\[
D = \frac{1}{10} \times 100\% = \frac{0.3}{1.2236} = 24.5\%
\]

The relative value of stage 2 of recovery i.e. recovery from grade 5 to 3 is given by the relative difficulty of recovery from grade 5 to 4 plus that of recovery from grade 4 to 3 divided by the total difficulty of recovery from grade 5 to 0 i.e.

\[
\begin{array}{c}
1 \\
\hline
1 2 3 4 5
\hline
D +D +D +D +D
\end{array}
\]

\[
D = \frac{2}{10} \times 100\% = \frac{0.5669}{1.2236} = 46\%
\]

Similarly, the relative values of stage 3 of recovery (to grade 2), stage 4 of recovery (to grade 1) and stage 5 of recovery (to grade 0) are given by:-
Stage 3 = D + D + D  
1  2  3  
X 100% = 66.61%

Stage 4 = D + D + D + D  
1  2  3  4  5  
X 100% = 79.69%

Stage 5 = D + D + D + D + D  
1  2  3  4  5  
X 100% = 100%

By definition, stage 0, that of no recovery from grade 5, is equal to 0%. For reading the menu, grade 4 neglect therefore represented 25% of total recovery; grade 3 neglect represented 46% recovery; grade 2, 67%; grade 1, 80%; and grade 0, 100% recovery.

Applying this method to all tests enabled the percentage recovery to be calculated for each grade on each test. The percentage score on each test could be summated and averaged for each patient's performance over the entire battery because the measurements on each test were now in equivalent units. This gave an overall measure of visual neglect recovery which was called the "Visual Neglect Recovery Index" (VNRI). A patient with maximum visual neglect on the battery had an VNRI score of 0% and a patient with no visual neglect had an VNRI score of 100%.

The correlation of the VNRI with the percentage recovery score on individual tests at 3 days was assessed by analysis of variance and by least significant difference analysis. The change in the mean VNRI values with time was examined for all 68 patients and for right and left hemisphere stroke patients separately.
2.7E PREDICTION OF THE SEVERITY OF VISUAL NEGLECT
AT 3 MONTHS AND AT 6 MONTHS POST-STROKE

The relationship between the severity of visual neglect (outcome) at 3 months and at 6 months, measured by the VNRI, and the clinical assessments (independent variables) made at 2-3 days was examined in the 68 patients in whom the VNRI was developed. Each assessment was coded numerically. The patient's age, severity of hemiparesis (motricity index), and severity of visual neglect (VNRI) were entered as continuous data in their original units of measurement. The other clinical assessments were coded 0/1 according to a present/absent (neglect phenomena and related disorders) or impaired/unimpaired categorization (level of consciousness, proprioception).

These variables were then used for Stepwise regression analysis in which an equation can be derived that relates the outcome "y" (in this case the VNRI at 3 or 6 months) to the clinical variables "x_1", "x_2", etc in each patient.

\[ y = a + b_1 x_1 + b_2 x_2 + b_3 x_3 \ldots \ldots \ldots \text{etc.} \]

In stepwise regression analysis the variables are added in turn to the equation and those that come out significant (F-ratios) are then retained in the model. The equation has a constant "a" and regression coefficients (b_1, b_2 etc) which can be calculated for each variable, which represents each variable's effect on outcome when the other variables are held constant. As each variable is added to the equation, the change in outcome and its statistical significance is measured. This allows only the most significant variables to be retained in the equation. The complex mathemat-
ics required to carry out this analysis is available in computer packages. The BMDP package (Dixon 1985) was used in this study.

The accuracy of the predictive equations thus derived were assessed and their possible application to the choice of patients for trials of treatment of visual neglect was considered.
2.7E PREDICTION OF THE LEVEL OF INDEPENDENCE IN SURVIVORS OF ACUTE STROKE AT 3 MONTHS AND 6 MONTHS.

Of the original 171 patients recruited for the study, 98 had been found to have visual neglect at 2-3 days post-stroke, 37 had no visual neglect and 36 were too aphasic or drowsy to be assessed for neglect. All patients were followed up at 3 months and at 6 months to determine outcome, with the following exceptions. Of the patients with visual neglect, 3 had pre-existing disability that affected their independence in self-care, 13 died of non-stroke related disease, 5 had second strokes and 2 refused follow-up. Of the patients without neglect, 2 had pre-existing disability, 2 died of other disease, 1 suffered a second stroke and 8 were lost to or refused follow-up. There were thus 75 patients with neglect, 24 without neglect whose 3 month outcome was known.

At 3 months 10 of the neglect patients had died of their stroke or of the consequences of stroke related immobility. None of those without neglect had died. There were thus 65 neglect patients and 24 non-neglect patients alive at 3 months whose outcome was known.

A further 2 patients were lost to 6 month follow-up, 1 died of other disease, 1 extended their stroke and 1 died of the consequences of stroke-related immobility. At 6 months the outcome was known in 60 surviving neglect patients and in 24 non-neglect patients.

Of the 36 unassessable patients, 27 were dead at 3 months, and the rest were severely dependent.

The relationship between the outcome groups "Independent",
The relationship between the outcome groups "Independent", "Mild", "Moderate" and "Severe" dependence and the clinical assessments made at 2-3 days (independent variables) was examined for all surviving patients in whom the 3 month and 6 month outcomes were known and who could be assessed for visual neglect at 2-3 days. Patients who could not be assessed for visual neglect at 2-3 days were excluded (Section 1.5.1) as were patients whose outcome was affected by other disease or pre-existing disability. Each independent variable was coded numerically. Chi-squared tests were used for categorical data and F-ratio tests for continuous data to determine which clinical variables were significant.

The significant variables were then used for linear logistic regression (Walker + Duncan 1967), in which an equation can be derived that relates the probability \( p \) of membership of any one outcome group \( y \) to the clinical variables \( x_1, x_2, x_3 \) etc observed in any one patient.

\[
p(y) = \frac{1}{1+e^{-(a + b_1 x_1 + b_2 x_2 + b_3 x_3 \ldots \ldots)}}
\]

The variables do not have to be normally distributed, which gives this method an advantage over discriminant function analysis (Press + Wilson 1978). Beginning with the independent variable that is most likely to discriminate between the various outcome groups, each variable is added in turn to the equation, a "stepwise" analysis of each one's discriminating function. Regression coefficients \( b_1 \), \( b_2 \), \( b_3 \) etc can be calculated for each variable that reflects each variable's value in separating the groups. The change in the separation of the groups and its statistical
significance is measured with the addition of each variable. This allows only the most discriminating variables to be retained in the equation, which has a different intercept \( a_1 \), \( a_2 \) etc for different outcome groups.

The complex mathematics required to carry out this analysis have recently been made available in computer packages such as SAS. (Harrel 1983). Linear logistic regression was carried out using the LOGIST procedure of SAS with the 3 outcome groups as the dependent variables and the clinical assessments at 2-3 days as the independent variables. A "p value for inclusion" of 0.05 was set and the best stepwise solution was sought.

Recent studies have predicted the outcome of stroke using similar statistical modelling techniques (Prescott et al 1982; Wade et al 1983; Wade and Hewer 1987; Allen 1984; Henley et al 1985; Fullerton et al 1988). Most have used Discriminant Function Analysis and may have had to categorize outcome into only two groups such as "independent" and "dependent or dead" (Prescott et al 1982; Allen 1984). Only the study by Fullerton and colleagues was able to use linear logistic modelling (1988) which has the advantage over discriminant function analysis that it does not require that the variables be normally distributed. Such a precondition is unlikely to be met in a population of acute stroke patients.
Figure 2.2 Left visual neglect on "Pointing to Objects".

Figure 2.3 "Food on a plate"
Driver killed, 30 hurt as packed train rams a loco

A Driver died trapped in his cab in a horror train smash last night. Thirty others were hurt as a passenger train rammed two coupled locomotives on a track snaking across the Derbyshire Pennines. The injured — three of them seriously — were rushed to hospital in a fleet of ambulances. Last night emergency workers were trying to free the body of the driver from the passenger train which was derailed.

More than 100 people were on the four-coach diesel when it crashed near the village of Chinley near Buxton. The alarm was raised by a young motor-cyclist who saw the crash and ran to a nearby school for help.

Two nurses on board the train...
Figure 2.6 Left visual neglect on "Line Cancellation", with a Right Hand Start (arrow).

Figure 2.7 Left visual neglect on "Star Cancellation", with a Right Hand Start.
Figure 2.8 Left visual neglect of unmarked coins on "Coin Selection".

Figure 2.9 Right visual neglect on Figure copying with crowding.

Figures 2.3, 2.4, 2.6-2.9 are copyright Thames Valley Test Company.
Figure 2.9
Right visual neglect on Figure copying with Crowding.

Figures 2.3, 2.4, 2.6-2.9
are copyright Thames Valley Test Company.
Section 3

RESULTS
3A STANDARDIZATION OF THE VISUAL NEGLECT TEST BATTERY.

3A.1 SUMMARY

The visual neglect battery was standardized on a subsample of forty-four consecutive patients with an acute hemispheric stroke and forty-seven independent age-matched controls. Control patients were also assessed for other neglect phenomena and related disorders.

(1) 55% of controls made at least one omission on the visual neglect test battery. Up to 43% made omissions on any one test.

(2) Increasing age and evidence of cognitive impairment appeared to affect performance on the battery. Cut-off points were chosen to distinguish between normal performance and visual neglect.

(3) The battery detected visual neglect in 72% of right and 62% of left hemisphere stroke patients at 3 days post-stroke. At 3 months, visual neglect persisted in 75% of surviving right and 33% of left hemisphere patients presenting with visual neglect.

(4) The graded scoring system suggested that visual neglect appeared to be greater after right hemisphere stroke than after left, and showed a significant reduction in neglect in many tests over 3 months.

(5) Validity of the battery was assessed in 21 patients (17 of whom had neglect on the battery) who were assessed for neglect on activities of daily living (ADL) by an occupational therapist. All but one of those with neglect on the battery had neglect in ADL.

(6) Interobserver-reliability was assessed by simultaneous scoring of 13 patients by two examiners and appeared to be
high for nearly every test of the battery.

(7) No control had hemi-inattention, allesthesia or any of the related disorders.

(8) 25% of controls made a small number of errors on testing for sensory extinction and 6% did for visual extinction. Many but not all of these controls made errors or omissions on other cognitive or visual neglect tests. Cut-off points were set to distinguish between normal and abnormal performance in testing for extinction.
3A.2  CONTROLS

3A.2.1 The number of controls making omissions on each neglect test

The number of controls making omissions was very small for most tests (Table 3A.1). The exceptions were Star Cancellation and Coin Sorting. Twenty-one controls made no omissions on any test, 12 made omissions on one test, 10 on two tests, 2 on three tests, 1 on four tests and 1 on six tests.

3A.2.2 The number and distribution of omissions on each test

For most tests the number of omissions was very small (Tables 3A.1, 3A.2). Performance on Star Cancellation (range 0-15; mean 2.71; s.d. 4.23) and Coin Sorting (range 0-3; mean 0.39; s.d. 0.77) were exceptions. No control made a Right Hand Start on Menu or Newspaper; one made a Right Hand Start on Line Cancellation and 3 did so on Star Cancellation. No control showed Crowding on copying the left figure.

3A.2.3 The influence of age on the number of omissions

13 out of 30 controls over the age of seventy made omissions on two or more tests, compared with 2 out of 17 aged seventy or less. This difference was significant (Chi Square = 4.853, p < 0.05).

In this sample, age appeared to have an effect on the number of omissions made on Star Cancellation (Figure 3A.1). Nine out of the 29 controls over the age of seventy omitted 6 or more stars, compared with 1 out of the 17 aged seventy or less. This difference is significant at the 0.05 level (Chi Square = 3.985).
Although not statistically significant, a similar trend was observed on Coin Sorting. Only 11 controls made omissions. Nine of them were aged over seventy and only 2 were seventy years old or less.

3A.2.4 Relation of KOLT and MTS scores to number of omissions on each test

The KOLT score (mean 31.26; s.d. 9.77; median 33.0; Q1 24.0; Q3 40.0) was significantly negatively correlated with age (r = -0.496; p < 0.01).

The KOLT scores were significantly negatively correlated with the number of omissions on Star Cancellation (r = -0.469; p < 0.01). Subsequent analysis showed that there was a cluster of high "Star" scores (i.e. 6 or more omissions) and declining KOLT scores (less than or equal to 27) (Figure 3A.2).

Table 3A.2 shows that controls who made omissions on Meal, Line Cancellation, Pointing, or on all parts of the Newspaper often had low KOLT scores (i.e. less than 23: Kendrick et al 1979) or borderline KOLT scores (i.e. 24-25). The KOLT score did not correlate with the number of omissions on Coin Sorting, although 4 out of 6 controls omitting two or more coins had KOLT scores of less than 23, compared with 3 out of 35 omitting less than two coins.

Thirty-eight controls were assessed on the MTS. Thirty-five scored at least 9 out of 10. One scored 8, had a KOLT score of 22 and made 4 omissions on Line Cancellation, 1 on Headlines, 6 on Article, 2 on Coin Sorting, and 13 on Star Cancellation. One scored 6 on the MTS, had a KOLT score, strangely, of 40 but made 13 omissions on Star Cancellation with a Right Hand Start. The remaining control scored 5 on
the MTS, made 7 omissions on Star Cancellation but refused to do the KOLT.

3A.2.5 Relationship between neglect test results

The numbers of omissions made by controls on Coin Sorting and Star Cancellation were significantly positively correlated with each other $r = 0.413; p < 0.01$.

Table 3A.2 shows that controls making omissions on one test often made omissions on other tests. Of the 3 controls with a Right Hand Start on Stars, one omitted 13 stars, the second had a Right Hand Start on Lines but made no omissions on any other test, and the third had a Right Hand Start on Stars in isolation.

3A.2.6 Relation of neglect test omissions to neurological findings

No control had any visual field defect, gaze paresis or cranial nerve palsies (corneal sensation was not tested). Two had minor signs of pyramidal tract damage, such as brisk reflexes, without weakness. One omitted part of the daisy (but in a non-lateralised manner), the other made 1 omission on Meal and 2 on Coins.

Proprioception scores were 10 out of 10 in all limbs in thirty-five controls, and 9 out of 10 in nine controls. One control (with sciatica) scored 8 in one limb.

On testing for Visual Extinction, 44 controls scored 5 out of 5 on DSS. Two scored 4 out of 5; one of these had a KOLT score of 21 and omitted 8 stars, the other had a KOLT score of 14 and a sensory extinction score of 3 out of 5. The remaining control scored 3 out of 5, had a KOLT score of 14 and omitted 3 Coins and 15 Stars.

On testing for Sensory Extinction to light touch, 35 controls scored 5 out of 5 on DSS; seven scored 4/5; three

77
scored 3/5; one scored 2/5 and one scored 0/5. Of the seven scoring 4/5, two made no omissions on neglect tests but had a KOLT score of 24 with high GDS scores of 5 and 8; the other five either made large numbers of omissions on neglect tests (8 Stars, 13 Stars, 2 Coins, 50 degrees on Pointing) or had a low KOLT score of 16. Of the three scoring 3/5, one had a KOLT score of 14 and a visual extinction score of 4; the second had a KOLT score of 22, omitted 13 stars, 2 coins, and 1 word on Headlines; the third had a normal KOLT and made no omissions on the neglect battery. The only control to score 2/5 also had a normal KOLT and made no omissions on neglect tests. The only control to score 0/5 made no omissions on neglect tests but tired of testing and refused to do the KOLT, MTS, and GDS.

No control showed hemi-inattention, allesthesia, anosognosia, anosodiaphoria, non-belonging, or gaze paresis.

3A.2.7 Relationship of omissions to Depression

Four controls were depressed, with GDS scores of 5-8. One was aged 72, had a KOLT score of 14, a visual extinction score of 3/5 and made 3 omissions on Coins and 15 omissions on Stars. The other three were younger, aged 57, 62, and 64, had KOLT scores of 23, 23, 24 respectively. Two of these made no omissions on any neglect test and the other made 1 omission on Article.

3A.2.8 Parameters of normal visuo-spatial functioning in the elderly

The controls were regarded as normal, by definition and the range of omissions observed (Table 3A.1) was taken as the normal range. Scores above this number of omissions on
any one of the 8 tests should be considered abnormal. Thus 2 or more omissions on Meal; any omission on Menu; any left or right omission on Copying the Left Figure; 5 or more omissions on Lines; 16 or more on Stars; 4 or more on Coins; 2 or more on Headlines; 2 or more on Paragraph; 7 or more on Article; and 50 or more degrees on Pointing was regarded as abnormal. A Right Hand Start on reading the Menu or the Newspaper, and crowding the Left Figures was also considered abnormal.

For visual and sensory extinction a score of 2 or less out of five on any one limb was taken as possibly abnormal performance depending on clinical context.

3A.3 STROKE PATIENTS

Definition of visual neglect

Visual neglect was considered to be present in a stroke patient if they made more omissions on any one test than the independent age-matched controls. Certain findings observed occasionally in controls were regarded as evidence of visual neglect in a stroke patient if there was supporting clinical evidence. In the same way, an isolated extensor plantar response, or other primitive reflex is considered of little significance in the elderly unless there are other clinical grounds suggesting that these are pathological (Broe et al 1976; Jenkyn et al 1985). Thus, any stroke patient making 3 unilateral omissions on Coins was considered to have visual neglect on that test if visual neglect was present on another test. Similarly, visual neglect was considered present in Stars when a stroke patient omitted between 6 and 15 stars if there were at least twice as many omissions on one side of the page as the other (Fullerton
et al 1986) and if visual neglect was present in another test. Also, a Right Hand Start on Line and Star Cancellation was taken as a sign of visual neglect if visual neglect was present on these or other tests. These various combinations of features were not observed in the controls. Finally, there is a likely error of 10 degrees between observers on Pointing to Objects, so that omission of 40 degrees was considered as a sign of visual neglect.

3A.3.1 Stroke patients at 3 days post-stroke

At 3 days post-stroke, 2 patients with a right hemisphere stroke could not be assessed on any test because of coma. All remaining 16 patients could be tested on Pointing, Meal, Menu, Newspaper and Lines (Table 3A.3). One patient refused to do Stars and Coins because they were tired. Another patient was unable to recognize the coins.

Five patients with a left hemisphere stroke could not be assessed at 3 days because of coma or severe aphasia. Most of the remaining 21 could be assessed on Pointing, Meal, Menu and Lines. Aphasia made it impossible for some patients to attempt Stars, Coins and Figure copying (Table 3A.3).

a). Number of patients showing visual neglect

At 3 days 13/18 (72%) patients with a right hemisphere stroke showed visual neglect on at least one test. Visual neglect was present in 16/26 (62%) patients with a Left hemisphere stroke.

b). The tests most likely to detect visual neglect

The tests most likely to detect visual neglect in a patient with a right hemisphere stroke were Newspaper, Stars, Pointing, Meal and Lines (Table 3A.3). Eleven of these patients demonstrated a Right Hand Start.
For patients with a left hemisphere stroke the most likely tests to detect visual neglect were Meal, Menu, Lines and Pointing (Table 3A.3). Five of these patients showed crowding. It should be noted that although only 10 patients could attempt Stars, 8 of these exhibited visual neglect on that test.

3A.3.2 Stroke patients at 3 months post-stroke (Table 3A.4)

The results of the visual neglect battery at 3 months post-stroke were examined in detail, because at this stage most neurological deficits due to stroke would be expected to have made the majority of their recovery. If visual neglect is amenable to therapy, it might be important to be able to detect it in those who are slow to rehabilitate, and a knowledge of the tests most sensitive to visual neglect at this stage would be useful.

Twelve of the 13 patients with visual neglect due to a right hemisphere stroke survived until follow-up at 3 months. One patient was depressed at this stage and refused to co-operate with any test. The 11 others were able to attempt nearly every test. Both patients who had originally been unable to do any test died.

Fourteen of the 16 patients with neglect due to a left hemisphere stroke survived until follow-up at 3 months. One of the five who had originally been unable to do any test survived. The 15 survivors were able to co-operate with nearly every test although language difficulty still prevented some patients understanding the Coins and Stars test requirements.
a). Number of patients showing visual neglect at 3 months

Visual neglect was present in 9 patients with a right hemisphere stroke (75%) and 5 left hemisphere stroke patients (33%).

b). Tests most likely to detect visual neglect at 3 months

In those with a right hemisphere stroke the tests most likely to detect visual neglect were Stars, Meal, Coins and Newspaper. A Right Hand Start was present in 9 of these patients. In patients with a left hemisphere stroke the tests most likely to detect visual neglect appeared to be Stars, Coins and Menu. No patient showed Crowding.

3A.3.4 Validity of the test battery

In order to ascertain the face validity of the test battery an Occupational therapist carried out an assessment on 21 of the patients, using the following checklist of "neglect behaviours". The occupational therapist was blind to the results of the test battery.

(1) Did the patient fail to orientate to environmental stimuli on the side opposite the cerebral lesion?

(2) Did the patient fail to dress, wash or groom the side of the body opposite the cerebral lesion?

(3) Did the patient knock into doorways or obstacles on the side opposite the cerebral lesion, when walking or using a wheelchair? If using the latter were they unable to turn towards the side opposite the lesion? If mobile, did the patient veer diagonally towards the side opposite the lesion?

(4) Did the patient show "motor neglect" (Section 1.2.3) i.e. could their failure or reluctance to use the limbs contralateral to the lesion be attributed to neglect rather
than weakness or apraxia?

(5) Did the patient show lack of awareness of their limbs with poor positioning? (Heilman et al 1985).

Four patients (2 right hemisphere, 2 left hemisphere) had no visual neglect on the battery and no neglect behaviours on the checklist compiled by the OT. The remaining 17, (12 right hemisphere, 5 left hemisphere), had visual neglect on the test battery. Six of these could not be assessed for motor neglect or neglect on walking due to the severity of their hemiparesis, but all 6 demonstrated neglect on every other item on the checklist, except for one patient who did not neglect on washing and dressing. Of the 11 other patients with neglect on the battery, 7 had neglect on at least 3 checklist items, and 2 had neglect on 2 items (which in each case included orientation or washing/dressing). One patient had neglect on only one item (orientation).

There was one patient who had marked left visual neglect on the battery, a left homonymous hemianopia and no hemiparesis, but no neglect on the checklist. This patient appeared to be a true exception, because even the two patients with visual neglect on just a single test of the battery neglected on 3 checklist items.

3A.3.5 Reliability of the test battery

Inter-observer reliability was established by the simultaneous scoring of 12 patients (8 right hemisphere, 4 left hemisphere) with visual neglect by two examiners trained in the administration of the battery.

Each patient was assessed on nearly every test, although only 11 were able to do Pointing, Meal, Menu and
Stars. There was agreement as to the presence or absence of visual neglect in every test except in the case of one 85 year old patient who omitted 4 coins. One examiner attributed this to lack of familiarity with the newer coins, rather than to visual neglect. The 2 observers agreed on the graded score on each test except in one patient who mumbled inaudibly when reading the Newspaper. One observer thus recorded 8 omissions on Headlines (grade 4) and 24 on Article (grade 2), the other recorded 9 (Grade 5) and 13 omissions (grade 1) respectively.

