THE CLINICAL ASSESSMENT AND REHABILITATION OF HEMINEGLECT IN ELDERLY STROKE PATIENTS

by

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Abstract

Unilateral neglect (UN) frequently occurs following stroke, and the presence of neglect can adversely affect functional recovery. It is important that physiotherapists are able to assess the common manifestations of neglect, and to provide effective rehabilitation for these patients. The main aims of this thesis were (i) to investigate how physiotherapists in the UK assess and treat visual neglect, (ii) to design and pilot a new test battery for assessing neglect at the impairment and activity levels, for use by therapists in the clinical setting, (iii) to establish the extent of reliability of three common tests for unilateral visual neglect, and (iv) to evaluate whether scanning and cueing, and limb activation strategies, would reduce unilateral visual neglect (UVN) in elderly stroke patients. The findings showed that (i) observation was the most frequently reported method to assess UVN, and that some effective strategies known to reduce UVN were infrequently listed by respondents; (ii) the Everyday Test Battery demonstrated validity and reliability in a small sample of elderly stroke patient with UVN; (iii) the Star Cancellation and Line Bisection tests, and the Baking Tray task demonstrated acceptable test-retest stability, which was highest when used with stroke patients with moderate to severe UVN; (iv) a significant reduction in UVN, in at least one of three tests for UVN, was demonstrated, in a series of single case experimental designs, by 10 of the 12 stroke patients who received one or other of the two treatment approaches stated above. The implications of this research are that clinical tests which enable assessment of neglect at the impairment and activity levels should be routinely used by physiotherapists in clinical practice, that results of repeated testing for neglect may need to be cautiously interpreted due to variability of performance over time, and that scanning and cueing, and limb activation strategies offer promise in the rehabilitation of elderly stroke patients suffering from UVN.

Dedication

To my husband Graham

(also to Frodo, Sam, and Estel, who set an example)

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LIST OF ABBREVIATIONS

ACPIN	Association of Chartered Physiotherapists Interested in Neurology
ADL	Activities of daily living
BI	Barthel Index
BIT	Behavioural Inattention Test
BTT	Baking Tray Task
CNS	Canadian Neurological Scale
CT	Computerised tomography
CVA	Cerebro-vascular accident
ETB	Everyday Test Battery
FIM	Functional Independence Measure
fMRI	Functional magnetic resonance imaging
LB	Line bisection
LLA	Left limb activation
LoA	Limits of agreement
MDT	Multi-disciplinary team
p/P	Probability value
PET	Positron emission tomography
RBIT	Rivermead Behavioural Inattention Test
RCT	Randomised controlled trial
RMI	Rivermead Mobility Index
RPAB	Rivermead Perceptual Assessment Battery
SCT	Star Cancellation Test
sd/SD	Standard deviation
SPSS	Statistics Package for the Social Sciences
TENS	Transcutaneous Neuromuscular Stimulation
UK	United Kingdom
USA	United States of America
ULN	Unilateral neglect
UN/UVN	Unilateral neglect
VSN	Visuospatial neglect

PUBLICATIONS AND CONFERENCE PRESENTATIONS DURING DOCTORAL CANDIDATURE (relating to thesis)

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*****Papers included in main body of thesis

~ Abstract and Paper in Appendices D and W respectively

APPENDICES

CHAPTER 1

INTRODUCTION

The topic of hemineglect is introduced, and the need for its assessment and rehabilitation outlined, to ‘set the scene’ for the thesis. Following this, aspects of this behavioural syndrome are outlined, manifestations of the disorder are defined, and the main theories used to explain the phenomenon are discussed. Next, the purpose and aims of the thesis are given. Finally, chapter contents will be outlined, in order to provide a ‘road map’ of the entire thesis.

1.1 Introduction

Approximately 100,000 first strokes occur in Britain each year, with prevalence likely to increase due to rising numbers of elderly in the population. Stroke consumes around 4% of NHS total expenditure (Royal College of Physicians, 2002), is the third highest cause of death in the UK, and is the largest single cause of major disability (Blais, 1994). Cognitive deficits are often found in stroke patients. Tatemichi et al. (1994) give a 35.2% incidence of cognitive deficits following stroke, which commonly involve language, memory, attention and orientation. One common cognitive deficit is that of hemineglect .

Hemineglect has been defined as

"…a deficit in processing or responding to sensory stimuli in the contralateral hemispace, a part of the own body, the part of an imagined scene, or may include the failure to act with the contralesional limbs despite intact motor functions."

(Kerkhoff, 2001, p.1))

Hemineglect often accompanies stroke, and is more common and persists for a longer time in patients with right-sided as opposed to left-sided brain damage (Stone et al., 1991b). Spontaneous recovery is frequent, but where neglect persists it can have a significant impact on the rehabilitation of stroke patients, delaying their progress and adversely affecting their functional outcome (Cherney, Halper, Kwasnica, Harvey & Zang, 2001).

1.2 The need for assessment and rehabilitation of hemineglect

In view of its frequent occurrence and impact upon recovery, the presence of hemineglect clearly presents a challenge to therapists during the rehabilitation process. There has been a relative failure to consider cognitive as opposed to physical factors in the management of the stroke patient (Finlayson, 1990). Physical rehabilitation relies on patient's learning capacity to carry over what is learned, and to generalize what has been learned in one situation to other similar situations. Attentional deficits may significantly affect effective learning.

In the National Clinical Guidelines for Stroke, The Royal College of Physicians (2002) provide two specific guidelines in relation to the management of stroke patients with neglect: firstly that “Every stroke rehabilitation service should have ready rapid access to expert neuropsychological expertise to assess patients.”; the second states “Patients with persistent visual neglect or visual field defects should be offered specific retraining strategies.” (Both of these guidelines are located in Section 9 – Rehabilitation Interventions, sub-section 9.1.2 - Cognitive Impairment).

In view of the needs to effectively a) identify the presence of hemineglect in stroke patients prior to planning of rehabilitation programmes, and b) plan appropriate rehabilitation programmes for stroke patients with hemineglect, a thorough knowledge of the subject is a pre-requisite. Plummer (2004) used a series of focus groups to investigate physiotherapists’ knowledge about neglect and its assessment. She found that physiotherapists had difficulty in classifying and diagnosing different types of neglect behaviour. They focussed upon the identification of the presence of neglect and its severity, rather than determining the specific type(s) of neglect manifested by the patient. Little attention has been given, by physiotherapists, to the formal assessment of hemineglect. Assessment tools used by therapists need to be valid, easy to administer (i.e. not require complex or expensive equipment), and appropriate for use in the clinical situation. By the same token, rehabilitation strategies used by physiotherapists to ameliorate hemineglect need to be similarly valid and clinically appropriate. The theme of this thesis will centre upon the assessment and rehabilitation of hemineglect in stroke patients in the clinical situation.

1.3 Clinical presentations of the syndrome of hemineglect

Neglect may significantly interfere with normal function and have detrimental effects on rehabilitation (Cherney et al., 2001). For example, patients may have problems in dressing, such as omitting the left sleeve or shoe, failing to find food on the left half of the plate, shaving or grooming only the right side of their body (Halligan & Marshall, 1993), reading, when they may omit letters or words on the left side of the page (Towle & Lincoln, 1991b), or mobilising in a wheelchair or walking, when they may bump into left-sided objects or doorways, and have difficulty making leftward turns (Lennon, 1994). Delays in the rehabilitation process will impinge on time of discharge home. Indeed, hemineglect is one of the best predictors of poor functional outcome following stroke (Jehkonen et al., 2000a; Paolucci, Antonucci, Grasso, & Pizzamiglio, 2001). Although spontaneous recovery is common, neglect may also persist for months (Jehkonen et al., 2000a), for a year (Appelross, Nydevik, Karlsson, Thorwells, & Seiger, 2004), or longer (Halligan, Marshall & Wade, 1989).

Neglect may occur plus or minus other primary sensory impairments including tactile, proprioceptive and visual loss, and motor impairments such as weakness or paralysis. Neglect signifies an impaired or lost ability to attend or react to stimuli occurring, usually, on the side opposite (contralateral) to the brain lesion. This impaired ability can present in all or some sensory modalities (visual, tactile, auditory, olfactory), or motor modalities, manifesting as either a reduced or non-use of the affected limbs, or a reluctance to move into contralesional space (Heilman, Watson & Valenstein, 2003). Neglect may even be limited to a representational deficit when the patient is able only to describe the right side of a mental image of an object or place (Beschin, Cocchini, Della Sala & Logie, 1997). The many-faceted nature of the syndrome may explain why several different terms are used in clinical practice e.g. hemineglect, inattention, sensory inattention, spatial neglect, visual neglect, hemispatial neglect, unilateral neglect, visuo-spatial neglect etc. Mesulam (1999, p.1341) captures the essence of neglect by stating:

"Neglect is not a disorder of seeing, hearing or moving but one of looking, detecting, listening and exploring. It is said to exist when the conscious impact of real or imagined events displays a spatially addressed bias in all frames of reference, including egocentric, allocentric, world-centred, object-centred and conceptual."

The potential clinical manifestations of the disorder are complex. Hemineglect does not occur solely to the contralesional side of space, but may also manifest to the contralesional side of the body or head midline of the patient (Heilman, Bowers & Watson, 1983), to the left of the hand during reaching and grasping actions (Buxbaum & Perdita, 2001) or to the left side of objects, even when they are located in ipsilesional space (Niemeier & Karnath, 2002). Hemineglect can occur in relation to the person (Beschin & Robertson, 1997), the near or reaching (peripersonal) space around the person (Halligan & Marshall, 1991), or far space, outside of reaching space (Berti & Frassinetti, 2000).

1.3.1 Anosognosia, hemianopia, and extinction.

Because neglect behaviour often co-occurs with clinical features such as denial of illness or anosognosia (Hartman-Maeir, Soroker, Oman & Katz, 2003), hemianopia (Cassidy, Bruce, Lewis & Gray, 1999), and extinction to bilateral simultaneous stimulation (Karnath, Himmelbach & Kuker, 2003) in various modalities (e.g. visual, tactile, auditory), it is often referred to as a syndrome. However, such accompanying features may also exist independently of neglect and vice versa (Cassidy et al., 1999; Jehkonen, Ahonen, Dastidar, Laippala & Vilkki, 2000b; Karnath et al., 2003). Incidence of anosognosia has been variously quoted as 17% (Appelros, Karlsson, Seiger & Nydevik, 2002) and 28% of right hemisphere strokes (Hartman-Maier, Soroker & Katz, 2001). When co-occurring with neglect, Pedersen, Jorgensen, Nakayama, Raaschou & Olsen (1996) found that the presence of anosognosia at one month post-stroke added to a poorer prognosis for motor and functional recovery. Such unawareness may interfere with the patient’s ability to recognise their disabilities and to avoid potentially hazardous activities (Heilman, Barrett & Adair, 1998).

Distinguishing neglect from hemianopia is not always possible. The standard bedside confrontation test for hemianopia requires the patient to focus attention on the examiner’s nose whilst reporting any movements made by the examiner’s fingers in either hemifield. This confrontation method is prone to the influence of attentional factors (Halligan & Marshall, 2002), in this case, the patient’s attention being focussed upon the examiner’s nose. This might help explain the high incidence (96%) of neglect patients who were also reported as having visual field defects on confrontation (Bisiach, Perani, Vallar & Berti, 1986). Perimetry testing of visual fields also requires central visual fixation while stimuli are flashed at random locations in the periphery. Patients with neglect are often not able to disengage attention from the central fixation, and cannot then perceive presented visual stimuli, in contralesional space. The attentional deficit may masquerade as a hemianopia. Indeed, Walker, Findlay, Young & Welch (1991) reported a patient, diagnosed as having hemianopia using standard perimetry, who was better able to detect and report left sided stimuli if the central fixation point was switched off 100 milliseconds before the visual stimuli were presented. The 100 milliseconds gap eliminated the attentional demand of having to maintain central fixation.

Extinction is defined as the inability to attend to or to report stimuli presented to the contralesional side of the body, when stimuli are simultaneously presented on both sides of the patient's body, when there is no primary sensory deficit (Kerkhoff, 2001). Extinction is therefore distinguishable from neglect, as the latter does not only manifest when there are competing stimuli (Karnath et al., 2003). Extinction can only be tested in patients who have no or only mild primary sensory deficit on single stimulation (Barbieri & De Renzi, 1989). For clinical purposes, only patients who can reliably report unilateral stimulation, and who do not have a contralesional sensory loss in the modality of interest, can be validly tested (Robertson and Halligan, 1999).

1.4 Manifestations of hemineglect

1.4.1 Neglect in sensory (input) modalities

Sensory neglect refers to a lack of awareness of sensory stimuli presented to the contralesional side (Heilman et al., 2003) and has been reported to occur in visuo-spatial, tactile, auditory and even olfactory modalities. Visuo-spatial neglect of contralesional objects during visual search is considered to be the most frequent behavioural deficit associated with right-sided brain damage (Gainotti, 1996), and is the most common of the neglect subtypes (Buxbaum et al., 2004). Neglect is more common and severe for visual than for non-visual stimuli (Bartolomeo & Chokron, 2002), perhaps because visual cues have greater ecological salience than tactile or auditory cues (Bartolomeo & Chokron, 2001). Tasks commonly used to assess visuo-spatial neglect include drawing, copying, target cancellation, line bisection and reading. However, the use of a pencil or pen for some tasks (e.g. cancellation or line bisection), involving a motor action as well as a perceptual response, does not allow a distinction between visual and motor neglect (see Section 1.5.3).

Tactile neglect is a failure to detect touch on the affected side, and would be difficult to demonstrate in the presence of a simultaneous primary sensory deficit. Nevertheless, an element of tactile neglect is implied by patients who present with left-sided anaesthesia, which is reduced when attention is specifically directed by the patient to the anaesthetic side (Gainotti, 1993).

Auditory neglect is less commonly found as sound detection per se is possible due to the fact that auditory pathways from each ear project to both sides of the brain. However, various difficulties in sound localization in contralateral space have been described (Pavani, Ladavas & Driver, 2003).

1.4.2 Representational neglect

Representational neglect occurs when a patient fails to report features on the contralesional side of an imagined scene, and is less frequently reported than visual neglect (Beschin et al., 1997; Bisiach & Luzzatti, 1978). Based on studies reviewed, Kerkhoff (2001) calculated that some 25% of patients with visual neglect would also show representational neglect. Bartolomeo, D’Erme and Gainotti (1994) considered that representational neglect occurred because the subject was unable to direct attention towards the contralesional side of the mental image. However, Della Sala, Logie, Beschin and Denis (2004) considered that representational neglect was due to damage to temporary storage systems of visuo-spatial working memory and not to an attentional deficit.

1.4.3 Neglect in output (motor) modalities

1.4.3.1 Motor neglect

Motor neglect is characterized by under-use of limbs on the contralesional side without any primary strength deficit (Laplane & Degos, 1983). Such patients may show lack of spontaneous or automatic limb use, but are able to move the limbs when attention is drawn to them, for example by a verbal command (Barbieri & De Renzi, 1989). The functional consequence of motor neglect is that patients who may have active voluntary movement of a limb, are still unable to use the limb for functional activity, at least during automatic movements, and may need to be prompted or cued to use the limb. Additionally, the co-concurrence of motor neglect with any primary strength deficit may add to the under-use problem, and affect successful rehabilitation.

1.4.3.2 Intentional neglect

Intentional neglect can be distinguished from ‘pure’ motor neglect described above, and refers to an inability or reluctance to execute motor acts in contralesional space, with either limb, in the absence of a primary motor deficit (Vallar, 1993). Heilman et al. (2003) expand the definition to include failures of movement initiation (akinesia) or delays of movement initiation (hypokinesia) which may or may not be towards contralesional hemispace, and which may involve the eyes, head, a limb or the whole body.

Akinesia or hypokinesia is usually identified using tests that do not involve visual feedback, in order to ‘decouple’ perceptual from intentional aspects of the task. Many clinical tests for neglect, such as line bisection and cancellation tasks, require both manual exploration and visual search. They are thus not able to differentiate between attentional-perceptual and motor-exploratory aspects of neglect, unless the method is modified, for example by using video feedback during line bisection to prevent direct viewing of the line, thus decoupling intentional from perceptual factors (Coslett, Bowers, Fitzpatrick, Haws & Heilman, 1990).

Some studies have suggested a link between anterior lesions and intentional deficits, (Bottinini, Sterzi & Vallar, 1992; Coslett et al., 1990). Conversely, Husain, Mattingley, Rorden & Driver (2000) found a link between a directional motor component deficit and parietal, but not frontal neglect. Their study included three patients with focal inferior right parietal and three with focal inferior right frontal lobe lesions. In contrast to previous studies (Bottini et al., 1992; Coslett et al., 1990), Husain et al. (2000) controlled for direction of arm movements. The task required patients to reach with the right hand to a target light on the left, or right, of a central fixation point, from a left, central, or right starting position. In this way, both ipsilesional and and contralesional reaches were performed. In all patients, reaches to left targets were slower than to right targets, indicating a rightward perceptual bias. However, only the three patients with parietal neglect dramatically improved initiation speed to left sided targets when a rightward reach from a left start was required. This indicated a rightward motor bias (leftward motor hypokinesia), in addition to any perceptual bias.

Mesulam (1999) cautions that it is unrealistic to expect a clear demarcation between parietal and frontal neglect, and many stroke patients with neglect will have extensive lesions not localized to frontal or parietal regions alone. The presence of intentional motor deficits might compound functional difficulties of patients with neglect when they need to find items on their neglected side, even when they are searching using their unaffected arm.

1.4.4 Neglect in different parts of space

In addition to neglect being distinguished by its modality (sensory, motor, or imaginal), it can also be defined by the distribution of attention within space. The space around people or objects is not considered to be continuous in all directions, in that there is a discontinuity between near space and far space, probably related to the type of action that occurs during visual exploration (i.e. manual in near space, or oculomotor in far space), showing the close links between perception and action (Berti & Rizzolatti, 2002).

Personal neglect refers to the reduced or absent exploration of the contralesional side of the body (Beschin & Robertson, 1997), and may manifest when the patient fails to put the left arm in the left sleeve when dressing, or fails to shave the left side of the face (Zoccolotti & Judica, 1991). Personal neglect may be associated with an inability to discriminate the position of the affected arm (Guariglia & Antonucci, 1992) when the patient may ‘forget’ the left limb, allowing it to hang over the side of the chair, which may lead to damage to the limb.

Peripersonal neglect refers to that which occurs within reaching space (Halligan & Marshall, 1991) and is demonstrated when patients omit food on the left side of the plate, or have difficulty finding an item on the left side of a bedside table. Neglect in this part of space is the one most commonly reported and assessed in most clinical tests (Robertson & Halligan, 1999). Extrapersonal neglect relates to neglect behaviour occurring in far space (Halligan & Marshall, 1991), when, for example, patients may fail to notice visitors approaching from the left side of the ward, or collide with items of furniture during ambulation.

Finally, neglect may not only occur in the contralesional side of space with reference to the person’s body or egocentric midline, but also in respect of the contralesional side of objects, even when they are presented in ipsilesional space (object-centred neglect). Walker and Young (1996) described a patient with right brain damage, three years post stroke, who had only mild visuo-spatial neglect during reading and cancellation tasks but who demonstrated marked neglect of the left side of objects, presented centrally in his visual field. Some patients may neglect the left side of objects whether they appear to the centre or to the left or right of their body midline (Chatterjee, 1994; Savazzi, Neppi-Modona, Zettin, Gindri & Posteraro, 2004). Therapists need to be aware that a patient with left-sided neglect may demonstrate neglect behaviour which is not necessarily restricted to the space on the left of the patient’s body midline.

1.4.5 Dissociations of various manifestations of neglect

Various dissociations of components of the neglect syndrome have been described, either in modality or in spatial domain. For example, motor-intentional versus sensory-perceptual forms (Buxbaum et al., 2004; Harvey, Kramer-McCaffery, Dow, Murphy & Gilchrist, 2002; Ladavas, 1994) egocentric versus object-centred (Chatterjee, 1994); personal versus extrapersonal (Beschin & Robertson, 1997; Buxbaum et al., 2004; Cocchini Beschin & Jehkonen, 2001) neglect in near versus far space (Berti et al., 2002; Halligan & Marshall, 1991). Dissociations between various manifestations of neglect are the rule rather than the exception (Mesulam, 1999). Dissociations have even been reported within the same modality. Halligan and Marshall (1992) and Binder, Marshall, Lazar, Benjamin & Mohr (1992) have demonstrated neglect during cancellation tasks, but not on line bisection, and vice versa.

Such dissociations provide clear evidence that neglect is not a unitary phenomenon, but a complex behavioural syndrome (Milner & Harvey, 1994) and support a multi-component model of attention (Binder et al., 1992; Umilta, 1995), where such fractionations are the manifestations of damage to specific components of the attentional neural network (Mesulam, 1999). There is, therefore, a strong case for utilisation of a battery of tests, rather than a single test, to identify the different manifestations of hemineglect.

1.5 Theories used to explain hemineglect

Neglect has been shown to manifest in a number of different modes and parts of space, and these types of neglect may dissociate and present in isolation or in combination. Halligan and Marshall (1994a) suggested that the existence of such a plethora of manifestations and dissociations has hindered a deeper understanding of the phenomenon of neglect. Gainotti (1994, p.127) also proposed that the search for basic mechanisms and fractionations of the syndrome should “try to converge upon more comprehensive interpretations”. Driver (1994, p.124) added that, although neglect is not a unitary phenomenon, it remains a useful overarching term to describe the disorder until a “parsimonious account of the full range of neglect disorders” is produced.

Robertson et al (1997a) provided evidence to support the idea of the existence of a non-lateralized sustained attentional or arousal system, considered to be controlled by the right hemisphere, and which exerts a modulatory influence over the lateralized right-brain dominant spatial attentional system. This non-lateralized system could explain variability in the behaviour and test performance of patients with neglect, as a function of their differential levels of general arousal.

Indeed, given the heterogeneity of the neglect syndrome, there is currently no exclusive or overarching theoretical model which can explain all manifestations and dissociations. The three principal theoretical accounts which are put forward, namely representational, attentional and intentional accounts, rather explain the different symptoms of neglect that have been described.