3A.3.6 Sensitivity to change in visual neglect

Table 3A.5 shows the median test scores of those patients presenting with visual neglect at 3 days post-stroke who survived and were able to be examined at 3 months. There were 11 with a right hemisphere stroke and 14 with a left hemisphere stroke. At 3 days visual neglect appears to have been more severe in patients with a right hemisphere stroke than in patients with a left hemisphere stroke, but the difference only reaches significance for Lines (p=0.0426; Mann-Whitney tests). At 3 months there had been a decline in the severity of visual neglect in right hemisphere patients on all tests. This was significant at the 0.02 (Wilcoxon tests) level for Lines, Stars and Pointing; and at the 0.05 level for Paragraph. There was also a decline in the severity of visual neglect in those with a left hemisphere stroke which was significant at the 0.01 level for Lines and at the 0.05 level for Pointing, Meal, Menu, and Stars.
TABLE 3A.1

<table>
<thead>
<tr>
<th>Neglect test (max.no. omissions)</th>
<th>No.controls tested</th>
<th>No.making omissions</th>
<th>Range of omissions</th>
<th>Cut-off point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meal (8)</td>
<td>47</td>
<td>2</td>
<td>0-1</td>
<td>2</td>
</tr>
<tr>
<td>Menu (24)</td>
<td>47</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Lines (36)</td>
<td>47</td>
<td>2</td>
<td>0-4</td>
<td>5</td>
</tr>
<tr>
<td>Stars (54)</td>
<td>46</td>
<td>20</td>
<td>0-15</td>
<td>16</td>
</tr>
<tr>
<td>Coins (18)</td>
<td>46</td>
<td>11</td>
<td>0-3</td>
<td>4</td>
</tr>
<tr>
<td>Pointing (180)</td>
<td>47</td>
<td>1</td>
<td>0-50deg</td>
<td>40deg</td>
</tr>
<tr>
<td>L. Figure (6)</td>
<td>47</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Newspaper a) Headlines (10)</td>
<td>47</td>
<td>1</td>
<td>0-1</td>
<td>2</td>
</tr>
<tr>
<td>b) Paragraph (5)</td>
<td>47</td>
<td>2</td>
<td>0-1</td>
<td>2</td>
</tr>
<tr>
<td>c) Article (117)</td>
<td>43</td>
<td>4</td>
<td>0-6</td>
<td>7</td>
</tr>
</tbody>
</table>

The number of controls making omissions on each neglect test, the range of omissions made by controls, and cut-off points used for abnormal visuo-spatial function.
<table>
<thead>
<tr>
<th>Test</th>
<th>No. omissions</th>
<th>No. controls making omissions</th>
<th>Age</th>
<th>KOLT score</th>
<th>Other neglect scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>MEAL</td>
<td>1</td>
<td>2</td>
<td>80</td>
<td>25</td>
<td>Point 50 Stars 3 Coins 1</td>
</tr>
<tr>
<td>LINES</td>
<td>1</td>
<td>1</td>
<td>65</td>
<td>33</td>
<td>Coins 2 Stars 2</td>
</tr>
<tr>
<td>POINTING</td>
<td>1</td>
<td>50</td>
<td>80</td>
<td>25</td>
<td>Meal 1 Stars 3 Coins 1</td>
</tr>
<tr>
<td>HEADLINES</td>
<td>1</td>
<td>1</td>
<td>78</td>
<td>22</td>
<td>Stars 13 Coins 2</td>
</tr>
<tr>
<td>PARAGRAPH</td>
<td>1</td>
<td>2</td>
<td>74</td>
<td>16</td>
<td>Stars 6</td>
</tr>
<tr>
<td>ARTICLES</td>
<td>1</td>
<td>1</td>
<td>57</td>
<td>24</td>
<td>-----</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1</td>
<td>82</td>
<td>25</td>
<td>Stars 3</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>1</td>
<td>77</td>
<td>24</td>
<td>Stars 10</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>1</td>
<td>78</td>
<td>22</td>
<td>Stars 13 Coins 2</td>
</tr>
</tbody>
</table>

Age, KOLT score and numbers of omissions made by controls on neglect tests.
### TABLE 3A.3

<table>
<thead>
<tr>
<th>TEST</th>
<th>Right hemisphere stroke (n = 18)</th>
<th>Left hemisphere stroke (n = 26)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. patients attempting test</td>
<td>No. with neglect</td>
</tr>
<tr>
<td>Point</td>
<td>16</td>
<td>11</td>
</tr>
<tr>
<td>Meal</td>
<td>16</td>
<td>10</td>
</tr>
<tr>
<td>Menu</td>
<td>16</td>
<td>8</td>
</tr>
<tr>
<td>Newspaper</td>
<td>16</td>
<td>13</td>
</tr>
<tr>
<td>Lines</td>
<td>16</td>
<td>10</td>
</tr>
<tr>
<td>Stars</td>
<td>15</td>
<td>11</td>
</tr>
<tr>
<td>Coins</td>
<td>14</td>
<td>7</td>
</tr>
<tr>
<td>L.Fig</td>
<td>--</td>
<td>--</td>
</tr>
</tbody>
</table>

Number of stroke patients able to attempt each test and number of patients showing visual neglect on each test at 3 days post-stroke.
**TABLE 3A.4**

<table>
<thead>
<tr>
<th>TEST</th>
<th>right hemisphere stroke (n=12)</th>
<th>left hemisphere stroke (n=15)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.patients attempting test</td>
<td>No.with neglect</td>
</tr>
<tr>
<td>Pointing</td>
<td>11</td>
<td>3</td>
</tr>
<tr>
<td>Meal</td>
<td>11</td>
<td>6</td>
</tr>
<tr>
<td>Menu</td>
<td>11</td>
<td>3</td>
</tr>
<tr>
<td>Newspaper</td>
<td>11</td>
<td>5</td>
</tr>
<tr>
<td>Lines</td>
<td>11</td>
<td>4</td>
</tr>
<tr>
<td>Stars</td>
<td>11</td>
<td>7</td>
</tr>
<tr>
<td>Coins</td>
<td>11</td>
<td>5</td>
</tr>
<tr>
<td>L.fig</td>
<td>--</td>
<td>--</td>
</tr>
</tbody>
</table>

Number of stroke patients with visual neglect able to attempt each test at 3 months post-stroke and the number with visual neglect on each test.
Severity of visual neglect at 3 days and at 3 months post-stroke in 11 patients with a right hemisphere stroke and in 14 patients with a left hemisphere stroke.
Figure 3A.1
Relationship between age and the number of omissions on Star Cancellation.

Figure 3A.2
Relationship between KOLT score and the number of omissions on Star Cancellation.
3B. THE INCIDENCE OF NEGLECT PHENOMENA AND RELATED DISORDERS IN PATIENTS WITH AN ACUTE STROKE

3B.1 SUMMARY

171 consecutive patients with an acute hemispheric stroke (69 right hemisphere, 102 left), were assessed for the presence of neglect phenomena and related disorders at 2-3 days post-stroke.

(1) Visual neglect was found in 82% of assessable right hemisphere patients and in 65% of left hemisphere patients.

(2) Hemi-inattention was found in 70% of right and 49% of left hemisphere strokes.

(3) Sensory extinction was found in 65% of right and 35% of left hemisphere patients; Visual extinction in 23% right and 2% left.

(4) Allesthesia was present in 57% of right, and 11% left hemisphere strokes.

(5) Anosognosia was found in 28% of right, and in 3% of left hemisphere strokes; anosodiaphoria in 27% (right), and 2% (left); non-belonging in 36% (right) and 29% (left).

(6) Gaze paresis was present in 29% of right and in 25% of left hemisphere lesions.

(7) Visual field defects were found in 36% of right and in 46% of left hemisphere strokes.

(8) Visual neglect occurred more frequently in left hemisphere stroke than previously reported. Although neglect phenomena and related disorders were associated with right hemisphere damage, it is possible that language difficulties obscured their presence in some patients with a left hemisphere stroke.
3B.2 Incidence and hemispheric association

Table 3B.1 shows the proportion of patients, out of all 171 patients (see Figure 2.1 on page 31 for summary of study design), that could not be assessed 2-3 days after a right or left hemisphere stroke due to severe dysphasia or impaired consciousness. Patients with a left hemisphere stroke appeared more difficult to assess for visual neglect, sensory extinction, allesthesia, anosognosia, anosodiaphoria and non-belonging, probably due to dysphasia.

Tables 3B.2 and 3B.3 show the incidence of the various neglect phenomena and related disorders 2-3 days after a right or left hemisphere stroke in assessable patients. Visual neglect was found in over 80% of right and in 65% of the left hemisphere strokes. Hemi-inattention was present in about two thirds of right and in half the left hemisphere strokes. Sensory extinction was present in two-thirds of right and in a third of left hemisphere strokes. Allesthesia was present in over half the right but in relatively few left hemisphere strokes. Anosognosia was found in a quarter of right but in very few left hemisphere stroke patients.

Neglect phenomena appeared to be more frequently associated with right hemisphere damage, as were anosognosia and anosodiaphoria.
TABLE 3B.1

Number of patients with right and left hemisphere stroke unable to be assessed for neglect phenomena and related disorders

<table>
<thead>
<tr>
<th></th>
<th>right hemisphere stroke (n=69)</th>
<th>left hemisphere stroke (n=102)</th>
<th>Difference in proportions unassessable patients (95% C.I.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>number (%) unassessable patients</td>
<td>number (%) unassessable patients</td>
<td></td>
</tr>
<tr>
<td>Visual neglect</td>
<td>8 (11)</td>
<td>28 (27)</td>
<td>16% (4%, 27%)</td>
</tr>
<tr>
<td>Hemi-inattention</td>
<td>6 (9)</td>
<td>15 (15)</td>
<td>6% (-4%, 16%)</td>
</tr>
<tr>
<td>Sensory extcntn</td>
<td>17 (25)</td>
<td>59 (58)</td>
<td>33% (20%, 47%)</td>
</tr>
<tr>
<td>Allesthesia*</td>
<td>10 (15)</td>
<td>56 (55)</td>
<td>40% (27%, 53%)</td>
</tr>
<tr>
<td>Visual extcntn</td>
<td>9 (13)</td>
<td>21 (21)</td>
<td>8% (-4%, 9%)</td>
</tr>
<tr>
<td>Anosognosia</td>
<td>9 (13)</td>
<td>46 (45)</td>
<td>32% (20%, 45%)</td>
</tr>
<tr>
<td>Anosodiaphoria</td>
<td>9 (13)</td>
<td>49 (48)</td>
<td>35% (22%, 48%)</td>
</tr>
<tr>
<td>Non-belonging</td>
<td>14 (20)</td>
<td>54 (53)</td>
<td>33% (19%, 46%)</td>
</tr>
<tr>
<td>Gaze paresis</td>
<td>0 (0)</td>
<td>3 (3)</td>
<td>3% (-3%, 6%)</td>
</tr>
<tr>
<td>Vis Field Dfct</td>
<td>8 (11)</td>
<td>9 (9)</td>
<td>2% (-7%, 19%)</td>
</tr>
</tbody>
</table>

* Assessment of allaesthesia omitted in 3 patients
TABLE 3B.2

<table>
<thead>
<tr>
<th>NEGLECT PHENOMENA</th>
<th>RIGHT HEMISPHERE STROKE</th>
<th>LEFT HEMISPHERE STROKE</th>
<th>DIFFERENCE IN PROPORTIONS v LEFT (95% C.I.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual Neglect</td>
<td>present 50 (82%)</td>
<td>48 (65%)</td>
<td>17% (3%,33%)</td>
</tr>
<tr>
<td></td>
<td>assessed 61</td>
<td>74</td>
<td></td>
</tr>
<tr>
<td>Hemi-inattentn</td>
<td>present 44 (70%)</td>
<td>43 (49%)</td>
<td>21% (5%,36%)</td>
</tr>
<tr>
<td></td>
<td>assessed 63</td>
<td>87</td>
<td></td>
</tr>
<tr>
<td>Sensory extctn</td>
<td>present 34 (65%)</td>
<td>15 (35%)</td>
<td>30% (12%,49%)</td>
</tr>
<tr>
<td></td>
<td>assessed 52</td>
<td>43</td>
<td></td>
</tr>
<tr>
<td>Allsthsia</td>
<td>present 32 (57%)</td>
<td>5 (11%)</td>
<td>46% (31%,62%)</td>
</tr>
<tr>
<td></td>
<td>assessed 56</td>
<td>46</td>
<td></td>
</tr>
<tr>
<td>Visual extctn</td>
<td>present 14 (23%)</td>
<td>2 (2%)</td>
<td>21% (10%,32%)</td>
</tr>
<tr>
<td></td>
<td>assessed 60</td>
<td>81</td>
<td></td>
</tr>
</tbody>
</table>

THE INCIDENCE OF NEGLECT PHENOMENA IN ACUTE STROKE
### TABLE 3B.3

<table>
<thead>
<tr>
<th>RELATED DISORDER</th>
<th>RIGHT HEMISPHERE STROKE</th>
<th>LEFT HEMISPHERE STROKE</th>
<th>DIFFERENCE IN PROPORTIONS RIGHT v LEFT (95% C.I.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anosognosia</td>
<td>present 17 (28%)</td>
<td>3 (5%)</td>
<td>23% (9%,36%)</td>
</tr>
<tr>
<td></td>
<td>assessed 60</td>
<td>56</td>
<td></td>
</tr>
<tr>
<td>Anosodia phoria</td>
<td>present 16 (27%)</td>
<td>1 (2%)</td>
<td>25% (13,37%)</td>
</tr>
<tr>
<td></td>
<td>assessed 60</td>
<td>53</td>
<td></td>
</tr>
<tr>
<td>Non-belonging</td>
<td>present 20 (36%)</td>
<td>14 (29%)</td>
<td>7% (-10%,25%)</td>
</tr>
<tr>
<td></td>
<td>assessed 55</td>
<td>48</td>
<td></td>
</tr>
<tr>
<td>Gaze paresis</td>
<td>present 20 (29%)</td>
<td>25 (25%)</td>
<td>4% (-10%,17%)</td>
</tr>
<tr>
<td></td>
<td>assessed 69</td>
<td>99</td>
<td></td>
</tr>
<tr>
<td>Visual field</td>
<td>present 22 (36%)</td>
<td>43 (46%)</td>
<td>10% (-6%,26%)</td>
</tr>
<tr>
<td></td>
<td>absent 61</td>
<td>93</td>
<td></td>
</tr>
</tbody>
</table>

THE INCIDENCE OF ANOSOGNOSIA AND RELATED DISORDERS IN ACUTE STROKE

95
3C. RECOVERY OF NEGLECT PHENOMENA AND RELATED DISORDERS AFTER ACUTE STROKE

3C.1 SUMMARY

Thirty four survivors of a right hemisphere stroke and 34 survivors of a left hemisphere stroke, all of whom presented with visual neglect were followed up for at least 3 months. Most patients were followed up for six months. The cumulative rates for resolution of neglect phenomena and related disorders were calculated (see Figure 2.1 for summary of study design).

(1) For most neglect phenomena and related disorders there was an early phase of rapid recovery in the first 10 days to 3 weeks, which plateaued at 3 months.

(2) Visual neglect resolved in about 70% of left and in about 25% of right hemisphere strokes at 3 months.

(3) Hemi-inattention resolved in 90% of left and in 40% of right hemisphere strokes at 3 months.

(4) In patients with a right hemisphere stroke, the recovery of sensory extinction and allesthesia followed a similar pattern to that of hemi-inattention.

(5) Visual extinction disappeared in 6 weeks in 90% of right hemisphere strokes.

(6) Cumulative recovery rates for sensory and visual extinction, allesthesia, anosognosia and anosognosic phenomena in left hemisphere stroke could not be given as they were present in so few patients.

(7) Anosognosia resolved in 60% of right hemisphere strokes in 3 weeks and had resolved in nearly all patients at 6 months. Anosodiaphoria and non-belonging followed a similar course.

(8) Visual field defects resolved in nearly 80% of left but
in only 40% of right hemisphere strokes at 3 months.

(9) Gaze paresis resolved in all surviving patients within 6 weeks.
3C.2 RECOVERY OF NEGLECT PHENOMENA

Incidence of neglect phenomena at 3 days in patients with visual neglect

At 2-3 days post-stroke 32 of the 34 patients with visual neglect due to a right hemisphere stroke (94%) had hemi-inattention, 22 (66%) had sensory extinction, 10 (30%) had visual extinction and 22 (66%) had allesthesia. Of the 34 patients with visual neglect due to a left hemisphere stroke, 20 (60%) had hemi-inattention. Only 6 (18%) had sensory extinction, 1 (3%) had allesthesia and 1 (3%) had visual extinction, but many patients could not be assessed for these because of aphasia.

3C.2.1 Visual neglect and hemi-inattention. (Figure 3C.1).
Recovery of visual neglect and hemi-inattention was observed more frequently and more rapidly in those with a left hemisphere stroke. At 6 weeks, visual neglect had resolved in nearly 60% of left hemisphere patients but in only 20% of right hemisphere patients. At 3 months, visual neglect had resolved in nearly three-quarters of left hemisphere patients with neglect but in only just over a quarter of right hemisphere patients with neglect.

Visual neglect resolved more slowly than hemi-inattention, probably because the tests used to detect visual neglect were more detailed and, therefore, sensitive than those used to detect hemi-inattention.

3C.2.2 Sensory extinction, allesthesia and visual extinction (Figure 3C.2)
For right hemisphere patients the resolution of sensory extinction and allesthesia was similar to that of hemi-inattention. Recovery of visual extinction was observed more
frequently and rapidly in most patients.

It should be noted that 2 patients who originally had sensory extinction were not re-examined after 10 days and that 1 patient with allesthesia was not examined after 3 weeks because their visual neglect had resolved.

The resolution of these phenomena in Left hemisphere patients is not shown in the figure because the numbers of patients presenting with these were so small. Of the 6 with sensory extinction, 2 were not followed up for more than 10 days because their visual neglect had resolved. Of the other 4, 1 recovered from sensory extinction at 6 weeks and 2 recovered at 3 months. The one patient with allesthesia was not followed for more than 6 weeks because their visual neglect had resolved. The one patient who presented with visual extinction resolved at 6 weeks.

3C.3 RECOVERY OF RELATED DISORDERS

Incidence of related disorders at 3 days in patients with visual neglect

At 2-3 days post-stroke 13 (39%) of the 34 right hemisphere patients with visual neglect had anosognosia, 11 (33%) had anosodiaphoria and 10 (30%) had non-belonging. Twelve (35%) had a hemianopia and 8 (24%) had a gaze paresis. Of the 34 left hemisphere patients 18 (54%) had a field defect, 6 (18%) had a gaze paresis, and 6 (18%) had non-belonging. None had anosognosia or anosodiaphoria.

3C.3.1 Recovery of Anosognosia, anosodiaphoria and non-belonging (Figure 3C.3).

In most right hemisphere patients anosognosia and anosodiaphoria recovered within 3 weeks. Non-belonging was slightly slower to resolve. All 3 resolved much more quick-
ly than visual neglect. It should be noted that one patient with non-belonging was not followed after 10 days and another was only followed for 6 weeks because visual neglect had resolved.

3C.3.2 Recovery of Gaze Paresis and Visual Field Defect (Figure 3C.4).

In both right hemisphere and left hemisphere patients recovery of gaze paresis was rapid and complete although it should be noted that all the patients with visual neglect who died as a result of their stroke, presented with a gaze paresis.

Recovery of a hemianopia was observed more frequently and rapidly in left hemisphere patients than in right hemisphere patients. For left hemisphere patients the recovery rate was very similar to that for hemi-inattention. It should be noted that one left hemisphere patient with a hemianopia was not followed after 3 months because their visual neglect had resolved. Five of the 6 right hemisphere patients in whom a hemianopia resolved were left with visual extinction which persisted for 6 months in 4 patients and which resolved at 3 weeks in 1 patient.
Figure 3C.1 Cumulative recovery of visual neglect and hemi-inattention in acute right (unbroken lines) and left (broken lines) hemisphere stroke.

Figure 3C.2 Cumulative recovery of neglect phenomena in acute right hemisphere stroke.
Figure 3C.3 Cumulative recovery of anosognosia, anosodiaphoria, and non-belonging in acute right hemisphere stroke.

Figure C.4 Cumulative recovery of gaze paresis and visual field defect in acute left (broken lines) and right hemisphere (unbroken lines) stroke.
3D. DEVELOPMENT OF AN OVERALL MEASURE OF VISUAL NEGLECT
THE VISUAL NEGLECT RECOVERY INDEX.

3D.1 SUMMARY
The 68 surviving patients that presented with visual neglect were followed for 3 months. Each patient's graded score on each test of the visual neglect battery was recorded at 3 days and at three months.

(1) The percentage recovery represented by each of the 0-5 grades in the individual tests of the battery was calculated so that performance on the entire battery could be expressed as a single percentage figure, the VNRI. This figure represented the percentage of complete recovery from the maximum visual neglect measurable.

(2) The VNRI showed that recovery was most rapid over the first 10 days and plateaued at 3 months, reaching 75% in most patients.

(3) The VNRI showed that visual neglect was more severe in right hemisphere stroke than in left at all time intervals up to 3 months, but not at 6 months.

(4) Least significant difference analyses and ANOVA suggested that the VNRI correlated with the individual test scores.
3D.2 THE VISUAL NEGLECT RECOVERY INDEX (VNRI)

3D.2.1 Percentage recovery represented by each grade on each test

The percentage recovery represented by each grade on each of the six tests is given in Table 3D.1. This table implies that it is as difficult to recover from grade 2 as grade 3 neglect on Line cancellation, for example, and that it is more difficult to recover from grade 3 neglect on Meal than from grade 3 on Lines.

The table was used to summate and average a patient's percentage recovery score on each test to give an overall measure of visual neglect, the VNRI. For example, a patient with grade 2 neglect on Meal (55% recovery), grade 3 on Menu (46% recovery), and grade 0 (100% recovery) on the other tests at 6 weeks post-stroke, has an average recovery score (VNRI) of 83.5%.

If a patient was able to attempt only 3 or 4 tests because of aphasia or tiredness, the VNRI was calculated from the results of those tests as measurements were now in equivalent non-arbitrary units of "percentage recovery".

3D.2.2 Change in VNRI over time

Figure 3D.1 shows a plot of the mean VNRI at different time intervals up to 6 months for all 68 surviving patients presenting with visual neglect at 3 days, and for right and left hemisphere patients taken separately. Table D.2 shows the mean and standard deviations.

Visual neglect recovers most quickly over the first 10 days and plateaus at 3 months. Recovery is significantly greater in those with a left hemisphere stroke than in
those with a right hemisphere stroke at 3 days \( (t=3.23; p<0.025) \), 10 days \( (t=2.89; p<0.05; n=64) \), 3 weeks \( (t=2.96; p<0.025; n=66) \), 6 weeks \( (t=3.7; p<0.005; n=66) \) and 3 months \( (t=3.55; p<0.005; n=68) \), but not at 6 months \( (t=1.94; p=0.4; n=62) \).

The recovery between 3 days and 10 days is significant for right hemisphere \( (t=5.77; df=32; p<0.002) \) and for left hemisphere strokes \( (t=5.43; df=30; p<0.002) \). Recovery between 10 days and 3 months is significant for both groups \( (RH: t=3.33; df=32; p<0.01; LH: t=3.72; df=30; p<0.002) \). The change from 3 to 6 months is significant for right hemisphere \( (t=2.57; df=27; p=0.04) \) but not for left hemisphere stroke \( (t=0.93; df=33; N.S.) \), who had mostly recovered anyway.

Many patients have little or no residual visual neglect at 3 months. This is true even of the 15 patients presenting with an VNRI of 0-20%, 7 of whom attained a 3 month score of at least 75% (Figure 3D.2). In the whole population only 7 patients had a 3 month VNRI of below 60%; all the rest, except for one, achieved a VNRI of at least 75%.

3D.2.3 Correlation of VNRI with individual test scores.

Change over time in the individual test scores, taken for all 68 patients, follows a similar pattern to that for the VNRI as a whole (Figure 3D.3). Performance on Star cancellation appeared to deteriorate between 3 and 6 months. This may be due to the fact that there was a significant subgroup in the earlier stages of testing who were too aphasic or drowsy to be tested on Stars, but who had a lot of neglect on this test later once their level of conscious-
ness or aphasia had improved. To a lesser extent this also applies to the Menu. At all stages post-stroke, there was a general trend showing that as recovery in each test increases so does recovery over the whole battery as reflected in the VNRI. One might expect this, given that the individual tests each contribute to the VNRI. An example of this, for "coins" is given in Figure 3D.4, which also illustrates the wide variation between individuals. Calculation of correlation coefficients is not valid because the individual test scores fall into categorical groups. Analysis of variance is difficult because some groups are very small. However, where it was possible ANOVA showed that at 3 days there was a significant difference between the VNRI means for each level of visual neglect on Meal (F=59.27 at 3,46 df) and on Pointing (F=27.13, at 3,45 df).

Least Significant Difference analysis on Meal and Pointing (Tables 3D.3 and 3D.4) shows that the four levels of visual neglect on meal at 3 days had significantly different mean VNRI values from each other. Thus neglect on Meal parallels neglect over the whole battery. Similar analysis showed that the first 3 levels of visual neglect on Pointing at 3 days had significantly different mean VNRI values but that there was no significant difference in the mean VNRI when the neglect on Pointing was 89 or 100%.
### Table 3D.1

Percentage of total neglect recovery on neglect tests

<table>
<thead>
<tr>
<th>Grade</th>
<th>MENU</th>
<th>MEAL</th>
<th>LINES</th>
<th>STARS</th>
<th>COINS</th>
<th>POINTING</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>25</td>
<td>0</td>
<td>27</td>
<td>19</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>46</td>
<td>16</td>
<td>73</td>
<td>30</td>
<td>32</td>
<td>29</td>
</tr>
<tr>
<td>2</td>
<td>67</td>
<td>55</td>
<td>73</td>
<td>57</td>
<td>32</td>
<td>89</td>
</tr>
<tr>
<td>1</td>
<td>80</td>
<td>---*</td>
<td>80</td>
<td>75</td>
<td>86</td>
<td>100</td>
</tr>
<tr>
<td>0</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

* = no grade 1 visual neglect on meal

Value of each grade on each test as a percentage of total visual neglect recovery on that test over three months.
<table>
<thead>
<tr>
<th>time</th>
<th>ALL Mean</th>
<th>S.D.</th>
<th>RH Mean</th>
<th>S.D.</th>
<th>LH Mean</th>
<th>S.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 days</td>
<td>56.81</td>
<td>33.00</td>
<td>44.71</td>
<td>34.39</td>
<td>68.91</td>
<td>26.97</td>
</tr>
<tr>
<td>10 days</td>
<td>76.94</td>
<td>30.21</td>
<td>66.94</td>
<td>35.41</td>
<td>87.58</td>
<td>18.74</td>
</tr>
<tr>
<td>3 weeks</td>
<td>78.64</td>
<td>33.31</td>
<td>69.90</td>
<td>35.92</td>
<td>89.29</td>
<td>12.29</td>
</tr>
<tr>
<td>6 weeks</td>
<td>83.67</td>
<td>24.24</td>
<td>73.36</td>
<td>29.54</td>
<td>93.76</td>
<td>10.54</td>
</tr>
<tr>
<td>3 months</td>
<td>88.16</td>
<td>21.71</td>
<td>79.53</td>
<td>27.52</td>
<td>96.79</td>
<td>6.77</td>
</tr>
<tr>
<td>6 months</td>
<td>90.97</td>
<td>18.58</td>
<td>86.04</td>
<td>22.04</td>
<td>95.03</td>
<td>14.25</td>
</tr>
</tbody>
</table>

The mean and standard deviation of the VNRI at different time intervals post-stroke for all patients (n=68) and for right (n=34) and left hemisphere (n=34) patients.
### Table 3D.3

<table>
<thead>
<tr>
<th>&quot;Meal&quot; test score</th>
<th>MEAN VNRI</th>
<th>No. patients</th>
<th>(S.D.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>at 3 days 0</td>
<td>10.875</td>
<td>8</td>
<td>(15.542)</td>
</tr>
<tr>
<td>(% recovery 16</td>
<td>30.25</td>
<td>8</td>
<td>(15.755)</td>
</tr>
<tr>
<td>54</td>
<td>56.444</td>
<td>9</td>
<td>(18.167)</td>
</tr>
<tr>
<td>100</td>
<td>87.280</td>
<td>25</td>
<td>(15.274)</td>
</tr>
</tbody>
</table>

Mean VNRI for different levels of visual neglect on Meal at 3 days post-stroke.

### Table 3D.4

<table>
<thead>
<tr>
<th>Test score on &quot;Pointing&quot; at 3 days</th>
<th>MEAN VNRI</th>
<th>No. Patients</th>
<th>(S.D.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>18.75</td>
<td>8</td>
<td>(26.408)</td>
</tr>
<tr>
<td>(% recovery 29)</td>
<td>50.462</td>
<td>13</td>
<td>(18.315)</td>
</tr>
<tr>
<td>89</td>
<td>75.000</td>
<td>7</td>
<td>(11.860)</td>
</tr>
<tr>
<td>100</td>
<td>83.619</td>
<td>21</td>
<td>(16.636)</td>
</tr>
</tbody>
</table>

Mean VNRI for different levels of visual neglect on Pointing at 3 days post-stroke.
Figure 3D.1 Change in visual neglect recovery index over time in patients with right (n=34) and left (n=34) hemisphere stroke.

Figure 3D.2 VNRI at 3 days and at 3 months in all patients.
Figure 3D.3 Change in individual neglect test scores with time.

Figure 3D.4 Relationship between VNRI and percentage neglect recovery on coins at 3 days and at 3 months post-stroke
3E. PREDICTION OF THE SEVERITY OF VISUAL NEGLEcT
AT 3 AND AT 6 MONTHS POST-STROKE

3E.1 SUMMARY

The 68 surviving patients that had presented with visual neglect at 2–3 days, and in whom the VNRI was developed, were followed for up to 6 months.

(1) Stepwise regression analysis showed that the severity of visual neglect (measured by the VNRI) at 3 months and at 6 months post-stroke could be predicted by the severity of visual neglect (VNRI) and the presence of anosognosia at 2–3 days.

(2) These two variables explained 53% of the variance at 3 months and 46% of the variance at 6 months.

(3) Residual analysis showed that there were no other predictors of outcome.

(4) Actual and predicted outcome matched well at the upper end of the range, but less so at the lower end.
3E.2 Significant predictor variables

At both time points two variables were found to make an individual independent contribution to the severity of visual neglect at 3 and at 6 months post-stroke. These were the severity of visual neglect and the presence of anosognosia at 2-3 days post-stroke. No other neglect phenomenon, related disorder or neurological deficit was found to be a significant predictor of outcome.

The following regression equations were derived which relate the severity of visual neglect at both time points to the significant predictor variables:

\[
VNRI \text{ (3 mths)} = 67 + 0.4 \times (VNRI \text{ 3 days}) - 15 \times \text{Anosognosia}
\]

\[
VNRI \text{ (6 mths)} = 74.5 + 0.3 \times (VNRI \text{ 3 days}) - 12 \times \text{Anosognosia}
\]

The equation for prediction at 3 months was based on 55 cases while that for 6 months was based on 49 cases. The independent variables explained 53% of the variance at 3 months and 46% at 6 months. The similarity of the equations demonstrated the consistency of the independent variables in predicting outcome. Residual analysis confirmed that there were no other significant predictors of outcome.

3E.3 Accuracy of prediction

Figure 3E.1 shows how the actual and predicted VNI scores at 3 months compare. Predicted and actual scores match well at the upper end of the VNI. At the lower end of the range, matching is poor, with frequent over-estimation of recovery. This was true at 6 months as well (Figure 3E.2). Residuals were plotted against the predicted values and also against all the variables, including those that were not in the model. Residual analysis showed a good scatter
of results and confirmed that there were no other significant predictors of outcome.
**Figure 3E.1** Comparison of actual and predicted VNRI scores at 3 months.

**Figure 3E.2** Comparison of actual and predicted VNRI scores at 6 months.
3F. PREDICTION OF INDEPENDENCE IN SELF CARE AT 3 AND AT 6 MONTHS IN STROKE SURVIVORS

3F.1 SUMMARY

Eighty nine survivors of acute stroke, 65 of whom presented with visual neglect, were followed for up to 6 months. Their level of independence at 3 and at 6 months was recorded (see Figure 2.1 for summary of study design).

(1) Linear logistic regression showed that the initial degree of paralysis (measured by the Motricity Index), the severity of neglect (measured by the Visual Neglect Recovery Index) and the patient's age were the significant predictors of independence (Barthel score 20), mild dependence (Barthel 15-19), and moderate/severe dependence (Barthel 0-14) at both time intervals.

(2) Regression equations were derived that correctly predicted 78% of outcomes, and had a sensitivity and specificity for "independence" of 84% and 90% respectively, a sensitivity and specificity for "moderate/severe dependence" of 89% and 80% and a sensitivity and specificity for "mild dependence" of 47% and 42%.
3F.2 Significant predictor variables.

Of the 3 month survivors 50 were independent, 19 mildly dependent, 10 moderately dependent and 10 severely dependent. At 6 months 54 were independent, 16 mildly, 7 moderately and 7 severely dependent. The severe and moderate groups were amalgamated as their numbers were too low for successful linear logistic regression.

Anova and Chi-squared tests showed that at both time points Level of consciousness, Gaze paresis, Visual Field Defect, Hemi-inattention, Visual Neglect Recovery Index and the Motricity Index were the significant predictor variables in survivors (Table 3F.1). It should be noted that extinction, allesthesia and proprioception are not included in the table because the number of patients that could be assessed for these was too small and reduced the number of patients with complete sets of data on which meaningful logistic regression analysis could be carried out. Linear logistic regression found that at both time points, 3 variables made an independent contribution to outcome in survivors: Visual Neglect Recovery Index, Motricity Index and age (Table 3F.2).

3F.3 Accuracy of Prediction

When each patients was assigned to the outcome group with the highest probability, the predictive accuracy of the statistical model at 3 months was 78%. 90% of independent and 80% of moderate/severe outcomes were correctly predicted. At 6 months the model had an overall predictive accuracy of 75%, with 91% of independent and 71% of moderate/severe outcomes being correctly predicted (Table 3F.3). Prediction of mild dependence was considerably less
accurate, many being predicted to be independent.
Table 3F.1

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>AT 3 MONTHS</th>
<th>AT 6 MONTHS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CHI (df)</td>
<td>CHI (df)</td>
</tr>
<tr>
<td></td>
<td>significance</td>
<td>significance</td>
</tr>
<tr>
<td>Conscious level</td>
<td>33.8 (2)</td>
<td>33.9 (2)</td>
</tr>
<tr>
<td></td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Gaze Paresis</td>
<td>18.2 (2)</td>
<td>19.4 (2)</td>
</tr>
<tr>
<td></td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Hemi-Inattention</td>
<td>22.3 (2)</td>
<td>20.4 (2)</td>
</tr>
<tr>
<td></td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Vis.Field defect</td>
<td>7.7 (2)</td>
<td>6.7 (2)</td>
</tr>
<tr>
<td></td>
<td>&lt;0.025</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>F-ratio</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>2.15</td>
<td>1.40</td>
</tr>
<tr>
<td></td>
<td>(2,87)</td>
<td>(2,82)</td>
</tr>
<tr>
<td></td>
<td>&gt;0.10</td>
<td>&gt;0.20</td>
</tr>
<tr>
<td>VNRI</td>
<td>39.70</td>
<td>30.72</td>
</tr>
<tr>
<td></td>
<td>(2,87)</td>
<td>(2,82)</td>
</tr>
<tr>
<td></td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Motricity Index</td>
<td>43.28</td>
<td>41.18</td>
</tr>
<tr>
<td></td>
<td>(2,87)</td>
<td>(2,82)</td>
</tr>
<tr>
<td></td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

Clinical variables at 2-3 days significantly associated with level independence at 3 months and at 6 months.
### Table 3F.2

<table>
<thead>
<tr>
<th>Variable</th>
<th>Regression Coefficient (b)</th>
<th>Significance Level</th>
<th>Regression Coefficient (b)</th>
<th>Significance Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power (MI)</td>
<td>0.0416</td>
<td>&lt;0.0001</td>
<td>0.0375</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Neglect (VNRI)</td>
<td>0.0441</td>
<td>&lt;0.0001</td>
<td>0.0381</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Age</td>
<td>-0.0967</td>
<td>0.0027</td>
<td>-0.0741</td>
<td>0.0194</td>
</tr>
<tr>
<td>Intercept a1</td>
<td>1.5067</td>
<td></td>
<td>1.0917</td>
<td></td>
</tr>
<tr>
<td>Intercept a2</td>
<td>3.9586</td>
<td></td>
<td>3.3572</td>
<td></td>
</tr>
</tbody>
</table>

The probability, \( p(1) \), of a patient being independent at 3 or 6 months is given by the equation

\[
p(1) = \frac{1}{1 + e^{- (a_1 + (b_1 \times MI) + (b_2 \times VNRI) + (b_3 \times age)}}
\]

The probability, \( p(2) \), of a patient being mildly dependent is given by the same equation with a different intercept, \( a_2 \).

The probability of moderate/severe dependence is given by

\[
l-p(1)-p(2)
\]

**REGRESSION COEFFICIENTS**

FOR SIGNIFICANT PREDICTOR VARIABLES.
Table 3F.3

Comparison of predicted and actual outcome at 3 and at 6 months.

<table>
<thead>
<tr>
<th>ACTUAL OUTCOME</th>
<th>PREDICTED OUTCOME</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>at 3 months</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Barthel 20</td>
<td>45</td>
<td>5</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Barthel 15-19</td>
<td>9</td>
<td>8</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Barthel 0-14</td>
<td>0</td>
<td>4</td>
<td>16</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>at 6 months</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Barthel 20</td>
<td>49</td>
<td>5</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Barthel 15-19</td>
<td>9</td>
<td>4</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Barthel 0-14</td>
<td>0</td>
<td>4</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Section 4

DISCUSSION
4A. STANDARDIZATION OF THE VISUAL NEGLECT TEST BATTERY.

4A.1 SUMMARY

(1) The omissions made by controls on the visual neglect battery were attributed to an age related decline in visuo-spatial function. Cut-off points were chosen to distinguish between such age-related impairment and visual neglect.

(2) In stroke patients, the battery was validated against an occupational therapist's assessment of neglect on self-care tasks.

(3) The inter-observer reliability was good.

(4) The battery was simple and quick to administer.

(5) It was sensitive to the presence of visual neglect, probably because it takes into account the behavioural inconsistency of visual neglect, using a wider range of tests than is the clinical convention. This is especially relevant to the detection of visual neglect in left hemisphere stroke.

(6) The battery is sensitive to change over time.

(7) It is suitable for use in patients with an acute stroke.
4A.2 CONTROLS

The control group was selected so that they were as representative as possible of the pre-morbid state of the local hospital-based stroke population, nearly all of whom (89%) were active, independent and living at home. To that end they were matched for age, and were drawn from the same geographical area. They were in good general health, despite being admitted to hospital for routine repeat checks or other elective procedures. The incidence of hypertension was similar to that in the stroke population, although that of diabetes was lower (0% to 8%). Only four showed depression on the GDS (three of them under the age of 65), only two had MTS scores below the cut-off point for the diagnosis of dementia.

Unlike many studies of neurological and cognitive function in the elderly this study recruited active and independent subjects, instead of medical in-patients (Savitsky + Madonick 1943; Mayne 1965; Prakash + Stern 1973; Stone et al 1987), residents of old people's homes or institutions (Laidlaw + Hamilton 1937; Plutchik et al 1968; Mehler 1985). In all these studies, depression, dementia or general ill-health might have affected the results of testing. Our controls were probably as active and independent as the "normal" elderly recruited from old people's clubs in other studies (Plutchik et al 1968; Kendrick et al 1979; Wade et al 1988).

The incidence of isolated pyramidal tract signs and proprioceptive loss was low, as reported in other studies (Pearson 1928; Howell 1949; Klawans et al 1971; Broe et al 1976). The KOLT scores in this study showed the expected
age-related decline (Kendrick et al 1979). The proportion of people with MTS scores below 7 was the same as that in a community study of perceptual function in elderly people which found that various tests of apraxia and spatial function were performed poorly or with difficulty by 18-59% of subjects (Eccles 1988). The current study's findings are consistent with those of Eccles' study. Fifty-five percent of our subjects made at least one omission on the entire battery. On one test, Star cancellation, 43% of subject made omissions. As with Eccles' study, age and cognitive impairment influenced performance.

The performance of the controls was regarded as normal and was used to set parameters to distinguish between normal and abnormal visuo-spatial function in the elderly (Wade et al 1988). These parameters were used to help define visuo-spatial neglect in patients with an acute stroke. The parameters of normal visuo-spatial function were set separately for each test, because visuo-spatial neglect may be task specific and may appear in one test but not in another (Section 1.4.3). This approach contrasts with that of the original study that developed the BIT. This set the cut-off point for detection of neglect for performance on the battery as a whole i.e. any patient making omissions or errors on two or more tests was considered to have neglect (Wilson et al 1987).

An age-related decline in neurological (Pearson 1928; Howell 1949; Klawans et al 1971; Broe et al 1976; Jenkyn et al 1985) and cognitive function (Kral 1962; Schaie 1983) is well recognised. Beginning in their late sixties and seventies (Schaie 1983), elderly subjects show cognitive changes which often coexist without significant disease, disabili-
ty or handicap (Sunderland et al 1986) and the same is true of neurological changes (Broe et al 1976). A recent study of over 2000 elderly people found that neurological signs consistent with diffuse cerebral disease are common but, taken in clinical context, are age-related and not pathological (Jenkyn et al 1985).

Such changes are often subtle (Huppert 1987) and the concept of an "age-related decline in intellectual efficiency" (Blessed et al 1968) is useful in accounting for findings such as visuo-spatial impairment, when they appear in clinical isolation. Visual neglect may be due to a disruption of the "attention-arousal" system (Section 1.2.6). "Attention" refers to a complex psychological construct whose neuro-anatomical pathways may be diffusely organized. It is reasonable to suggest that when the efficiency of this system is affected by age-related decline, subtle visuo-spatial impairments may appear on detailed clinical examination. When the performance of a control is impaired to a disproportionate degree, one might speculate as to the presence of a focal element in the disturbance of cerebral function (Zangwill 1964). Such a case is the control who omitted four Lines (3 left, 1 right); one word on Headlines (one left); and thirteen Stars (9 left, 4 right). This might represent ischaemia or a focal parietal presentation of Alzheimer's disease (Crystal et al 1982; Celsis et al 1987).

It has been suggested that poor visual acuity may account for impairments suggestive of visual neglect in, for example, drawing tests (Eccles 1988). In the present study visual acuity as measured by the ability to read small
newsprint was adequate in all but four subjects. Two of these made no omissions on any other test. A third made one omission on Coins, one on Paragraph, three on Stars, had a KOLT score of 11 and made 6 errors on the speech assessment. The fourth made 8 omissions on Stars and had a KOLT score of 21. Poor visual acuity thus remains a possible contributing factor in impaired performance in some controls.

4A.3 STROKE PATIENTS

Once the control results had been used to set a range of normal performance the visual neglect battery was evaluated as a clinical tool for detecting and monitoring visual neglect inpatients with an acute stroke. The battery satisfies the basic requirements for a good assessment of any neurological deficit after a stroke. That is, it is relevant, valid and reliable simple to administer, sensitive and able to give a result that can be communicated to other colleagues (Wade et al 1985).

The battery includes tests from the BIT that simulate everyday activities e.g. reading, looking round the room, selecting coins, and eating. These tests would seem to be more relevant to real life than abstract paper and pencil tests and will indicate to therapists appropriate areas for treatment (Wilson et al 1987, 1987a).

4A.3.1 Validity of the battery

The validity study found that sixteen out of seventeen patients with neglect on the battery, had neglect on the OT checklist. This method of validating clinical tests of neglect has been used by Battersby and colleagues. They found that neglect on clinical testing did not always
generalize to daily activities (Battersby et al 1956; Weinburg et al 1977). We observed one such patient, but cannot say whether such a discrepancy is an example of the behavioural inconsistency of neglect (Mesulam 1981; Friedland + Weinstein 1977) or of a dissociation between neglect in different tasks (Bisiach et al 1986). The checklist was not graded for severity of neglect on each item, so we cannot comment on the correlation of different degrees of neglect on the battery and on the checklist.

4A.3.2 Reliability of the battery

In 12 patients assessed by two observers, the reliability of the battery was good with respect to the presence and severity of neglect in each test. Inter-test reliability was not assessed, but visual neglect is known to fluctuate (Wade et al 1988; Friedland + Weinstein 1977) and to be influenced by factors such as fatigue, time of day and previous activities (Wilson et al 1987). A separate inter-test reliability study is currently being carried out.

The tests are easy for an examiner to administer. The presence of aphasia was not as great an obstacle to assessment as had been anticipated because sufficient gestural comprehension was often retained to allow co-operation with the tests even in the presence of major deficits of verbal comprehension and word production. Seven consecutive patients whose performance was timed, completed the tests in a mean (s.d.) time of 11 minutes 10 seconds (3 mins.11 secs.).

4A.3.3 Sensitivity of the battery

The battery appeared to be sensitive to the presence of visual neglect, and to changes in its severity over time.
More patients with an acute stroke seemed to have visual neglect than has been reported in other studies which have used a simple line cancellation and figure copying battery (Cutting 1978; Fullerton et al 1986). Had Lines been used as the sole test of visual neglect the incidence of visual neglect would have been 55% (right hemisphere) and 42% (left hemisphere) at 3 days post-stroke. At 3 months visual neglect would have been evident in only 36% of those with a right hemisphere stroke and in none of those with a left hemisphere stroke. The likely reason for this higher incidence of visual neglect is that visual neglect was considered to be present if it appeared in only one test (Ogden 1985). Various studies suggest that visual neglect may be task-specific (Section 1.4.3). Assessment of patients by a larger battery is therefore more likely to result in the detection of visual neglect than assessment by a one or two test battery (Ogden 1985). The use of a larger battery has a particular bearing on the detection of visual neglect in those with a left hemisphere stroke. Although some patients were unable to understand what was required in one or two of the tests, they were often able to understand and attempt other tests.