1.5.1 Representational accounts

The view of neglect as a disorder of mental representation was originally put forward by Bisiach and Luzzati (1978). They reported that two patients, with right-sided brain damage, when asked to imagine and describe a scene from a familiar Italian piazza, either omitted description of buildings on the left side or transposed them to the right. When asked to describe the scene from the opposite side of the square, subjects now reported the formerly ignored buildings and failed to report the ones previously described. The inability of these subjects to form a complete representation of space in their 'mind's eye' was interpreted by Bisiach and Luzzati as evidence that hemispatial neglect is caused by a deficit in the ability to form complete internal representations of space. However, the representation is not 'lost' but merely inaccessible to automatic scanning. If patients are cued to the contralesional side of a mental image, performance is much improved (Bisiach & Luzzatti, 1978). Indeed, Riddoch and Humphreys (1987) argued that if neglect is caused by a disordered representation of space, then techniques that cue attention to the affected side should have no effect upon performance.

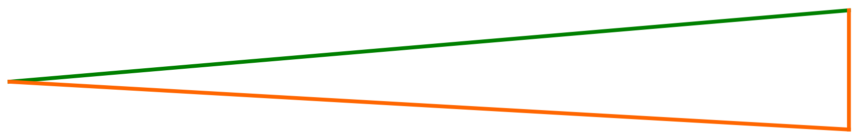
Other workers have also reported the occurrence of neglect of mental images, in a subject who performed normally on standard tests of personal and visuo-spatial neglect (Beschin et al., 1997), while other studies have described subjects with visual neglect in the absence of representational neglect (Bartolomeo et al., 1994; Cantagallo & Della Sala, 1998). These dissociations would seem to refute the idea of representational neglect as an overall model. The representational model does not account for the greater incidence and severity of hemineglect following right-sided brain damage. Bartolomeo and Chokron (2001) argued that studies demonstrating representational neglect merely show that an imaginal deficit may be a part of the neglect syndrome, and that different mechanisms may mediate perceptual and imaginal manifestations. Thus representational neglect might be considered to be a description of one of the many manifestations of the neglect syndrome, rather than an account or explanation for the syndrome per se.

1.5.2 Attentional accounts

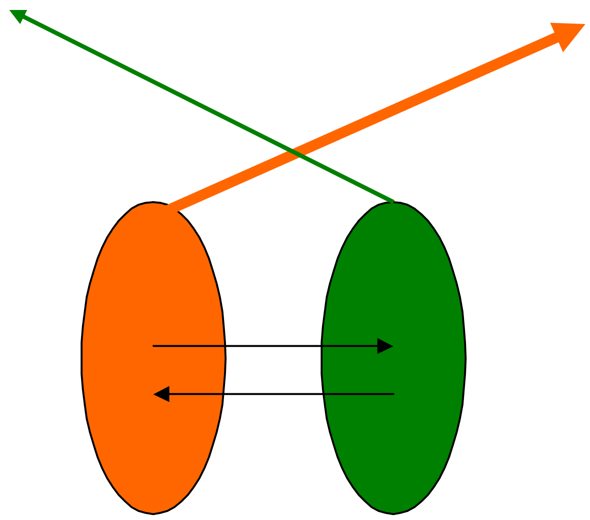
Attentional accounts propose that neglect results from damage to the attentional orienting system. Attentional theories of neglect imply that patients are unable to shift their attention to the contralateral side of space, coupled with a strong tendency to orient towards ipsilateral space. This combination leads to the patient being unaware of stimuli in the contralesional field.

The attentional hypothesis was proposed by Kinsbourne (1977; 1987; 1993; 1994). According to this model, each hemisphere is responsible for shifting attention towards contralateral hemispace. The processes involved in producing the orienting responses are considered to be reciprocally connected, so that one hemisphere inhibits the other (the 'opponent processor model'). The model (Figure1.1) also assumes that in the normal brain, the left hemisphere has a stronger orienting tendency than the right hemisphere. Thus, following right-sided damage, there would be a comparatively stronger rightward orienting response, due to disinhibition of the left hemisphere, which now strongly orients towards right hemispace. Furthermore, for patients with left visual neglect, Kinsbourne (1993) proposed an *attentional gradient* across both hemispaces, increasingly strong as attention shifts in a rightwards direction. Attention is then directed to the right side of a stimulus, even when it is presented in the right hemifield. This hypothesis is consistent with findings that patients may neglect the left side of objects even when they are presented in right hemispace (Walker & Young, 1996). Support for an attentional gradient was provided by the findings of Butler, Eskes and Vandorpe (2004), who showed a significant left to right increased gradient of target detection during visual scanning from left to right in their group of seven subjects with left-sided neglect and right brain damage.

Heilman and Van Den Abell (1980) and Mesulam (1981) proposed that the right hemisphere was dominant for spatial attention to both right and left hemispace, while the left hemisphere was only specialized for right hemispace (Figure 1.2). This counters the assumption of the left hemisphere dominance for attentional orienting in Kinsbourne's model. Support for right hemisphere dominance also comes from positron emission tomography (PET) data which show a preferential involvement of the right parietal lobe for both right and left-sided attentional shifts, whereas the left parietal lobe is only activated by shifts in the right hemifield (Corbetta, Miezen, Shulman & Petersen, 1993). This hemispheric asymmetry results in the left hemisphere being able to direct attention only into right hemispace, whereas the right hemisphere is able to direct attention to both sides of space. The right hemisphere dominance model thus explains why patients with right brain damage may lose ability to pay attention to stimuli in left hemispace whilst retaining the ability to attend to right hemispace. On the other hand, patients with left brain damage would still retain the capacity to attend to right hemispace via the undamaged right hemisphere with its bi-directional capabilities.



Attention gradient increases in a rightward direction →



In the normal brain:

1.Left hemisphere controls attention shifts to right

Right hemisphere controls attention shifts to the left

2.Each hemisphere has an inhibitory effect upon the opposite hemisphere

3.The left hemisphere has a stronger orienting tendency than the right hemisphere

A pathological attentional gradient across both hemispaces is proposed which increases strongly as attention shifts in a rightward direction (emerges with right brain damage)

Figure 1.1 The 'Opponent Processor' model (Kinsbourne, 1987; 1993)

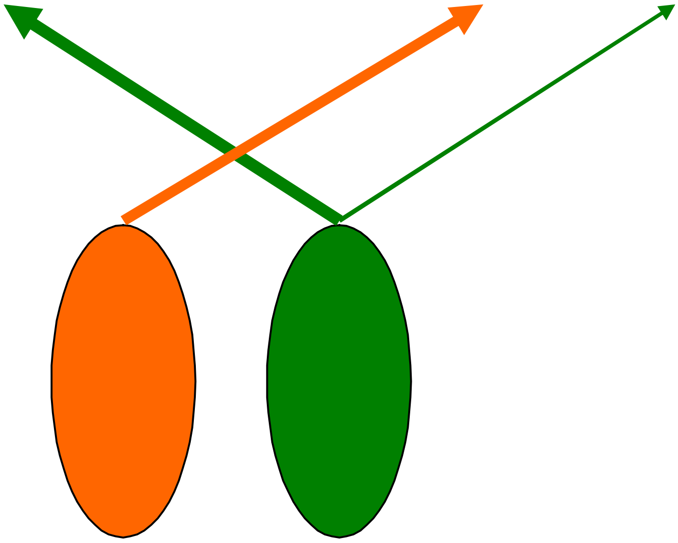


Figure 1.2 Right hemisphere dominance model for spatial attention (Heilman & Van Den Abell, 1980)

This notion of hemispheric asymmetry may also help to explain why neglect is more severe, and more frequent after right hemisphere lesions. Right hemisphere dominance for spatial attention, particularly involving the right parietal lobe, has been demonstrated by several anatomical imaging studies (Gitelman et al. 1996; 1999; Perry & Zeki, 2000).

Gainotti (1994) postulated that the overaction of attention towards ipsilesional space leads to a “sort of magnetic capture of attention by right sided stimuli.” This idea is similar to the ‘disengagement hypothesis’ (Posner, 1994) which proposed that neglect, rather than just an orienting deficit, is due to difficulty in *disengaging* attention from the ipsilesional side. Gainotti, D'Erme and Bartolomeo (1991) demonstrated experimentally that neglect involves early orientation towards ipsilesional space, which, they state, cannot be explained solely by a difficulty in disengaging attention from the previous focus. Gainotti et al. (1991) also hypothesized that there may be a dissociation between the loss of ability to orient automatically, with preservation of the ability to voluntarily orient, because their subjects had most difficulty in automatic orienting as opposed to voluntary orienting tasks. Indeed, Riddoch and Humphreys (1983) have shown that rightward line bisection errors were reduced when the patients were cued to voluntarily attend to the neglected left side of the line.

Neither the 'disengagement' model described by Posner (1994) nor the existence of an attentional gradient proposed by Kinsbourne (1993) are considered to fully explain the processes underlying unilateral spatial neglect. Sacher et al. (2004) found, in a small sample of eight patients with right brain damage, large variations between patients in their expression of deficits showing 'disengagement' and/or 'gradient' related attentional behaviours, using a spatial cueing paradigm and a signal detection task respectively. However, neglect was diagnosed using tests for tactile extinction (which may dissociate from neglect), and only three patients showed neglect using the Behavioural Inattention Test (Wilson, Cockburn & Halligan, 1987a), which limits the validity of the conclusions of Sacher et al. (2004).

The *rightward orientation bias*, postulated by the opponent processor model, is supported by findings of Ladavas, Petronio and Umilta (1990) who found that patients with left neglect responded faster than controls to right-sided than to left-sided targets, even when the stimuli were presented in the right visual field. In a later study, Ladavas, Umilta, Ziani, Brogi and Minarini (1993) reported that performance of patients with left neglect improved when stimuli on the right were removed following detection. However, defective rather than hyperattention to the right is proposed by Bartolomeo and Chokron (1999), when they demonstrated that reaction time to right-sided targets increased with increasing severity of left neglect.

The attentional account is thus able to accommodate not only observations that events and objects in contralesional space are neglected, but also that neglect patients showed reduced attention to the left side of stimuli in intact right hemispace (Ladavas, 1990). Attentional models can also account for the phenomenon of extinction (section 1.3.1), which representational accounts cannot.

Finally, Robertson, Tegner, Tham, Lo and Nimmo-Smith (1995) highlighted a further attentional deficit which may be important in neglect. They suggested that neglect not only results from impaired orientation of attention, but also from damage to an alerting or arousal system situated bilaterally, but with right hemisphere dominance. This system is considered to be non-lateralised, and damage results in overall low levels of alertness. Robertson and colleagues (1995) suggested that this helps explain why left brain damaged patients may recover faster, because their intact alerting system on the right can therefore compensate for their attentional deficits.

1.5.3 Motor intentional accounts

The motor-intention account states that, although subjects may be aware of stimuli in contralateral hemispace, they may either fail to initiate, or show slowness in, a movement towards the stimulus, or have a bias to act in a rightward direction (Heilman et al., 2003).

Standard tests for left neglect such as cancellation and line bisection, do not distinguish between perceptual and motor biases, because they require the patient to move leftwards, towards left visual stimuli, with the right hand (Husain et al., 2000). For example, subjects with left hemineglect usually make rightward errors when bisecting a horizontal line (Friedman, 1990). This behaviour can be explained by a representational account, in that the subject may be unable to generate a complete internal map of the entire line, or by an attentional account, in that they do not direct attention to the left portion of the line in order to realize it's full extent. An alternative explanation might be that subjects with neglect have difficulty initiating, or slowness in executing a motor response with the ipsilesional limb towards neglected hemispace, which could explain defective motor performance in any task demanding movement in this direction.

This action-intention impairment was described as 'directional hypokinesia' by Heilman, Bowers, Coslett, Whelan and Watson (1985), and is distinct from motor neglect which involves reduced or non-use of the contralesional limb, without any primary strength deficit (Laplane & Degos, 1983), which may be ameliorated by directing attention towards it (Kerkhoff, 2001). A motor bias is also evident in the rightward deviation of the eyes of patients with neglect. The directional gaze bias is not due to paralysis of the oculomotor muscles, as patients are able to voluntary move their eyes leftwards in response to a verbal command (Heilman, Watson & Valenstein, 2002). A motor bias was also used to explain the behaviour of subjects with left neglect who deviated to the right during straight-ahead pointing with eyes closed (Heilman et al., 1983). A rightward directional motor bias was found by Husain and co-workers (2000), in that three of their six patients with left neglect due to right-sidedparietal damage, who were slower to initiate reaches to the left than to the right, were able to speed up when reaching rightwards from a left, rather than a central start.

Recently, Gore, Rodriguez and Baylis (2002) tested five patients with right parietal lesions and neglect, using either a reaching (motor) task (touch an illuminated key on right or left of central fixation) or a verbal response (perceptual) to target (say which side the illuminated key was on). The patients were able to locate a target, cued by colour, in both conditions when each task was performed separately, but made left-sided errors when the tasks were 'interleaved' randomly. Errors were only made when the response (manual or verbal) was different to the response they had just made. Gore et al. (2002) suggested that these findings showed that the parietal cortex is necessary for coding the action to be performed to a target, as well as paying attention to the spatial location of the target, in other words that attention is action-based. The relationship of the parietal lobe with neglect, and role of the parietal lobe in perception and action, was also noted by Husain et al. (2000). The close coupling of perception and action during visually guided grasping has also been noted by Marotta, McKeeff and Behrmann (2003).

1.5.4 Summary

The debate about which explanation best accounts for the phenomenon of neglect continues. The principal explanations include representational, attentional and intentional accounts. The representational account posits that neglect is due to a failure to construct, in the brain, a complete mental image of contralesional space. Attentional accounts of neglect suggest that patients fail to shift their attention to contralesional space, and also have a bias to direct their attention ipsilesionally, so that the patient is unaware of contralesional (usually left-sided) stimuli. The action-intention account proposes that neglect can result from impairments in performing motor acts with the right arm towards left space. Other aspects of neglect may not necessarily be lateralized, and a non-lateralized impairment of general alertness or arousal has also been considered as a component deficit of the neglect syndrome.

Indeed, some authors (Driver, 1994; Posner, 1994) consider that the distinction drawn between attentional and representational accounts is not helpful because attentional networks are as important, both in the formation and scanning of any mental image, as they are in the perception of events or objects in external space. Finally, Kerkhoff (2001, p.19) points out that, because every account of neglect may be able to explain some features of neglect but not others, "mutual influences between the theories and research paradigms in the study of neglect … might be more fruitful".

1.6 Purpose and aims of the thesis

With the above considerations in mind, the purposes of this thesis were to gain further insight into the assessment and rehabilitation of hemineglect in stroke patients, to design a clinically useful test battery which provides information about the functional behaviour of patients with neglect, to investigate the reliability of three tests for unilateral visual neglect (UVN), and to investigate the effectiveness of rehabilitation strategies which physiotherapist might use to ameliorate hemineglect in elderly stroke patients.

Specifically, the main aims of the thesis were to:

1 Investigate current physiotherapy practice in the United Kingdom (UK) in relation to the assessment and rehabilitation of hemineglect in stroke patients.
2 Develop a simple test battery for the assessment of (UVN) which could be easily produced by therapists and used in the standard clinical setting.
3 Investigate the test-retest reliability of tests for UVN chosen as the primary outcome measure for the subsequent rehabilitation study.
4 Investigate the efficacy of two different rehabilitation approaches for the amelioration of UVN in stroke patients.

1.7 Organisation of thesis chapters

Chapters 2 and 3 review in more detail the nature of hemineglect, and its clinical assessment and rehabilitation which is the primary focus of this thesis, by way of presentation of two published papers on the topic. Evaluation of literature published after these papers appeared in press is additionally included.

Following these reviews, in Chapter 4, a survey design study will address current physiotherapy practice in the United Kingdom, in relation to the way in which physiotherapists assess and treat hemineglect in stroke patients. This is the first time a national survey to investigate this topic has been undertaken and the findings will be presented as a published paper. This study addresses the first aim.

Many tests used to assess neglect are based upon pencil-and-paper tasks, such as cancellation and line bisection tasks, copying and drawing tasks, and reading. There have been some attempts to develop assessments that are more functionally based and more ecologically valid, in order to provide a more clinically relevant picture of the patient's problems. These tests will be reviewed in Chapter 5, and, following this, a study (published as an abstract – see Appendix D) will be presented of the development of a simple test battery to assess visual neglect in elderly stroke patients. The items chosen for the battery were selected on the basis that they could easily be produced by therapists, using available materials, and were appropriate for use in the standard clinical setting. This study addresses the second aim of the thesis.

Prior to the presentation of a rehabilitation study, Chapter 6 addresses the test-retest reliability of the three standardised tests commonly chosen to assess UVN; the Star Cancellation Test and the Line Bisection Test, both sub-tests from the Behavioural Inattention Test (Conventional) Test Battery (Wilson et al., 1987a), and the Baking Tray Task (Tham & Tegner, 1996). This is the first study to investigate reliability of these three tests on a large sample of both 'normal' elderly subjects and elderly stroke patients, and it addresses the third aim. Because these three tests were chosen as outcome measures for the subsequent rehabilitation study, a published study of the reliability of these three tests is presented.

In the final study, a series of seven patients is presented in Chapter 7, as a published paper, to investigate the efficacy of two different approaches to rehabilitation, and this study addresses the fourth and final aim. Five subjects received a ‘scanning and cueing’ approach, and two a ‘limb activation’ approach. A non-concurrent, multiple-baseline-across-subjects single system (n=1) experimental design was chosen with an initial baseline phase (A), a treatment phase (B) lasting for three weeks, and a three-week, no treatment follow up phase (A). Following publication, five more patients were recruited to the study. Full results are reported here.

A summary of the studies undertaken, and final conclusions and recommendations are presented in Chapter 8. Throughout the thesis, emphasis will be given to approaches to assessment of hemineglect and rehabilitation strategies for UVN that are clinically realistic, and that can be easily accessed and administered by therapists. Additionally, such approaches do not rely upon expensive ‘high-tech’ equipment or materials, which may not be appropriate for use by therapists in routine clinical settings.

CHAPTER 2

THE NATURE OF HEMINEGLECT AND ITS CLINICAL ASSESSMENT IN STROKE PATIENTS

The anatomical correlates of hemineglect, incidence of hemineglect and it's impact on recovery of function are briefly reviewed. Following on, the assessment of hemineglect is reviewed in more detail, including tests for neglect in various modalities; visuo-spatial neglect, personal and extrapersonal neglect, motor neglect and directional hypokinesia. Finally, the use of test batteries is discussed, and a questionnaire relating to the impact of neglect on everyday life is described. Supplementary update information is provided following presentation of the published paper.

This Chapter is presented as a published paper:

Bailey, M.J., & Riddoch, M.J. (1999). Hemineglect. Part 1. The nature of hemineglect and its clinical assessment in stroke patients: an overview. *Physical Therapy Reviews, 4,* 67-75.

The paper is presented exactly as it was published, but using numbered sections for consistency of presentation.

Following presentation of the published paper, a brief review of other relevant papers not cited in this paper will be presented to ensure that information is current and comprehensive.

Abstract

Hemineglect is an attentional disorder with quoted incidence varying widely between studies, from 10% to as high as 82% during the acute phase post stroke. Neglect is typically transitory and only persists in a more chronic fashion in a minority of patients. The precise relationship between the presence of neglect and reduced functional ability is not entirely clear, however, there is evidence of an association. Neglect is commonly assessed clinically using a variety of ‘pencil and paper’ tests; most of these primarily assess perceptual forms of neglect. Other tests are described which are considered to differentiate personal from extrapersonal, and motor from perceptual forms of the disorder. Due to the multi-modal nature of neglect, a battery of tests rather than a single test may, in addition to being more sensitive, enable assessment of different forms of neglect. Tests that have demonstrated validity, sensitivity, and published cut-off scores are suggested for use by therapists in the clinical situation.

2.1 Introduction

Some 100,000 first strokes occur in Britain each year, with prevalence likely to increase due to rising numbers of elderly in the population (Blais, 1994). In addition to motor, sensory and communication problems, such patients may also suffer from cognitive deficits such as attention, recognition and executive disorders (Riddoch, Humphreys & Bateman, 1995a); possibly the most common are attentional disorders such as hemineglect (Stone, Halligan & Greenwood, 1993a). Patients with neglect can be very disabled; they may behave as if whole areas of space on the contralateral side to their lesion no longer exist. They appear unaware of stimuli, objects and even people located in contralesional space, and may sit or lie with their head and eyes deviated to the ipsilesional side. Activities of daily living (ADL) may be adversely affected; thus, during navigation patients with hemineglect may collide with objects, at meal times they may leave food on one side of the plate, and when grooming they may fail to shave one half of the face, or brush their hair, on the contralesional side.

It is generally accepted that left hemineglect following right brain damage is more common, more severe and also longer lasting than right hemineglect following left-sided brain damage (Halligan & Marshall, 1994a). Hemineglect has been defined as:

"A failure to report, respond or orient to novel or meaningful stimuli presented contralaterally to a brain lesion, and not attributable to primary sensory or motor deficits". (Heilman, Watson & Valenstein, 1993, p.276).

Neglect is commonly viewed as a disorder of attention (Kinsbourne, 1994). The right hemisphere is thought to be dominant for attention, which would account for the greater prevalence of neglect following right hemisphere lesions (McGlone, Losier & Black, 1997), an idea which is supported by positron emission tomographic (PET) studies (Corbetta et al., 1993; Posner & Raichle, 1994). Attention is thought to include several components such as disengaging attention from its current locus, orienting to a new location, and focusing attention on a given location (Posner, 1994). All these components are necessary for everyday interactions with the environment. In addition, some authors have argued that neglect is a disorder of internal representation of objects in the external world, demonstrated in tasks where patients have failed to report the left side of scenes or objects in mental imagery (Rizzolatti & Berti, 1993; Beschin et al., 1997).

2.2 Anatomical correlates

Neglect is most commonly related to posterior parietal lobe damage, particularly of the right hemisphere, although it may also be associated with lesions of other cortical and subcortical sites such as frontal and cingulate cortex, thalamus and basal ganglia (Samuelsson, Jensen, Ekholm, Naver & Blomstrand, 1997). Recent PET scans have provided evidence for a distributed network of attention (Posner & Raichle, 1994). Neglect is not a unitary phenomenon and Mesulam (1994) has suggested that different types of neglect may develop according to the location of the brain lesion; for instance, the anatomical correlates of motor and sensory components of neglect have been shown to be related to frontal and parietal lesions respectively (Binder et al., 1992; Ladavas et al., 1993; Tegner & Levander, 1991).

2.3 The multi-modal nature of neglect

Hemineglect is a complex phenomenon which can affect any sensory modality (e.g., visual, tactile, auditory, olfactory) and may be manifest in manual, ocular, verbal and navigational motor output (Beaton & McCarthy, 1993; Coslett et al., 1990). It can affect personal space (Beschin & Robertson, 1997), as well as near and far extrapersonal space (Bisiach et al., 1986). Heilman, Valenstein and Watson (1994) subdivide neglect into inattention (sensory neglect), disorders of intention and action (motor neglect), and disorders of mental representational. A useful summary of the functional fractionations of neglect is given by Riddoch and Humphreys (1994).

2.4 Incidence, recovery, and impact on functional activities of daily living

The quoted incidence of neglect varies widely between studies, ranging from 10% to 82%, and is typically found more frequently following right rather than left cerebral lesions (Pedersen, Jorgensen, Nakayama, Raaschou, & Olsen 1997; Stone et al, 1993a; Sunderland, Wade & Langton Hewer, 1987; Zoccolotti et al., 1989). Such variation is probably due to differences in the number, type and sensitivity of tests used to identify neglect, patient selection criteria, and time since onset of stroke. Patients with left brain damage are not always included in studies because of the obvious difficulty in testing patients with communication problems, and this group may sometimes be under-represented. In addition, estimates using patient samples from rehabilitation settings may give higher incidence, as the selection is biased towards moderate or severe strokes where a higher incidence of neglect might be expected (Zoccolotti et al., 1989). Neglect is frequently observed to be a transitory phenomenon and may only be present during the acute stage of stroke, recovering in 4-6 weeks. Paolucci et al. (1996a) and Sunderland et al. (1987) have reported that significant neglect was rarely observed at 6 months post-stroke. Stone, Patel and Greenwood (1992) followed-up 68 patients with visual neglect and found that recovery was most rapid over the first 10 days and plateaued at 3 months, at which time only eight patients still showed severe neglect. However, Denes, Semenza, Stoppa and Lis (1982) found that of eight patients (out of 24) who showed neglect at 7 weeks post-stroke, seven still showed neglect 6 months later. Thus, neglect may persist, in a minority of patients, for several months or even for several years (Halligan et al., 1989). Interpretation of the findings of rehabilitation studies can be complicated by the tendency to use heterogeneous groups of patients at different stages of recovery from neglect. A summary overview of studies examining the time course of recovery from hemineglect is presented in Appendix A.

There is considerable evidence of a relationship between neglect or hemi-inattention and functional outcome (Blanc-Garin, 1994; Chen Sea, Henderson & Cermak, 1993; Denes et al., 1982; Kinsella, Olver, Ng, Packer & Stark, 1993; Paolucci et al., 1996a; Robertson, Ridgeway, Greenfield & Parr, 1997c; Stone, Patel & Greenwood, 1993b). Chen Sea et al. (1993) studied 64 patients with right-sided brain damage at 2 and 6 months post-stroke, and found that the group with hemi-inattention (n=22) had significantly reduced ADL ability, even when the effects of sensory, motor and visual factors had been excluded. Dressing and mobility were most affected. Denes et al. (1982) compared 24 patients with right cerebro-vascular accident (CVA), and 24 with left CVA six months post stroke. The groups did not differ at initial assessment (around 7-8 weeks post stroke) in age, stroke severity, motor ability, ADL or intellectual level. Eight patients in the right CVA group had neglect, and five in the left CVA group. Neglect was assessed by one copying task, which may have been insufficiently sensitive, thus underestimating the incidence of neglect. At 6 months, they found that the right brain damaged group had significantly less functional recovery than the left brain damaged group. Seven patients with right CVA and two with left CVA still showed neglect. Analysis of covariance showed that neglect was the only factor which was significantly related to ADL outcome, although anosognosia (i.e. unawareness or denial of illness) may also have been a confounding factor in this study. Kinsella et al. (1993) assessed a total of 67 right brain damaged patients for ADL, using the Barthel Index (BI), and for neglect using a battery of tests, at 6 weeks post-stroke. Severity of neglect was found to correlate independently and significantly with ADL at 3 and 6 month follow-up, with self-care factors being more strongly related than mobility factors. Stroke severity, measured by impairment of mobility, was not found to be related. Paolucci et al. (1996a) found that severity of stroke and hemineglect were the strongest prognostic factors for ADL abilities and mobility (also mortality and length of hospital stay). Their group of 47 patients with hemineglect still had a significantly higher risk of poor autonomy and impaired mobility than patients with no neglect, even after allowing for age and stroke severity; however, presence of anosognosia was not assessed. Robertson et al. (1997c) found that attentional deficits in a group of 47 right hemisphere damaged patients, if present at 2 months post-stroke, predicted motor and functional recovery at two years. Sustained attention was measured using three standard tests of everyday attention, so neglect *per se* was not measured. Stone et al. (1993a) found, in a representative sample of elderly stroke patients measured with a (modified) version of the Rivermead Behavioural Inattention Test (RBIT), developed by Wilson, Cockburn and Halligan (1987b), that severity of neglect at 2-3 days post-stroke was one of several significant independent predictors of ADL outcome at 3 and 6 months (the other factors being age and severity of weakness). Limitations of the study identified by the authors included lack of standardization of remedial therapy given, and varying pre-stroke levels of independence. Factors such as proprioception, visual field defects and anosognosia were also identified, but not found to be independently related to ADL outcome.

However, other studies suggest that the presence of factors such as anosognosia, or other perceptual problems are confounding variables which may explain the link between neglect and ADL (Edmans & Lincoln, 1990;1991b; Gialanella & Mattioli, 1992; Pedersen et al., 1997). Gialanella and Mattioli (1992) compared three groups of patients with left hemiplegia, one (n=12) with neglect, one (n=9) with neglect and anosognosia, and one (n=24) with neither, at one and 5 months post -stroke. The presence of anosognosia, but not neglect *per se* was found to be related to a significantly worse outcome for motor and functional recovery. Anosognosia was measured using a 4-point scale (from 0 = the disorder (of hemiplegia) is reported spontaneously, to 3 = no acknowledgement can be obtained even on direct questioning). However, group numbers were small, and neglect may have been underestimated, as only a single (cancellation) task was used in its measurement. Additionally, the groups were not matched for stroke severity or functional ability at the outset. Pedersen et al. (1997) have also argued that neglect *per se* has a lesser effect on functional outcome than either stroke severity or anosognosia. Edmans and Lincoln (1990; 1991b) found a significant correlation between perceptual problems and independence in ADL at 1 month and 2 years post-stroke, in a sample of 75 left-sided and 75 right-sided strokes. Although hemineglect was a component of the perceptual problems, it was not found to be independently correlated with total ADL performance for the group as a whole (Edmans & Lincoln, 1991b). However, significant relationships were found between neglect, as measured by a cancellation task, and total ADL performance for the sub group with right brain damage.

In summary, although some findings are conflicting, there appears to be a definite relationship between the presence of neglect and functional outcome several months later. As neglect has been shown to recover spontaneously in many patients during the acute phase, particularly if it is mild, it would appear that elderly patients with moderate or severe chronic neglect, likely to have right-sided brain damage, are those most likely to show ADL deficits, particularly if they initially suffer a severe stroke and additionally show anosognosia. This group are likely to comprise a small percentage of elderly stroke patients, particularly if identified using only one or two tests for neglect as opposed to a larger test battery.

2.5 Assessment of hemineglect

Neglect behaviour can be elicited by a wide variety of clinical tests including cancellation of target stimuli, bisection of lines, drawing and copying tasks, reading, description of objects seen in extrapersonal space, and functional tasks such as dressing, feeding, and navigation by wheelchair or walking. Extinction (the intact ability to report either left or right unilateral stimulation, but impaired ability to report simultaneous bilaterally presented stimuli) may be associated with neglect, although a double dissociation has been reported (Weinstein, 1994). Standardised extinction tests for visual, tactile or auditory modes have been described (Kinsella, Packer, Ng, Olver & Stark, 1995). The presence of visual extinction, and hemianopia, or other visual field defects, can complicate the interpretation of assessment of visuo-spatial neglect.

Neglect is a complex phenomenon and, as Wade (1992) points out, it is difficult to be certain what any particular test is assessing. For instance, neglect is known to exist in different parts of space (personal, peripersonal, extrapersonal), and in different forms (e.g. motor and sensory). For a test battery to be sufficiently sensitive, it must include assessment for all the different forms of neglect, so that appropriate rehabilitation can be targeted and evaluated.

2.6 Tests that may be applied at the 'bed-side'

Many tests can be easily applied at the 'bed-side' using simple equipment such as pencil and paper, everyday objects, or reading materials.

2.6.1 Tests for visuo-spatial neglect

2.6.1.1 Cancellation tests

Cancellation tests include line cancellation and the Star Cancellation Test (SCT), which are sub-tests of the RBIT (Wilson et al., 1987b), and other letter and symbol cancellation tests. Most cancellation tests require the subject to cross out stimuli placed across an A4 page. Patients with visuo-spatial neglect typically miss out stimuli in neglected hemispace. The SCT requires the patient to cross out 54 small stars across a page, 27 in the left half and 27 in the right half (see Figure 1) and it is considered to be particularly sensitive (Marsh & Kersel, 1993; Pizzamiglio et al., 1992b). It is a useful predictor of functional outcome at discharge, and scores on the BI have been found to significantly correlate with errors in star cancellation (Friedman, 1992; Halligan, Donegan & Marshall, 1992b). The SCT and the letter cancellation task are characterised by the inclusion of distractors (e.g. shapes or letters which must be ignored), together with target shapes or letters, which increase sensitivity by involving selective attentional processes (Kaplan et al., 1991).

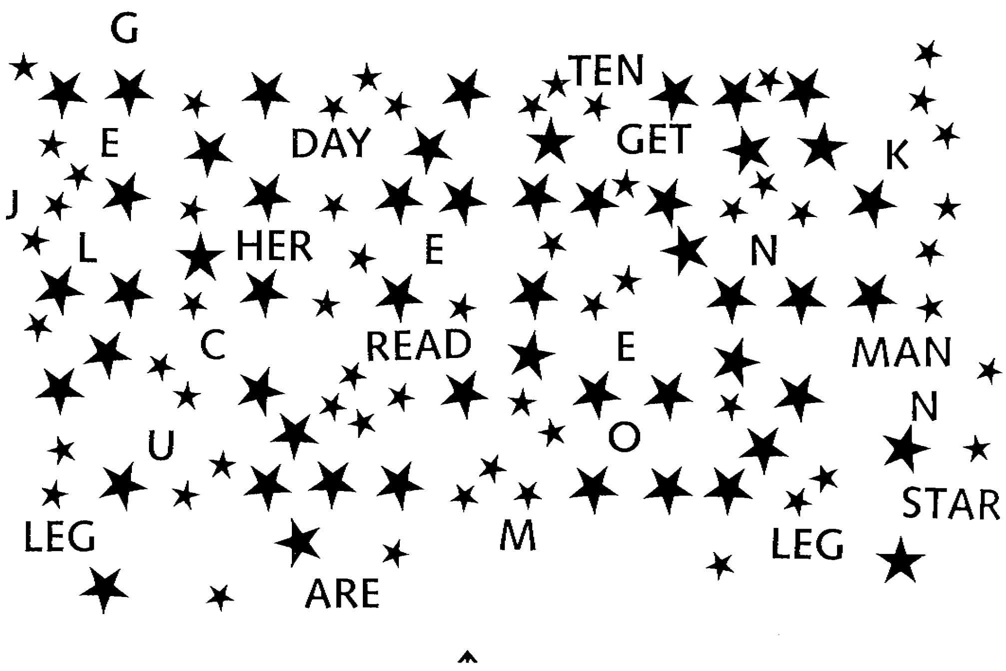


Figure 2.1 The Star Cancellation Test (reproduced with kind permission from the Thames Valley Company, Bury St Edmonds, Suffolk, UK).

Sensitivity of the SCT can also be increased by use of a ‘star ratio’ (ratio of stars cancelled in the left half of the sheet divided by the total number of stars cancelled), this giving better indication of unilateral neglect (Friedman, 1992). Thus, a star ratio of

0 would indicate severe left neglect, whereas a ratio of 0.5 would indicate symmetrical test performance. Performance on the SCT has been found to be age-related (Stone, Halligan, Wilson, Greenwood & Marshall, 1991a), leading Friedman (1992) to suggest a cut-off point of 44 out of a total of 54 for stroke patients over 70 years of age (the cut-off score recommended by the RBIT is 51). The SCT can be used to assess performance over time, and is quick and easy to administer.

2.6.1.2 Line bisection

Line bisection (LB) tasks require the subject to mark the perceived central point of a (usually horizontal) line drawn on paper. Normal subjects usually make small leftward errors, neglect patients typically make medium to large errors towards the ipsilesional side (Riddoch & Humphreys, 1983). Direction and size of error can be influenced by which hand is used to perform the line bisection task. If the ipsilesional hand is used, attention may be drawn to the ipsilesional side of the paper thus increasing the error, the reverse may result by using the contralesional hand (Milner, Brechman & Pagliarini, 1992). Position of the line on the page can affect bisection error (Koyama, Ishiai, Seki & Nakayama, 1997). Using the right hand to bisect, patients with left unilateral neglect made largest errors when the lines were on the left side of the page, medium errors with central lines, and smallest errors with lines on the right hand side of the page. In addition, line length may affect bisection error, increased errors being found with longer lines, although this may be modulated by the severity of neglect; severe neglecters are unaffected by line length (Koyama et al., 1997). The presence of a letter at one or other end of the line, to be identified by the patient prior to bisection, can act as an attentional cue to that end of the line and affect the size of the bisection error. Assuming left unilateral neglect, the error is reduced with a left-sided letter and increased with a right-sided letter (Milner et al., 1992; Riddoch & Humphreys, 1983). Size of line bisection error to identify neglect varies widely. Using a 20cm line, Friedman (1990) considered normal performance to be 0-6mm error, mild neglect 7-15mm error, severe neglect 16mm error or more; a ‘moderate’ neglect category was not included. The study was based on 82 elderly acute stroke patients, 40 with neglect, 42 without. A 20cm centrally positioned line was bisected only once, which may not have accurately reflected individual performance. They concluded that line bisection was a useful screening test for neglect, but was not useful for accurate selection of candidates for rehabilitation units. Using data from a centrally positioned 20cm horizontal line, Koyama et al. (1997) defined mild left unilateral visual neglect as a ‘small’ to 3.3cm error, moderate neglect as 3.3-5.5cm error, and severe neglect as more than 5.5cm error. The bisection was repeated eight times and a mean value obtained. However, Halligan et al. (1989) found that line bisection identified only 53% of the patients who scored below cut-off on the RBIT pencil and paper sub-test, suggesting that line bisection alone may not be a particularly sensitive test. It may be more useful when used as part of a battery of tests, such as the RBIT. If used as a simple clinical test, the length and position of the line should be standardised, say 20cm length, drawn horizontally, and centrally placed on a sheet of A4 paper. In addition, bisection errors should be averaged from several attempts.

2.6.1.3 Copying and drawing tasks

Neglect in copying and drawing tasks, such as ‘draw-a-clockface’ or ‘copy a simple drawing of a daisy’, is demonstrated by incomplete drawing by the patient who may even omit an entire half of the picture on the neglected side. A problem with drawing tasks is subjectivity in interpretation of the results (Friedman, 1991). Halligan et al. (1989) point out that such drawing tasks may be popular as a simple clinical tool, but such tests failed to identify 63% of neglect patients in a non-acute sample. In addition, clock drawing can reflect general cognitive impairment (Friedman, 1991), or constructional apraxia (Agrell, Dehlin & Dahlgren, 1997), as well as spatial neglect.

2.6.1.4 Imagery tests

Imagery tasks have been used to directly assess internal representations of space, where patients were asked to describe a familiar scene. Typically, patients omitted to name buildings or other features on the left of the scene (Bisiach & Luzzatti, 1978). A similar task could be implemented clinically by asking the patient to describe objects appearing in a familiar environment from memory, perhaps a description of a room at home. Patients with representational difficulties may omit description of objects mentally appearing in neglected hemispace. Of course, a carer’s prior accurate description of the room layout would be a pre-requisite!

2.6.2 Tests for personal and extrapersonal neglect

Personal neglect can be tested by asking the patient to reach out to touch their other hand on the neglected side. The scale for scoring is 0 = patient promptly reaches for target, 1 = target is reached with hesitation and search, 2 = search is interrupted before target is reached, and 3 = no movement towards target is performed (Bisiach et al., 1986). Tests to differentiate personal from extrapersonal neglect have been described by Zoccolotti and Judica (1991), and require no special apparatus. They include tasks such as serving tea, card dealing, and description of the environment to assess extrapersonal neglect, and utilising common objects such as a comb or razor, to assess personal neglect. Zoccolotti and Judica (1991) give details of administration and observation scores. Spatial neglect within reaching space has also been tested using the 'Baking Tray Task' (Tham & Tegner 1996). The patient is asked to spread out sixteen 3.5cm cubes evenly across a board "as if they were buns on a baking tray", without time limit. Patients with left-sided neglect tend to place more than half of the 'buns' on the right side of the board, and distributions more skewed than 7 on the left side and 9 on the right side of the board are considered abnormal. An A4 sized version of the larger 75 x 100cm board (using the same size cubes) was found to be almost as sensitive and more convenient to use. This test was shown to be more sensitive than either line or letter cancellation tests, and is simple to administer and score. It was based on 52 stroke patients, 19 of whom had neglect, and 30 controls (Tham & Tegner, 1996). While validity was demonstrated, no data were given to indicate reliability, and control subjects were not age-matched.

2.6.3 Tests for motor neglect and directional motor neglect

Motor neglect has been defined by Laplane and Degos (1983) as " an underutilisation of one side, without defects of strength, reflexes or sensibility". Motor neglect, apart from clinical observation of obvious features (e.g. when a patient with minimal or no paralysis of the arm fails to use it) appears more difficult both to assess, and to differentiate from visuo-perceptual neglect. Motor neglect has been tested using tasks which involve bi-manual co-ordinated movements during spontaneous motor behaviour, such as folding a sheet of paper and placing it in an envelope, and shuffling and dealing cards (Barbieri & de Renzi, 1989). Such tasks would obviously exclude patients with moderate or severe paresis of the affected upper limb. True motor neglect must be distinguished from directional motor neglect (also known as 'directional hypokinesia' or 'intentional neglect') which is manifested by an inability to initiate movements towards the neglected side, even when the unaffected hand is used (Simon, Hegarty & Mehler, 1995). Both motor and directional motor neglect can dissociate from perceptual neglect (Barbieri & de Renzi, 1989; Ladavas et al., 1993). Indeed, a number of paper and pencil tests described above involve directional motor as well as perceptual responses. Tests to differentiate perceptual from directional motor components of neglect have been developed but require validation and standardisation. Several such tests, which are based on subjects making a motor response across into neglected hemispace with the unaffected upper limb to a stimulus presented in the opposite half of space, include the 'Landmark Task' (Harvey & Milner, 1995), a pulley system for line bisection (Bisiach, Geminiani, Berti & Rusconi, 1990), and a similar task, but using a mirror (Tegner & Levander, 1991). However, many of these tests are rather complex to set up and some require special apparatus. Tests which may be easier to use (and to score) in the clinical situation include those of Ladavas et al. (1993) and Maeshima et al. (1997b) who used tasks involving picking up objects, with and without vision, to differentiate motor and perceptual neglect. The simplest is perhaps the exploratory-motor task of Maeshima, Nakai, Itakura, Komai and Dohi (1997a). This requires the blindfolded patient to move 16 marbles, spaced evenly across a board, to the right edge and then off the board, without sweeping. Any marbles left on the board are regarded as 'error'. The task is repeated without the blindfold (visual counting task) and the patient is asked to count, without pointing to them, the number of marbles seen. Normal controls made no error; patients who made errors only in the blindfold condition were considered to show motor neglect, patients with visual neglect made errors only in the eyes open condition. Although validity could be questioned, the conclusions are strengthened by the fact that those identified with motor neglect showed frontal lobe lesions on computed tomography. Locomotor neglect has been tested by a use of a navigation task, which is clearly described by Robertson, Hogg and McMillan (1998a), but only used on one patient. This involved construction of a route through the hospital consisting of seven doorways and three corridors. The patient was assessed as walking 'centrally' if he kept within a central 2m wide area within the corridor, and whether he veered to either side of a mark defining the centre of the doorway. All 10 points on the route were assessed twice. Neglect was evidenced by the number of times the patient veered to the right at each point. This test lacks control data and also needs repetition with larger numbers of patients with neglect; however, it would be easy to apply in the clinical situation.

2.6.4 Single test or a test battery?

Use of a single test may underestimate the extent of neglect in a population, as it may not be sensitive to some forms of neglect, and thus a battery of tests may be better. In addition, some tests lack functional relevance. The RBIT was developed to overcome these problems (Wilson et al., 1987b). It is standardised and has published validity and reliability. It includes six pencil and paper tests (Star, letter and line cancellation, line bisection, figure and shape copying) and a number of behavioural tests (picture scanning, telephone dialling, menu reading, telling and setting the time, coin sorting, address and sentence copying, map navigation, and card sorting). The RBIT only assesses for visuo-spatial neglect and, although the behavioural sub-tests are described as being functionally relevant, some tests could be argued to have only tenuous links to real life situations (picture scanning, reading a menu, sorting playing cards). Another commonly used test battery is the Rivermead Perceptual Assessment Battery (Whiting, Lincoln, Bhavnani & Cockburn, 1985). However, it was designed for assessment of general perceptual deficits and not neglect specifically, although three sub-tests in the battery of 16 would test for neglect (e.g. cancellation and copying tasks). Both of these test batteries mainly assess aspects of visual or visuo-spatial ability, and do not directly address problems of personal, extrapersonal, motor, or directional motor neglect.

2.6.5 Neglect questionnaires

Lakshmi, Tallis, Ribbands and Hollis (1991) have developed a neglect questionnaire which is for non-acute stroke patients and requires yes/no answers to five simple questions such as “Do you/ does she or he - bump into things on the affected side/ignore one side in dressing, feeding or washing"; information on reliability was not given. Towle and Lincoln (1991a) also measured patients' subjective experience of neglect using a 45-item, six category questionnaire about frequency of problems encountered in everyday life. The six categories included mobility, wheelchair use, communication, personal care, domestic activities and leisure activities. Validity was shown by correlation with the SCT. Identical questionnaires were completed by both the patient and their friend/relative. The nature of the questions suggested that the questionnaire would not be suitable for use with acute stroke patients. Such questionnaires may not be valid if the patient is suspected of suffering from anosognosia.