There is no one standard method of measuring visual neglect (Fullerton et al 1986; Wade et al 1988; Ogden 1985; Wilson et al 1987). Some sensitive tests in our battery are not scorable, for example Right Hand Start and Crowding but they remain useful clinical signs of visual neglect, possibly reflecting abnormalities in eye movements reported in patients with unilateral brain damage who begin visual search tasks by exploring ipsilateral space (Chedru et al 1973; Chain et al 1979). The method of expressing the
percentage of items omitted from each test as a grade on a 0-5 scale is simple and each grade is easily understood. It avoids giving too much weight to small changes over time in the raw score and expresses the result of each test in the same arbitrary units. Although these units, like those in the MRC grading of weakness, have no intrinsic value, they do enable change to be monitored. The finding that visual neglect is more severe in those with a right hemisphere stroke than in those with a left hemisphere stroke is consistent with other reports (Chain et al 1979; Chedru et al 1973). The scoring system is not as useful as an overall score, but takes into account the patients performance over a variety of tests.

In conclusion, the battery takes into account the behavioural inconsistency of visual neglect and is suitable for use with patients after an acute stroke. It is a valid, reliable and sensitive test battery.
4B. THE INCIDENCE OF NEGLECT PHENOMENA AND RELATED DISORDERS IN PATIENTS WITH AN ACUTE STROKE.

4B.1 SUMMARY

(1) This is the first study to report the incidence of different neglect phenomena and related disorders in patients with right hemisphere and in those with left hemisphere stroke.

(2) The higher incidence of visual neglect and hemi-inattention reported in this study can probably be attributed to the use of a larger and more sensitive testing procedure. This is particularly true for left hemisphere stroke.

(3) It is hard to compare the incidence of extinction and anaesthesia with that reported in other studies, because the latter have not tested for these phenomena in as great detail.

(4) Inter-clinician variability might explain the wide variation in the reported incidences of anosognosia and visual field defect given in different studies.

(5) Although neglect phenomena and related disorders were associated with right hemisphere damage, it is possible that language difficulties obscured their presence in some patients with a left hemisphere stroke. Nonetheless, this association is consistent with the evidence that suggests that the right hemisphere is specialized for the distribution of sensory attention to environmental space.
4B.2 Neglect phenomena

This is the first study to report the incidence of different forms of neglect and related disorders in acute stroke affecting either hemisphere. Visual neglect was found to be more common than in other studies of acute stroke (Fullerton et al 1986; Cutting 1978; ier et al 1983; Vallar + Perani 1986). Eighty two per cent of assessable right hemisphere strokes had visual neglect compared to 70% (Fullerton et al 1986) (95% C.I. for difference in proportions 3%, 26%); and 43% (Vallar + Perani 1986) (95% C.I. for difference in proportions 26%, 53%). Sixty five per cent of assessable left hemisphere strokes had visual neglect, compared to 40% (Fullerton et al 1986) (95% C.I. for difference in proportions 10%, 41%). It is hard to compare these findings with those of Cutting (1978) who studied stroke patients with particular reference to anosognosia. Although he gives an incidence for visual neglect of 50% in right and 0% in left hemisphere stroke, it is not clear how many of these patients were unassessable for neglect.

The higher incidence for visual neglect reported in the current study can probably be attributed to the use of a larger and thus more sensitive battery (Section 4A.3.2) than previous studies. Given the poorer prognosis for patients with visual neglect, and their possible need for intensive specialized treatment, the early accurate detection of such patients may have important implications for allocation of rehabilitation resources. Had line cancellation, for example, been used as the sole test, as in Fullerton et al's study (1986), the incidence of visual neglect
would have been identical to that in their study of acute stroke.

Hier et al's study (1983) of patients with an acute right hemisphere stroke reported a similar incidence of visual neglect to the current study's (85%; 95% C.I. for difference in proportions -10%, 17%), despite using only one test, a drawing task. However, this figure needs to be interpreted with caution for the population was atypical of the general stroke population, in that patients who were obtunded, had a lacunar infarct or a normal CT brain scan were excluded. In addition, no data was presented concerning the validity, reliability or control performance of their drawing task. This is important because, firstly, the interpretation of drawing tasks may be subjective and made difficult by structural disorganization and other problems of perception or praxis (Battersby et al 1956; Andrews et al 1980). Secondly, most patients with a stroke are over the age of 65 and up to 47% of controls in this age group perform poorly on drawing tasks (Eccles 1988).

A higher incidence of hemi-inattention was found in right hemisphere stroke (70%) than in Hier et al's study (46%) (1983) (95% C.I. for difference in proportions 4%, 43%). They defined "neglect of left hemispace" as "the spontaneous failure to attend or turn to visual or auditory stimuli presented from the left". The definition used in the present study was broader in that it included assessment of eye movements, mobility, grooming and posture. This might, in part, explain our higher incidence. The incidence of hemi-inattention in left hemisphere stroke was 42% in the current study. No previous study has reported on this
Sensory extinction was found to be as common in assessable right hemisphere stroke as in Hier et al's patients (1983) (65% v 63% respectively, 95% C.I. for difference in proportions -18%, 22%). Sensory extinction was present in 35% of assessable left hemisphere strokes. No other study has reported on this variable. One study, however, found that in a group of patients with mixed cerebral pathology, sensory extinction occurred after left brain damage but less commonly than after right brain damage (Schwartz et al 1979).

The only study to report the incidence of visual extinction after stroke (Wade 1984) gives a combined incidence for assessable left and right stroke of 11% similar to that of the current study (13%) (95% C.I. for difference in proportions -4%, 9%). The only study of aanaesthesia after stroke was confined to patients with thalamic or putaminal haemorrhage, none of whom had neglect (Kawamura et al 1987).

4B.3 Related disorders

Of the related disorders, anosognosia was found to be less common in assessable right hemisphere stroke (28%) than in Cutting's study(1978) (58%) (95% C.I. for difference in proportions 12%, 48%). Anosodiaphoria was however, more common in assessable right hemisphere strokes (27%) than in Cutting's (1978) study (4%) 95% C.I. for difference in proportions 9%, 36%). It is not immediately clear why there should be such variation. Cutting developed a formal questionnaire to assess these disorders, which was used in this study. It is possible that in the absence of specific instructions as to the diagnostic criteria for these disor-
ders, inter-clinician variability would arise. Garraway and colleagues (1976) have amply demonstrated this with respect to the introduction of new assessment protocols for stroke patients. However, the incidence of anosognosia in assessable left hemisphere stroke was similar (5%) to that in Cutting's study (14%) (95% C.I. for difference in proportions -7%, 24%). The incidence of anosodiaphoria in left hemisphere stroke was also similar in both studies (2% and 10% respectively; 95% C.I. for difference in proportions -5%, 21%). The similarity may relate to the difficulties of assessing patients with dysphasia. The figure for anosognosia in right hemisphere stroke was similar to that reported by Hier et al (1983) (36%) (95% C.I. for difference in proportions -10%, 27%). It is hard to compare the current study's figure with that of Willanger et al (1981) who found anosognosia in 25% of right hemisphere strokes, for it is unclear how long post-stroke their patients were examined.

The incidence of a visual field defect in assessable right hemisphere stroke (36%) is similar to that reported by Hier et al (46%) (1983) (95% C.I. for difference in proportions -9%, 30%). No other study gives a figure for visual field defects in acute left hemisphere stroke. It should be noted that visual field defects can occur in the absence of visual neglect and vice versa (Halligan et al 1991). Clinico-anatomical studies have shown that surgery restricted to the medial occipital lobe causes restriction of visual fields but not visual neglect and that patients with posterior cerebral infarcts have isolated hemianopias unless the lesion involves the temporal or parietal lobes.
The incidence of gaze paresis in the present study was similar for right and left hemisphere stroke. This fails to confirm the findings of De Renzi and colleagues (1982), who reported an association with right hemisphere stroke (35% right; 21% left). However, it should be noted that what DeRenzi et al regarded as the mildest form of gaze paresis, loss of spontaneous ocular scanning movements to the side opposite the lesion in the absence of a frank gaze paresis, was regarded in the present study as a "gaze preference" (Watson + Heilman 1979) and as such, a form of hemi-inattention (Section 2.3.11). It is not clear from their study how many presented with this form of gaze paresis, so further comparisons are hard to make.

4B.4 Right hemisphere association

The finding that neglect phenomena and most related disorders were associated with right hemisphere stroke is consistent with most other studies (Fullerton et al 1986; Cutting 1978; Haecen 1962). Visual neglect, which is the only neglect phenomenon to be previously studied in left hemisphere stroke, was much more common than in earlier studies. However this study did not replicate the finding reported in the standardization of the visual neglect battery (Section 3A.3.1a) and in other studies that visual neglect is equally common in right or left sided lesions (Albert 1973; Chain et al 1979; Ogden 1985). These studies were based either on smaller populations, or on non-acute stroke patients or on groups of mixed, predominantly non-vascular pathology. It is however possible that the association of some neglect phenomena and related disorders with
right hemisphere stroke might still be an artefact of the difficulty of assessing dysphasic left hemisphere patients (Table 3B.1) (Brain 1945; Battersby et al 1956). Nonetheless, this association is consistent with the view that, although both hemispheres have the capacity to attend to contralateral stimuli, the non-dominant hemisphere is specialized for the distribution of sensory attention (Section 1.2.7).
4C. RECOVERY OF NEGLECT PHENOMENA AND RELATED DISORDERS
AFTER ACUTE STROKE

4C.1 SUMMARY

(1) The early phase of relatively rapid recovery of most neglect phenomena and related disorders in the first 10 days to 3 weeks, followed by a plateauing-off at about 3 months, is consistent with the recovery pattern reported for most-neurological deficits after stroke.

(2) The slower recovery of visual and hemi-inattention in right hemisphere patients reported in this study, compared to other reports, may reflect the more detailed and sensitive testing used here.

(3) The slower recovery of visual and hemi-inattention in right hemisphere stroke, compared to that in left hemisphere stroke, may reflect an initial difference in severity, and may be due to the specialization of that hemisphere for the distribution of sensory attention.
4C.2 Comparison other studies

Only two other studies have examined the recovery of visual neglect in patients seen in the first week post-stroke (Hier et al 1983a; Wade et al 1988). In the first, Hier and colleagues studied a population somewhat different from the general hospital-based acute stroke population (Section 4B.2). Recovery of allesthesia, anosodiaphoria, and gaze paresis were not assessed. They found recovery of visual and hemi-inattention to be faster than that reported in the present study with a median time to recovery of 8 or 9 weeks respectively. This may reflect the more detailed and sensitive testing for these phenomena in the current study.

On the other hand, the recovery of sensory extinction, anosognosia and visual field defects was much faster in the present study, whereas Hier et al reported a median time to recovery of 43, 11, and 32 weeks respectively. It is of interest to note that in the current study a hemianopia resolved more quickly and frequently in patients with visual neglect due to a left hemisphere stroke than in those with visual neglect due to a right hemisphere stroke (Figure 3C.4). It is possible that in right hemisphere patients with severe visual neglect one might be unable to distinguish between hemi-inattention and a hemianopia on clinical grounds, although the two are doubly dissociable as are visual neglect and hemianopia. A hemianopia can, occur in the absence of neglect and vice versa (Bisiach et al 1986a; Gordon et al 1985; Ishiai et al 1987). Clinico-anatomical studies have shown that surgery restricted to the medial occipital lobe causes restriction of visual
fields but not visual neglect (Weiskrantz + Warrington 1974) and that patients with posterior cerebral infarcts have isolated hemianopias unless the lesion involves the temporal or parietal lobes (McCauley + Ross-Russell 1974; Koboyashi et al 1985).

It is also possible that some left hemisphere patients considered to have a hemianopia were falsely categorized as such because of the difficulty of assessing aphasic patients. In addition, the absence of a blink response to threat, on which basis a hemi-anopia was considered to be present in seven left hemisphere patients, might reflect hemi-inattention rather than a hemianopia. In view of this possibility it is of interest that the recovery curves of hemi-inattention and hemianopia are so similar in left hemisphere patients. The recovery rate of hemianopia in those seven patients was no different from the rest of the hemianopic left hemisphere patients.

The only other study (Wade et al 1988) to report the resolution of visual neglect in acute stroke used a number cancellation test, the result of which, the authors stated, was not always easy to interpret. Nonetheless, they were able to identify 15 patients (6 left hemisphere, 9 right hemisphere) with visual neglect out of a total of 62 patients. At 3 months, visual neglect had resolved in every patient, with an early phase of fast recovery. The incidence at 3 months was uncertain although the authors quote other work showing that recovery could continue at 6-12 months. It is difficult to compare results since only one test of visual neglect was used and the study could not comment on any right hemisphere-left hemisphere difference given the sample size.
The present study suggests an early phase of relatively rapid recovery of most neglect phenomena and related disorders in the first 10 days to 3 weeks, followed by a plateauing-off at about 3 months. Other studies (Section 1.5) have reported a similar time course to the recovery of a variety of neurological impairments, such as power loss, and disabilities, such as self-care and mobility, but used scales to measure the degree of deficit or disability. It is therefore hard to compare the present study, which examines neurological deficits, all of which are assessed as being present or absent. Nonetheless the pattern of a phase of early rapid recovery with a plateauing off at 3 months appears to hold true. The rapid recovery of gaze paresis in surviving patients is similar to that reported in DeRenzi et al's study (1982).

This study has demonstrated an interhemispheric difference in the resolution of visual and hemi-inattention. Both were present for longer after right hemisphere stroke. This may relate to a difference in the initial severity (Tables 3A.5, 3D.2) and probably reflects the specialized role of the right hemisphere in the spatial distribution of sensory attention (Section 1.2.7).
4D. DEVELOPMENT OF AN OVERALL MEASURE OF VISUAL NEGLECT:--
THE VISUAL NEGLECT RECOVERY INDEX

4D.1 SUMMARY

(1) The VNRI has the advantage of expressing performance on
the visual neglect battery as a single figure instead of as
a profile of graded scores on individual tests.

(2) It is a better option than summating and averaging the
graded scores because it expresses each grade in equivalent
units of "neglect recovery", instead of arbitrary units of
no real value.

(3) There is reasonable correlation between the VNRI and
the individual test scores.

(4) The rate of recovery of visual neglect described by the
VNRI is consistent with that of most stroke-related neuro­
logical deficits.

(5) The finding that visual neglect is more severe in right
hemisphere stroke is consistent with previous studies and
with evidence suggesting that the right hemisphere is
dominant for sensory attention.
4D.2 Advantage of the VNRI

The visual neglect recovery index was developed in this study to provide a single overall measure of visual neglect. This expresses a patient's performance on the visual neglect test battery as a percentage of complete recovery from the maximum visual neglect measurable.

The advantage that the VNRI has over the previous method of expressing performance on the battery as a profile of graded scores on the individual tests, is that the result is given as a single figure. This makes it easier for clinicians to express the severity of visual neglect and compare patients' performance. It is a better option than summating and averaging the graded scores of individual tests because the VNRI expresses each grade in equivalent units of "neglect recovery" instead of arbitrary units of no real value. Visual neglect may be task-specific (De Castello + Warrington 1987) and the VNRI may facilitate comparison between performance on different tests better than the original grading system. The VNRI is probably a reasonable reflection of the individual test scores, for both follow a similar pattern of change with time and the results of those Least Significant Difference analyses and ANOVA that were possible (Tables 3D.3, 3D.4), provide further support for the correlation of the two. This suggests that if a patient is unable to do 1 or 2 tests because of aphasia or drowsiness, the VNRI derived from the tests done by the patient is probably representative of their visual neglect on the entire battery. It could be argued that one test is as useful as the entire battery, but recent work has illustrated the differential sensitivi-
ty of individual tests (Halligan et al 1989) and stressed that use of only one test might result in failure to detect a significant proportion of patients with visual neglect (Section 4B.2). The index, like the Behavioural Inattention Test (Wilson et al 1987, 1987a) from which the battery was derived, does not lateralize the omissions but, in practice, only 2% of test results are not clearly lateralized.

4D.3 Recovery of visual neglect

The rate of recovery of visual neglect is similar to that reported for other neurological deficits or disabilities in stroke. The present investigation is the only detailed study of the recovery of visual neglect in stroke survivors that has assessed visual neglect with a larger test battery than is the clinical convention and which assesses the severity of visual neglect rather than its presence or absence (Hier et al 1983a). Wade et al (1988) examined the recovery of visual neglect using a number cancellation task. This test, as the authors point out, was itself difficult to interpret. In addition, by using only one test, the presence of visual neglect may therefore have been underestimated and they only found 15 out of 68 patients to have visual neglect. Despite these difficulties they too report rapid reduction of neglect in the first 10 days with resolution in most patients at 3 months.

The VNRI shows that visual neglect makes a reasonable recovery in most patients and that even if it persists at 3 months in as many as 75% of patients with a right hemisphere stroke (Figure 3C.1), its severity at that stage tends to be mild (Table 3D.2, Figure 3D.1). It should be noted that all patients with a VNRI at 3 months of less
than 75% had a right hemisphere stroke and that only 2 of those with a left hemisphere stroke had a VNRI at 3 months of less than 80%.

The VNRI shows a significant difference in the severity of visual neglect between those with right and left hemispheric stroke, which confirms the findings of other studies (Chedru et al 1973; Chain et al 1979), the earlier findings of this study (Section 3A.3.6), and probably explains why it persists for longer in right hemisphere stroke (Figure 3C.1). This is consistent with the view that the right hemisphere is dominant for the distribution of sensory attention to environmental space (Section 1.2.7).
4E PREDICTION OF THE SEVERITY OF VISUAL NEGLECT
AT 3 AND AT 6 MONTHS POST-STROKE

4E.1 SUMMARY

(1) The statistical model predicting the recovery of visual neglect is based on a representative sample of acute stroke patients, makes clinical sense, and is accurate at the upper range of recovery.

(2) It is less accurate at the lower end of the range, probably because there were too few such patients to allow more accurate stepwise regression analysis.

(3) The regression equations generated were simple and may enable clinicians to select patients for intensive treatment of visual neglect.
4E.2 The statistical model

Any statistical model which predicts the outcome of stroke should be based on a representative sample of patients, give a result that makes clinical sense, and be accurate. Preferably, the resultant equation should be simple and the methods used related to standard clinical practice.

The model produced by the current study is based on a sample of stroke patients admitted to a district general hospital. The significant predictive variables included in the model make clinical sense in that the initial severity of visual neglect affects its severity at 3 months and at 6 months. The influence of anosognosia on outcome is of particular interest. Patients with anosognosia had a significantly greater degree of visual neglect (mean VNRI 34%, s.d. 38%) than those without anosognosia (mean VNRI 62%, s.d. 31%; t=12.87, df 53, p<0.0005). Anosognosia may therefore be regarded as an indicator of severe visual neglect (Friedland + Weinstein 1977), and hence, poor recovery, even though the two deficits have been shown to be clinically dissociable (Bisiach et al 1986a) and even though some patients with anosognosia had little visual neglect.

The predictive equations are simple, and are consistent for both time points. There was good matching of actual and predicted recovery at the upper range, but less so at the lower range, where prediction of the exact severity of visual neglect in the worst patients was imprecise. This is likely to be because there were too few such patients at 3 months to allow more accurate stepwise regression analysis: only seven patients had a VNRI < 60%, all the
rest, except for one, had a VNRI of at least 75%. This may also explain why the severity of visual neglect in the poor outcome group tended to be over-estimated. Some of the inaccuracies in prediction may also reflect the failure to standardize remedial therapy in the population studied; hence some patients may have received more treatment for visual neglect than others. The best test of the model's accuracy would be to carry out the prediction analysis on a new sample of patients. This would also demonstrate that the predictive power of the VNRI was not solely the result of the statistical tautology inherent in its development.

Nonetheless, it is apparent that in most patients visual neglect makes a good recovery. The predictive equations may be of value in trials of intensive treatment of visual neglect, where they could be used to randomize patients into treatment groups matched according to their prognosis (Section 1.3.2). For example, all but one of those whose VNRI at 3 months was <75% had a predicted VNRI of <75% and it might be from this group of patients that candidates for such treatment might come. However, the current study demonstrates the difficulty of recruiting sufficient patients for such a trial, given the generally good prognosis for the recovery of visual neglect.
4F. PREDICTION OF INDEPENDENCE IN SELF CARE AT 3 AND AT 6 MONTHS IN STROKE SURVIVORS

4F.1 SUMMARY

(1) The statistical model predicting the level of independence achieved by stroke patients with visual neglect is based on a representative sample of patients, makes clinical sense and is accurate in predicting independence and moderate/severe dependence.

(2) The accuracy of the model may have been affected by other factors not taken into account, such as the pre-stroke level of independence and lack of standardized treatment.

(3) The regression equations generated by the model are relatively simple, requiring assessment of only two clinical variables using standardized clinical methods.

(4) Although the regression equations may be limited in predicting outcome for individual patients, they may be useful in selecting comparable groups of patients for trials of treatment of visual neglect.
4F.2 The statistical model

The statistical model resulting from the present study is based on a representative sample of stroke patients presenting to a district general hospital. The significant predictive factors make clinical sense. Power loss (Allen 1984; Marquardsen 1969; Wade et al 1983; Wade + Hewer 1987; Fullerton et al 1988) has previously been identified as a prognostic factor as have both the presence (Adams and Hurvitz 1962; Feigenson et al 1975; Kinsella and Ford 1980; Denes et al 1982) and the severity (Fullerton et al 1988) of visual neglect. Motor skills are important in self care, and the difficulties of using a hemiparetic limb in that side of space, or of compensating by using the non-weakened limb in that side of space, would be exacerbated by visual neglect.

Although ANOVA did not show that age was significant on its own, it was significant when taken into account with the other variables in logistic regression. The adverse effect of age has been noted in other studies (Marquardsen 1969; Wade et al 1983; ade + Hewer 1987; Allen 1984; Henley et al 1985). This may reflect loss of neurological reserve after injury to the brain but may also reflect lower expectations of physicians and therapists for older patients and thus less sustained attempts at active rehabilitation.

The predictive accuracy of the model was high for independence (sensitivity 84%, specificity 90% at 3 months) and for moderate/severe dependence (sensitivity 89%, specificity 80%). Prediction of mild dependence was less accurate. The accuracy of prediction in this and other (Fullerton et al 1988; Allen 1984; Henley et al 1985; Prescott et al
1982) prognostic studies of stroke may be limited by several factors. First, neither remedial therapy nor medical treatment is likely to have been standardized in the sample of patients examined; although nearly all patients received occupational as well as physiotherapy, none received specialized therapy for visual neglect and many of those who reached a Barthel score of 20 received less therapy than those with worse outcomes. Second, the pre-stroke level of independence may not have been clearly established. This may explain why, for example, a significant proportion of patients predicted to be independent in fact had a Barthel score of 18-19, owing to pre-existing inability to bath or to climb stairs; future studies should probably take this into account. Third, factors such as motivation, known to affect outcome (Henley et al 1985) may not be measured.