In light of the multi-modal nature of neglect, it is probably wise to use a battery that includes tests for several different modalities. A number of tests have been described above, and the inclusions are not exhaustive, but many require further validation and standardisation.

2.7 Summary and conclusions

Unilateral neglect is a cognitive deficit, commonly associated with right-sided brain lesions, which can manifest in a number of sensory and motor modes. The presence of neglect can complicate the functional rehabilitation of stroke patients. It is difficult to accurately assess, due to its multi-modal presentation; consequently a battery of tests, in addition to clinical observation, may be needed to identify the specific type(s) of neglect presented by a patient. Of the tests reviewed above, the following are recommended for sensitivity in detection of neglect, ease of use, simplicity and objectivity of scoring and published control data for cut-off scores: for visuo-spatial neglect, the SCT, and the Line Bisection Test; for personal neglect the 'utilising common objects test' (Zoccolotti & Judica (1991); for extrapersonal/reaching space neglect the 'Baking Tray Task' (Tham & Tegner, 1996), and for directional motor neglect the 'exploratory-motor task' (Maeshima et al., 1997a). Standard clinical confrontation tests for extinction in various modes can also be undertaken (Heilman et al., 1993). Careful clinical observation, though subjective, is also valuable. Such a battery of assessment should be administered by therapists during both the acute and rehabilitation stages post-stroke (e.g. on admission and at 3-week intervals), to monitor signs of either spontaneous recovery or persistence of hemineglect, and to enable appropriate rehabilitation programmes to be designed which target the specific deficit(s) identified.

Material supplementary to preceding published paper to ensure currency of information

2.8 Anatomical correlates of hemineglect – update

2.8.1 Cortical and subcortical components

Unilateral neglect is particularly associated with lesions in the posterior parietal cortex, supplied by the middle cerebral artery, specifically the inferior parietal lobule (Perry & Zeki, 2000; Vallar, 2001). The posterior parietal cortex is the area where all sensory information is collected and integrated, and from where motor acts of reaching towards and manipulation of an object in the environment are coordinated (Mesulam, 1999). In addition to parietal lesions, other areas implicated in neglect, which are functionally interconnected with the parietal cortex, include parts of the frontal lobe, including the frontal eye fields and cingulate gyrus (Mesulam, 1999) and subcortical structures including the thalamus and basal ganglia (Damasio, Damasio & Chang Chui, 1980; Gitelman et al., 1999; Karnath, Himmelbach & Rorden, 2002).

The frontal component is considered to coordinate the motor programmes activated during the scanning and visual exploration of space (Mesulam, 1981) involving both covert and overt shifts of directed attention (Corbetta, 1998). In a magnetic resonance imaging (MRI) study of stroke patients with and without neglect, Mort et al. (2003) found that, out of 24 patients with visual neglect and with lesions in the right middle cerebral artery territory, eight had damage involving the frontal lobes. However, as four control subjects without neglect had similar damage, and many of the neglect subjects additionally had posterior parietal damage, Mort et al. (2003) emphasize that further study is required to demonstrate any independent frontal contribution to neglect. The limbic component (anterior cingulate gyrus of the medial frontal cortex) may be concerned with motivational aspects of attention, particularly the relevance or important to the subject, at any particular time, of a stimulus occurring in extrapersonal space (Heilman et al., 2003). The actual role of this limbic component in relation to neglect is the least well understood (Mesulam, 1999). A recent study by Karnath et al. (2003) found that 21 out of 48 acute stroke patients with visual neglect had damage that was limited to, or included, lesions of the thalamus or basal ganglia. Maguire and

Ogden (2002) found that the persistence of neglect was related to extensive cortical lesions, and that the basal ganglia were also commonly involved.

2.8.2 An attentional network

The idea that normal attentional processes rely on the integrity of an attentional network has a long history in cognitive neuropsychology (Mesulam, 1981). This tradition continues with the recent proposal of Heilman et al. (2003) that neglect is an attentional-arousal disorder induced by dysfuction of a cortico-limbic reticular attentional network. Mesulam (1999) emphasized that all core components of the network for attention work in synchrony, and that spatial attention is thus an emergent property of the network as a whole, and not merely a summation of its component parts. Furthermore, he suggests that large lesions involving the core parietal and frontal areas are likely to result in the multimodal deficits of the neglect syndrome, whereas more discrete lesions which disconnect parts of the network from other brain areas might result in modality specific deficits. Lesions limited to the subcortical white matter are rarely associated with unilateral neglect (Vallar & Perani, 1986).

The notion of a relationship between motor biases in unilateral neglect and anterior brain regions such as frontal lobe and basal ganglia, and a relationship between sensory-perceptual biases with posterior damage in the tempero-parieto-occipital region (Milner, Harvey, Roberts & Forster, 1993; Tegner & Levander, 1991), has recently been challenged (Husain et al., 2000; Vallar Bottini & Paulesu, 2003). Vallar and colleagues (2003) review the evidence for such a link and conclude that it is conflicting, and also that patients may show motor or perceptual biases depending on the task.

2.8.3 Limitations of correlational studies

There are some problems, particularly in the earlier research correlating specific brain regions with presence of unilateral neglect. One factor relates to the methods used to determine such links, as earlier studies (e.g. Damasio et al., 1980; Samuelsson et al., 1997; Vallar & Perani, 1986), using computerised tomography (CT) scans, provide relatively coarse images with poor spatial accuracy. Mort et al. (2003) point out that the slice thickness of most CT scans is greater than those obtained using higher resolution functional magnetic resonance imaging (fMRI), which they used to demonstrate links between the inferior parietal lobe and visual neglect. However, Vallar et al. (2003) state that few fMRI studies have been performed specifically to investigate unilateral neglect. Other recent advances have used PET, which measures haemodynamic changes in blood flow in the brain. Corbetta et al. (1993) used PET to show that the parietal lobe was the main structure involved in switching attention between locations. Thus more recent studies providing better spatial and temporal resolution for images (Ances & D'Esposito, 2000), using fMRI (Maguire & Ogden, 2002; Mort et al., 2003) or PET (Corbett et al., 1993), may be more valid. Another non-invasive technique used is that of electroencephalography to relate brain activity occurring during particular behaviours of subjects. Daffner et al. (2003) used this method to show that the prefrontal cortex and the posterior parietal lobe were both components of a cerebral network which mediated attention to novel events.

Another difficulty with some earlier anatomical correlation studies relates to the way in which unilateral neglect was identified and assessed. For example, some studies only used one test to assess neglect, and validity of the chosen test was not reported (Damasio et al., 1980; Vallar & Perani, 1986). Because of the many ways in which the neglect syndrome can present, a battery of tests rather than one single test is needed to assess these various manifestations (Bailey, Riddoch & Crome, 2000). Thus, neural correlates of various subtypes of the disorder need further investigation. Indeed, Vallar et al. (2003) argue that current understanding about anatomical correlates of unilateral neglect is largely related to only one manifestation, that of visual neglect in extrapersonal (near) space. Further studies are needed to map the precise anatomical correlates of the different types unilateral neglect, using valid test batteries in order to identify its various manifestations.

2.9 Incidence, recovery, and impact on functional activities of daily living - update

2.9.1 Frequency of occurrence

As outlined in section 2.4, frequency of occurrence of unilateral neglect varies considerably from one study to another, depending on the selection criteria for the sample (including aetiology, size and location of cerebral lesion, age, and time since onset of stroke), and methods used to identify the presence of unilateral neglect. However, the increased frequency of occurrence of unilateral neglect following right as opposed to left-sided brain damage has been supported by a systematic review of 30 studies by Bowen, McKenna and Tallis (1999). Indeed, other recent studies using similar methodological factors as those studies reviewed by Bowen et al. (1999), have reported an incidence of unilateral neglect in acute stroke, using bisection, cancellation and copying tasks, of 39% of right and 8% of left brain damaged patients (Bailey et al., 2000 [sample of 42 patients]), 49% (Buxbaum et al., 2004 [sample of 86 patients with right sided lesions only]). In those studies which separately studied patients with left-sided brain damage, incidences of right unilateral neglect of between 3% and 65% have been reported (Denes et al., 1982; Edmans, 1987; Pedersen et al., 1997; Stone et al., 1991b, 1993a; Sunderland et al., 1987; Zoccolotti et al., 1989), the wide variation being due to factors outlined above.

It must also be considered that use only of conventional pencil-and-paper tasks will not necessarily reflect real-life difficulties of participants with neglect, and so tests included in any battery may need to include ecologically valid functional tests (Bowen et al., 1999). Indeed, Appelros, Nydevik, Karlsson, Thorwells and Seiger (2003) found that some patients, who showed clear clinical signs of neglect, judged by observation of their behaviour in the hospital ward (e.g. bumping into objects on left during ambulation, and omitting the left side of garments while dressing), were able to 'pass' the conventional tests.

2.9.2 Recovery

Recent studies have confirmed the finding that most patients recover from clinically apparent manifestations of neglect (such as a tendency for ipsilesional orientation, and reduced visual exploration of contralateral hemispace) within the first three months post-stroke (Jehkonen et al., 2000a). However, Jehkonen et al. (2000a) assessed neglect using the Behavioral Inattention Test battery (Wilson et al., 1987a), which only assesses visuospatial neglect in reaching space. Appelros et al. (2004) assessed visuospatial neglect within personal, reaching, and far space, in a sample of 37 elderly right brain damaged patients with first stroke, followed up at 6 months and one year post stroke. Baseline data was obtained at 2-4 weeks post stroke, in order to include patients with established unilateral neglect. They concluded that neglect in reaching space diminished within six months, although complete recovery only occurred in 13% of the sample. However, neglect in personal and far space recovered faster, with 52% and 46% recovery respectively at the six-month period. There was no significant further improvement after six months for neglect in any of the three domains, at the one-year follow-up. The much reduced recovery rate found by Appelros and co-workers compared with others (e.g. Hier, Mondlock & Caplan, 1983; Stone et al, 1992) may relate to the later timing of the inclusion, as patients with more transient neglect may have recovered in the first few weeks post stroke. Appelros and colleagues (2004) therefore suggest that the optimum time for assessing unilateral neglect is a couple of weeks post stroke.

Support for the notion of persisting neglect being related to impairment of sustained attention, found by Hjaltson, Tegner, Tham, Levander and Ericson (1996) is given in a study by Robertson et al. (1995) in which chronic (mean 70 weeks, range 12-196 weeks post-stroke) and stable neglect in eight patients improved after sustained attention training. Robertson (2001) reviews the evidence and concludes that impaired sustained attention must coexist with spatially biased neglect in order for clinically significant neglect to persist.

2.9.3 Impact on functional activities of daily living

Further recent studies confirm the strong link between the presence of unilateral neglect and poorer functional outcome (Appelross et al., 2004; Cassidy Lewis & Gray, 1998; Cherney et al., 2001; Jehkonen et al., 2000a; Kalra, Perez, Gupta & Wittink, 1997; Katz, Hartman-Maeir, Ring & Soroker, 1999; Paolucci et al., 2001). If neglect has an adverse affect upon functional ability of the patient then this in turn can lengthen their stay in hospital (Cassidy et al., 1998) and may affect their potential to return to independent living (Kalra et al., 1997; Pedersen et al., 1997). Additionally, poor awareness and lack of insight into such problems (anosognosia), which may co-concur with hemineglect, may reduce the patient's ability to compensate for their problems (Jehkonen et al., 2000a).

Kalra et al. (1997) in their study in a UK stroke unit, investigated factors associated with outcome, including ADL assessed by the BI. They compared groups with (n=47) and without visual neglect (n=99), but with comparable motor deficits and stroke pathology. They found that participants with neglect, (who were twice as likely to have right-sided brain damage), despite having similar discharge destinations to those without neglect, had lower ADL scores, were hospitalized for twice as long and required more therapy input than those without neglect. Cherney et al. (2001) in their USA study showed that, out of 52 consecutively admitted stroke participants, those with neglect on admission (n=36) had longer lengths of rehabilitation than those without, and that the presence of neglect (identified using all the sub-tests of the BIT) and its severity were related to reading and writing outcomes, as well as function and mobility (measured by the Functional Independence Measure, or FIM). They only included participants with right-sided brain damage. The FIM and BIT were also used in Israel by Katz et al. (1999), to assess ADL and neglect respectively in 40 patients with first stroke. They also noted that participants with neglect had longer lengths of hospital stay, and were more impaired in ADL at admission, and at six-month follow-up. A further study by Cassidy et al. (1998) in the UK examined a group of 66 participants with right-sided brain damage to calculate the relationship between scores on the BIT (conventional sub-test) for visuo-spatial neglect, and BI for ADL. In contrast to some studies, they found no relationship between neglect and ADL at admission, but significant correlations were found between these two scores at one, two and three-month follow-up.

The impact of neglect upon function appeared to be even longer lasting in a recent study in Finland by Jehkonen et al. (2000a). They found that neglect scores in a sample of 56 participants, with right-sided brain damage, on the behavioural sub-tests of the BIT, were the best single predictor of functional outcome, measured by the Frenchay Activities Index, accounting for 73% of the variance at three-months, 64% of the variance at six-months and 61% of the variance at one-year follow-up. Stroke severity and age were also important factors at three months, but only neglect and age remained in the regression model at six months and one year. Despite the long-term persistence of neglect and its impact on function, only 8% of their participants still had neglect at one year, and the majority did not demonstrate neglect on testing after three months. Therefore, the authors, in discussing why neglect should be such a strong predictor, hypothesized that those with chronic neglect may have additionally suffered from attention/arousal deficits which could prevent them from learning compensatory strategies. Alternatively, some degree of residual neglect, not measurable on formal testing, may still have impacted upon ADL ability. As anosognosia was not assessed, this is another variable that may have been related to the findings.

Chen-Sea (2001) looked at the effects of a combination of personal and extra-personal neglect upon ADL, in 44 stroke patients at entry to the study, 14 weeks post-stroke. Concurrent extra-personal and personal neglect was related to significantly lower ADL scores than extra-personal neglect only. Personal neglect was identified using the draw-a-man test, which is of questionable validity for this purpose (because it assesses visuo-spatial neglect in extra-personal and not personal space per se) and extra-personal (i.e. visual neglect) by the Chinese word cancellation test. However, because sub-groups were small (seven participants showed extra-personal neglect only, two personal neglect only, and 11 with both), and the parametric statistical analysis used was inappropriate, the conclusions must be interpreted with caution. Furthermore, the mean age of participants was less than 60, and 50% of the sample had haemorrhagic stroke, and thus would not be comparable to a UK stroke population.

All the studies reviewed thus far have indicated that all participants received routine rehabilitation during hospitalisation, although details are not given, and specific treatment of hemineglect was not included. Paolucci et al. (2001), however, gave full details of additional specific therapy for neglect given to patients. They found that stroke severity was the most important prognostic factor for poor ADL outcome, but that, when severity and age were adjusted for, neglect remained a significant predictor. The sample sizes of 176 subjects included elderly first stroke patients with both right and left-sided brain damage, between five and eight weeks post-stroke on admission. Neglect was defined as below cut-off score in three out of four standardized tests, ADL was assessed using the Barthel Index (BI), mobility using the Rivermead Mobility Index (RMI), and stroke severity using the Canadian Neurological Scale (CNS). In common with their earlier study (Paolucci et al, 1996a), Paolucci et al. (2001) reported that, on admission, patients in the neglect groups had significantly worse function (mobility and ADL) than the patients without neglect. Both neglect and non-neglect groups then received standard and comparable amounts of rehabilitation (based on the Bobath approach) for stroke, and, additionally, standard amounts of specific cognitive therapy for the neglect group. Paolucci and colleagues (2001) showed that effectiveness of rehabilitation (adjusted for differences between groups on ADL and mobility scores on admission) was low for the neglect group and high for the groups without neglect. All measurements were blinded in their study. They found that 66.3% participants in the neglect group (compared with 27.2% of those without neglect) were unable to transfer from bed to chair without help on discharge. Additionally participants with neglect were more likely to have had an infarct affecting the territory of the right middle cerebral artery (judged using CT and MRI scans), especially large lesions in the fronto-temporo-parietal cortex. Unfortunately, anosognosia was not included in their assessment battery. Buxbaum et al. (2004) did include anosognosia in their assessment battery, and found that the neglect syndrome *per se*, rather than overall stroke severity, was predictive of poorer functional outcome for stroke patients with right-sided brain damage.

Patients with neglect may be at even more of a disadvantage when additional attentional loads are placed upon them, as may often be the case in a busy environment when, for example, they have to get dressed whilst maintaining balance and perhaps listening to a conversation. Indeed, Suzuki, Chen and Kondo (1997) found that, when combining tests of visual attention during a stepping activity, stroke participants once more showed neglect behaviour which had not been elicited by pencil and paper tests alone.

Most studies reviewed included predominantly elderly participants aged between 60 and 80 years, and most included only participants identified with the more commonly presentation of visuo-spatial neglect in extra-personal space, usually tested with a variety of cancellation, copying and drawing tasks, or line bisection. Thus the impact upon ADL of other forms of neglect (such as motor neglect, or directional hypokinesia, or neglect of objects in far as opposed to near or personal space) have yet to be investigated. The ability to predict functional recovery is important so that best use can be made of limited rehabilitation resources, by targeting patients less likely to recover spontaneously.

2.10 Additional assessment tests for hemineglect - update

Papers related to assessment of hemineglect obtained since publication of the preceding paper will be reviewed in this section. Assessments include tests for visuo-spatial neglect, personal neglect, imaginal neglect, and the functional consequences of neglect using a questionnaire based on direct observation of patient behaviour by the therapist.

2.10.1 Visuo-spatial neglect

A recent screening test for visual neglect in near space, the Balloons Test, has been described by Edgeworth, Robertson and McMillan (1998). The authors claim that it is simple to administer and is a reliable test for visual neglect. In addition, the contribution of visual field defects to contralateral omissions can be evaluated. The test was validated using 72 right-handed stroke patients with recent right-sided brain damage, and 55 non brain damaged age-matched controls. Unfortunately, no further details concerning reliability or cut-off scores are provided (Edgeworth et al., 1998). Patients are required to cancel targets on two separate sheets. The first sheet contains 202 circles, randomly arranged, of which 22 (targets) have a vertical line (balloons), the second sheet is identical except that the position of balloons and circles is now reversed and the targets are now the 22 circles. Each sheet is time-limited to six minutes. The first task is easier than the second because the ‘balloons’ tend to ‘pop out’ during visual search (Treisman & Gelade, 1980). In contrast, the second sheet requires a more attentionally demanding active visual search for the circle targets, which do not ‘pop out’. A ‘feature present’ (the balloon string on the first sheet) is easier to detect than a ‘feature absent. Edgeworth et al. (1998) argue that performance on the two tasks should not differ in patients with visual field defects; the contralesional side of both sheets will be similarly affected by the field cut, and performance should be the same in both conditions. If a patient is suffering an attentional disorder, fewer targets will be detected on the second sheet, as it is a more attentionally demanding task.

A novel method of monitoring the process as well as test outcome during completion of two standard tests for neglect (line bisection and line cancellation) was devised by Potter et al. (2000). They used a graphics tablet on which was placed the sheet of paper with the test material. A computer was then used to record the timing and location and precise movements of the pen used by the patient during the bisection or cancellation tasks. In this way, process parameters such as the side of the start position, the speed of pen movement towards either side of space, time between cancellations, any perseverating behaviour (repeated cancelling of same target) could be later analysed, in addition to outcome (test score). They used this equipment to compare two groups of stroke patients (median 4-5 weeks post-stroke, range 1-118 weeks) with right-sided brain damage (30 with and 57 without neglect, determined using the BIT (Wilson et al., 1987a) and found significant between group differences in both process and outcome of bisection and cancellation. Finally, a third group of 13 age-matched non-stroke patients were compared with the 57 stroke patients with right brain damage but no neglect, and significant differences were found between the groups on process measures but not outcome measures. The authors suggest these findings may be explained by subtle differences, related to attention and execution of activity in stroke patients, which are not detected by conventional testing. The record of process, the authors point out, might be of value when monitoring changes in neglect behaviour over time, and enable assessment of the process of test completion in addition to obtaining a final test score. Such measures could provide useful opportunities for future studies into the neuropsychological basis of neglect, and its natural history, although the study by Potter et al. (2000) only measured neglect behaviour at one point in time. However, although useful for research purposes, this analysis is likely to be time-consuming, and requires special equipment which may not be available in the standard clinical situation. Further study is required to determine the reliability of this form of assessment.

Because the use of line bisection and cancellation tasks may assess different aspects of spatial attention and motor exploration, performance in each may doubly dissociate, and neither, used alone, may be as sensitive as a combination of the two, Lee et al. (2004) have designed a new test which combines elements of both bisection and cancellation tests. This Character-line Bisection Task consists of two sub-tests; strings (in horizontal rows on a sheet of A4 paper) of target and non-target letters (Letter-line), or symbols (Star-line). Subjects have to find the target letter or symbol that is closest to the midline of the character line. In a large sample (n=80) of stroke patients with visuo-spatial neglect, the two sub-tests were found to have good concurrent validity (compared with a standardised test battery), high test-retest reliability (Pearson's r=.814 for Letter-line and r=.706 for Star-line) in 21 patients tested within 24 hours for the second time. The Letter-line and Star-line tests were able to detect 90.9% and 87.3% respectively of subjects with hemineglect (defined using a cut-off score of more than two standard deviations from the mean score on the neglect test battery of the control group). No differential performance behaviour was reported between the sub-tests, so presumably the Letter-line would be the test of choice in terms of highest reliability and sensitivity. However, the letters used were from the Korean alphabet and the test may need to be revalidated using alphabet characters from other languages.

2.10.2 Personal neglect

To provide a more sensitive measure of personal neglect, Beschin and Robertson (1997) used Zoccolotti and Judica's (1991) test, which involved an observer rating the patient's performance on three tasks, using a comb, putting on spectacles, and using a razor (for men) or powder compact (for women). Scoring was on a 4-point scale ranging from 0 (normal) to 3 (severe deficit). The adapted test of Beschin and

Robertson (1997) used only the comb and razor/powder compact, and the observer had to count the number of strokes (of comb, razor or compact) used by the patient on the left side or right side of the head, or ‘ambiguous’, in a 30-second period. A ‘left over total’ score could then be calculated as an index of personal neglect. The term ‘ambiguous’ was not defined, however, this revised test would provide a numerical score (interval in nature), likely to be more sensitive and objective than the original rank-ordered scoring scale of Zoccolotti and Judica (1991). Additionally, Beschin and Robertson (1997) provided evidence of reliability in 43 stroke subjects, 15 of whom were right brain damaged with neglect, 16 without neglect, and 12 left brain damaged patients. Correlation between test and retest was .94 for the group as a whole, also for a subgroup, which consisted of patients with right-sided brain damage, 10 of whom also had extrapersonal neglect, five of whom did not. This subgroup showed a significant lateral bias during comb and razor/compact test (less than 35% of strokes performed on the left side compared to the right). This figure of 35% was used as a cut-off score to define personal neglect, as no age-matched control subjects (n=17) scored less. No patients with left brain damage scored below cut-off for personal neglect. This adapted test would be easy to administer and score in the clinical situation. The type of correlational analysis used to determine test-retest reliability is not described. Further study is required, to establish intra and inter-tester reliability, using analysis that would indicate the actual maximum range of difference in score that might be expected between test and retest, and utilising larger samples.

Because the procedures described by Beschin and Robertson (1997) assess performance on tasks which focus only on the subject’s face, Cocchini et al., (2001) devised the ‘Fluff Test’ in which 24 cardboard circles, 2cm in diameter, are attached to the patient's clothes (whilst the patient is blindfolded and distracted with conversation) using Velcro. Distribution is three on the right and three on the left of the central body midline area, six along the left arm, six along the left leg, six along the right leg, giving a total of 15 targets on the left side of the body and 9 on the right side. No targets are placed on the right arm as this is used for finding targets and removing them whilst blindfolded. The numbers are reversed for patients with left sided stroke. A topographical diagram is provided by Cocchini et al. (2000). There is no time limit. Because the percentage of ipsilesional targets detached by all 38 stroke patients was not significantly different from the 38 right handed controls, the cut-off score, based upon the lowest score in the control group, was calculated as the percentage of stickers removed from the contralesional side (less than 13 out of 15, or 86.7%). The test is easy to administer and score, and test-retest reliability for percentages of contralesional targets was demonstrated ($r=.89$, $p<.05$) for the entire group of 38 right handed stroke patients, 27 with right and 11 with left sided lesions (the only patients with extrapersonal neglect were 14 of the those with right sided brain damage). A subgroup of 14 of these 38 patients, who scored below cut-off on the Fluff Test (10 with right brain damage and extrapersonal neglect; two with right and two with left brain damage and no neglect) showed test-retest reliability of .79 ($p<.05$). The choice of Pearson's correlation coefficient is not the most appropriate statistical analysis to demonstrate test-retest reliability (see Chapter 6), and gives no indication of actual maximum range of differences that might be expected (in percentage of contralesional targets removed) between test and retest, for the majority of cases. Inter-tester reliability also needs to be determined, and appropriate reliability testing using larger samples is required. Furthermore, correlation between the Fluff Test and the comb and razor/compact test (Beschin and Robertson, 1997) was very low ($r=.15$), and double dissociations between performance on the two tests were found (of 21 patients with right brain damage, five were impaired on the Fluff Test only, and four on the comb and razor/compact test only). This finding suggests that the two tests may not be measuring the same construct. Perhaps because the Fluff Test is performed without vision, it is measuring the patient's mental representational ability, alternatively perhaps personal neglect is selective for particular body parts. For these reasons, the Fluff Test could perhaps be used together with the comb and razor/compact test to assess personal neglect. Finally, in common with many tests requiring the patient to manually explore the contralesional side of space, the presence of directional hypokinesia may also affect patient performance on either of these tests for personal neglect, making interpretation of the tests difficult.

2.10.3 Imaginal Neglect

Testing neglect of mental images, or internal representations of space, may require the patient to describe familiar scenes (see section 2.6.1.4.), however, as not all scenes familiar to the patient will be familiar to the tester, this test could be difficult to administer in the clinical situation. The O'Clock test (Grossi, Angelini, Pecchinendal & Pizzamiglio, 1993) was designed to overcome such difficulties. However, 24 stroke patients with hemineglect were examined for inclusion in the study, but only ten, with right brain damage and "mild to moderate neglect", were able to perform the tests, seven due to inability to read the analogue clock in its right and left halves, and three due to fatigue. This suggests that this test for imaginal neglect might not be suitable for a large proportion of stroke patients with neglect. This factor would limit the clinical utility of the test. The ten patients who were suitable were then asked to imagine a pair of clock faces indicating different times proposed by the tester (one with one hand in the right and the other with one hand in the left half of the clock face, the other hand being either on the hour or half hour). These times involved only half hours or hours, for example 9.30 or 3.00, to avoid times that might be too difficult to imagine. Patients were then asked to state on which of the clocks the hands defined the larger angle. The imaginal task was given in four blocks of ten pairs of clock faces (one right and one left condition) each. Patients had several minutes rest between each block. The entire task was then repeated twice, with a different block order. Responses were scored as either correct or incorrect. Results showed that patients performed around 10% worse in the left compared to the right hand clock face condition. This test has the advantage of not requiring images to be produced by the patient from long-term memory, also the images are standardised. However, as the authors point out, the patient would have a 50% chance on each trial of obtaining a correct answer by guessing, consequently individual assessment differences may not be significant because they are too small. The authors suggest that this problem can be overcome by repeating the task many times in different sessions, however this could produce a fatigue effect that might affect performance. Indeed, the authors found evidence of a fatigue effect as “imaginal neglect for the left side became progressively more evident during the course of the experiment”. They interpret this finding as support for the hypothesis that imaginal neglect occurs due to diminished attentional resources being allocated to left imaginal space, rather than a difficulty in generating left sided mental images. Repeated testing such as that recommended by Grossi et al. (1993) may not be clinically realistic in terms of time needed for testing. Furthermore, the test assumes skills of telling the time, and the concept of angles and comparison of their relative sizes. Such abilities may need to be established prior to administration of the test. Evidence of test reliability was not provided by Grossi et al. (1993). In view of the need for further study including a control group, and a larger and more representative patient sample, and in addition to the other limitations discussed above, this test is not currently recommended for use in the clinical situation.

2.10.4 The Catherine Bergego Scale

Another questionnaire (for others see section 2.6.5), the Catherine Bergego Scale, to evaluate the functional consequences of unilateral neglect was designed by Azouvi and colleagues (1996), and found to be reliable (interrater reliability r_s =.96), although test-retest reliability has yet to be demonstrated, and valid (related to the BI, r_s=.63) for use with stroke patients, and more sensitive than conventional paper and pencil tasks (Azouvi et al., 2003). It has an advantage over the Subjective Neglect Questionnaire (Towle & Lincoln, 1991a) as the same questions can be used for both patients and carers, allowing some estimate to be made of patients' denial of their problems (anosognosia). The therapist, using direct observation of patient behaviour, completes a ten-item questionnaire assessing aspects of everyday behaviour, such as whether the patient fails to detect food on the left side of the plate. If a difficulty is present, the therapist is then asked if they find the deficit to be mild, moderate or severe, and the behaviour is scored accordingly. It is not clear whether the observations are to be made over a period of time, or on a 'one-off' basis. This test has been standardised on 50 stroke patients with right-sided brain damage and is clearly based on 'real-life' everyday patient function. The authors point out that a positive aspect of their test is that observation of the patient's behaviour in a naturalistic setting, which is less likely to be as stressful (and therefore arousing) as a clinical test situation, and may result in a truer measure of neglect. While the test has obvious clinical utility, it does require acute and thorough observation over time by the therapist, and relies upon their judgement of observed patient behaviour (e.g. during grooming or shaving, or direction of the patient's spontaneous gaze). This introduces an element of subjectivity. Furthermore, three of the ten activities (collisions with left-sided objects, finding one's way when walking around, and finding left-sided personal belongings) relate to subjects who are independently mobile, either whilst walking or driving a wheelchair. Fourteen per cent of the sample of 50 patients were not able to be scored on the dressing question, due to dressing apraxia, which was difficult to differentiate from neglect. The authors note that the examiners used were all experienced therapists who were familiar with rehabilitation of neglect, and that a training period would be necessary before scoring patients with this scale. This test may help to address the problem found by Appelros et al. (2003). This was that patients who scored normally on a battery of conventional, pencil-and-paper tests, nevertheless exhibited clinical signs of neglect, as judged by the therapist's report, based on ward observations. A further advantage of this questionnaire is that it includes personal, peripersonal and extrapersonal items. However, it does not differentiate which types of neglect may be contributing to the observed abnormalities in performance. Furthermore, in severely impaired patients, it can be difficult to determine the relative contributions of neglect and primary sensory or motor loss, or dressing apraxia, to the performance deficits shown by the patient. Nevertheless, it may be a useful tool for measuring the functional impact of neglect in a range of everyday activities.

2.10.5 Summary of recent studies on the assessment of hemineglect

The previous conclusions (section 2.7) are still considered to be valid, however the Balloons Test may be clinically helpful to differentiate between neglect and visual field defects, provided these two conditions do not co-occur. For the assessment of personal neglect, the adapted comb-and-razor test (Beschin & Robertson, 1997) is considered preferable to the earlier test for personal neglect recommended (‘utilising common objects’, Zoccolotti & Judica, 1991), as it is likely to be more sensitive. The Fluff Test, although it may be a useful adjunct to the comb-and razor test, is not recommended for clinical use at present, as it requires stronger evidence of its validity and reliability. The O’Clock test (Grossi et al., 1993) for imaginal neglect and the use of a graphics tablet (Potter et al., 2000) for evaluating behavioural processes during completion of pencil-and-paper neglect tests may both be of value in the research setting, but are not so suitable for clinical application. The Catherine Bergego Scale could usefully be applied to evaluate the everyday consequences of neglect. It is important that the functional difficulties of stroke patients with neglect are documented, and this questionnaire adds a degree of objectivity to purely clinical observation and description. It can additionally be used to assess the degree of denial by the patient of their difficulties, which is important, because such anosognosia may be an added barrier to successful rehabilitation.

CHAPTER 3

REHABILITATION TECHNIQUES AND STRATEGIES

Approaches to the rehabilitation of hemineglect are presented in this chapter, including attentional strategies, the use of visual cues and visual scanning, the effects of increasing arousal, the use of limb activation strategies or spatio-motor cueing, and manipulation of sensory input. Supplementary information is provided following presentation of the published paper.

This Chapter is presented as a published paper:

Bailey, M.J., & Riddoch, M.J. (1999). Hemineglect. Part 2. Rehabilitation techniques and strategies. ***Physical Therapy Reviews*****,** ***4,*** **77-85.**

The paper is presented exactly as it was published, but using numbered sections for consistency of presentation.

Following presentation of the published paper, a brief review of recent relevant papers will be presented to ensure that information is current and comprehensive. Summary findings from the review in Chapter 3 are used as a basis for the design of a series of single case experimental studies presented in Chapter 7.

Abstract

Hemineglect may complicate recovery of function in stroke patients. Although many studies have demonstrated success in reducing unilateral neglect during or immediately after treatment, longer term carry-over or generalisation to untrained tasks has proved more difficult. However, a number of recent studies have shown promise, both in reducing neglect and improving performance in everyday tasks. Strategies found to be particularly useful include sustaining arousal during scanning activities which incorporate attentional cues on the neglected side, and encourage activation of contralesional limbs. Motor imagery techniques have also been effective in reducing neglect and improving everyday function. Other techniques reviewed include a number of specific stimulation strategies, and the reduction of sensory input to the undamaged hemisphere. Unfortunately, these strategies may reduce neglect during stimulation, or for a short time afterwards, but have not been shown to carry-over or to generalize. Practical suggestions are made to enable therapists to incorporate potentially successful strategies into rehabilitation programmes in clinical settings.

3.1 Introduction

Care of stroke patients accounts for around 4% of the total National Health Service budget in the U.K. (Blais, 1994), and although no precise figures are available, considerable resources are allocated to stroke rehabilitation[1]. A significant percentage of stroke patients, particularly those with right-sided brain damage, may present with symptoms of neglect which may affect their ability to benefit maximally from therapeutic rehabilitation (Kalra et al., 1997). The multi-modal nature of neglect makes identification, assessment and selection of appropriate treatment strategies a complex affair (Roden, 1997).

There are a number of recent reviews[2] of the rehabilitation of neglect (Calvanio, Levone & Petrone, 1993; Chatterjee, 1995; Cleaves & Inglis, 1997; Cooke, 1992; Gouvier and Cubic, 1991; Herman, 1991; Lin, 1995; Robertson, 1993; 1994; Roden, 1997). Most of these reviews provide support for the use of rehabilitative strategies such as visual scanning and/or the use of verbal and visual cues to direct attention towards neglected hemispace, and activation of limbs on the contralesional side (see below). They also emphasise the need to incorporate training strategies into tasks which are functionally relevant for the patient to encourage transfer of training (Calvanio et al., 1993). Active (rather than passive) patient participation in training, and sufficient intensity of training, are considered to be important (Calvanio et al., 1993). The use of specific sensory stimulation (e.g. vestibular stimulation) is

[1] The Royal College of Physicians (2002) states that stroke accounts for 4% of NHS expenditure, is the third highest cause of death in the UK, and the biggest single cause of major disability.
[2] More recent reviews include Bowen & Cross, 2000; Bowen et al, 2003; Diamond, 2001; Freeman, 2000; Manly, 2002; Pierce & Buxbaum, 2002; Plummer et al, 2001. See also section 3.4.5.

considered to hold promise (Chatterjee, 1995; Cleaves & Inglis, 1997) despite its transient impact upon neglect. In general, many of the strategies reviewed have been shown to reduce neglect, at least in the short term, but the success of training, in generalization to non-trained tasks, including activities of daily living (ADL) has been limited. However, some studies appear promising and have been shown to reduce neglect for a sustained period and to improve functional ability (Antonucci et al., 1995; Lennon, 1992; Paolucci et al., 1996b; Pizzamiglio et al., 1992a; Robertson, North & Geggie, 1992; Smania, Bazoli, Piva & Guidetti, 1997; Webster et al., 1984; Wiart et al., 1997) also decreased length of hospital stay (Kalra et al., 1997).

3.2 Approaches to rehabilitation of neglect

Patients with movement dysfunction must learn again how to perform motor tasks necessary for daily living. Sustained attention is a prerequisite for motor and other learning following stroke (Robertson et al., 1997c) because without this ability, patients will not be able to attend to or focus upon relevant sensory information needed to guide motor actions. Many rehabilitation strategies are focused on improving attentional abilities, either by techniques considered to increase stimulation of the ipsilesional hemisphere (Paolucci et al., 1996b), or by reducing stimulation to the contralesional hemisphere (Arai, Ohi, Sasaki, Nobuto & Tanaka, 1997). Other strategies, based on representational accounts of neglect, are aimed at manipulation of input of sensory information to facilitate a more normal internal representation of objects in the external world (Smania et al., 1997). In the following sections we provide a review of the different rehabilitation strategies.

3.2.1 Attentional strategies

Strategies to increase attention include the use of visual scanning (Antonucci et al., 1995; Edmans & Lincoln, 1989; 1991a; Fanthome, Lincoln, Drummond, Walker & Edmans, 1995; Paolucci et al., 1996b; Pizzamiglio et al., 1992a; Robertson, Gray, Pentland & Waite, 1990; Wagenaar, Van Wieringen, Netelenbos, Meijer & Kuik, 1992; Webster et al., 1984; Weinberg et al., 1977, 1979; Wiart et al., 1997) and visual, verbal or motor cues (Halligan et al., 1992b; Lennon, 1994; Riddoch & Humphreys, 1983; Riddoch et al., 1995c; Seron, Deloche & Coyetter, 1989) to direct attention towards contralesional hemispace, and activation of contralateral limbs (Kalra et al.,1997; Robertson & North, 1992; 1993; 1994; Robertson et al., 1992), to increase arousal of the damaged right hemisphere. Sustained attention/arousal strategies have also been used (Robertson & Cashman, 1991; Robertson et al., 1992; Robertson et al., 1995; Robertson et al., 1998a; Robertson, Mattingley, Rorden & Driver, 1998b). Substitution of automatic orienting of attention, considered to be affected in unilateral spatial neglect, with volitional orienting of attention, subserved by the intact left hemisphere, may assist in the rehabilitation of neglect (Gainotti, 1996). Additional techniques to increase stimulation to the right side of the brain include vestibular, visual, proprioceptive, somatosensory, auditory and electrical stimulation to the left side of the body or in left hemispace (Butter and Kirsch, 1992; Hommel et al., 1990; Karnath, 1996; Karnath, Christ & Hartje, 1993; Prada & Tallis, 1995; Rode et al., 1992; Vallar, Bottini, Rusconi & Sterzi, 1993; Vallar, Guariglia, Magnotti & Pizzamiglio, 1995a; Vallar, Papagano, Rusconi & Bisiach, 1995b; Vallar et al., 1995c). Methods to reduce sensory input to the contralesional hemisphere include the use of hemifield goggles, and eye-patching (Arai et al., 1997; Butter & Kirsch, 1992; Harrell, Kramer-Stutts & Zolten, 1995; Soroker, Cohen, Baratz, Glicksohn & Myslobodsky, 1994).

3.2.2 The use of cues and visual scanning to direct attention to left hemispace

Cueing is used to draw attention towards target stimuli, and is considered to improve detection (Posner, 1980). Cues are commonly visual (e.g. coloured markers), verbal (e.g. instructing the patient to "look to the left") or motor (e.g. use of the left hand at the left margin of a task). For best effect, visual cues should be explicitly reported by the patient (Riddoch & Humphreys, 1983).

Left sided cueing has been shown in the laboratory to reduce left-sided neglect (Halligan, Burn, Marshall & Wade, 1992a; Riddoch & Humphreys, 1983; Riddoch et al., 1995c; Seron et al.,1989). A single left side cue (to be verbally reported by the patient) significantly decreased neglect, whereas neglect was significantly increased by a single right side cue (Riddoch & Humphreys, 1983). Riddoch et al. (1995c) showed that in the reading of single words (a visual task), a single left sided visual cue (coloured sticker) reduced left side neglect errors, while a motion cue (positioning the finger on the left side) had no such effect. However, when the patient was instructed to copy the same words (a motor task), there was no beneficial effect of a visual cue, but a motion cue was found to reduce the neglect. These findings suggest that cueing may be modularity specific. In addition, Riddoch et al. (1995c) point out that an explicit report of a visual cue is necessary in order for it to be effective, as the mere presence of the cue had little effect on performance. Unfortunately, the effects of cueing are disappointingly short term (Halligan et al., 1992b) and ineffective in producing long term gains or generalization to tasks not originally trained (Seron et al., 1989). There are clear implications for rehabilitation here. In order to optimise cueing effects, cueing strategies should be used in conjunction with more general attention arousing activities; in addition, patients should be encouraged to *generate* cues themselves (such as continual reminders to look to the affected side) rather than having to rely on external agents.

Similar effects were shown in a more behaviourally relevant study by Lennon (1994) in which a patient with neglect, who tended to collide into left-sided objects, was successfully trained to navigate around these obstacles, in a gymnasium, when salient coloured markers were used. The study differs from the laboratory experiments of Riddoch and colleagues (1995c) in that the patient did not have to report the cue but merely to avoid marked objects. Nonetheless, cues significantly increased the tendency to avoid left-side objects. However, the improvement was environment-specific and training had to be repeated in the patient's home. Had active report of the cues been used rather than passive observation, better generalization may have resulted.

The principles of scanning training have been usefully summarised by Diller and Riley (1993). Patients with neglect are inclined to scan from the right and ignore most of the stimuli in the left visual field (Weinberg et al., 1977). However, systematic training of visual scanning reduced neglect and improved scanning behaviour during tasks such as reading and writing. Training consisted of around 20 hours, spread over a 1-month period, of scanning rows of coloured lights across a board using slow and systematic left to right search. Verbal and visual cues were used. The patient initiated the task by saying "anchor left", at the same time they were cued by distinctive yellow tape at the far left side of the board. Once the initial left-sided target had been found, the task was to follow a light sequence from far left to the right side of the board. Training progressed to use of the left arm as a left-sided cue, instead of the yellow tape. While the procedures worked well for the scanning task, and generalized to performance on other visual tasks such as reading and writing, there was no transfer of training to other tasks involving spatial awareness. A randomised controlled trial (RCT) by Weinberg et al., (1979) incorporated additional training involving proprioceptive biofeedback; this required the patient to (i) identify where they had been touched on their back, and (ii) to estimate the length of various plexiglass rods. Results showed that the patients in the experimental group performed significantly better than controls in a pre-post test design, and the improvement generalized to tests of object assembly and estimation of body midline. These tests were different from the training tasks. These improvements were in addition to improvement in non-trained reading and writing tasks, as found in their previous study (Weinberg et al., 1977). Patients with more severe problems showed greatest improvements. Unfortunately, no follow-up study was performed to determine whether the effects were maintained in the longer term. In a thorough and careful review, evaluating the studies by Weinberg and colleagues (1977; 1979), Calvanio et al. (1993) concluded that their relative success was due to several factors: (i) a narrow training focus concentrating upon one aspect of cognitive dysfunction (i.e. neglect), (ii) active participation by the patient, and (iii) intensive training of 4-5 hours per week. They also point out that maximum generalization occurred on tasks which were similar to the training tasks. This highlights the principle of specificity of training (Schmidt, 1982) and emphasises the importance of incorporating training techniques into functional activities.

Similar scanning strategies were used by Webster et al. (1984) for three stroke patients with chronic left neglect. Stable visual/perceptual deficits, scanning behaviour and wheelchair navigation around an obstacle course were demonstrated over at least two consecutive assessments spaced one week apart during the baseline phase. Subjects rolled the wheelchair towards the scanning apparatus during the daily 45-minute scanning training (based upon that used by Weinberg et al., 1977; 1979) which lasted for 6-12 weeks. Considerable improvements in visual scanning were found, and maintained at one year follow-up, and generalization to non-trained tasks, shown by reduction in errors during navigation of an obstacle course in two of the three subjects at the end of the study.