The predictive equations derived from the model are relatively simple, requiring assessment of only two clinical variables, visual neglect and power. The assessment of power is closely related to the standard clinical method, and the VNRI is based on the Behavioural Inattention Test (Wilson et al 1987), which is being increasingly used by occupational therapists. The neccessary mathematics can be performed by a basic pocket calculator. The equation is a little simpler than those produced by Fullerton et al (1988), which contain 6 variables, some of which have to be weighted (Hodkinson's Mental Test Score) and some of which (eg leg power, arm function) are not standardized measures.

The current study confirmed the findings of Fullerton et al that the initial severity of visual neglect was a predictor of outcome, and that being "unassessable " for
neglect was a good predictor of death (Section 2.7F). However, the study avoided the possibility of exaggerating the association of neglect with a poor outcome, by not allocating the mean VNRI score to the "unassessables" and by not including death as an outcome. Moreover, use of a larger battery to assess visual neglect increased the detection of patients with this deficit. When death was included as an additional outcome, logistic regression found that the same factors (power loss, neglect and age) were significant. 88% of independent, 37% of mildly dependent and 88% of moderate/severely dependent outcomes were correctly predicted, but only 10% of deaths probably because their number was so small. The separation of "dependent" patients into two groups that reflected the practical difficulties of arranging a discharge, facilitates identification of a group in particular need of attention. Had a larger number of patients been recruited, this might have allowed separation of the "moderate/severe" dependency outcome group into its two constituent groups, which might have enhanced the usefulness of the study. Consideration should be given by future prognostic studies to prediction of functional recovery from the clinical features present at 3 weeks rather than at 3 days, as at this time, the majority of deaths have occurred (Wade + Hewer 1985a; Aho et al 1980), the rapid phase of early recovery has ended (Wade et al 1985a) and any cerebral oedema will have resolved (Spatz 1939; Skriver + Olsen 1981), leaving a "core" neurological lesion.

Lincoln et al (1990) have recently pointed out the limitations of prognostic studies in predicting exact outcome for
individual patients, but stressed their usefulness in targeting a group of patients in need of special intervention. The regression equations generated by the current study could be used in such a manner to select patients for trials of treatment of visual neglect.
references

Adams GF, Hurwitz LJ. (1963)
Mental barriers to recovery from strokes.

Cerebrovascular disease in the community; results of a WHO collaborative study.

Albert ML. (1973)
A simple test of neglect.
Neurol 23:658-64.

Allen CMC. 1983
Clinical diagnosis of the acute stroke syndrome.

Allen CMC. (1984)
Predicting the outcome of acute stroke: a prognostic score.
J Neurol Neurosurg Psychiat 47:475-80.

Allen CMC. (1984a)
The accurate diagnosis and prognosis of acute stroke.
Correlation of clinical features with computed tomographic appearances and functional outcome.
MD Thesis. Univ Camb.

The prognostic value of picture drawings by stroke patients.

The rate of recovery from stroke and its measurement.

Anzola GP, Bertolini A, Buchtel HA, Rizzolati G. (1977)
Spatial compatibility and anatomical factors in simple and choice reaction time.

Ashburn A. (1982)
A physical assessment for stroke patients.

Babinski MJ. (1914)
Contribution a l'etude des troubles mentaux dans l'hemiplegie organique cerebrale.

A prospective study of cerebrovascular disease in the community: the Oxfordshire Community Stroke Project 1981-86.Methodology, demography and incident cases of first ever stroke.
Bard G, Hirschberg GG. (1965) 
Recovery of voluntary motion in upper extremity following hemiplegia. 

Battersby WS, Bender MR, Pollack M, Kahn RL. (1956) 
Unilateral "spatial agnosia" ("inattention") in patients with cerebral lesions. 
Brain 79: 68-93.

Bender M, Farlow LT. (1945) 
Phenomena of visual extinction in homonymous fields and psychologic principles involved. 

Bisiach E, Luzzatti C. (1978) 
Unilateral neglect, representational schema and consciousness. 
Cortex 14:29-33.

Brain and conscious representation of outside reality. 
Neuropsychologia 19:543-51.

Unilateral neglect: personal and extra-personal. 

Bisiach E, Vallar G, Perani D, Papgno C, Berti A. (1986a) 
Unawareness of disease following lesions of the right hemisphere: anosognosia for hemiplegia and hemianopia. 
Neuropsychologia 24: 471-82.

Blessed G, Tomlinson BE, Roth M. (1968) 
The association between quantitative measures of dementia and senile changes in the cerebral grey matter of elderly subjects. 

Brain WR. (1941) 
Visual disorientation with special reference to lesions of the right cerebral hemisphere. 
Brain 64:244-272.

Brain WR. (1945) 
Speech and handedness. 
Lancet. 2: 837-842.

Neurological disorders in the elderly at home. 

Campbell DC, Oxbury SM. (1976) 
Recovery from unilateral spatial neglect? 
Cortex 12:303-312.
Focal cerebral hypoperfusion and selective cognitive deficit in dementia of the Alzheimer's type.

Chain F, Leblanc M, Chedru F, L'Hermitte F. (1979)
Negligence visuelle dans les lesions posterieures de l'hemisphere gauche.
Rev Neurol 135:105-126.

Chedru F, Leblanc M, L'Hermitte F. (1973)
Visual searching in normal and brain-damaged subjects (a contribution to the study of uni-lateral attention).
Cortex 9:94-111.

The Barthel Index :a reliability study.
Int Disabil Studies. 10:61-3.

Critchley M. (1949)
The phenomenon of tactile inattention with special reference to parietal lesions.
Brain. 72: 538-61.

Biopsy-proved Alzheimer's disease presenting as right parietal lobe syndrome.

Cutting J. (1978)
The study of anosognosia.

Damasio AR, Damasio H, Chui HC. (1980)
Neglect following damage to frontal lobe or basal ganglia.

Predicting the stroke patient's ability to live independently.

De Lacy Costello A, Warrington EK. (1987)
The dissociation of visuospatial neglect and neglect dyslexia.
J Neurol Neurosurg Psychiat 50: 1110-6.

Conjugate gaze paralysis in stroke patients with unilateral damage.

Motor evaluation in vascular hemiplegia.

Unilateral spatial neglect and recovery from hemiplegia. A follow-up study.
Brain 105: 543-52.
Dennis MS, Warlow CP. (1987).
Stroke: Incidence, risk factors and outcome.

Dixon WJ. (1985)

Measuring disability after a stroke.

Eccles JT. (1988)
What is normal in the elderly?.
In: Wattis, Hindmarsh, eds. Psychological aspects of the elderly.

Feigenson JS, Mccarthy ML, Greenberg SD, Feigenson WD. (1977)
Factors influencing outcome and length of stay in a stroke rehabilitation unit. Part 2. Comparison of 318 screened and 248 unscreened patients.
Stroke 8:657-662.

Fisher CM (1982).
Lacunar strokes and infarcts: a review.

Friedland RP, Weinstein EA. (1977)
Hemi-inattention and hemisphere specialization: introduction and historical review.


Albert's test: a neglected test of perceptual neglect.

Prognostic indices in stroke.

Patterns of drawing disability in right and left hemispheric patients.
Neuropsychologia 8:379-84.

Qualitative analysis of unilateral spatial neglect in relation to laterality of cerebral lesions.


Heron A, Chown S. (1967)  

Hier DB, Davis KR, Richardson Jr EP, Mohr JP. (1977)  

Hier DB, Mondlock J, Caplan LR. (1983)  
Behavioural abnormalities after right hemisphere stroke. Neurology 33:337-44.

Hier DB, Mondlock J, Caplan LR. (1983a)  

Hodkinson HM. (1972)  

Holmes G. (1918)  

Howell TH. (1949)  

Huppert FA. (1967)  

Isaacs B, Marks R. (1973)  
Determinants of outcome of stroke rehabilitation. Age Aging 2: 139-49.


Laplace D, Degos JD. (1983)
Motor neglect.

Leicester J, Sidman M, Stoddard LT, Mohr JP. (1969)
Some determinants of visual neglect.

Stroke rehabilitation: outcome and prediction.

Lincoln N, Whiting (1980)
An ADL assessment for stroke patients.

The accuracy of predictions abut progress of patients on a stroke unit.
J Neurol Neurosurg Psychiatry 53:972-5.

McFie J, Piercy MF, Zangwill OL. (1950)
Visuo-spatial agnosia associated with lesions of the right cerebral hemisphere.
Brain 73:167-89.

Marquardsen J. (1969)
The natural history of acute cerebrovascular disease: a retrospective study of 769 patients.

Mayne N. (1965)
Neuropathy in the diabetic and non-diabetic populations.

Selective association of hemi-neglect syndromes with multiple idiopathic falls in the institutionalized elderly.
Ann Neurol 18:125.

Mesulam M-M. (1981)
A cortical network for directed attention and unilateral neglect.

Mesulam MM. (1983)
The functional anatomy and hemispheric specialization for directed attention. The role of the parietal lobe and its connectivity.

Oxbury JM, Campbell DC, Oxbury SM. (1974)
Unilateral spatial neglect and impairment of spatial analysis and visual perception.
Brain 97:551-64.
Oxbury JM, Greenhall RCD, Grainger KMR. (1975)
Predicting outcome of stroke: acute stage after cerebral infarction.

Ogden JA. (1985)
Anterior-posterior interhemispheric differences in the loci of lesions producing visual hemi-neglect.
Brain Cognit 4:59-75.

Patterson A, Zangwill O. (1944)
Disorders of visual space perception associated with lesions of the right cerebral hemisphere.
Brain 67:331-58.

Pearson GHJ. (1928)
Effect of age on vibratory sensibility.
Arch Neurol Psychiatr. 20:482-6.

Correlation of cholinergic abnormalities with senile plaques and mental test scores in senile dementia.

Plutchik H, Conte HR, Weiner MB, Teresi J. (1978)
Studies of body image.4. Figure drawings in normal and abnormal geriatric and non-geriatric groups.
J Gerontol 33:68-75.

Prakash C, Stern G. (1973)
Neurological signs in the elderly.
Age Ageing 2:24-7.

Prescott RJ, Garraway WM, Akhtar AJ. (1982)
Predicting functional outcome following acute stroke using a standard clinical examination.

Choosing between logistic regression and discriminant analysis.

Microcomputer-based cognitive rehabilitation of visual neglect: three multiple baseline single-case studies.
Brain Injury 2:151-163.

Robertson IH, Gray JM, Pentland B, Waite LJ. (1990)
A randomized controlled trial of microcomputer-based rehabilitation for unilateral left visual neglect.

Robinson DL, Goldberg ME, Stanton GB. (1978)
Parietal association cortex in the primate: sensory mechanisms and behavioural modulations.
CAMDEX...A standardized instrument for the diagnosis of mental disorder in the elderly with special reference to the early detection of dementia.

Rout MW. (1978)
Disorders of perception in stroke.
Age Ageing; supplement:22-6.

Reliability and accuracy of the Glasgow Coma Scale with experienced and inexperienced users.

Clinical diagnosis of intracranial haemorrhage using Guy's Hospital score.

Savitsky N, Madonick MJ. (1943)
Statistical control studies in neurology 1. The Babinski sign.

Schaie KW. (1983)

Schenkenberg T, Bradford DC, Ajax ET. (1980)
Line bisection and unilateral visual neglect in patients with neurological impairment.
Neurology 30:509-17.

Schwartz AS, Matchok PL, Kreinick CJ, Flynn RE. (1979)
The assymetric lateralisation of tactile extinction in patients with unilateral cerebral dysfunction.
Brain 102:669-684.

Repeatability and reliability of a modified activiteis of daily living (ADL) index in studies of chronic disability.

Recovery after stroke.
J Neurol Neurosurg Psychiat 46:5-8.

Skriver EB, Olsen TS. (1982)
Contrast enhancement of cerebral infarcts. Incidence and clinical value in different states of cerebral infarction.
Neuroradiol. 23:259_65.

Spatz H. (1939)
Z.Neurol 167:301-49.


Wade DT, Wood VA, Hewer RL. (1988)
Recovery of cognitive function soon after stroke; a study of visual neglect, attention span and verbal recall.

Walker SH, Duncan DB. (1967)
Estimation of the probability of an event as a function of several independent variables.

Watson RT, Heilman KM. (1979)
Thalamic neglect.

Watson RT, Heilman KM, Cauthen JC, King FA. (1973)
Neglect after cingullectomy.

Neglect after mesencephalic reticular formation lesions.

Watson RT, Valenstein E, Heilman KM. (1981)
Thalamic neglect: Possible role of the medial thalamus and nucleus reticularis in behaviour.
Arch Neurol 38:501-7.

Visual scanning training effect on reading related tasks in acquired right brain damage.
Arch Phys Med Rehabil 58:479-86.

Training sensory awareness and spatial organization in people with right brain damage.

Denial and neglect of hemiparesis in right sided apoplectic lesions.

Development of a behavioural test of visuo-spatial neglect.

Behavioural Inattention Test. Thames Valley Test Company, 34-36 High Street, Titchfield, Fareham, Hants PO14 4AF.

Development and validation of a geriatric depression screening scale: a preliminary report.
Zangwill OL. (1964)
Psychopathology of dementia.
The assessment of visuo-spatial neglect after acute stroke

S P Stone, B Wilson, A Wroot, P W Halligan, L S Lange, J C Marshall, R J Greenwood

Abstract
Forty four consecutive patients with acute hemispheric stroke and forty seven elderly controls with no neurological disease were assessed for visuo-spatial neglect, using a modified neglect test battery. Neglect was found to be equally common in patients with right hemispheric and left hemisphere stroke three days after stroke (72% versus 62%). It was more severe in those with a right hemisphere stroke and resolved more frequently in those with a left hemisphere stroke. The battery was validated against an occupational therapist's assessment of neglect on self-care tasks. The inter-observer reliability was good and it was possible to monitor changes over time with the battery.

Visuo-spatial neglect is an important predictor of poor outcome after stroke.\(^{3,5}\) The natural history of neglect after stroke, however, remains unclear. Estimates of the frequency of visuo-spatial neglect (33–85% in right and 0–25% in left hemisphere strokes) and of the frequency of recovery (0–50% in right and 60% in left hemisphere stroke) vary widely.\(^{6–10}\) The variation in these estimates is the result, firstly, of the use of different tests to detect visuo-spatial neglect and, secondly, of the use of only one or two tests chosen often on the basis of their simplicity. This practise is unsatisfactory, because clinical neglect is not an all or none phenomenon.\(^{11,12}\) Neglect is not observed in all activities or all clinical tests at any one time.\(^{13}\) It cannot therefore be assumed that all tests assess or measure the same neuropsychological variable or mechanism.\(^{14,15}\)

Over 50 bedside tests of visuo-spatial neglect have been used in various combinations. The tests most commonly used are probably line cancellation and drawing tasks.\(^{16–18}\) Recently, Wilson et al developed the Behavioural Inattention Test (BIT),\(^{17,18}\) which was standardised on convalescent stroke patients. The BIT has been shortened and modified for use with acute stroke patients.\(^{19}\) The aim of the current study was to evaluate this modified battery as a clinical tool for detecting and monitoring visuo-spatial neglect in patients with an acute stroke.

Method
Forty four consecutive patients with a mean (SD) age 71±2 (12±8) years, who had been admitted to hospital with an acute hemispheric stroke, were investigated. Eighteen had a right hemispheric stroke, 26 had a left hemispheric stroke. The diagnosis was confirmed by a physician (SPS) who administered the test battery at three days. Patients were re-examined at three months because after this interval most neurological deficits, including visuo-spatial neglect, made most of their recovery.\(^{3,20,21}\) All patients received a non-contrast CT brain scan at three to five days. Two patients had a haemorrhage, the rest had an infarct. In 21 patients (48%), the findings on examination were validated against an occupational therapist's assessment of neglect in activities of daily living (ADL). Inter-observer reliability was also established using 12 of the stroke patients.

Forty seven age-matched controls were also examined once (see following paper).

The neglect test battery
All tests were presented in front of the subject's midline with the examiner seated directly opposite. No time limit was imposed. After patients had completed a test they were asked to check that they had finished. Some patients were unable to attempt tests due to the level of consciousness, language difficulties or fatigue. A fundamental feature of patients with visuo-spatial neglect due to a right hemisphere lesion is that they begin tasks on the right hand side.\(^{22,23}\) In four of the eight tests, the presence of a "Right Hand Start" was assessed. The tests were administered in the following order.

1) POINTING TO OBJECTS LOCATED ABOUT THE WARD\(^{23}\) (fig 1) The patient was asked to point to and name all the objects that they could see on both sides scattered about their hospital room or ward. The examiner stood directly

![Diagram](image-url)
2) FOOD ON A PLATE. Patients were asked to point to each food item in a lifestyle colour photograph of a plate containing eight foods. Where necessary the examiner demonstrated what was required. The total number of items omitted was recorded. Correct verbal identification of the food items was not required.

3) READING A MENU (fig 2). The patient was asked to open and read aloud from a menu that listed 12 items of food on the left page and 12 on the right. The number of words omitted on the left, right, and in total was recorded. Aphasic patients were allowed to point to words. In a patient with a right hemisphere stroke "Right Hand Start" was defined as a failure to begin reading from the first left hand column (see arrow on fig 2).

4) READING A NEWSPAPER ARTICLE (adapted from 17) (fig 3). Patients were asked to read the "newspaper" extract aloud. The examiner marked on a photocopy any words omitted. Some patients were unable to read small print, so the number of words omitted from the headlines (10 words in bold print), the paragraph (five words in smaller capitals) and the article (117 words in small newprint) were recorded separately. The presence or absence of "Right Hand Start" was recorded. This test was not given to patients with a left hemisphere stroke because the pilot study that modified the BIT found that most of them had reading difficulties.

5) LINE CANCELLATION (adapted from 17,18) (fig 4). The patient was presented with a sheet of paper on which 40 one inch lines had been marked in seven columns. The patient was required to cross out all the lines on the page after the examiner had demonstrated what was required by crossing out the four lines in the centre column. A "Right Hand Start" was considered present if the first lines to be cancelled were in the sixth or seventh columns on the right of the page (see arrow in fig 4). The number of lines omitted on the right, left and in total was recorded. If the patient's dominant hand was too weak to cross out lines and they were unable to use the other hand, they were allowed to point to each line, which the examiner then crossed out.

6) STAR CANCELLATION (fig 5). Patients were presented with 56 small stars mixed up with many large stars and capital letters. They were instructed to cross out the small stars after the examiner had demonstrated this, crossing out two centrally positioned small stars. The number of small stars omitted on the left, the right and in total was recorded. A "Right Hand Start" was considered present if the...
The assessment of visuo-spatial neglect after acute stroke

Figure 6 Left visuo-spatial neglect on Coin selection (unmarked coins).

Figure 7 Right visuo-spatial neglect on Figure copying with Crowding.

Patient began cancelling stars in the right hand third of the page. Patients with a weak dominant hand were allowed to point to each star.

7) Coin Selection (fig 6) A large card (32 x 21 cm) with three coins of each of the following values (2p, 5p, 10p, 20p, 50p, £1) was presented to the patient with the three five pence coins on the side opposite their cerebral lesion. The patient was asked to point to each of the coins in turn. The examiner noted the results on a photocopy of the test card. The number of omissions on the left, right and in total was recorded. Occasionally the examiner placed a loose coin of the value required in front of aphasice patients or wrote the value of the coin on a piece of paper to help them understand which coin was required.

8) Figure copying from the left (fig 7) The patient was presented with a piece of paper divided into six squares. In the three squares on the left were figures of a four pointed star, a cube and a daisy. These were to be copied into the empty three spaces on the right side. The number of major omissions (for example, half a cube) and the number of minor omissions (for example, a leaf) was recorded for each figure. Each major omission was given an arbitrary score of two and each minor omission a score of one. This test was not given to those patients with a right hemisphere stroke as the pilot study that modified the BIT indicated that this test was less sensitive than many others. It proved useful, however, for patients with left hemisphere stroke who often ignored the empty right spaces and “crowded” their copies into the left hand side of the page.

Criteria for Visuo-Spatial Neglect

To establish a normal range of performance for each test the controls were examined; these results are given in an accompanying paper. Visuo-spatial neglect was considered present in patients if they made more omissions on any one test than the age-matched controls. Thus two or more omissions on meal; one or more on menu; five or more on lines; 16 or more on stars; four or more on coins; two or more on headlines; two or more on paragraph; seven or more on article; and 50 or more degrees on pointing was regarded as evidence of neglect. Major or minor omissions on left figure copying, Crowding and a Right Hand Start on the reading tests never occurred in controls and were thus considered clinical indicators of neglect.

In addition, any stroke patient making three unilateral omissions on coin sorting was considered to have neglect on that test if neglect was also present on another test. Similarly, neglect was considered present in star cancellation when a stroke patient omitted between six and 15 stars if there were at least twice as many omissions on one side of the page as the other and if neglect was present in another test. Also, a Right Hand Start on line and star cancellation was taken as indication of neglect if neglect was present on these or other tests. Combinations of these features were not observed in the controls.

Scoring the Tests

The total number of omissions made on lines, stars, meal, menu and coins was expressed as a percentage of the total number of items in each test. The number of degrees omitted on pointing was expressed as a percentage of 180 degrees. The number of words omitted in headlines was expressed as a percentage out of 10, the number omitted on Paragraph as a percentage of five, and the number in the Article was expressed as a percentage of 117. The score for figure copying was converted into a percentage (of a maximum score of six).
The percentage score on each test was then graded: Grade 0: no neglect; Grade 1: up to 20% of items omitted on the test; Grade 2: 21-40% items omitted; Grade 3: 41-60%; Grade 4: 61-80%; Grade 5: 81-100%. Right Hand Start and Crowding were both considered to be qualitative rather than quantitative measures of neglect and were noted but not scored.

Results
1. Stroke patients three days after stroke (table 1)
At three days after stroke, two patients with a right hemisphere stroke could not be assessed on any test because of coma. All remaining 16 patients could be tested on Pointing, Meal, Newspaper and Lines. One patient was too tired to do stars or coins, another could not recognise coins.

Five patients with a left hemisphere stroke could not be assessed at three days because of coma or severe aphasia. Most of the remaining 21 could be assessed on Pointing, Meal, Menu and Lines. Aphasia made it impossible for some patients to attempt Stars, Coins and Figure copying because they were unable to understand the instructions.

At three days 13/18 (72%) patients with a right hemisphere stroke showed neglect on at least one test. Neglect was present in 16/26 (62%) patients with a left hemisphere stroke.

The tests most likely to detect neglect in a patient with a right hemisphere stroke were Newspaper, Stars, Pointing, Meal and Lines (table 1). Eleven of these patients demonstrated a Right Hand Start.

For patients with a left hemisphere stroke the most likely tests to detect neglect were Meal, Menu, Lines and Pointing (table 1). Five of these patients showed Crowding. Although only 10 patients could attempt Stars, eight of these exhibited neglect on that test.