More recently, Antonucci et al. (1995) also showed that scanning training could generalize to tasks not used during training. In their study, 20 elderly patients with identified hemineglect and right hemisphere lesions were randomly assigned to an immediate or a delayed treatment group. Average onset time since stroke was around 80 days. The immediate group received specific spatial scanning training for 8 weeks, during which time the delayed group received non-specific cognitive intervention (puzzles, chess, card games etc.) for three 1-hour sessions per week for the 8 weeks, given by a volunteer, who was blind to the study aims. The delayed group thus acted as a control. Specific neglect training consisted of five 1-hour sessions per week using four different procedures: visual scanning of digits on a screen, reading & copying from newspapers, copying (on the right side) of line drawings presented on the left side, and verbal description of scenes of black and white pictures. Left-sided verbal and visual cues were provided for all procedures in the early stages and reduced over time as improvement was shown. Significant improvements in a number of standard neglect tests were found after the specific training between the immediate treatment group compared with the delayed (control) group. The groups were then crossed over, so the delayed group received specific rehabilitation for the second 8-week period. Significant effects of training were also found after training in the delayed group; however, comparisons between the two groups could not be made because most of the patients in the immediate group were discharged after rehabilitation. Generalization of improvement to other untrained tasks was also shown. Importantly, the study also demonstrated that training effectiveness seems to be fairly independent of time interval since the stroke. In a replication of the above study, Paolucci et al. (1996b) found that, in addition to a significant reduction in neglect, improvement carried over to mobility and function as shown by significant changes in the Rivermead Mobility and Barthel Indices respectively. Other studies have also shown positive effects of specific visual scanning training regimes, for example that of Pizzamiglio et al. (1992a). In this study, 13 patients with stable hemineglect (at least 3 months post-stroke) demonstrated significant improvements in performance on a standard battery of tests for neglect after 40 therapy sessions. In addition, there were significant improvements in function as measured by a semi-structured scale for the functional evaluation of hemineglect (Zoccolotti & Judica, 1991). Unfortunately, since no form of control was used, it is not possible to attribute the improvement specifically to the intervention used.

The studies outlined above have focused on visual scanning. In an interesting, and possibly more relevant study to everyday functioning, Wiart et al. (1997) combined visual scanning techniques with axial trunk rotation (turning the trunk to the left during scanning). Feedback of success in visual scanning was by auditory and visual methods, thus enabling the patients to benefit from multi-modal stimulation of attention during exploration in the neglected hemifield. This study included an RCT using 22 patients and a second trial which used 5 patients with neglect of more than 6 months duration (no controls). Significant improvement in neglect and also ADL function (measured with the Functional Independence Measure), which proved to be stable at least one month post-treatment, was shown in both studies.

In contrast to the above studies, Wagenaar et al. (1992) found that visual scanning training improved visual scanning behaviour but there was no transfer of training to wheelchair navigation in 5 separate patients using a single-case design. The authors point out that it might be more effective to train scanning behaviour while the patients are actually mobilising in their wheelchairs. This had previously been demonstrated by Webster et al. (1984). Robertson et al. (1990) also found that computer based visual scanning training was ineffective in reducing unilateral neglect in a group of 36 patients; they consequently surmised that it might be more profitable to use training stimuli which would appear in patients' everyday lives. Disappointing results have also been reported by Edmans and Lincoln (1989; 1991a) and by Fanthome et al. (1995b), all of whom used single subject design. All the studies used varieties of visual scanning training and left sided visual cues; the studies by Edmans and Lincoln also measured ADL changes. Their treatment sessions lasted 45 minutes for three times per week over 4-week treatment phases. Patients received standard physiotherapy and occupational therapy during baseline and treatment phases. Any small improvements made in neglect or ADL ability could not generally be attributed to treatment effects and could equally have been due to practice or spontaneous recovery, as the authors point out. Fanthome and co-workers (1995) did not measure ADL but found that, although significant improvement in neglect scores over time occurred, these improvements also occurred in baseline phases so could not be attributed to treatment effects, and were probably due to spontaneous recovery.

There are some common features of these studies which may explain some of the negative outcomes. Training intensity may have been insufficient, as none used more than 2.5 hours per week. All used tests for neglect that were dissimilar to the training procedures, whereas training effects are more likely to show up in similar tasks. The studies by Edmans and Lincoln (1989; 1991a) did not have a narrow training focus, and aimed to treat a variety of perceptual problems. Where inattention was specifically targeted, training details were not given, merely that they included “activities encouraging the patient to scan”. Additionally, the study by Edmans and Lincoln (1989) used only left brain damaged subjects, who may have responded differently to the training than subjects with right-sided damage. The approach of incorporating specific training strategies for neglect into functional activities of relevance to the patient may be also be an important factor to improve transferability of skills. Thus features of successful studies highlighted by Calvanio et al. (1993) were not all present in all of the above studies with negative outcome.

3.2.3 Effects of increasing arousal

Robertson et al. (1995) postulated that if sustained attention could be increased, this would have a positive effect on unilateral neglect, via the lateralised orienting system located in the posterior parietal lobe (Posner & Peterson, 1990). They reported this to be the case in a group of eight right brain damaged patients where significant improvements in neglect and sustained attention were demonstrated after training, compared with baseline phases. Duration of treatment effects lasted from 24 hours to 14 days. The training procedure, lasting for 5 1-hour sessions, encouraged subjects to move from external regulation of their sustained attention (the trainer knocked loudly on the desk every 20-40 seconds and said "Attend!" in a loud voice), through overt self-regulation (the patient took over to say "Attend!" when the trainer knocked) and finally to covert self-regulation (the patient was reminded to both knock and say "Attend!", first out loud, later sub-vocally) and finally the patient signalled when they were 'mentally' knocking the desk. Patients were encouraged to apply this strategy in everyday situations. Other studies have also demonstrated positive outcomes from the use of verbal self-cueing and verbal self-instruction, in the learning of wheelchair transfer skills, using single subject designs (Lennon, 1992; Stanton et al., 1983), and in an RCT using only four patients (Loomis & Boersma, 1982). Such strategies could be usefully incorporated into ADL and other activities, and reinforced by other team members between therapy sessions. Use of this strategy would necessitate careful task analysis prior to training.

A 'neglect alert device' in the form of a buzzer has been effectively used to increase arousal and improve sustained attention during contralesional arm activation (Robertson et al., 1992; Robertson et al. 1998a) and as auditory feedback and arousal to encourage heel-strike during walking (Robertson & Cashman, 1991). These studies were all single subject designs. The first approach, where the patient must make a self-directed active response to turn the buzzer off temporarily, may be better, as it involves internal mediation of arousal. In contrast, use of the buzzer as auditory feedback is externally mediated and also highly task specific, and so may be less effective. Replication of these studies is needed, using larger samples.

3.2.4 Effects of spatio-motor cueing on hemineglect

In right brain damaged patients, motor responses are usually made using the right arm (i) because most people are right hand dominant and (ii) the left arm may be paralysed. As the right arm is controlled by the intact left hemisphere, activating it may exacerbate neglect. Halligan et al. (1992b) found that line bisection performance using the left hand was improved compared to use of the right hand, in a single patient. They suggested this was either because the left hand acted as a spatial attentional cue, or that it increased activation of the right hemisphere; however using the right hand in left hemispace also reduced neglect, supporting the cueing explanation. This notwithstanding, the hemispheric activation explanation has been used to account for the positive results found in a number of other studies which show that even quite small movements of contralateral upper and lower limbs can significantly reduce neglect in single cases (Robertson et al.,1992; Robertson & North, 1992, 1993, 1994). In an RCT using spatio-motor cueing techniques Kalra et al. (1997) found significant reduction in neglect and length of hospital stay in the experimental group (n=24) compared with the controls (n=23). Robertson and North (1992) found, in a single case study, that the reduction in neglect was as great when the moving fingers were not visible to the patient as when they were, also movement of the left hand in right hemispace had no effect upon neglect, nor did right hand movement in left hemispace. They established that that contralesional hand activity in contralesional hemispace reduced neglect for several weeks after training and improved performance in everyday activities. Interestingly, Robertson and North's subsequent study in 1994 showed that the advantage conferred by left hand activation was reduced or even negated when the right hand was *simultaneously* moved, whether in right or left hemispace. Moreover, concurrent right hand activation in right hemispace not only cancelled the left hand advantage, but actually reversed it. Although such studies need replication with larger numbers, the findings may have implications for physical rehabilitation if bilateral limb movements are encouraged; although bilateral movement is often necessary, opportunity must be provided for unilateral activation of hemiplegic limbs. All staff involved in rehabilitation of patients with neglect should encourage this unilateral activation to ensure high training intensity. During therapy sessions, maximum use of the contralesional limbs in neglected hemispace should be encouraged, even if there is only minimal voluntary activity present. Such movement should be incorporated into functionally related activity wherever possible, and the patient encouraged to look at the limb. Even when no movement is possible, the left arm could still be placed on the left margin of functional tasks such as personal grooming and feeding, acting as a "passive perceptual anchor" (Robertson et al., 1992). Visual and sensory cues could also be given to encourage motor activity on the affected side (e.g Anderson & Choy, 1970; Prada & Tallis, 1995).

3.2.5 Sensory stimulation strategies

The following approaches also use various forms of sensory stimulation which may act as sensory cues to draw attention towards the neglected side. An early report proposed the use of a programme of sensory stimulation, involving stroking, brushing and icing of the contralateral limbs, activation of the contralateral upper limb, and encouragement to cross the body midline during movement (Anderson & Choy, 1970). Unfortunately, outcomes were not systematically assessed.

More recently, Hommel et al. (1990) found that tactile stimulation such as tapping had no effect on neglect in a sample of 14 stroke patients. However, the stimulus was minimal and involved merely tapping the patients' cheek with a pencil. Nevertheless, in the same study, using the same sample, bilateral auditory stimulation did significantly reduce neglect, but only during stimulation. The most effective stimulus turned out to be the playing of taped classical music, or 'white noise', via headphones (see also Tromp, Michels & Mulder, 1993). The effect was explained by the notion of preferential activation of the right hemisphere. Music with words had no effect, perhaps because it required left hemispheric processing. No controls or blinded outcome measures were used, which weakens the conclusions of these studies.

Electrical stimulation providing a tingling sensation was found to reduce neglect and other perceptual difficulties in two patients with right-sided brain damage (Prada & Tallis, 1995). Stimulation was applied over the dorsal surface of the left forearm for a continuous 3 hours per day for 1 month. Increased attention to the neglected side was the explanation given for the treatment effect. Carry-over effects have not been measured in these studies to assess whether the effect is longer lasting or whether the patient may habituate to the stimulus. Electrical stimulation applied just below the left occiput using transcutaneous electrical nerve stimulation (TENS) was also found to significantly reduce neglect for 30 minutes post-treatment, assessed by letter cancellation, in 13 out of 14 subjects with visuo-spatial neglect (Vallar et al., 1995c). Guariglia, Lippolis and Pizzamiglio (1998) also found positive effects by using TENS on the left side of the neck in a group of nine right brain damaged patients with unilateral neglect. They demonstrated improvements in performance (during stimulation) on the left side of mental representations of objects in drawing and shape comparison tasks, as well as on the left side of mental images of space (description of familiar shapes).

Karnath et al. (1993) demonstrated significant reduction in neglect, during stimulation, in three patients, using a hand-held mechanical vibrator over the contralateral posterior neck muscles. A similar reduction in neglect was found without vibration but when the trunk was axially rotated 15 degrees to the left, with the head facing straight ahead. Opposite sided vibrations or rotations had no effect on neglect, nor did vibration applied to the left hand.

The above techniques are all potentially available, and familiar, to physiotherapists, and could be easily used in the clinical situation. The fact that they have thus far been shown to have only a transitory effect upon neglect, and no generalization to functional tasks, may limit their utility. Further studies with larger subject numbers and blinding of outcome measures are needed to assess whether these techniques could be used at the beginning of a treatment session to somehow prime brain areas responsible for spatial perception, as suggested for caloric stimulation, by Cleaves and Inglis (1997).

Caloric stimulation (the contralesional ear canal is irrigated with iced water) to stimulate the vestibular system (Rode et al., 1992; Vallar et al., 1993; 1995b) and optokinetic stimulation using leftward moving transient visual stimuli on a computer screen (Butter and Kirsch, 1992, 1995; Karnath, 1996; Vallar et al., 1995a) have also been found to reduce neglect either during stimulation, or for a very short time post stimulation, but no carry-over to other tasks has been found. Such optokinetic stimulation additionally improved contralesional motor weakness of the hand (during stimulation) in two patients with unilateral neglect (Vallar et al., 1997b). Rode, Tiliket, Charlopain and Boisson (1998) also found a significant reduction in postural asymmetry by vestibular caloric stimulation in left hemiparetic patients. These techniques are less appropriate for use by the physiotherapist in the clinical situation.

An RCT using 39 stroke patients with neglect was undertaken by Rossi, Kheyfets and Reding (1990) who investigated the use of yoked (Fresnel) prisms attached to spectacles. The prisms displace peripheral images on the neglected left to a more central location in the visual field. This allows correct visuo-spatial information to be received by brain areas concerned with balance and body orientation in space. Significant reduction in neglect at the end of 4 weeks of prism-wearing was found, although no significant change in ADL function. Body posture and balance was not directly assessed, although Padula and Argyris (1996) suggest that normalised midline shift might produce posture and balance improvements. Indeed, Rossetti et al. (1998) in their RCT of 16 stroke patients with left sided neglect who wore the prisms, found that the experimental group's perception of body midline shifted more centrally and their neglect was significantly reduced compared with controls, for "at least two hours" post-treatment. Further study is needed to assess if there is any longer term carry-over effects, as this would represent interesting application for rehabilitation of stroke patients who have postural and balance difficulties.

3.2.6 Reducing sensory input to the undamaged hemisphere

In contrast to approaches where attempts are made to boost activation of the damaged hemisphere, other studies have attempted to reduce activation of the undamaged hemisphere. These include the wearing of hemifield goggles which occlude the right halves of both visual fields (Harrell et al., 1995), glasses which have dark glass in the right half of each lens to reduce light penetration to 8% (Arai et al., 1997), and use of an opaque eye patch on the right eye (Butter & Kirsch, 1992; Soroker et al., 1994). In general, decreased neglect is only observed during or immediately post-treatment and no carry-over effects have been found. However, one patient reported by Arai et al. (1997), eight months post-stroke, could completely avoid collision when wearing the glasses, having had a history of repeated collisions with left side objects when walking prior to the therapy. Again, these studies used small samples (between 6 and 18 patients) with no controls.

3.2.7 Other approaches

Visual feedback using video improved performance of several functional tasks in four patients with stable neglect (Soderback, Bengtsson, Ginsburg & Ekholm, 1992) and in a small group study (Tham & Tegner, 1997). Performance did not generalize to tasks other than those used for video-feedback, although the technique may be useful during rehabilitation. An advantage of video is that the patients' neglected side appears on the screen on the non-neglected side, and errors can thus be observed by the patient.

Smania et al. (1997) used visuo-motor imagery techniques during rehabilitation of two elderly stroke patients with severe and chronic (7 months post stroke) left neglect, who were both severely impaired in motor and sensory function. Both had received prolonged motor rehabilitation and were both able to stand and walk with the aid of a tripod. Assessment, in this single case design, took place pre and post intervention and at 6 months follow up. The test procedure was extremely wide ranging including a number of tests for neglect and everyday function. A five-item questionnaire was given to carers about the patient's performance during routine family activities. The training procedure consisted of two types of task: visual imagery and movement imagery. Each training session lasted 50 minutes and there were 40 sessions in all. The visual imagery involved mental imaging tasks such as description of a familiar room, or path, or geographic area. Motor imagery consisted of the patient describing a body posture or movement sequence by imagining them. Results showed that the imagery training significantly improved neglect and function and that this improvement was stable at the 6 month assessment period, suggesting a long term effect. There was clear generalization, or transfer of training, as testing procedures evaluated a wide range of abilities which were not used in the treatment programme.

Such imagery training has potential for use as part of a rehabilitation programme, but may need specialist support (i.e. of a clinical psychologist) and would need patients with the cognitive ability to co-operate.

3.3 Conclusion

Strategies which appear to hold most promise, both to reduce neglect and to transfer to ADL function, and which are perhaps better suited to incorporation within physical rehabilitation sessions, include visual scanning, use of visual and motor cues, verbal self-cueing and activation of limbs on the neglected side. The patient's own level of awareness of their neglect can be harnessed, enabling the therapist to design suitable treatment strategies for the patient, encouraging the use of self-instructional and self-monitoring methods Golisz (1998). Use of video for feedback, and mental imagery training also show promise. Other strategies reviewed, such as sensory stimulation of vestibular, visual, and proprioceptive systems, seem less useful at present, both because they have not been shown to generalize, and also because they require equipment and facilities not routinely available. Key factors in success of approaches seem to be specific training focus and high intensity of training, coupled with incorporation of training techniques into functional activity where possible, with the patient as active participant, to try and overcome problems with carry-over. Maximisation of training intensity might be best achieved using a team approach, including professional staff as well as carers and relatives, all of whom could be taught to use appropriate training strategies throughout the course of the patient's daily life.

3.4 Additional information concerning the rehabilitation of hemineglect (supplementary to preceding published paper)

This section reviews more recent research (obtained after publication of the preceding paper) into strategies used to ameliorate unilateral neglect. Additional review of the use of visual cues and scanning, and contralesional limb activation, can also be found in the publication presented in Chapter 7, Sections 7.2. and 7.3.

3.4.1 Use of cues and visual scanning to direct attention to left hemispace

Following success of their training programme to improve safety during wheelchair mobility (Webster et al., 1984), Webster et al. (2001) used a computer-assisted training programme, using a wheelchair simulator, to improve wheelchair mobility in patients with unilateral neglect. Forty patients (38 male) with right-sided brain damage and left neglect were assigned to either a treatment or a control group. Patients were average

60 years of age, and approximately 23 weeks post-stroke. Their neglect was identified by deficits in one or both of two standardised tests, letter cancellation and copying of drawings. Allocation to groups was not random, although groups were equivalent for age, education, time post-stroke, and performance on screening measures for neglect. All received standard rehabilitation throughout the study, which included real-life training in wheelchair mobility. Patients in the treatment group received variable amounts of training, between 12 and 20 sessions each lasting for 45 minutes, and consisting of five modules of increasing complexity through which the patients progressed, determined by achieving 70% accuracy on any module. Modules 1-3 involved, in order, visual scanning of coloured numbers projected onto a white wall, manual tracking using a 'trackball' controlling an arrow that could follow a red target projected onto a black background, and detection of new images on a screen, which appeared whilst images of a wheelchair travelling down a road were being displayed. All displays were projected onto a surface (8x6) ft., however, distance of the patient from the display was not stated. Module 4 involved patients steering a 'virtual' wheelchair along a 'virtual' obstacle course; first using a hand-controlled button press, progressing to two foot pedals allowing left and right movement, and a right-sided wheel, allowing forward and backward movement. The final module was a simulated wheelchair obstacle course involving 90 degree turns to left and right. Training effectiveness was assessed, immediately following the treatment period, using a real-life wheelchair obstacle course similar to the simulated one, and hospital 'incident reports' involving falls or 'patient mistakes' (not defined). Additionally, the two simulated wheelchair courses of modules 4-5 were re-tested. Assessments were not blinded which might lead to bias. No longer-term follow-up assessments were undertaken after patients had been discharged. Results showed that trained patients

made fewer errors and hit fewer left-sided objects than controls in the real and simulated wheelchair tasks, and fewer trained patients experienced falls during their in-patient stay. Unfortunately, no evidence was provided that average length of stay, or mobility level between the two groups was comparable at outset. Although results indicate beneficial effects of computer scanning training, which generalized to real life activity during wheelchair mobility, the training modules would require complex equipment and software and considerable time input from specialist staff. All of these factors have financial implications, and the training procedure might be logistically difficult to set up in the standard clinical setting. Finally, there may be less emphasis in the UK on wheelchair training, compared with the USA where this study took place, and greater emphasis on achievement of walking mobility following stroke.

The use of electrically-powered wheelchairs in the UK remains “novel” (Dawson & Thornton, 2003). Indeed, the presence of visual neglect is a guideline safety exclusion criterion for provision of such a wheelchair (Franks, Ward, Orwell, McCullagh & Belcher, 2000). To ascertain whether patients with neglect are able to successfully drive a power chair, Dawson and Thornton used a single case experimental design (ABA, each phase lasting two weeks). Two male stroke patients were included (aged 67 and 70 years, and 32 and 20 days post-stroke respectively) with right brain damage (assessed by CT scan) and left neglect (assessed using the BIT, conventional and behavioural sub-tests). Training in the B phase took place for 30 minutes every weekday, during which time each patient practiced steering their powered chair around the hospital environment, starting with a clear corridor and progressing through a busy corridor, finally driving in and out of a small bathroom. No verbal feedback was given (to minimise left hemisphere stimulation), but the trainer would assist in steering if the patient had difficulties. Assessment, every weekday during all phases, involved each patient negotiating an obstacle course, including two doorways and five pairs of equivalent objects, one on each side, whilst driving a powered wheelchair at fixed speed. Number of collisions and time taken was recorded. Additionally, neglect was assessed on weekdays during all phases using the SCT and the Baking Tray Task (BTT). Bias may have occurred because no assessments were blinded. Results showed that one patient showed reduced number of collisions, and reduced time taken to complete the obstacle course, between the first A phase and the B phase, also between B and second A phases. However, neglect measures showed that this patient had reached normal performance on the SCT and the BTT by the start of the intervention phase. The second participant showed stable, severe neglect over all three phases, but marked reduction in left collisions during the first A phase, and reduced time taken during the final A phase. Thus, for one patient, improved performance may have been due to spontaneous resolution of their neglect, for the other, it may have been due to a practice effect gained during measurement of performance on the obstacle course. There is no evidence of specific improvement tied to the intervention during the treatment phase. Nevertheless, as the authors point out, both patients did learn to drive the powered wheelchair, albeit, perhaps, due to practice on the obstacle course used for assessment, reinforcing the notion that task-specific training should be used as the basis for treatment interventions.

To further investigate the value of task-specific functional training, Cherney, Halper and Papachronis (2003) used an intervention with one treatment group (one 58 year old female and one 66 year old male) that allowed repetitive practice during the functional task of oral reading, and another intervention using visual scanning practice to try to modify selective visual attention in a second group (one 53 and one 86 years old, both females). Participants were randomly assigned to groups. All four patients had right hemisphere stroke and left neglect, were right-handed, at least seven months post-stroke, and had ‘clinical evidence’ of neglect, which was not further defined. All patients received 20 sessions of the intervention, but further details of timing are not provided. The oral reading intervention involved the patient reading a paragraph aloud, whilst pointing to each word. Vertical anchoring lines were used to encourage scanning to the left, and the task was increased in difficulty over time by reducing font size, and line spacing, and increasing number of lines and paragraphs to be read. Accuracy of 100% over three consecutive paragraphs was required before progressing to the next level of difficulty. Visual scanning treatment consisted of cancellation tasks, again using increasing levels of difficulty from orderly to random arrangement of letters, and with increasing numbers of target and distractor letters. Accuracy of 90% within one minute over three trials was required before moving up a level. At all levels, physical cues (moving the patient’s hand), verbal cues, and visual cues using a red line on the left page margin, were used. Assessment of selective attention (using the Stroop test) and neglect (using the BIT conventional and behavioural sub-tests) were made pre and post-treatment. Additionally, all patients were required to identify five names from the left sided page of a phone book. This was assumed to be a functional task to assess ability to attend to the left side of space, and was timed, and undertaken prior to every treatment session. Descriptive analysis only was provided, due to the small sample, and although some small improvements were shown in some outcome measures for some patients, there was insufficient evidence to suggest that either treatment approach was successful or that one was superior to the other. The lack of information given regarding timings of treatment sessions would make study replication impossible. A single-subject experimental design might have been more appropriate when such small numbers of subjects were available. Additionally, the inappropriate randomised group design, lack of blinding, lack of control, use of a non-validated measure for a functional task, and measurement of neglect and attention being made only pre and post treatment, are all factors which contribute to the poor methodological quality of this study.

Scanning and cueing to encourage left visual search, and using strategies based upon those designed by previous workers (Pizzamiglio et al., 1992a; Antonucci et al., 1995; Paolucci et al., 1996b), and described in Section 3.2.2 above, were also used by Rusconi, Meinecke, Sbrissa and Bernardini (2002). Twenty elderly patients with right brain damage and left visuo-spatial neglect, all 5-15 weeks post-stroke, were randomly allocated to one of four treatment groups. All groups received scanning training for five one-hour sessions per week for 8 weeks consisting of reading, drawing and copying, and object matching-to-name tasks. Group 1 received only this scanning training, Group 2 received this plus specific verbal and visual cueing and verbal feedback of performance, Group 3 received the same as Group 1 but additionally TENS was administered to the posterior left neck muscles for the duration of each session, Group 4 received the same as Group 2, with the addition of TENS. All four groups showed significant improvements in neglect assessed using cancellation tasks, line bisection and reading, and in function, assessed using the Barthel Index, at both 4 and 8 weeks after the start of training. These findings, however, must be treated with some caution, as no control was used, and stability of performance for neglect and functional level was not demonstrated at the outset of the study. Therefore the impact of spontaneous recovery, or any specific effect of the rehabilitation received from therapists (but not described), cannot be excluded. Interestingly, clock drawing remained unchanged and severely impaired at the end of training. The authors suggest this may be because the imagery component of this task was not susceptible to the type of training used in the study.

3.4.2 Contralesional limb activation

The use of contralesional limb activation was based on evidence that use of the left limb, whilst undertaking standard tests of neglect such as line bisection, leads to improved performance (Joanette, Brouchon, Gauthier & Samson, 1986). Robertson and colleagues have extended these findings (e.g. Robertson & North, 1992; 1993; 1994; Robertson et al., 1992, 1998a; Robertson & Hawkins, 1999) and have shown that unilateral neglect can be reduced if tasks are undertaken using the contralesional hand. From these findings, the notion of limb activation therapy was developed, which involves moving the contralesional arm, or leg, in contralesional hemispace. Significant improvements in neglect were found even when arm movements were small (e.g. Robertson & North, 1994). Of interest is that not only were short-term reductions in neglect found but that the effect generalized to improvements in everyday function (Robertson et al., 1992). The explanation of the therapeutic effect of limb activation therapy has been that the multiple representations of space including personal, extrapersonal and even locomotor frames of reference, interact together to form a co-ordinated spatial reference system (Robertson & North, 1992). Thus, if the left limb is moved within left hemispace, the left half of both the personal and extrapersonal spatial sectors may become activated, which in turn activates motor circuits in the damaged right hemisphere, causing a reduction in neglect (Maddicks, Marzillier & Parker, 2003).

Robertson et al. (1998a) showed, in a well-designed (n=1) study, that limb activation therapy reduced neglect in personal, peripersonal and locomotor space in response to training, in a single patient aged 22 years, 18 months post right-sided brain injury. However, only neglect in peripersonal space, assessed using the BTT, was maintained after the end of training, at nine-day follow-up. Training consisted of 18 days of limb activation during performance of a range of therapy activities, and involved the use of a buzzer (neglect alert device) that emitted a noise at 8-second intervals, and which had to be turned off by the patient, using his left hand. Robertson et al. (1998) speculated that the training effect may not have been long-lasting because the hair combing and walking tasks (number of times patient veered to the right at specific points over a fixed route), used to assess neglect in personal and locomotor space respectively, may have been inherently more effortful tasks for the patient to perform, due to his motor and sensory loss, leading to less spontaneous use of the left arm during such activities. The navigation task was designed for the study and not previously validated.

The study by Robertson et al. (1998a) was extended and replicated by Maddicks et al. (2003) with a 55-year-old patient with left visuo-spatial neglect, 8 weeks following an infarct in the territory of the right occipital, parietal and temporal lobes. Treatment (turning off a buzzer) lasted 40 minutes, daily, over each 5-day period of the treatment phases (ABABA design). Due to insufficient left arm movement, the patient used his left leg to turn off a buzzer. Normal occupational therapy continued through all phases.

No significant overall effects of treatment were found, but significant effects of the first treatment phase were found for neglect in peripersonal and far space, and the improvement was maintained for far space. No improvement was found in daily life tasks. The subject showed no personal neglect at the outset. The authors concede that spontaneous recovery may be an alternative explanation, although measures of peripersonal neglect returned to baseline and reduction of neglect did not persist after the first treatment phase. Unfortunately, although tasks used to assess neglect in the three spatial domains were designed to be less effortful than tasks used by Robertson et al. (1998a), they were not previously validated, and may therefore not have been satisfactory measures of neglect. Other alternative explanations for the lack of effect could be insufficient intensity and/or length of treatment phases, use of the leg rather than the arm, which may have been less effective, and finally that limb activation was not combined with any therapy activity, as it was in the study by Robertson et al. (1998a).

Wilson, Manly, Coyle and Robertson, (2000) used either left limb activation (five minutes of left hand tapping on a table, prior to activity during a daily self-care programme) or self-alerting strategies (for five minutes each day prior to self care activities) first described by Robertson et al. (1995). This study (Wilson et al., 2000) used a single case experimental design, with two subjects. All phases of both single case designs lasted for 10 days. For one patient an ABA design was used. Limb activation resulted in significant improvements in several sub-tests of the BIT, also a reduction in the number of verbal prompts required during self-care activity, maintained at second baseline, in one patient. In the second patient, an ABACA design was used, limb activation being used in the first treatment phase (B) and self-alerting in the second treatment phase (C). Both types of training produced significant reductions in the one outcome measure used (the number of verbal prompts required during self-care activity), immediately following limb activation, but slightly delayed following self-alerting, both improvements being maintained at second baseline. A limitation of this study is lack of blinding of outcome. Furthermore, as the first patient was only six weeks post-stroke, although the use of ABA-type design mitigates against this, it remains possible that spontaneous recovery coincided with the improvement shown during the first treatment phase, and this is an alternative explanation for the findings. Nevertheless, each individual strategy may have reduced neglect and improved performance in self-care activities.

Limb activation training, using a ‘buzzer’ electronic device which emitted a tone, cancelled by left arm movement, was used by O’Neill and McMillan (2004) in their single case experimental design. Comparing intervention to baseline phases, significant improvements were found in Star Cancellation, but not Line Bisection, and a significantly increased rate of recovery of left upper limb function (assessed using the Motricity Index, arm data only). The two-week baseline phase consisted of routine occupational therapy lasting 45 minutes, four times per week. This therapy continued during the intervention phase, when the ‘buzzer’ device, worn during all occupational therapy sessions, was activated. The intervention phase lasted for four weeks. The assessor was blind to onset of limb activation training. The 54-year old patient was described as having minimal left arm movement, and his Motricity Index upper limb score was 45 and stable at baseline, but reached 65 by the end of the intervention phase. This change may have been related to the improvement in his Barthel Index score (55 to 85), taken pre and post-treatment, as a result of increased left side awareness and/or use, although the authors concede that there is no direct evidence for such an interpretation. Spontaneous recovery is an alternative explanation for the positive findings of this study; however, some control was provided by starting the study at 10 weeks post-stroke. The patient had only mild visual neglect, with only six to eight total omissions on Star Cancellation during baseline, which reduced to between one and three omissions during the intervention phase. Such small reductions might also indicate a learning effect due to repeated testing. A longer baseline phase would have provided stronger evidence of stability of all measurements. The study also requires repetition across patients and settings.

The addition of limb activation with other strategies has been successfully used before. Samuel et al. (2000) combined limb activation with use of the left arm as a ‘visual anchor’ (see Section 7.3). Brunila, Lincoln, Lindell, Tenovuo and Hamalainen (2002) also demonstrated positive results by combining visual training with left arm activation in the rehabilitation of visual neglect. They commented that, due to hemiplegia, many stroke patients may have insufficient voluntary movement in the left limb to perform the necessary activation. Nevertheless, Samuel et al. (2000) had previously reported that two patients with minimal left shoulder movement showed reduction in neglect following limb activation therapy. Brunila et al. (2002) used a single case ABA design, with four patients all under 60 years of age, each phase lasting for three weeks, and first baseline assessment being around eight weeks post-stroke. Assessment consisted of seven tests for visual neglect (five from the BIT conventional sub-tests, one Rey figure-copying task and a picture scanning task) administered once per week for the nine weeks. This only provided three time periods of assessment during each phase, which precluded statistical analysis of individual results. Treatment consisted of four sessions per week, each lasting for one hour, and consisting of visuospatial tasks requiring scanning of the whole visual field. Thus some tasks were similar to tasks used to assess neglect, and practice may have influenced performance. During visuo-spatial training, patients were additionally required to activate the left limb every five seconds, either by clenching the left fist repeatedly (one patient with full arm use), or to lift their shoulder (for the remaining three patients with minimal to full shoulder movement). Descriptive analysis of individual results showed that most improvement occurred, during the treatment period, for three of the four patients during the article reading test, and all four showed improvement in cancellation tests. The patient with the most arm use, who also had the most severe neglect, responded best to treatment. She additionally showed further improvement after a second period of treatment at seven months post-stroke, after the period when any spontaneous recovery might be assumed to have occurred. Of course, an obvious problem of combination training is the inability to separate out any treatment effects for the individual strategies. Other limitations of this study are that assessments were not blinded, and baseline stability of test performance was not demonstrated, partly due to insufficient data points being collected for each phase. Finally, effects of treatment on any activities of daily living, and, in three patients, any longer term amelioration of neglect following second baseline phase were not assessed.

In addition to the use of single subject designs, some efficacy of limb activation in the reduction of neglect has also been shown using a group design. Kalra and colleagues (1997) undertook a randomised trial with blinded outcome measures. The control group (n = 25) received 'conventional therapy' which consisted of " restoration of normal tone, movement patterns, and motor activity before addressing skilled functional activity". The experimental group (n = 25) received a 'modified approach' combining the conventional approach with visual and sensory cueing of motor activity on the affected side (although no further details of the limb activation strategy used were given) and early focus upon personal care and mobility skills during rehabilitation. Both groups were comparable at baseline for age, gender, impairment including visuo-spatial neglect, and disability. Assessment occurred at the time of randomisation (median of 6 days post-stroke) and after 12 weeks. Results showed an increase just short of significance in Barthel score at 12 weeks (14 versus 12.5) and a significant reduction in length of hospitalisation (42 versus 66 days) in the experimental group who received limb activation and early functional practice incorporated into their rehabilitation programme, compared with the control group. Visuo-spatial neglect, as measured by sub-tests of the Rivermead Perceptual Assessment Battery (Whiting et al., 1985) was also significantly reduced in the experimental group. Although these results are promising, the groups were still fairly small, and it is not clear which particular intervention was responsible for the change. Additionally, spontaneous recovery may have differentially affected subjects in each group. Nevertheless, this is one of only a few studies which has used randomisation and blinding procedures and larger than customary sample size. It was unfortunate that more detail was not provided about the rehabilitation in the two arms of the study.

Robertson, McMillan, MacLeod, Edgeworth and Brock (2002) used a single-blind randomised control trial of 39 elderly patients with right-sided brain damage (around 20 weeks post-stroke) and left-sided visuo-spatial neglect (screened using Star Cancellation and Line Bisection). They compared limb activation (using a buzzer attached to the left wrist, leg, or shoulder, which emitted a tone if the patient did not move within a set period of time) combined with ‘perceptual’ training (consisting of encouraging scanning and using verbal cueing during a variety of games and reading activities), with perceptual training alone. Both groups were comparable at outset on variables of interest. All patients received a total of eight hours of treatment over 12 weeks. Follow-up at 3,6, 18 and 24 months post treatment indicated that, at each time period, the only outcome measure to show significant improvement of the combined treatment group compared with ‘perceptual’ training only, was the Motricity Index (left side). The mean difference at the 24-month assessment was 14 points on the index scale, suggesting improvements had persisted after the end of treatment. The effect was described as ‘large’ although whether or not such change was clinically significant was not addressed, and as no details of the index were provided to enable an estimate to be made. Neglect per se (measured using the BIT, the ‘Comb and Razor’ test, and the Landmark task) showed no significant change. The authors concluded that the limb activation training resulted in increased attention to the left, which would have increased the probability of left-sided movement. This being the case, significantly improved scores on the neglect tests might have been expected, but were not found. Possible reasons for such an anomaly were not discussed. Perhaps limb activation training did not improve performance in the tasks used to assess neglect because such tasks were functionally dissimilar and did not require the left limb to be used. However, reductions in neglect following limb activation training have been found previously in single case experiments by Robertson and colleagues. It may be that individual positive responses may have occurred but would be obscured during data analysis by group.

Previous work by Robertson and North (1993) had shown that passive (left finger), as opposed to active left limb movement did not ameliorate neglect, however some more recent studies (Eskes, Butler, McDonald, Harrison & Phillips, 2003; Frassinetti, Rossi & Ladavas, 2001; Ladavas, Berti, Ruozzi & Barboni, 1997) have reported that neglect can be reduced by passive movement of the left upper limb. Frassinetti and colleagues (2001), in a well-controlled study, used eight patients with stroke and left-sided visual neglect, only one of whom was able to use his left arm, all having proprioceptive deficits in the distal joints, but preserved position sense for proximal left upper limb joints. Patients were between one and 30 months post-stroke, and between 55 and 79 years of age. Neglect in different experimental conditions was assessed using an object naming task, an object cancellation task, and line bisection, all performed in both near and far space (using a light pen for pointing and a stick for reaching). Passive movement of the limb was achieved using a mechanical apparatus which provided abduction and adduction of the shoulder. Patients performed each of the two assessment tasks, in a total of 14 conditions, always starting with baseline (arms resting on legs), and including passive movement of each arm, and naming of, pointing to, and reaching objects in near space, or projected onto a screen for far space. Conditions were similar for the line bisection task. Results demonstrated that left neglect was significantly reduced, in both near and far space, in all patients, and for all tasks, but only during passive left limb movement (compared with all other conditions), whether or not the right limb was concurrently actively moving during cancellation and line bisection tasks. Frassinetti and colleagues surmised that the effect may not have been shown by Robertson and North's study (1993) as the passive finger movement used may have been too weak to overcome competition from concurrent right limb movement. They suggest that the passive movement in their study involved a more complex movement, and was sufficiently strong to compete with active right limb movements occurring during reaching and pointing responses. This more complex movement, which involved the elbow and shoulder joints, and arm and forearm muscles, would have provided a large amount of proprioceptive input from skin, muscle spindle and Golgi tendon organs, which relays to and activates the contralateral somatosensory areas in the posterior parietal cortex. Such stimulation, the authors argue, would assist in the building of a unitary representation of space which in turn modulates neglect. General increase in arousal during passive movement was not considered to be an explanation, as similar right passive limb movement did not produce a treatment effect. This study demonstrated reduction of neglect only during stimulation, and further studies are needed to discover whether such passive activation would have a longer lasting effect on neglect, and if any generalization to improvements in daily living activities might also occur. If so, this would be a promising technique indeed, as it would be easy to apply in the clinical situation, and be appropriate for the many patients who have no active movement in their affected arms. Repetition using passive movement to the lower limb would also be of value. The patients in the study by Frassinetti and colleagues (2001) all had preserved proximal upper limb position sense. Repeat studies may be necessary to investigate whether or not the same results would obtain in a patient sample with loss of such position sense on the affected side.

In a further study (Eskes et al., 2003), both passive and active limb movements involving the left hand were found to reduce left neglect, assessed by detection of verbally reported letter targets (improvement of 17% on left sided but not right-sided detection). However, the effects were only measured during left limb activity (electrical stimulation to produce ‘passive’ finger extension, or active ‘button press’). Although there was a control (no movement) group, which improved upon the study by Ladavas and colleagues (1997), the lack of a control group using comparable right-sided limb movement means that effects could have been due to increased general arousal due to stimulation. Furthermore, the small group size (the same subjects were in each of the three groups, but only three able to participate in the active movement group, eight in the passive movement group, and all nine patients in the control) limits generalizability of findings. The underlying mechanism for the effect was considered to be related to proprioceptive input rather than active motor output, as passive movement also produced an effect. However, use of an electrical stimulus would have provided a sensory stimulus in addition to the proprioceptive stimulation occurring during the elicited passive movement, making it difficult to compare findings with other studies who used different methods of producing passive movement.

Whether or not any effect of passive movement upon neglect would be maintained post limb activation, or have any functional significance in everyday activity requires further investigation, as neither factor was assessed by the studies of Ladavas et al. (1997), Frassinetti et al. (2001) or Eskes et al. (2003). Furthermore, such studies require replication with larger samples and better control. However, such an approach could have clear therapeutic application, being simple to use, and of particular value for the many patients unable to actively move their left arm.

3.4.3 Sensory stimulation strategies

Prada and Tallis (1995) (see section 3.2.5) found that tactile cueing, in an attempt to increase use of the affected limb and increase awareness of neglected hemispace, using electrical stimulation (contingent upon movement of the unaffected side) of the affected hand, reduced neglect. Subsequent research (Yates, Bowen, Mukhtar, Hill & Tallis, 2000) using the stimulator and stimulation dose used by Prada and Tallis (1995) failed to demonstrate any effect of this method upon neglect. This study used one 89 year-old patient, with left visual neglect, and an ABAB design, each phase lasting one month. Both Star Cancellation and Menu Reading improved over the four months, irrespective of whether stimulation was provided or not. The BTT scores were ‘erratic’, and there was wide variation of all scores during each phase, therefore no statistical analysis was performed, and conclusions were drawn based solely upon visual inspection of line graphs. The authors noted that the patient improved markedly over the course of the study in the use of her left arm in activities of daily living, although this was a subjective observation.

Yates et al. (2000) considered that one reason for their failure to reduce neglect may have been due to the lack of active participation by the patient, who was a passive recipient of the therapy. Indeed, Robertson and Murre (1999) argue that the individual’s active involvement in rehabilitation is essential. Therefore, the study by Yates et al. (2000) was repeated and refined by Wenman and colleagues (2003) by combining the tactile electrical stimulation, delivered to the affected hand and contingent upon movement of the unaffected hand, with self-instructional training (previously described by Robertson et al. (1995): see section 3.2.3) used to encourage the patient to engage in simple activities involving visual search to the left, and manual activity using the affected limb in left space. A single case experimental design was used, and included two male patients, aged 43 and 70, with right brain damage (20 and 28 weeks post-stroke respectively) and left neglect. The study consisted of 12 phases (six treatment and six no treatment), administered in random order. Neglect was assessed using both impairment (SCT and LB) and activity level (BTT and Menu Reading) measures, three times per phase, and function measured at the start and end of the whole trial using the BI. One patient did show gradual improvement over time on Star Cancellation and Menu Reading, however no reduction in neglect specifically tied to treatment phases was found for either patient, neither were there any significant changes to the Barthel scores. Performance of both patients was very variable within each phase, making the fitting of regression lines difficult. The collection of more than three data points per phase would have made analysis of trends within each phase and comparison between phases less problematic, and increased the statistical power to detect small changes in performance. The authors concede that neither patient complied fully with the intended treatment schedule, although activity between phases was still comparable.

Previous work on the effectiveness of posterior neck muscle vibration had only measured neglect performance during stimulation (Karnath et al., 1993; see section 3.2.5). However, a recent study (Schindler, Kerkhoff, Karnath, Keller & Goldenberg, 2002) has demonstrated beneficial effects that generalized beyond the tasks practiced and lead to longer lasting improvements. After a three-week baseline, which established stability of all outcome measures, 20 patients, on average five months post-stroke, with unilateral visuo-spatial neglect were given visual exploration training using a computer for 30 weekday sessions each lasting 40 minutes. For the first 15 sessions, half the patients had their posterior neck muscles on the contralesional side stimulated with a vibrating disc while they were doing the training programme; the other half had visual exploration training only. After that, the groups swapped treatments for the next

15 sessions. Perception of midline and exploration deficits in both visual and tactile modalities were tested. In addition, patients were assessed on a reading task and their carers were given a questionnaire to rate incidence of everyday problems relating to neglect. Reduction in symptoms of neglect was achieved in both the trained visual and untrained tactile exploration mode after training combined with neck vibration. Reading performance improved and the incidence of everyday problems also reduced. The improvement was still evident two months after the completion of treatment. In contrast visual exploration training alone resulted in only small benefits in visual exploration and there was no transfer to other tasks. The neck vibration treatment would be inexpensive and easy to apply in the clinical situation, could be used as an adjunct to rehabilitation activities, and does not require patients to have awareness of their condition. Nevertheless, application of the vibration would require substantial trained personnel and time resources. Patients were, on average younger (mean age 48 years) than the typical stroke population. This study would warrant replication using a larger sample of elderly patients to allow better generalizability to a more typical stroke population.