2. Stroke patients three months after stroke (table 2)
Twelve of the 13 patients with neglect due to a right hemisphere stroke survived until follow up at three months. One patient was too depressed to be tested. The 11 others were able to attempt most tests. Both patients who had originally been unable to do any test died.

Fourteen of the 16 patients with neglect due to a left hemisphere stroke survived until follow up at three months. One of the five who had originally been unable to do any test survived. The 15 survivors were able to cooperate on nearly every test although language difficulty still prevented some patients understanding the Coins and Stars test requirements.

Neglect was present in nine patients with a right hemisphere stroke (75%) and five left hemisphere stroke patients (33%).

In those with a right hemisphere stroke the tests most likely to detect neglect were Stars, Meal, Coins and Newspaper. A Right Hand Start was present in nine of these patients. In patients with a left hemisphere stroke the tests most likely to detect neglect were Menu, Stars and Coins.

3. Validity of the test battery
To ascertain the validity of the test battery an occupational therapist blind to the results of the battery carried out an assessment on 21 of the patients, using the following checklist of "neglect behaviours".

1) Did the patient fail to orientate to environmental stimuli on the side opposite the cerebral lesion?
2) Did the patient fail to dress, wash or groom their contralateral side?
3) Did the patient bump into doorways or obstacles on the contralateral side, when walking or using a wheelchair? If using the latter, were they unable to turn contralaterally? If mobile, did the patient veer diagonally towards the contralateral side?
4) Could any failure or reluctance to use the contralateral limbs be attributed to neglect rather than weakness or apraxia?
5) Did the patient show lack of awareness of limbs with poor positioning?

Four patients (two with a right, two with a left hemisphere stroke) had no neglect on the battery and none on the occupational therapist's checklist. The remaining 17, (12 with a right, five with a left hemisphere stroke), had visuo-spatial neglect on the test battery. Thirteen of these had neglect on at least three checklist items, two had neglect on two items (orientation, washing dressing), and one neglected on one item (orientation). One patient with marked left visuo-spatial neglect on the battery, a left homonymous hemianopia; and no hemiparesis, had no neglect on the checklist.

Table 1: Number of stroke patients able to attempt each test at three days and number with neglect on each test

<table>
<thead>
<tr>
<th>Test</th>
<th>Right hemisphere stroke (n = 16)</th>
<th>Left hemisphere stroke (n = 26)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pointing</td>
<td>Number patients attempting test</td>
<td>Number with neglect</td>
</tr>
<tr>
<td>Meal</td>
<td>16</td>
<td>10</td>
</tr>
<tr>
<td>Menu</td>
<td>16</td>
<td>10</td>
</tr>
<tr>
<td>Newspaper</td>
<td>16</td>
<td>13</td>
</tr>
<tr>
<td>Lines</td>
<td>16</td>
<td>10</td>
</tr>
<tr>
<td>Stars</td>
<td>15</td>
<td>11</td>
</tr>
<tr>
<td>Coins</td>
<td>14</td>
<td>7</td>
</tr>
<tr>
<td>L fig</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

Table 2: Number of stroke patients able to attempt each test at three months and number with neglect on each test

<table>
<thead>
<tr>
<th>Test</th>
<th>Right hemisphere stroke (n = 12)</th>
<th>Left hemisphere stroke (n = 15)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pointing</td>
<td>Number patients attempting test</td>
<td>Number with neglect</td>
</tr>
<tr>
<td>Meal</td>
<td>11</td>
<td>6</td>
</tr>
<tr>
<td>Menu</td>
<td>11</td>
<td>3</td>
</tr>
<tr>
<td>Newspaper</td>
<td>11</td>
<td>5</td>
</tr>
<tr>
<td>Lines</td>
<td>11</td>
<td>4</td>
</tr>
<tr>
<td>Stars</td>
<td>11</td>
<td>7</td>
</tr>
<tr>
<td>Coins</td>
<td>11</td>
<td>5</td>
</tr>
<tr>
<td>L fig</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>
The assessment of visuo-spatial neglect after acute stroke

Table 3 Severity of neglect in 11 patients with a right hemisphere and in 14 patients with a left hemisphere stroke at three days and at three months after stroke

<table>
<thead>
<tr>
<th>Test</th>
<th>Right hemisphere stroke</th>
<th>Left hemisphere stroke</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3 days</td>
<td>Medium score</td>
</tr>
<tr>
<td>Pointing</td>
<td>3-0</td>
<td>0-0</td>
</tr>
<tr>
<td>Meal</td>
<td>3-0</td>
<td>1-0</td>
</tr>
<tr>
<td>Menu</td>
<td>3-0</td>
<td>0-0</td>
</tr>
<tr>
<td>Lines</td>
<td>4-0</td>
<td>0-0</td>
</tr>
<tr>
<td>Stars</td>
<td>3-0</td>
<td>2-0</td>
</tr>
<tr>
<td>Coins</td>
<td>3-0</td>
<td>2-0</td>
</tr>
<tr>
<td>Headlines</td>
<td>1-0</td>
<td>0-0</td>
</tr>
<tr>
<td>Paragraph</td>
<td>4-0</td>
<td>0-0</td>
</tr>
<tr>
<td>Article</td>
<td>2-0</td>
<td>0-0</td>
</tr>
<tr>
<td>L. fig</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

4 Reliability of the test battery
Inter-observer reliability was established by the simultaneous scoring of 12 patients (eight with a right and four with a left hemisphere stroke) with neglect by two examiners trained in the administration of the battery.

Each patient was assessed on nearly every test, although only 11 were able to do Pointing, Meal, Menu and Stars. There was agreement as to the presence or absence of neglect in every test except in Coins in one patient to whom the newer coins may have been unfamiliar. Both observers agreed on the graded score on each test except in Newspaper in one patient who mumbled inaudibly.

5 Sensitivity to changes in neglect
Table 3 shows the median test scores of those patients presenting with neglect at three days after stroke who survived and were able to be examined at three months. There were 11 with a right and 14 with a left hemisphere stroke.

At three days neglect was greater in patients with a right than in patients with a left hemisphere stroke, but the difference only reached significance for Lines (p = 0.04; Mann-Whitney tests). At three months neglect had declined on all tests in right hemisphere patients. This was significant at the 0.02 level for Lines, Stars, and Pointing; and at the 0.05 level for Paragraph. Neglect also declined in left hemisphere strokes. This was significant at the 0.01 level for Lines, and at the 0.05 level for Pointing, Meal, Menu, and Stars (Wilcoxon tests).

Discussion
The study describes the use of a test battery to detect, measure and monitor visuo-spatial neglect. It is relevant, valid, reliable, simple to administer, sensitive and gives a result that can be communicated to fellow professionals.26

The battery includes tests from the BIT which simulate performance in everyday activities, for example, reading, looking around the room, selecting coins, and eating. These tests would seem more relevant to real life and may indicate to therapists appropriate areas for treatment.2728 The validity study showed that 16 out of 17 patients with neglect on the battery, had neglect on the OT checklist. This method of validating clinical tests of neglect has been used by Battersby et al who found that neglect on clinical testing did not always generalise to daily activities.2930 We observed one such patient, but cannot say whether such a discrepancy is an example of a dissociation between neglect in different tasks.25

In 12 patients assessed by two observers, the reliability of the battery was good with respect to the presence and severity of neglect in each test. The tests were easy to administer. The presence of aphasia was not as great an obstacle to assessment as had been anticipated. Although some patients were unable to understand what was required in some tests, they often understood and attempted others. This may be why neglect was nearly as common after left hemisphere stroke as after right. Other workers have found this2526 but the classic view is that neglect is associated almost solely with right brain damage.35

There is no one standard method of measuring neglect.1718192026 Some sensitive indicators in our battery are not scorable on an ordinal scale, for example Right Hand Stunt and Crowding but they remain useful clinical signs of neglect, possibly reflecting abnormalities in eye movements reported in patients with unilateral brain damage who begin visual search tasks by exploring ipsilesional space.3233 Expressing the percentage of items omitted from each test as a score on a 0-5 scale is simple and each grade is easily understood. It avoids giving too much weight to small changes over time in the raw score, expresses the result of each test in the same arbitrary units and enables change to be monitored. Our observation that neglect is more severe in those with a right than in those with a left hemisphere stroke is consistent with other reports.2534
In conclusion, the battery takes into account the behavioural inconsistency of neglect and is suitable for use with patients after an acute stroke.

SPS was supported by a grant from the Chest Heart and Stroke Association. We are grateful to Dr RJ Jenner, Consultant in Rehabilitation, and in particular to Dr C.M. Allen, Consultant Neurologist, Addenbrookes, Cambridge for early discussions; and also the library staff of the Royal Society of Medicine.

Figures 2, 4-7 are produced with kind permission of the Thames Valley Test Company.

7 Oxbury J, Campbell DC, Oxbury SM. Unilateral spatial neglect and impaired spatial analysis and visual perception. Brain 1974;97:551-64.
The Incidence of Neglect Phenomena and Related Disorders in Patients with and cute Right or Left Hemisphere Stroke

S. P. STONE, P. W. HALLIGAN, R. J. GREENWOOD

Summary
We studied 171 consecutive patients with an acute hemispheric stroke (69 right hemisphere, 102 left), at 2-3 days post-stroke. A standardized test battery, previously validated in patients with acute stroke, was used to detect a wide variety of neglect phenomena and related disorders.

Visual neglect was found in 82% of assessable right hemisphere patients and 65% of left hemisphere patients. Hemi-inattention was found in 70% of right and 49% of left hemisphere strokes. Tactile extinction was found in 65% of right and 35% of left hemisphere patients; allaesthesia in 57% (right), and 11% (left); visual extinction in 23% (right) 2% (left). Anosognosia was found in 28% (right), and 5% (left); anosodiaphoria in 27% (right), and 2% (left); non-belonging in 36% (right) and 29% (left).

Visual neglect occurred more commonly in left hemisphere stroke than previously reported. Although neglect phenomena and related disorders were associated with right hemisphere damage, it is possible that language difficulties obscured their presence in some patients with a left hemisphere stroke.

Introduction
Heilman et al. [1] defined the 'neglect syndrome' in patients with a cerebral lesion as failure to orientate, report or respond to relevant stimuli on the side opposite to their lesion. By definition, neglect cannot be considered present if the failure to respond can be attributed to primary sensory or motor loss. The syndrome is characterized by several forms of neglect (neglect phenomena), including visual neglect, hemi-inattention, sensory extinction, visual extinction, and allaesthesia [1]. It is often accompanied by various 'related disorders': anosognosia, anosodiaphoria, non-belonging, visual-field defects, and gaze paresis.

The neglect syndrome is an established predictor of poor outcome after stroke [2-5]. Patients with the syndrome may require intensive rehabilitation programmes [6], but the natural history of the syndrome in stroke remains unclear. Furthermore, the incidence of the various forms of neglect is unknown. Some studies have excluded patients with left hemisphere stroke and others have investigated only visual neglect.

Visual neglect is the most intensively studied form of neglect in stroke, yet estimates of its incidence vary widely (33-85% in right and 0-24% in left hemisphere stroke) [3-5, 7-10]. It has been suggested that the classic association of visual neglect with right brain damage [11] might be an artefact of the difficulty of assessing dysphasic patients [5, 12, 13]. Indeed, some
studies have found visual neglect to be equally
common in left and right hemisphere lesions
[14-16]. This variation is largely due, firstly, to
differences in the timing of examination after
the stroke; secondly, to the use of different tests
to detect visual neglect (which may be task
specific [17, 18]); and, thirdly, to the use of small
and insensitive test batteries [14, 16].

As part of a larger study describing the
natural history and prognosis of the neglect
syndrome in acute stroke, we sought to estab­
lish the incidence of the different forms of
neglect and their related disorders in patients
with left, as well as right hemisphere stroke. All
patients were seen at 2–3 days post-stroke. A
standardized test battery, validated in acute
stroke patients [14] and aged-matched controls
[19], was used to detect neglect phenomena and
related disorders.

Methods
Patient characteristics: One hundred and seventy-one
consecutive patients (mean age 72.37 years, SD 12.11, range 28–100 years) admitted to St Bartholo­
mews and Homerton Hospitals, in the City and
Hackney Health District, London, with an acute
hemispheric first stroke were recruited to the study.
All patients were admitted as emergencies under the
care of general physicians, except for one admitted by
a geriatrician, and two admitted by neurosurgeons.

Patients were registered for the study by daily
contact with the previous day’s admitting medical
team and were first assessed for the study at 2–3 days
post-stroke, by a physician (S.P.S.) who confirmed
the diagnosis of stroke, using the WHO definition
[20]. Patten’s criteria were used to define a hemi­
spheric stroke [21]. Patients with subarachnoid
haemorrhage were excluded from the study, as were
patients whose stroke occurred more than 3 days
prior to assessment.

Sixty-nine of the patients (40%) had a right
hemisphere and 102 (60%) had a left hemisphere
stroke. Thirteen patients (8%) had lacunar strokes;
11 of the pure motor hemisimparesis variety and 2 of the
sensorimotor type [22]. Ninety-one patients (53%) were
women.

One hundred and twenty-seven patients received a
CT brain scan at 3–5 days, and 44 were assessed by
the Guy’s Hospital diagnostic score [23] to determine
whether the stroke was haemorrhagic (14 patients) or
ischaemic (157 patients), according to standard cut­
off points [24]. Of those who were scanned, 48 (38%) had
no visible lesion, 37 (29%) had cortical lesions,
20 (16%) had deep lesions and 22 (17%) had both.
The 30-day case fatality rate was 27%.

All patients were assessed for the presence of
neglect phenomena and related disorders using the
following test procedures.

Neglect Phenomena

1. Visual neglect: Patients were considered to have
visual neglect if they ignored relevant contralateral
visual stimuli on a battery of clinical bedside tests.
The battery was a modified form of the Behavioural
Inattention Test [25, 26], that had been validated and
standardized in patients with an acute stroke [14],
using data from age-matched controls [19]. It con­
sists of the following tests: pointing to objects
scattered around the room; reading a menu; cancel­
ing lines on a piece of paper; cancelling stars;
selecting coins from an array on a card; reading a
newspaper article (right hemisphere patients only);
copying a daisy, cube and star from the left-hand side
of the page (left hemisphere patients only). Visual
neglect was considered present when it appeared in a
single test [14, 16], for it may be task specific and may
not be present in all tests at any one time [17, 18].

2. Hemi-inattention: was regarded as present if the
subject’s general spontaneous behaviour during
examination suggested an inability to orientate or
respond correctly to environmental stimuli on one
side, irrespective of modality (e.g. people approac­
hing, noises or activity in the ward). Details of its
assessment are given in a previous study [19].

3. Tactile extinction: was assessed by the technique
of double simultaneous stimulation, giving bilateral
stimuli a total of five times [19]. On the basis of age­
matched control data, extinction was considered
present if two or less of the bilateral stimuli were
correctly identified [19].

4. Visual extinction: was assessed by double simul­
taneous stimulation in the same way [19].

5. Allaesthesia was regarded as present if subjects
consistently attributed sensory stimulation of one
side to stimulation of the other or if they consistently
moved the limbs on one side when requested to move
the limbs on the other [1]. On the basis of age­
matched control data, it was considered present if it
was elicited on at least two occasions during routine
diagnostic motor testing [19].

Neglect-related Disorders

Anosognosia (denial or lack of awareness of a hemi­
paresis), anosodiaphoria (indifference to perceived
weakness) and non-belonging (a feeling that an
affected limb did not belong to the individual) were assessed using the method described by Cutting [7, 19]. Details of the assessment of gaze paresis and visual field defects are given in a previous study [19]. Where dysphasia or impaired consciousness prevented assessment of any neglect phenomenon or related disorder, the patient was considered to be 'unassessable' for that neurological deficit. Where these impaired the assessment of visual fields, the presence or absence of the blink response to threat was noted [27]. Strategies for testing left hemisphere patients for visual neglect are described elsewhere [14].

The association of neglect phenomena and related disorders with right or left hemisphere damage was examined using 95% confidence intervals for the difference between proportions.

Results

Table I shows the proportion of patients who could not be assessed. Patients with a left hemisphere stroke appeared more difficult to assess for visual neglect, tactile extinction, allaesthesia, anosognosia, anosodiaphoria and non-belonging, probably due to dysphasia.

Tables II and III show the incidence of the various neglect phenomena and related disorders 2-3 days after a right or left hemisphere stroke in assessable patients. Visual neglect was found in over 80% of right and in 65% of the left hemisphere strokes. Hemi-inattention was present in about two-thirds of right and in half the left hemisphere strokes. Tactile extinction was present in two-thirds of right and in a third of left hemisphere strokes. Allaesthesia was present in over half the right but in fewer left hemisphere strokes. Anosognosia was found in a quarter of right but in very few left hemisphere stroke patients.

Neglect phenomena appeared to be more frequently associated with right hemisphere damage, as were anosognosia and anosodiaphoria.

Discussion

This is the first study to report the incidence of different forms of neglect and related disorders in acute stroke affecting either hemisphere. We found visual neglect to be more common than in other studies of acute stroke [5, 7, 9, 10]. Eighty-two per cent of assessable right hemisphere strokes had visual neglect compared with 70% [5] (95% CI for difference in proportions 3%, 26%); and 43% [10] (95% CI for difference in proportions 26%, 53%). Sixty-

Table I. Number of patients with right and left hemisphere stroke unable to be assessed for neglect phenomena and related disorders

<table>
<thead>
<tr>
<th>Neglect phenomena or related disorders</th>
<th>No. (%) of unassessable patients</th>
<th>Right hemisphere stroke (n = 69)</th>
<th>Left hemisphere stroke (n = 102)</th>
<th>Difference in proportions of unassessable patients (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual neglect</td>
<td>8 (11)</td>
<td>28 (27)</td>
<td>16% (4%, 27%)</td>
<td></td>
</tr>
<tr>
<td>Hemi-inattention</td>
<td>6 (9)</td>
<td>15 (15)</td>
<td>6% (-4%, 16%)</td>
<td></td>
</tr>
<tr>
<td>Tactile extinction</td>
<td>17 (25)</td>
<td>59 (58)</td>
<td>33% (20%, 47%)</td>
<td></td>
</tr>
<tr>
<td>Allaesthesia*</td>
<td>10 (15)</td>
<td>56 (55)</td>
<td>40% (27%, 53%)</td>
<td></td>
</tr>
<tr>
<td>Visual extinction</td>
<td>9 (13)</td>
<td>21 (21)</td>
<td>8% (-4%, 9%)</td>
<td></td>
</tr>
<tr>
<td>Anosognosia</td>
<td>9 (13)</td>
<td>46 (45)</td>
<td>32% (20%, 45%)</td>
<td></td>
</tr>
<tr>
<td>Anosodiaphoria</td>
<td>9 (13)</td>
<td>49 (48)</td>
<td>35% (22%, 48%)</td>
<td></td>
</tr>
<tr>
<td>Non-belonging</td>
<td>14 (20)</td>
<td>54 (53)</td>
<td>33% (19%, 46%)</td>
<td></td>
</tr>
<tr>
<td>Gaze paresis</td>
<td>0 (0)</td>
<td>3 (3)</td>
<td>3% (-3%, 6%)</td>
<td></td>
</tr>
<tr>
<td>Visual field defect</td>
<td>8 (11)</td>
<td>9 (9)</td>
<td>2% (-7%, 19%)</td>
<td></td>
</tr>
</tbody>
</table>

* Assessment of allaesthesia omitted in three patients.
five per cent of assessable left hemisphere strokes had visual neglect, compared with 40% [5] (95% CI for difference in proportions 10%, 41%). It is hard to compare our findings with those of Cutting [7] who studied stroke patients with particular reference to anosognosia. Although he gives an incidence for visual neglect of 50% in right and 0% in left hemisphere stroke, it is not clear how many of these patients were unassessable for neglect.

Our higher incidence for visual neglect can probably be attributed to our use of a larger and thus more sensitive battery [14, 16] than previous studies. Given the poorer prognosis for patients with visual neglect, and their possible need for intensive specialized treatment, the early accurate detection of such patients may have important implications for allocation of rehabilitation resources. Had we used, for example, line cancellation, as our sole test, as did Fullerton et al. [5], the incidence of visual neglect would have been identical to that in their study of acute stroke. The differential sensitivity of individual tests will be the subject of a future study.

Hier et al. [19] reported a similar incidence of visual neglect to ours in their study of patients with an acute right hemisphere stroke (85%; 95% CI for difference in proportions -10%, 17%), despite using only one test, a drawing task. However, this figure needs to be interpreted with caution for the population was atypical of the general stroke population in that patients who were obtunded, had a lacunar infarct or a normal CT brain scan were excluded. In addition, no data were present concerning the validity, reliability or control performance of their drawing task. This is important because firstly, the interpretation of drawing tasks may be subjective and made difficult by structural disorganization and other problems of perception or praxis [13, 28];
secondly, most patients with a stroke are over the age of 65 and up to 47% of controls in this age group perform poorly on drawing tasks [29].

We found a higher incidence of hemi-inattention in right hemisphere stroke (70%) than did Hier et al. (46%) [9] (95% CI for difference in proportions 4%, 43%). They defined 'neglect of left hemispace' as 'the spontaneous failure to attend or turn to visual or auditory stimuli presented from the left'. Our definition was broader in that it included assessment of eye movements, mobility, grooming and posture. This might, in part, explain our higher incidence. We found the incidence of hemi-inattention in left hemisphere stroke to be 42%. No previous study has reported on this variable.

We found tactile extinction in assessable right hemisphere stroke to be as common as in the study of Heir et al. [9] (65% vs 63%, respectively, 95% CI for difference in proportions -18%, 22%). We found tactile extinction in 35% of assessable left hemisphere strokes. No other study has reported on this variable. One study, however, found that in a group of patients with mixed cerebral pathology, tactile extinction occurred after left brain damage but less commonly than after right brain damage [30].

The only study to report the incidence of visual extinction after stroke [31] gave a combined incidence for assessable left and right stroke of 11%, similar to our figure of 13% (95% CI for difference in proportions -4%, 9%). The only study of allaeesthesia after stroke was confined to patients with thalamic or putaminal haemorrhage, none of whom had neglect [32].

Of the related disorders, we found anosognosia to be less common in assessable right hemisphere stroke (28%) than did Cutting (58%) [7] (95% CI for difference in proportions 12%, 48%). Anosodiaphoria was however, more common in our series of assessable right hemisphere strokes (27%) than in Cutting's study (4%) [7] (95% CI for difference in proportions 9%, 36%). It is not immediately clear why there should be such variation. Cutting developed a formal questionnaire to assess these disorders, which was used in this study. It is possible that, in the absence of specific instructions as to the diagnostic criteria for these disorders, inter-clinician variability would arise. Garraway and colleagues have amply demonstrated this with respect to the introduction of new assessment protocols for stroke patients [33]. However, we found the incidence of anosognosia in assessable left hemisphere stroke to be similar (5%) to that in Cutting's study (14%) (95% CI for difference in proportions 7%, 24%). The incidence of anosodiaphoria in left hemisphere stroke was also similar in both studies (2% and 10% respectively; 95% CI for difference in proportions -5%, 21%). The similarity may relate to the difficulties of assessing patients with dysphasia. Our figure for anosognosia in right hemisphere stroke was similar to that reported by Hier et al. (36%) [9] (95% CI for difference in proportions -10%, 27%). It is hard to compare our figure with that of Willanger et al. who found anosognosia in 25% of right hemisphere strokes, for it is unclear how long post-stroke their patients were examined [34].

The incidence of a visual-field defect in assessable right hemisphere stroke (36%) is similar to that reported by Hier et al. (46%) [9] (95% CI for difference in proportions -9%, 30%). No other study gives a figure for visual-field defects in acute left hemisphere stroke. It should be noted that visual-field defects can occur in the absence of visual neglect and vice versa [35]. Clinico-anatomical studies have shown that surgery restricted to medial occipital lobe causes restriction of visual fields but not visual neglect and that patients with posterior cerebral infarcts have isolated hemianopia unless the lesion involves the temporal or parietal lobes [36–9].

The incidence of gaze paresis in the present study was similar for right and left hemisphere stroke. This fails to confirm the findings of DeRenzi and colleagues [40], who reported an association with right hemisphere stroke (35% right; 21% left). However, it should be noted that what DeRenzi et al. regarded as the mildest form of gaze paresis, loss of spontaneous ocular scanning movements to the side opposite the lesion in the absence of a frank gaze paresis, was regarded in the present study as a 'gaze preference' [41] and as such, a form of hemi-inattention. It is not clear from their study how many
presented with this form of gaze paresis, so further comparisons are hard to make.

Our finding that neglect phenomena and most related disorders were associated with right hemisphere stroke is consistent with most other studies [5, 7, 11]. Visual neglect, which is the only neglect phenomenon to be previously studied in left hemisphere stroke, was much more common than in earlier studies. However, we did not replicate the findings of studies that reported visual neglect to be equally common in right- or left-sided lesions. These studies were based either on smaller populations, or on non­acute stroke patients or on groups of mixed, predominantly non-vascular pathology [14-16]. It is however possible that the association of some neglect phenomena and related disorders with right hemisphere stroke might still be an artefact of the difficulty of assessing dysphasic left hemisphere patients (Table I) [12, 13]. None the less, this association is consistent with the view that, although both hemispheres have the capacity to attend to contralateral stimuli, the non-dominant hemisphere is specialized for the distribution of sensory attention [42].

Acknowledgements

The authors thank Dr J. C. Marshall (Neuropsychology Unit, University of Oxford) for helpful criticism; Ms P. Patel (Department of Computer Studies, St Bartholomew’s Hospital) and Ms. Caroline Sabin (Department of Public Health, Royal Free Hospital) for statistical analysis and advice.

S.P.S. was supported by a grant from the Chest, Heart and Stroke Association (SAPS, PW H).

References

8. Oxbury JM, Campbell DC, Oxbury SM. Unilateral spatial neglect and impairment of spatial analysis and visual perception. Brain 1974;97:551-64.
NEGLIGENCE PHENOMENA IN ACUTE HEMISPHERIC STROKE


Authors addresses
S. P. Stone, R. J. Greenwood
Department of Neurosciences, St Bartholomew’s Hospital, West Smithfield, London EC1A 7BE
P. W. Halligan
University Department of Clinical Neurology and Rivermead Rehabilitation Centre, Oxford

Received in revised form 3 April 1992
Measuring visual neglect in acute stroke and predicting its recovery: the visual neglect recovery index

SP Stone, P Patel, RJ Greenwood, PW Halligan

Abstract
An overall measure of the recovery of visual neglect in patients with an acute stroke is described: The "Visual Neglect Recovery Index" (VNRI) expresses the amount of visual neglect on a battery of visual neglect tests as a percentage of complete recovery from the maximal visual neglect measurable. The principles underlying the development of the index are similar to those involved in the development of the Motricity Index for hemiplegia. A population of 68 survivors of stroke who presented with visual neglect at two to three days were followed for up to six months. The VNRI showed that neglect was greater in those with right hemisphere stroke than in those with left hemisphere stroke and that recovery was most rapid over the first 10 days and reached a plateau at three months. Most patients, including many with severe initial visual neglect, showed little visual neglect at three months. Stepwise regression analysis showed that the severity of visual neglect at three months and at six months post-stroke could be predicted by the severity of visual neglect and the presence of anosognosia at two to three days. A regression equation was produced which may enable clinicians to select patients for intensive treatment of visual neglect.

Visual neglect may recover in some patients with an acute stroke but for some it represents a serious rehabilitation problem. At present, opinion is divided as to the effectiveness of neuropsychological treatments for visual neglect. To date, no trial has randomised patients according to prognosis because the features that predict recovery are unknown. Knowledge of these are essential to select comparable groups of patients for controlled trials of treatment. Only then can the best use be made of intensive rehabilitation resources.

Some of the reasons why the predictive features are unknown are because previous studies have examined patients at different times post-stroke, have not used clear definitions of neglect phenomena and have used different tests to detect visual neglect. We have recently developed a standardised test battery for the assessment of visual neglect and other neglect phenomena in patients with an acute stroke. We report the findings of a study in which patients with visual neglect at two to three days were followed for up to six months post-stroke. To express performance on the tests of the battery as a single overall figure, a visual neglect index was developed, which was then used to predict the severity of visual neglect at three and six months post-stroke.

The test battery is a modified form of the Behavioural Inattention Test. Performance on each test of the battery is expressed as a grade on a 0–5 scale that reflects the percentage of items omitted on each test (grade 0: no neglect; grade 1: 0–20%; grade 2: 21–40%; grade 3: 41–60%; grade 4: 61–80%; grade 5: 81–100%). Although, this grading system provides a profile of scores and is sensitive to change it is not as useful as a single overall score. The simplest solution would appear to be to summate and average the graded scores on the entire battery. This, however, cannot be done for two reasons. First, these grades are in arbitrary units of no real value, so they cannot be treated as continuous variables. Second, some patients are unable to do all the tests because of aphasia or drowsiness. Since it cannot be assumed that each test measures the same neuropsychological variable, grade 3 neglect on one test may not be equivalent to grade 3 neglect on another.

The problem is similar to that encountered when trying to express the power loss after stroke as an overall score. Demeurisse et al. overcame this problem by developing the Motricity Index. This converted the arbitrary 0–5 grades of the MRC scale for muscle movements at individual joints into a single overall figure expressing the power as a percentage of "total motor recovery"; 0% represents no recovery and 100% full recovery from total hemiplegia. The principles underlying the development of the motricity index were used to create an overall measure of visual neglect recovery, the "Visual Neglect Recovery Index" (VNRI), from the graded performance of patients on the individual tests in the neglect test battery. This measure was then used in predicting recovery of visual neglect.

Method
One hundred and seventy one consecutive patients with an acute hemispheric first stroke were examined for evidence of visual neglect at two to three days post-stroke using the neglect test battery as described. The presence of the following neglect phenomena and related disorders was also assessed using standardised measures and was recorded as present (1) or absent (0): behavioural neglect, visual extinction, sensory extinction, allaeesthesia, anosog-
nosia visual field defect and gaze paresis. The patient's age was noted. The severity of power loss was assessed using the Motricity Index. The level of consciousness was recorded as unimpaired (0), drowsy or comatose (1).

A group of 68 patients (34 right hemisphere and 34 left hemisphere) presenting with visual neglect, who survived at least three months and whose subsequent course was unaffected by other disease or a second stroke formed the study population. These patients were re-examined at 10 days, three weeks, six weeks and three months. Patients were seen again at six months but six were lost to further follow up, one died of other disease, one died of the late complications of stroke induced immobility and one suffered a second stroke. Follow up was discontinued when visual neglect appeared to have resolved.

Each patient's graded score on each test of the battery at three days and at three months was recorded. Three months was chosen as the end point because the majority of patients made some progress to the end of the period (third month). If neglect had resolved in a patient at three weeks it was assumed that no visual neglect would have been present at three months.

The battery includes six tests which are done by both right and left hemisphere stroke patients: indicating items of food on a plate (meal), reading a menu (menu), selecting named coins from an array on a card (coins), pointing to objects scattered round the room (pointing), cancelling lines on a piece of paper (lines) and cancelling stars (stars). Performance on each was graded 0-5, as above.

For each test a double entry table was constructed, such as that for Reading the Menu (table 1). The figures in the first vertical column refer to the number of patients who had grade 0, 1, 2, 3, 4, or 5 neglect on the Menu at three days post-stroke who also had grade 0 on that test at three months. The second vertical column gives the number of patients whose initial grade was 0, 1, 2, 3, 4 or 5 and whose final grade at three months was grade 1, and so on. Using the method described for weighting the stages in the Motricity Index, the difficulty experienced by individual patients in progressing, in Menu, from one grade to the next over the first three months was compared with the total difficulty experienced in progressing from maximum neglect (grade 5) to no neglect (grade 0), over that period (Appendix).

The relative difficulty was expressed as a percentage so that, for example, change from grade 3 to 2 neglect on Menu was equivalent to progress from 46-57% of total neglect recovery.

Applying the method to all tests enabled the percentage recovery to be calculated for each test and the total recovery at three months.

The correlation of the VNRI with the percentage recovery score on individual tests at three days was assessed by analysis of variance and by least significant difference analysis. The change in the mean VNRI values with time was examined for all 68 patients and for right and left hemisphere stroke patients separately.

Table 2: Value of each grade on each test as a percentage of total visual neglect recovery on that test over three months

<table>
<thead>
<tr>
<th>Grade visual neglect</th>
<th>MENU</th>
<th>MEAL</th>
<th>LINES</th>
<th>STARS</th>
<th>COINS</th>
<th>POINTING</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

* = no grade 1 visual neglect on meal (ref: 1, 2)
0% = maximum visual neglect
100% = no visual neglect
Results

1) Percentage recovery represented by each grade on each test

The percentage recovery represented by each grade on each of the six tests is given in Table 2. This table, for example, suggests that it is just as difficult to recover from grade 2 as grade 3 neglect on Line cancellation; that it is more difficult to recover from grade 3 neglect on Meal than from grade 3 on Line cancellation.

The table was used to summate and average a patient's percentage recovery score on each test to give an overall measure of visual neglect. For example, a patient with grade 2 neglect on Meal (55% recovery), grade 3 on Menu (46% recovery), and grade 0 (100% recovery) on the other tests at six weeks post-stroke, has an average recovery score (VNRI) of 83.5%.

If a patient was able to attempt only three or four tests because of aphasias or tiredness, the VNRI was calculated from the results of those tests as measurements were now in equivalent non-arbitrary units of "percentage recovery".

2) Change in VNRI over time

Figure 1 shows a plot of the mean VNRI at different time intervals up to six months for right and left hemisphere patients taken separately.

Visual neglect recovers most quickly over the first 10 days and reaches a plateau at three months. Recovery is significantly greater in those with a left hemisphere stroke than in those with a right hemisphere stroke at three days (t = 3.23; p < 0.025; n = 68), 10 days (t = 2.89; p < 0.05; n = 64), three weeks (t = 2.96; p < 0.025; n = 66), six weeks (t = 3.7; p < 0.005; n = 66) and three months (t = 3.53; p < 0.005; n = 68), but not at six months (t = 1.94; p = 0.4; n = 62).

The recovery between three days and 10 days is significant for right hemisphere (t = 5.77; df = 32; p < 0.002) and for left hemisphere strokes (t = 5.43; df = 30; p < 0.002). Recovery between 10 days and three months is significant for both groups (right hemisphere: t = 3.33; df = 32; p < 0.01; left hemisphere: t = 3.72; df = 30; p < 0.002). The change from three to six months is significant for right hemisphere (t = 2.57; df = 27; p = 0.04) but not for left hemisphere stroke (t = 0.93; df = 33; N.S.).

Many patients have little or no residual visual neglect at three months. This is true even of the 15 patients presenting with a VNRI of 0-20%, seven of whom attained a three month score of at least 75% (figure 2). In the whole population only seven patients had a three month VNRI of below 60%; all, except one, had a VNRI of at least 75%.

3) Correlation of VNRI with individual test scores

Change over time in the individual test scores, taken for all 68 patients, follows a similar pattern to that for the VNRI as a whole (figure 3). Star cancellation recovers least. At all stages post-stroke, there was a general trend showing that as recovery in each test increases so does recovery over the whole battery as reflected in the VNRI, although detailed examination shows wide variation between individuals. Calculation of correlation coefficients is not valid because the individual test scores fall into categorical groups. Analysis of variance is difficult because some groups are very small. However, where it was possible ANOVA showed that at three days there was a significant difference between the VNRI means for each level of visual neglect on Meal (F = 59.27 at 3.46 df) and on Pointing (F = 27.13, at 3.45 df). This was confirmed by Least Significant Difference analysis.

4) Prediction of the severity of visual neglect at three and six months

At both time points two variables were found to make an individual independent contribu-
The rate of recovery of visual neglect demonstrated by the VNRI is similar to that reported for other neurological deficits or disabilites in stroke and by a much smaller study of visual neglect which used only one test. Recovery is slower for those with a right hemisphere stroke and continues between three and six months. The hemispheric difference in severity is consistent with findings of other studies. The VNRI at two to three days and the presence or absence of anosognosia can be used to predict the degree of recovery of visual neglect. These predictor variables make clinical sense in that the initial severity of visual neglect affects its severity at three months and at six months. The influence of anosognosia on outcome is of particular interest. Patients with anosognosia had a significantly greater degree of visual neglect (mean VNRI 34%, SD 38%) than those without anosognosia (mean VNRI 62%, SD 31%; t = 12.87, df 53, p < 0.0005). The presence of anosognosia may therefore be regarded as an indicator of severe visual neglect and hence, poor recovery, even though operational definitions of the two deficits have been shown to be clinically dissociable. However, in this study, a few patients with anosognosia had little visual neglect.

The predictive equations derived are simple and are consistent for both time points. There was good matching of actual and predicted recovery at the upper end of the VNRI. At the lowest end of the range, matching is poor, with frequent over-estimation of recovery. This was true at six months as well.

Residuals were plotted against the predicted values and also against the variables that were not in the model. Residual analysis showed a good scatter of results and confirmed that there were no other significant predictors of outcome.

Discussion

The VNRI expresses a patient's performance on a standardised battery of tests as a percentage of complete recovery from the maximum visual neglect measurable. It enables clinicians to express the severity of visual neglect as a single figure and may help predict outcome. It is a better option than summing and averaging the graded scores of individual tests because the VNRI expresses each grade in equivalent units of "neglect recovery" instead of arbitrary units of no real value. Visual neglect may be task-specific and the VNRI may facilitate comparison between performance on different tests. There is reasonable correlation between individual test scores and the VNRI, suggesting that if a patient is unable to do one or two tests because of aphasias or drowsiness, the VNRI derived from the tests done by the patient is probably representative of their visual neglect on the entire battery. It could be argued that one test could be as useful as the entire battery, but recent work has illustrated the differential sensitivity of individual tests and stressed that use of only one test might result in failure to detect a significant proportion of patients with neglect. The index, like the BIT from which the test battery was derived, does not specifically lateralise the omissions, but in practice, only 2% of test results are not clearly lateralised.

The VNRI at two to three days and the presence or absence of anosognosia can be used to predict the degree of recovery of visual neglect. These predictor variables make clinical sense in that the initial severity of visual neglect affects its severity at three months and at six months. The influence of anosognosia on outcome is of particular interest. Patients with anosognosia had a significantly greater degree of visual neglect (mean VNRI 34%, SD 38%) than those without anosognosia (mean VNRI 62%, SD 31%; t = 12.87, df 53, p < 0.0005). The presence of anosognosia may therefore be regarded as an indicator of severe visual neglect and hence, poor recovery, even though operational definitions of the two deficits have been shown to be clinically dissociable. However, in this study, a few patients with anosognosia had little visual neglect.

The predictive equations derived are simple and are consistent for both time points. There was good matching of actual and predicted recovery at the upper end of the VNRI. At the lowest end of the range, matching is poor, with frequent over-estimation of recovery. This was true at six months as well.

Residuals were plotted against the predicted values and also against the variables that were not in the model. Residual analysis showed a good scatter of results and confirmed that there were no other significant predictors of outcome.

Discussion

The VNRI expresses a patient's performance on a standardised battery of tests as a percentage of complete recovery from the maximum visual neglect measurable. It enables clinicians to express the severity of visual neglect as a single figure and may help predict outcome. It is a better option than summing and averaging the graded scores of individual tests because the VNRI expresses each grade in equivalent units of "neglect recovery" instead of arbitrary units of no real value. Visual neglect may be task-specific and the VNRI may facilitate comparison between performance on different tests. There is reasonable correlation between individual test scores and the VNRI, suggesting that if a patient is unable to do one or two tests because of aphasias or drowsiness, the VNRI derived from the tests done by the patient is probably representative of their visual neglect on the entire battery. It could be argued that one test could be as useful as the entire battery, but recent work has illustrated the differential sensitivity of individual tests and stressed that use of only one test might result in failure to detect a significant proportion of patients with neglect. The index, like the BIT from which the test battery was derived, does not specifically lateralise the omissions, but in practice, only 2% of test results are not clearly lateralised.

The rate of recovery of visual neglect demonstrated by the VNRI is similar to that reported for other neurological deficits or disabilities in stroke and by a much smaller study of visual neglect which used only one test. Recovery is slower for those with a right hemisphere stroke and continues between three and six months. The hemispheric difference in severity is consistent with findings of other studies. The VNRI at two to three days and the presence or absence of anosognosia can be used to predict the degree of recovery of visual neglect. These predictor variables make clinical sense in that the initial severity of visual neglect affects its severity at three months and at six months. The influence of anosognosia on outcome is of particular interest. Patients with anosognosia had a significantly greater degree of visual neglect (mean VNRI 34%, SD 38%) than those without anosognosia (mean VNRI 62%, SD 31%; t = 12.87, df 53, p < 0.0005). The presence of anosognosia may therefore be regarded as an indicator of severe visual neglect and hence, poor recovery, even though operational definitions of the two deficits have been shown to be clinically dissociable. However, in this study, a few patients with anosognosia had little visual neglect.

The predictive equations derived are simple and are consistent for both time points. There was good matching of actual and predicted recovery at the upper end of the VNRI. At the lowest end of the range, however, prediction of the exact severity of visual neglect in the worst patients was less precise. This is likely to be because there were too few such patients at three months to allow more accurate stepwise regression analysis. Nonetheless, of the eight patients with a three month VNRI of <75%, seven were correctly predicted as such and it is from this group that candidates for intensive treatment of neglect might be expected to come. Some of the inaccuracies in prediction may also reflect the failure to standardise remedial therapy in the population studied; hence some patients may have received more treatment for visual neglect than others. The best test of the model's accuracy would be to carry out the prediction analysis on a new sample of patients. This would also demonstrate that the predictive power of the VNRI was not solely the result of the statistical tautology inherent in its development.

Nonetheless, it is apparent that in most patients visual neglect makes a good recovery. The predictive equations may be of use...
in randomising patients for trials of intensive treatment of visual neglect. For example, all but one of those whose VNRI at three months was 75% had a predicted VNRI of <75% and it might be from this group of patients that candidates for such treatment might come. The current study demonstrates the difficulty of recruiting sufficient patients for such a trial, given the generally good prognosis for the recovery of visual neglect.

Appendix

Table 1 shows that in Reading the Menu there were 8 patients who initially had grade 5 neglect on this test. Seven of these (3 + 0 + 2 + 0 + 0 + 2 + 2) improved over 3 months. The percentage (X') of those who recovered from grade 5 to grade 4 at some stage over the 3 months is 7/8 x 100%, that is, 87.5%. Similarly, the number of patients whose initial grade at 3 days was grade 4 or who had recovered from grade 5 to 4 at some stage over the 3 months is 7 + 1 + 2 + 1 + 0 + 3 + 0 + 0 + 2 + 2 = 18. Sixteen of these (7 + 1 + 2 + 1 + 3 + 0 + 0 + 2) recovered from grade 4 to 3 at some time over the 3 months. The percentage (X') who recovered from grade 4 to 3 is, therefore, 16/18 x 100% (that is, 88%). Similar percentages X', X', X' were calculated for the patients recovering from Grade 3 to 2, 2 to 1, and 1 to 0 at some stage over 3 months.

If every patient had had grade 5 neglect at 3 days the percentage of those who would have recovered from grade 5 to 0 over 3 months would be

\[ X' \times X' \times X' \times X' \times X' \times 100\% = \frac{100}{100} = 100\% \]

The percentage of patients who did not recover from grade 5 to 4 is 100 - X', from grade 4 to 3 is 100 - X' and so on. The percentage who would not have recovered from grade 5 to 0 can be given by

\[ 100 - \frac{X' \times X' \times X' \times X' \times X'}{100} = 0\% \]

The coefficients D', D', D', D', D' comparing the relative difficulty in recovering from grade 5 to 4, grade 4 to 3 etc. with that of total recovery of neglect from grade 5 to 0 over 3 months are derived as follows:

\[ D' = \frac{100 - X'}{100 - X' - X' - X' - X'} = 0\% \]

The percentage of patients who initially had grade 5 neglect on this test. Seven of these (3 + 0 + 2 + 0 + 0 + 2 + 2) improved over 3 months. The percentage (X') of those who recovered from grade 5 to grade 4 at some stage over the 3 months is 7/8 x 100%, that is, 87.5%. Similarly, the number of patients whose initial grade at 3 days was grade 4 or who had recovered from grade 5 to 4 at some stage over the 3 months is 7 + 1 + 2 + 1 + 0 + 3 + 0 + 0 + 2 + 2 = 18. Sixteen of these (7 + 1 + 2 + 1 + 3 + 0 + 0 + 2) recovered from grade 4 to 3 at some time over the 3 months. The percentage (X') who recovered from grade 4 to 3 is, therefore, 16/18 x 100% (that is, 88%). Similar percentages X', X', X' were calculated for the patients recovering from Grade 3 to 2, 2 to 1, and 1 to 0 at some stage over 3 months.

If every patient had had grade 5 neglect at 3 days the percentage of those who would have recovered from grade 5 to 0 over 3 months would be

\[ X' \times X' \times X' \times X' \times X' \times 100\% = \frac{100}{100} = 100\% \]

The percentage of patients who did not recover from grade 5 to 4 is 100 - X', from grade 4 to 3 is 100 - X' and so on. The percentage who would not have recovered from grade 5 to 0 can be given by

\[ 100 - \frac{X' \times X' \times X' \times X' \times X'}{100} = 0\% \]

The coefficients D', D', D', D', D' comparing the relative difficulty in recovering from grade 5 to 4, grade 4 to 3 etc. with that of total recovery of neglect from grade 5 to 0 over 3 months are derived as follows:

\[ D' = \frac{100 - X'}{100 - X' - X' - X' - X'} = 0\% \]

The percentage of patients who initially had grade 5 neglect on this test. Seven of these (3 + 0 + 2 + 0 + 0 + 2 + 2) improved over 3 months. The percentage (X') of those who recovered from grade 5 to grade 4 at some stage over the 3 months is 7/8 x 100%, that is, 87.5%. Similarly, the number of patients whose initial grade at 3 days was grade 4 or who had recovered from grade 5 to 4 at some stage over the 3 months is 7 + 1 + 2 + 1 + 0 + 3 + 0 + 0 + 2 + 2 = 18. Sixteen of these (7 + 1 + 2 + 1 + 3 + 0 + 0 + 2) recovered from grade 4 to 3 at some time over the 3 months. The percentage (X') who recovered from grade 4 to 3 is, therefore, 16/18 x 100% (that is, 88%). Similar percentages X', X', X' were calculated for the patients recovering from Grade 3 to 2, 2 to 1, and 1 to 0 at some stage over 3 months.

If every patient had had grade 5 neglect at 3 days the percentage of those who would have recovered from grade 5 to 0 over 3 months would be

\[ X' \times X' \times X' \times X' \times X' \times 100\% = \frac{100}{100} = 100\% \]

The percentage of patients who did not recover from grade 5 to 4 is 100 - X', from grade 4 to 3 is 100 - X' and so on. The percentage who would not have recovered from grade 5 to 0 can be given by

\[ 100 - \frac{X' \times X' \times X' \times X' \times X'}{100} = 0\% \]

The coefficients D', D', D', D', D' comparing the relative difficulty in recovering from grade 5 to 4, grade 4 to 3 etc. with that of total recovery of neglect from grade 5 to 0 over 3 months are derived as follows:

\[ D' = \frac{100 - X'}{100 - X' - X' - X' - X'} = 0\% \]

The percentage of patients who initially had grade 5 neglect on this test. Seven of these (3 + 0 + 2 + 0 + 0 + 2 + 2) improved over 3 months. The percentage (X') of those who recovered from grade 5 to grade 4 at some stage over the 3 months is 7/8 x 100%, that is, 87.5%. Similarly, the number of patients whose initial grade at 3 days was grade 4 or who had recovered from grade 5 to 4 at some stage over the 3 months is 7 + 1 + 2 + 1 + 0 + 3 + 0 + 0 + 2 + 2 = 18. Sixteen of these (7 + 1 + 2 + 1 + 3 + 0 + 0 + 2) recovered from grade 4 to 3 at some time over the 3 months. The percentage (X') who recovered from grade 4 to 3 is, therefore, 16/18 x 100% (that is, 88%). Similar percentages X', X', X' were calculated for the patients recovering from Grade 3 to 2, 2 to 1, and 1 to 0 at some stage over 3 months.

If every patient had had grade 5 neglect at 3 days the percentage of those who would have recovered from grade 5 to 0 over 3 months would be

\[ X' \times X' \times X' \times X' \times X' \times 100\% = \frac{100}{100} = 100\% \]

The percentage of patients who did not recover from grade 5 to 4 is 100 - X', from grade 4 to 3 is 100 - X' and so on. The percentage who would not have recovered from grade 5 to 0 can be given by

\[ 100 - \frac{X' \times X' \times X' \times X' \times X'}{100} = 0\% \]
The relative value of stage 2 of recovery—recovery from grade 5 to 3—is given by the relative difficulty of recovery from grade 5 to 4 plus that of recovery from grade 4 to 3 divided by the total difficulty of recovery from grade 5 to 0 that is
\[
\frac{D^1 + D^2}{D^0 + D^1 + D^2 + D^3 + D^4} \times 100\% = \frac{0.5669}{1.2236} = 46\%
\]

The relative values of stage 3 of recovery (to grade 2), stage 4 of recovery (to grade 1) and stage 5 of recovery (to grade 0) can be similarly deduced.

By definition, stage 0, that of no recovery from grade 5, is equal to 0%. For reading the menu, grade 4 neglect therefore represented 25% of total recovery; grade 3 neglect represented 46% recovery; grade 2, 67%; grade 1, 80%; and grade 0, 100% recovery.
Performance of age-matched controls on a battery of visuo-spatial neglect tests

S P Stone, P W Halligan, B Wilson, R J Greenwood, J C Marshall

Abstract
Examination of 47 independent elderly subjects, matched with a population of patients with acute stroke, found that 55% made at least one omission on a battery of neglect tests. Up to 43% made omissions on any one test. Increasing age and other evidence of cognitive impairment were associated with impaired performance on the battery. Omissions were attributed to an age-related decline in visuo-spatial function. Cut-off points are provided to distinguish between such age-related impairment and visuo-spatial neglect. The importance of age-matched control studies in developing tests of cognitive impairment in stroke research is highlighted.

Patients with visuo-spatial neglect due to a unilateral cerebral lesion ignore relevant visual stimuli on the side opposite the lesion when performing simple everyday tasks.1,2 A test battery, the Behavioural Inattention Test (BIT), capable of detecting and measuring visuospatial neglect has recently been developed.3,4 It has been modified for use on patients with an acute stroke (see previous paper). Given that nearly half of all those suffering an acute stroke are over 75 years of age5 and that age-related neurological6 and cognitive changes7 are common, it is necessary to know how the normal elderly perform on this test battery to interpret the findings observed in a stroke population of a similar age. Our study investigates this question.

Method
Forty seven controls were recruited. The mean (SD) age of the controls was 71.6 (12.77) years (range 34-93). Six subjects were left handed. Eight had been treated for hypertension; none had diabetes. Each was resident in the City and Hackney Health District, had no history of neurological disease, and was independent in selfcare. The sample was recruited from patients in general good health admitted for elective procedures or investigations (for example, joint replacements, cystoscopy, lithotripsy) to the urological and kidney, carcinoma of the bowel or lung: were excluded. Those at risk of small vessel disease due to diabetes or hypertension were included as were those with cardiovascular disease for these are common disorders within the general and stroke populations. The sample was matched for age in 10 year cohorts with a population of 160 consecutive patients admitted to local hospitals with an acute stroke, mean (SD) age 72.1 (12.6) years.

Subjects were examined for evidence of neglect phenomena such as visual and sensory extinction, hemi-inattention and allaesthesia and for related disorders (anosognosia, anosodiaphoria, non-belonging, visual field defects and gaze paresis). Each subject was administered, in the following order, the modified BIT; Kendrick's Object Learning Test (KOLT), which is a sensitive measure of diffuse brain pathology that correlates with other cognitive assessments;9 Hodkinson's Mental Test Score (MTS);10 and the Geriatric Depression Scale (GDS), which has been specifically developed for elderly people.11 Power, visual fields, cranial nerve function, light touch and reflexes were assessed in the standard manner at the bedside.11 Proprioception was measured by a method similar to that described by Mayne.14

"Hemi-inattention" was regarded as present if the subject's general spontaneous behaviour during examination suggested an inability to orientate or respond correctly to environmental stimuli on one side (for example, people approaching, noises or activity in the ward).15 It was also regarded as present if the subject failed to shave or position their glasses properly on one side of their face;15 consistently bumped into obstacles or doorways on one side when mobile;16iners appeared unaware of their contralateral limbs and let them remain in uncomfortable or unnatural positions.17

"Sensory extinction" was assessed by the technique of double simultaneous stimulation (DSS).15 Bilateral stimuli were given a total of five times and the number of correct responses out of five was recorded. "Visual extinction" was also assessed by double simultaneous stimulation on full confrontation testing, subjects being asked to report movement of the examiner's fingers.15

"Allaesthesia" was regarded as present if subjects consistently attributed sensory stimulation of one side to stimulation of the other or if they consistently moved the limbs on one side when requested to move the limbs on the other.1 The number of times that this happened during examination for sensorimotor deficits was noted.
Anosognosia, anosodiaphoria and non-belonging were assessed by a modified version of Cutting's questionnaire. Gaze paresis was assessed by the ability of the subject to track a moving object (the examiner's finger) from right to left and back again, using a modified version of the method by De Renzi et al. The modified Behavioural Inattention Test is described in the accompanying paper. The Geriatric Depression Scale (GDS), the Mental Test Score (MTS) and Kendrick's Object Learning Test (KOLT) were also administered.

Results

1) The number of controls making omissions on each neglect test

The number of controls making omissions was very small for most tests (table 1). The exceptions were Star Cancellation and Coin sorting. Twenty one controls made no omissions on any test, 12 made omissions on one test, 10 on two tests, two on three tests, one on four tests and one on six tests.

2) The number and distribution of omissions on each test

For most tests the number of omissions was very small (tables 1 and 2). Performance on Star cancellation (range 0-15; mean 27; SD 42) and Coin sorting (range 0-3; mean 0.4; SD 0.77) were exceptions. No control made a Right Hand Start on Menu or Newspaper; one made a Right Hand Start on Line cancellation and three did so on Star cancellation. No control showed crowding on copying the left figure.

3) The influence of age on the number of omissions

Thirteen of 30 controls over the age of seventy made omissions on two or more tests, compared with two of 17 aged seventy or less. This difference was significant (Chi square = 4.85, p < 0.05).

In this sample, age had an effect on the number of omissions on Star cancellation (fig 1). Nine of the 29 controls over the age of seventy omitted six or more stars, compared with one out of the 17 aged seventy or less. This difference is significant at the 0.05 level (Chi square = 3-98).

Although not statistically significant, a similar trend was observed on Coin sorting. Only 11 controls made omissions. Nine of them were aged over 70 and only two were 70 years old or less.

4) Relation of KOLT and MTS scores to number of omissions on each test

Declining KOLT scores (mean 31-26; SD 9.77; median 33-0; Q1 24-0; Q3 40.0) were significantly correlated with increasing age (r = -0.496; p < 0.01). Declining KOLT scores were significantly correlated with an increasing number of omissions on Star cancellation (r = -0.47; p < 0.01). Subsequent analysis showed that there was a cluster of high "star" scores (that is, six or more omissions) and declining KOLT scores (less than or equal to 27) (fig 2).

Table 1 shows that controls who made omissions on Meal, Line cancellation, Pointing, and all parts of the Newspaper task often had low KOLT scores (that is, less than 23; ref 22) or borderline KOLT scores (that is, 23-25).

The KOLT score did not correlate with the number of omissions on Coin sorting, although four out of six controls omitting two or more coins had KOLT scores of less than 23, compared with three out of 35 omitting less than two coins.

Thirty eight controls were assessed on the MTS. Thirty five scored at least nine out of 10. One scored eight, had a KOLT score of 22 and

---

Table 1 The number of controls making omissions on each neglect test, the range of omissions and cut-off points for abnormal visuo-spatial function

<table>
<thead>
<tr>
<th>Neglect test (maximum number possible omissions)</th>
<th>Number of controls tested</th>
<th>Number making omissions</th>
<th>Range of omissions</th>
<th>Cut-off point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meal (8)</td>
<td>47</td>
<td>2</td>
<td>0-1</td>
<td>2</td>
</tr>
<tr>
<td>Menu (24)</td>
<td>47</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Lines (36)</td>
<td>47</td>
<td>2</td>
<td>0-4</td>
<td>5</td>
</tr>
<tr>
<td>Stars (54)</td>
<td>46</td>
<td>20</td>
<td>0-15</td>
<td>16</td>
</tr>
<tr>
<td>Coins (18)</td>
<td>46</td>
<td>11</td>
<td>0-3</td>
<td>4</td>
</tr>
<tr>
<td>Pointing (180)</td>
<td>47</td>
<td>1</td>
<td>0-50 deg</td>
<td>50 deg</td>
</tr>
<tr>
<td>L. Figure (6)</td>
<td>47</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Newspaper</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a) Headlines (10)</td>
<td>47</td>
<td>1</td>
<td>0-1</td>
<td>2</td>
</tr>
<tr>
<td>b) Paragraph (5)</td>
<td>47</td>
<td>2</td>
<td>0-1</td>
<td>2</td>
</tr>
<tr>
<td>c) Article (117)</td>
<td>43</td>
<td>4</td>
<td>0-6</td>
<td>7</td>
</tr>
</tbody>
</table>

---

Table 2 Age, KOLT score and numbers of omissions made by controls on neglect tests

<table>
<thead>
<tr>
<th>Test</th>
<th>Number of omissions</th>
<th>Number controls making omissions</th>
<th>Age</th>
<th>KOLT score</th>
<th>Other neglect scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>MEAL</td>
<td>1</td>
<td>2</td>
<td>80</td>
<td>25</td>
<td>Point 50</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Stars 3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Coins 3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Stars 2</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>1</td>
<td>65</td>
<td>33</td>
<td>Stars 2</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>1</td>
<td>78</td>
<td>22</td>
<td>Stars 13</td>
</tr>
<tr>
<td>POINTING</td>
<td>1</td>
<td>50</td>
<td>80</td>
<td>25</td>
<td>Coin 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Coin 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Coin 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Star 13</td>
</tr>
<tr>
<td>HEADLINES</td>
<td>1</td>
<td>1</td>
<td>78</td>
<td>22</td>
<td>Coin 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Coin 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Coin 1</td>
</tr>
<tr>
<td>PARAGRAP</td>
<td>1</td>
<td>2</td>
<td>82</td>
<td>11</td>
<td>Star 6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Stars 3</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>1</td>
<td>82</td>
<td>11</td>
<td>Stars 3</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>1</td>
<td>82</td>
<td>25</td>
<td>Stars 10</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>1</td>
<td>77</td>
<td>24</td>
<td>Star 13</td>
</tr>
<tr>
<td>ARTICL</td>
<td>1</td>
<td>1</td>
<td>78</td>
<td>22</td>
<td>Coins 2</td>
</tr>
</tbody>
</table>
made four omissions on Line cancellation, one on Headlines, six on Article, two on Coin sorting, and 13 on Star cancellation. One scored six on the MTS, had a KOLT score of 40 but made 13 omissions on Star cancellation with a Right Hand Start. The remaining control scored five on the MTS, made seven omissions on Star cancellation but refused to do the KOLT.

5) EFFECT OF VISUAL ACUITY ON NEGLECT TEST OMISSIONS
Visual acuity, as measured by the ability to read small newsprint was adequate in all but four subjects. Two of these made no omissions on any other test. A third made one omission on Coins, one in Paragraph, three on Stars and had a KOLT score of 11. The fourth made eight omissions on Stars and had a KOLT score of 21. Poor visual acuity thus remains a possible contributing factor in impaired performance in a few patients as noted by Eccles.

6) RELATIONSHIP BETWEEN NEGLECT TEST RESULTS
The numbers of omissions made by controls on Coin sorting and Star cancellation were significantly correlated (r = 0.41; p < 0.01). Table 2 shows that controls making omissions on one test often made omissions on other tests. Of the three controls with a Right Hand Start on Stars, one omitted 13 stars, the second had a Right Hand Start on Lines but made no omissions on any other test, and the third had a Right Hand Start on Stars in isolation.

7) RELATION OF NEGLECT TEST OMISIONS TO NEUROLOGICAL FINDINGS
No control demonstrated any visual field defect, gaze paresis or cranial nerve palsies (corneal sensation was not tested). Two controls had minor signs of pyramidal tract damage without weakness. One of these omitted part of the daint (but in a non-lateralised manner), the other made one omission on Meal and two on Coins.

Proprioception scores were 10 out of 10 in all limbs in 35 controls, and nine out of 10 in nine controls. One control (with sciatica) scored eight in one limb.

On testing for Visual Extinction, 44 (94%) controls scored five out of five on DSS. Two scored 4/5 and one scored 3/5. Those scoring less than five all had low KOLT scores (14-21) and made large numbers of omissions on neglect tests (for example, three Coins, 15 Stars).

On testing for Sensory Extinction, 35 (75%) controls scored five out of five on DSS; seven scored 4/5; three scored 3/5; one scored 2/5 and one scored 0/5. Some controls scoring less than five made no omissions on neglect tests and had normal KOLT scores. Many, however, either made large numbers of omissions on neglect tests (for example, eight stars, 13 Stars, two Coins, 50 degrees on Pointing) or had low KOLT scores.

No control showed hemi-inattention, alaesthesia, anosognosia, anosodiaphoria, non-belonging, or gaze paresis.

8) RELATIONSHIP OF OMISIONS TO DEPRESSION
Four controls were depressed, with GDS scores of 5-8. One was aged 72, had a KOLT score of 14, a visual extinction score of 3/5 and made three omissions on Coin sorting and 15 omissions on Star cancellation. The other three were younger, aged 57, 62 and 64, and had KOLT scores of 23, 23 and 24 respectively. Two of these made no omissions on any neglect test and the other made one omission on Article.

9) PARAMETERS OF NORMAL VISUO-SPATIAL FUNCTIONING IN THE ELDERLY
The controls were regarded as normal by definition, and the range of omissions observed (table 1) was taken as the parameters of normal performance. Scores above this number of omissions on any one of the eight tests are considered abnormal. Thus two or more omissions on Meal; any omission on Menu; any left or right omission on Copying the Left Figure; five or more omissions on Line cancellation; 16 or more on Star cancellation; four or more on Coin sorting; two or more on Headlines; two or more on Paragraph; seven or more on Article; and 50 or more degrees on Pointing was regarded as abnormal. Right Hand Start on reading the Menu or Newspaper, and crowding of the Left Figures was also considered to be an indicator of abnormal performance.

Discussion
This group of subjects was selected as a control group for the stroke population for whom the test battery is intended. They were as representative as possible of the pre-morbid state of this local hospital-based stroke population, nearly all of whom (89%) were active, independent and living at home. To that end they were matched for age, and were drawn from the same geographical area. They were in good general health, despite being admitted to hospital for routine repeat checks or other elective procedures.

This is one of the first studies to investigate visuo-spatial functioning in the elderly. Unlike other studies of neurological and cognitive function in the elderly this study recruited active and independent subjects, instead of
medical inpatients,\textsuperscript{13,14} residents of elderly people's homes or institutions.\textsuperscript{15} In all these studies, depression, dementia or general ill-health might have affected the results of testing. Our controls were probably as active and independent as the "normal" elderly recruited from elderly people's clubs in other studies.\textsuperscript{1,2,22}

A community study by Eccles\textsuperscript{2} of perceptual function in elderly people found that various tests of apraxia and spatial function were performed poorly or with difficulty by 18-59% of subjects. These included tests commonly used to detect visuo-spatial neglect such as drawing a clockface or a human figure, the Formboard and the Posting Box. Wade et al studied the performance of active independent elderly people in a number cancellation task designed to detect visuo-spatial neglect and found that 63% made omissions.\textsuperscript{22} Our findings are consistent with the results of both these studies. Fifty five per cent of our subjects made at least one omission on the entire battery. On one test, Star cancellation, 43% of subjects made omissions. As with the study by Eccles,\textsuperscript{2} age and cognitive impairment influenced performance. As with the study by Eccles,\textsuperscript{2} age and cognitive impairment influenced performance.

The performance of the controls was used to set the parameters with which to distinguish between normal and abnormal visuo-spatial function in the elderly.\textsuperscript{23} These parameters have been used to help define visuo-spatial neglect in patients with an acute stroke (see accompanying paper). The parameters of normal visuo-spatial function were set separately for each test, as visuo-spatial neglect has been shown to be task specific\textsuperscript{24} and may appear on one test but not on another.\textsuperscript{2,25}

An age-related decline in neurological\textsuperscript{2} and cognitive function\textsuperscript{26} is well known. Beginning in their late sixties and seventies,\textsuperscript{9} elderly subjects show cognitive changes which often coexist without significant disease, disability or handicap\textsuperscript{27} and the same is true of neurological changes.\textsuperscript{31} A recent study of over 2000 elderly people showed that neurological signs consistent with diffuse cerebral disease are common but, taken in clinical context, are age-related and not pathological.\textsuperscript{7}

Such changes are often subtle and the concept of an "age-related decline in intellectual efficiency"\textsuperscript{28} is useful in accounting for findings such as visuo-spatial impairment, when they appear in clinical isolation. Visuo-spatial neglect may be due to a disruption of the "attention-arousal" system.\textsuperscript{1} "Attention" refers to a complex psychological construct\textsuperscript{29} whose neuro-anatomical pathways may be diffusely organised.\textsuperscript{30} It is reasonable to suggest that when the efficiency of this system is affected by age-related decline, subtle visuo-spatial impairments may appear on detailed clinical examination.
CORRIGENDA


page 11: "experience difficulties reading (Weinberg et al 1977)" instead of "reading and driving (Lorenze + Cancro 1962)"


page 53: 2.3.1 not 2.2.1.

page 55: same corrigendum as page 20.


ADDENDUM

Diller L, Weinberg J. (1970)
Evidence of accident-prone behaviour in hemiplegic patients.
Arch Phys Med Rehabil 51:358-63

Diller L, Weinberg J. (1977)
Hemi-inattention in rehabilitation: the evolution of a rational remediation programme.
Advances in Neurology 18:63-82.

Heilman KM, Valenstein E. (1979)
Mechanisms underlying hemispatial neglect.
Ann Neurol 5:166-70.

Howes D, Boiler F. (1975)
Simple reaction time: evidence for focal impairment from lesions of the right hemisphere.
Brain 98:317-32.

Katz S, Ford AB, Chinn AB, Newill VA. (1966)
Part III. Long term course of 159 patients.
Medicine (Baltimore) 45:236-46.

Hemispheric lateralization of spatial contrast sensitivity.
Ann Neurol 17: 141-145.

Labi MLC, Phillips TF, Gresham GE. (1980)
Psychosocial disability in physically restored long term stroke survivors.
Arch Phys Med Rehabil 61:561-5

McCauley DL, Ross-Russel RW. (1979)
Correlation of CAT scan and visual field defects in vascular lesions of the posterior visual pathways.
J Neurol Neurosurg Psychiatry 42:298-311.

Pappworth MH. (1984)
Butterworth.

Schwartz AS, Marchok PL, Flynn (1977)
A sensitive test for tactile extinctions: results in patients with parietal and frontal lobe disease.
J Neurol Neurosurg Psychiatry 40:228-33.

Intensive rehabilitation after stroke: service implications.
Community Medicine 3:210-16.

Stroke rehabilitation units in the United Kingdom.

Valenstein E, Heilman KM. (1981)
Unilateral hypokinesia and motor extinction.

Wade DT, Wood VA, Hewer RL. (1985b)
Use of hospital resources by acute stroke patients.

Wade DT. (1986)
Stroke assessment: it's time we all spoke the same language.
Geriatric Medicine 16(5):11-12.

Weatherall DJ, Ledingham JCG, Warrell DA (eds). 1987
Oxford University Press.

Visual capacity in the hemianopic field following a restricted occipital ablation.
Brain 97: 709-728.

Yates JA. (1986)
Geriatric Depression Scale.
Psychopharmacol Bull 24: 709-10.
CONJOINT WORK

The following work on this thesis was my own: the original idea, the selection of clinical tests and outcome measures, the recruitment, examination of and follow up of patients and controls, the choice of statistical methods. I received advice on the neurophysical aspects of the study from Dr B Wilson PhD (Univ. Southampton) and Dr P W Halligan PhD (Oxford Univ.) The statistical analysis was carried out by Mrs P Patel MSc, (Computer Studies, St Bartholomew's). The inter-observer reliability and validity studies of the test battery were carried out with the help and advice of two occupational therapists (Alison Wroot and Claudia Wallis) from St Bartholomew's Hospital.

The entire thesis was written by myself, as were the published papers, again with relevant advice from Drs Wilson and Halligan and Mrs P Patel. Graphs were drawn by Departments of Medical Illustration and Photography, St Bartholomew's Hospital.

Supervision was given by Dr R J Greenwood, MD FRCP (St Bartholomew's Hospital) and financial support by the Chest, Heart and Stroke Association.