The explanation of the observed effects of neck vibration, that stimulation influences cortical structures which are able to synthesise afferent inputs to build correct egocentric spatial representations, has also been used to explain the therapeutic effects of other sensory stimulation strategies, including vestibular stimulation, and the adaptive effect of prism glasses (also see section 3.2.5). One problem with vestibular stimulation is that the caloric irrigation used involves some patient discomfort, and induces nystagmus. Rorsman, Magnusson and Johansson (1999) used vestibular galvanic stimulation, which does not produce discomfort. Using elderly stroke patients, with right brain damage and visuo-spatial neglect, they found reductions in neglect in the treatment group (n=7) compared with a control (n=7). However, the effects were only measured during the application of the stimulation, and previous studies have failed to demonstrate any carry-over effects. The technique would be less appropriate for use by therapists in the clinical situation.

In contrast to the direct manipulation of sensory input by various forms of stimulation, Rossetti and colleagues (1998) investigated the adaptive after-effects of wearing prism glasses following a short visuo-motor adaptation period (see section 3.2.5). Since their first report of the reduction of neglect, lasting up to two hours post-treatment, produced by this adaptive effect, recent research has repeated the findings (Farne, Rossetti, Toniolo & Ladavas, 2002) and additionally found that reductions in neglect were maintained at 5-week follow-up (Frassinetti, Angeli, Meneghello, Avanzi & Ladavas, 2002). Farne and co-workers (2002) used a single session of prismatic adaptation to a standard pointing task lasting 5-7 minutes. The group consisted of six patients, aged 50-85 years, between two and eight months post-stroke. The results showed that neglect was reduced by around 25% in a wide range of tests for visuo-spatial neglect, including reading, and that the effect lasted at least 24 hours. The effect was not maintained at one-week follow-up, and neglect measures had, by then, returned to baseline. This provides some indication that the therapeutic effect was not due to spontaneous recovery. Furthermore, a second single exposure to prisms, given after the one-week follow-up, produced similar reductions in neglect coincident with the exposure, in a sub-group of four patients. Inclusion of a control group would have strengthened the conclusions. Frassinetti et al. (2002) found the adaptive effect upon neglect, in standard and behavioural tests and in all spatial domains, was maintained for up to five weeks in a group of six patients with right brain damage and left visuo-spatial neglect, mean age 64 years, compared with a matched control group. However, the exposure was much more intense than the single exposures used in previous studies, and patients received the treatment twice daily over a two week period. Any effect upon activities of daily living was not assessed, and, although no improvement in motor function was found, this was only assessed in two patients in the experimental group. In terms of the effect of prism adaptation upon functional ability, a previous study (Tilikete et al., 2001) did find a reduction of postural imbalance in a group of five stroke patients with right brain damage following brief (3 minute) prism adaptation which deviated the visual field to the right. Postural imbalance was assessed by measuring the lateral displacement of the centre of pressure between the two feet during quiet standing. No effect was found in the five control patients or the five who used leftward prism adaptation. Whether or not the demonstrated significant shift of the centre of pressure to a more central position, in the rightward deviating prism group, carried over to an improved functional balance during standing and walking was not investigated. Advantages of this prism technique are that it involves a relatively short period of patient training, does not require the patient to be aware of their neglect, and could be suitable for application in the clinical situation.

3.4.4 Other approaches

Encouraging patients to self-cue to look to the left has been incorporated into visual imagery approaches (see section 3.2.7) using the ‘Lighthouse Strategy’ (Niemeier, 1998; Niemeier, Cifu & Kishore, 2001). Niemeier (1998) first used this idea, in which patients are asked to imagine their eyes as horizontal-sweeping beams of a lighthouse, and subsequently cued (by visual and verbal reminders) to use this image during functional and therapy training tasks. A group of 16 elderly stroke patients, with left or right visuo-spatial neglect, attending as day patients, showed significant improvement in a verbal cancellation task, compared with a matched control group (only three in each group had right neglect). Niemeier subjectively reported that the treatment group were described by carers as being safer during ambulation. However, functional ability was not formally assessed. The 'Lighthouse Strategy' was used with the experimental group during their stay on a rehabilitation unit, in conjunction with normal therapy, while the control group received just normal therapy. It was not clear whether the length of out-patient rehabilitation, hence 'dosage' of treatment provided, was comparable between groups, nor whether neglect severity was equivalent between groups at the outset.

Niemeier et al. (2001) extended their previous work to in-patients and found, in a pre-post test design, that the treated group performed significantly better than the waiting list controls in a verbal cancellation task, also functional tasks of route finding whilst walking or using a wheelchair. Groups were small, ten in one, nine in the other, and consisted of a mixture of stroke patients and patients with traumatic brain injury, with right or left sided lesions. No evidence was provided that groups were comparable on neglect severity or functional ability at the outset. Finally, although the average length of patient stay was three weeks, during which time three 30-minute sessions of training in use of the 'Lighthouse Strategy' were given, there was no indication that all patients in the treatment group received comparable amounts of therapy, and presumably the waiting list control group received no therapy. Assessments were not blinded. In view of the methodological limitations of this study, the conclusions must be viewed with some caution.

Functional change was also assessed in a later study (Niemeier, 2002) in a single patient with left neglect who was taught, over three sessions, to use the 'Lighthouse Strategy' during all activities during her stay as an in-patient. Carers and staff encouraged the patient to use the strategy. After four weeks of rehabilitation, the patient had improved on performance on a verbal cancellation task, and a range of self-care activities, progressing from requiring maximal assistance to a 'modified independent level' assessed using a standardised functional test. Assessment was not blinded. Progress could also be due to spontaneous recovery, as the patient was only two weeks post-stroke. Furthermore, a single case design might have established baseline stability of performance, not possible with the pre-post test design used.

This mental imagery strategy may increase the patient's awareness of their neglect, which may be an important factor in helping patients to compensate for their neglect during activities of daily living (Tham, Ginsburg, Fisher & Tegner, 2001). It would also require that the patient is cognitively able to successfully use the strategy, also that carers, and ward staff are consistent in reinforcing the strategy with the patient. Although the 'Lighthouse Strategy' may well be helpful in the clinical management of neglect, further studies are required to overcome the methodological limitations of the existing research, described above.

A new technique has been described by Ramachandran et al. (1999) proposing the use of a mirror to reduce neglect. They found that twelve patients with left visual neglect responded in one of two ways when required to reach for an object on their left side while watching it's reflection in a mirror positioned vertically on their right side in the sagittal plane. The first group reached correctly into left space, and seemed to be helped by the reflected image on their right, which they were able to perceive; the second group reached into the mirror itself trying to grasp the reflection. The authors speculated that, in some patients, use of a mirror might be therapeutically useful in treating neglect; this interesting idea requires experimental testing.

Visuo-motor feedback training using long metal rods was used by Robertson, Nico and Hood (1997b) to examine the effects of proprioceptive feedback on neglect. They found that neglect reduced in the short term when subjects (n=16) had to grip the perceived centre of the rod than when they had merely to point to the perceived centre. The technique was used by Harvey, Hood, North and Robertson (2003) to assess whether any longer term benefits might be obtained. Fourteen patients with left neglect were pseudorandomly allocated to treatment or control groups. No difference was found between groups on parameters of interest including neglect severity. All patients were at least 5 months post-stroke, and so had chronic neglect. The treatment regime involved the patients practicing, using three wooden rods 50, 75 and 100cm in length, first over a 3-day period with the experimenter present, then independently for 10 days at home, patients performing a 'sequence of nine-rod lifts four or eight times daily'. Patients had to reach, lift and balance the rods at the centre until 'satisfied with the judged central grip'. The control patients merely reached and lifted the right side of the rod only so received visual but not additional proprioceptive feedback. Significant improvements were found for the treatment group compared with controls for 46% of the battery of neglect tests (the conventional sub-tests of the BIT, but not the behavioural sub-tests or the Balloons Test) given at 1-month follow-up. Unfortunately, improvements did not generalize to everyday functional ability assessed using the BI and patient and carer neglect rating scores. The technique is simple to use and could easily be incorporated into a rehabilitation programme for patients with neglect.

3.4.5 Recent reviews of therapy

Recent reviews of the rehabilitation of neglect support various treatment approaches (Bowen & Cross, 2000; Diamond, 2001; Freeman, 2000; Manly, 2002; Pierce & Buxbaum, 2002; Plummer, Morris & Dunai, 2001). Bowen and Cross (2000) and Pierce and Buxbaum (2002) both list the methodological shortcomings of many studies, including factors such as inadequate control for spontaneous recovery, lack of blinding, and small sample size. They emphasise the need to assess whether training generalizes to functional tasks, and how long any positive effects might last, a point also made by Manly (2002). There is a need to tailor treatment of neglect to the individual patient, taking into account the type of neglect that is manifested (Pierce & Buxbaum, 2002; Plummer et al., 2001). Diamond (2001) considers that the use of video feedback during therapy, training in visual imagery, and eye-patching techniques are newer strategies that may be clinically effective. Freeman (2000) also supports the use of partial visual occlusion, as used in eye-patching or the use of hemifield goggles, and suggests this could be usefully combined with limb activation strategies. She considers that such techniques would be easy to incorporate into a home treatment programme. Combination of techniques is also advocated by Plummer et al. (2001), who suggest that incorporating the use of visual cues on the affected side with activation of the affected limb, might be a beneficial approach.

A Cochrane systematic review and meta-analysis of 15 randomised and controlled trials found some evidence that cognitive rehabilitation resulted in improvements on impairment level measures (Bowen, Lincoln & Dewey, 2003). However, the effect of such rehabilitation at the level of functional ability was unclear. The review concluded that there was "sufficiently compelling evidence to encourage further trials of cognitive rehabilitation for neglect".

3.4.6 Summary of recent studies

Further evidence has been provided of the value of using visual scanning and cueing strategies, left limb activation, and some sensory stimulation techniques, notably posterior neck muscle vibration, and the adaptive effect of prism glasses, in reducing neglect and improving some aspects of everyday activity. However, these latter two strategies do require special equipment, and, although showing some promise, they may not be suitable for some elderly patients who may not be able to tolerate the necessary treatment regimes. More research is required into the longer term and carry-over effects of both more intense prism adaptation, neck muscle vibration, and the effects of passive movement in larger and more representative samples of elderly stroke patients. However, all studies reviewed have some methodological shortcomings, and so their conclusions must still be viewed with caution. In the light of recent studies, techniques that seem to hold most promise, in terms of their clinical utility, positive effect upon hemineglect and function, and some evidence of longer term carry-over, include the use of scanning and cueing strategies and contralesional limb activation approaches. Such techniques should, for best effect, be incorporated into therapy sessions and the everyday functional activities performed by the patient, to maximise carry-over. These strategies could be easily reinforced throughout the day, by carers and members of the multidisciplinary team, to maximise training intensity. Use of mental imagery may also be therapeutically effective, and could easily be incorporated into scanning and cueing, and limb activation approaches. Finally, treatment may need to be individually designed and focussed upon the type(s) of neglect manifested by each patient.

3.5 Implications for design of experimental study presented in Chapter 7

Based upon these conclusions, a series of single case experimental studies were designed, for use with elderly stroke patients suffering from left unilateral visuo-spatial hemineglect, utilising either scanning and cueing (incorporating the use of mental imagery), or contralesional limb activation approaches, to investigate whether such approaches would reduce neglect and improve function. This study is reported in Chapter 7.

CHAPTER 4

IS NEGLECT NEGLECTED BY THE PHYSIOTHERAPIST? A QUESTIONNAIRE SURVEY.

Hemineglect is associated with poor functional outcome in stroke patients. Physiotherapists need to effectively assess and treat this problem. Knowledge about current clinical practice in this area is necessary to stimulate discussion and to enhance rehabilitation research. A survey was undertaken to gather information about these issues, using a sample of 250 members of the neurology Clinical Interest Group, Association of Chartered Physiotherapists Interested in Neurology (ACPIN). A retrospective study critique is also provided.

This chapter is presented as a published paper:

Bailey, M.J., Mears, J., & Riddoch, J. (1998). Is neglect neglected by the physiotherapist? *British Journal of Therapy and Rehabilitation, 5* (11), 567-572.

The study conception, questionnaire design, and data analysis, and the writing of the paper were undertaken by M.J.Bailey. Data were collected by J.Mears as part of her undergraduate project.

The information about the pilot study, and details of the content of the Questionnaire were not included in the published paper due to constraints of word limit, and are therefore included below. The actual questionnaire used is in Appendix B.

4.1 Pilot Study

A pilot questionnaire consisting of 11 main questions was circulated to eight physiotherapists, working with stroke patients in the Stoke-on-Trent area, who did not participate in the main study. The aim of the questionnaire was (i) to identify the tests used (by physiotherapists, and other health care professionals) to identify hemineglect in stroke patients, and (ii) to investigate the strategies and techniques a physiotherapist might choose to use in their rehabilitation of hemineglect in stroke patients. Tests included in the questionnaire to identify hemineglect had been previously identified from the literature as being commonly used in the clinical situation, and likely to be reasonably familiar to physiotherapists. Strategies and techniques included in the questionnaire had been identified from the literature as being therapeutically useful. However, some strategies included, such as the use of ice, massage, use of inflatable splints, positioning of objects (such as the patient's locker) on the patient's affected side, have not been supported by research, but are commonly used in clinical practice.

Reponses to the pilot questionnaire indicated that minor modifications to the wording were required to avoid ambiguity and enhance clarity. The revised questionnaire used in the study is presented in Appendix B.

4.2 The Questionnaire

Question 1 enabled respondents not currently working with, or not recently working with stroke patients to be excluded from analysis. Questions 2-5 gathered demographic information about respondents, including grade, years since qualification, and which qualifications were held, and location of the rehabilitation setting where physiotherapists worked with stroke patients.

Questions 6-11 related to assessment and treatment strategies used. Question 6a asked whether hemineglect was or was not routinely identified by at least one member of the multi-disciplinary team. Question 6b listed six multi-disciplinary team members (doctor, occupational therapist, clinical psychologist, nurse, speech and language therapist, and ‘other’) and asked respondents to indicate all those who would be likely to identify hemineglect in patients. Question 6c asked if the professionals identified used a specific test for hemineglect, and Question 6d asked which tests were used. Question 7a asked if the respondents identified the presence of hemineglect in patients, and asked if this was done by observation of clinical manifestations, or use of specific tests, or both. Question 7b listed a choice of six commonly used tests for hemineglect and asked respondents to indicate which they used, and a seventh option of ‘other’ was also included, to be specified by the respondent. The tests included were the BIT (Wilson et al, 1987a), the SCT (from the BIT), letter or line cancellation tests, figure or picture copying, drawing tests (e.g. ‘draw a clock’ or ‘draw a daisy’), tests for extinction to bilateral simultaneous stimulation in tactile or visual modes, and ‘other’. Question 8a asked whether or not specific treatment strategies were used, for a patient presenting with hemineglect. Question 8b listed 26 strategies which might be used during rehabilitation specifically aimed at ameliorating hemineglect. Respondents were asked to indicate all that they used in clinical practice. Strategies included minimising visual environmental stimuli on the non-affected side, provision of visual feedback using mirrors, maximising sensory awareness to the affected side by stimulation (by touch, voice, ice, weight-bearing, encouraging use of the affected limb, and other listed specific stimulation techniques). Specific stimulation techniques including vestibular, optokinetc, mechanical, electrical, visual and auditory stimulation, also the use of eye-patching, hemifield goggles, and binocular prisms.

Question 9 asked respondents to identify whether they had gained knowledge of hemineglect and its treatment at undergraduate or postgraduate level, and, if gained post-registration, whether this had been via in-service training, courses and conferences, other colleagues, or self-directed study. Question 10 was an open question asking which, if any, of the listed treatment techniques were found by respondents to be particularly useful. The final Question 11 was another open question that asked if respondents used any other treatment strategies or techniques not previously listed.

The remainder of this chapter presents the paper exactly as it was published, but using numbered sections for consistency of presentation. Raw data are presented in Appendix C.

4.3 Introduction

Some 32% of stroke patients, (usually those with right sided brain damage), may present with symptoms of hemineglect affecting their ability to benefit maximally from therapeutic rehabilitation (Blanc-Garin, 1994; Kalra et al., 1997; Paolucci et al.,1996b). Hemineglect has been defined as:

"A failure to report, respond or orient to novel or meaningful stimuli presented contralaterally to a brain lesion, and not attributable to primary sensory or motor defects". Heilman et al. (1993, p.276)

Hemineglect is considered to be a disorder of attention (Kinsbourne, 1994). If a stroke patient cannot sustain attention for more than a short period, they may also be unable to attend to relevant proprioceptive and other inputs to relearn motor and other skills (Robertson et al., 1998a). Therefore, attentional deficits such as hemineglect should routinely be assessed to enable appropriate therapy to be given. Physiotherapists working with neurological patients should be able to clinically identify and treat attentional disorders (Ashburn, 1998).

4.4 Is neglect neglected?

Physical therapy for stroke patients tends to focus upon physical problems, although psychological and social problems may also have significant effects upon rehabilitation outcome (Riddoch, Humphreys & Bateman, 1995b; Stachura, 1994). Laidler (1994) and Carr and Shepherd (1996) both acknowledge the need for therapy which incorporates treatment to reduce cognitive deficits such as neglect.

Strategies suggested include general advice regarding 'accurate limb positioning to stimulate spatial awareness' (Laidler, 1994), use of everyday activities to reinforce attention to the affected (contralesional) side (Laidler, 1994), and encouraging movement of and weight bearing through the affected side Davies (1985). Carr and Shepherd (1996) also advised that therapists and other staff should approach and speak to the patient from their affected side. No evidence is provided for the efficacy of such strategies in reducing neglect, or improving functional ability. However, assessment of neglect and therapy to reduce neglect is well documented in the literature (Chatterjee, 1995; Lin, 1995; Roden, 1997).

4.5 Purpose of the survey.

There is increasing pressure for therapists to justify their interventions and to use evidence based practice (Partridge, 1996). To enhance research into the assessment and rehabilitation of hemineglect, knowledge about current clinical practice regarding the assessment and treatment of hemineglect in stroke patients by physiotherapists was needed. The study outlined in this article was designed to gather such information.

4.6 Method

University Ethical Committee approval (Appendix V) was obtained before the study. A questionnaire was designed by the authors to reflect the study purpose. Following piloting and subsequent revision, the questionnaire was sent to 250 randomly selected (by computer from the full membership list) members of the Association of Chartered Physiotherapists Interested in Neurology (ACPIN) throughout the UK, who had previously consented to participate in survey research.

A reminder questionnaire was sent to non-respondents 2 months after the first mailing. Of those who replied, those members who were not currently working with adult stroke patients, or who had not worked with this patient group during the last year, were excluded from analysis. The questionnaire was divided into two sections. The first, with five items, was to ascertain professional details about the respondent. The second, with eleven items, was to obtain information regarding assessment and treatment of hemineglect. In relation to the assessment, questions asked which members of the team identified neglect and how it was assessed. In relation to treatment, respondents were asked to choose, from a comprehensive list, which strategies they used to specifically reduce neglect. In addition, respondents were asked how they had learned about neglect. There were fourteen closed, and two open questions to allow respondents some flexibility in their replies.

4.7 Results.

The two mailings yielded a final total response rate of 91%. Of these 227 responses, 60 were excluded from analysis as they did not meet the inclusion criteria. Thus a total of 167 questionnaires (67%) were analysed.

4.7.1 Professional details of respondents and location for physiotherapy treatment.

Occupational grades of respondents are shown in Figure 4.1. All physiotherapists had been qualified for at least 6 years, with 84% being qualified for longer than 17 years. Of the sample, 10% possessed a first degree, 6% also had a higher degree. Stroke patients were treated in a wide variety of settings. During the acute phase of stroke, 70% of physiotherapy treatment took place on general medical wards or elderly care units, with around 30% of physiotherapy treatments equally divided between hospital stroke units or community settings, mostly via domicillary visits.

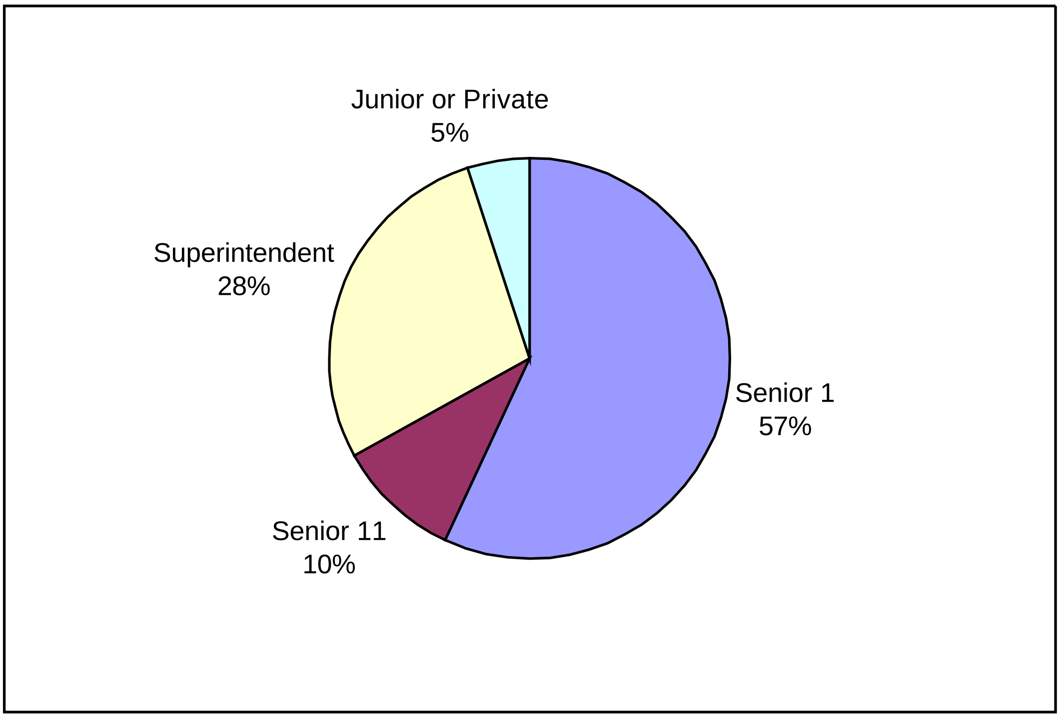


Figure 4.1 Professional Grade of Respondents

Location for physiotherapy treatment during the rehabilitation phase are shown in Figure 4.2.

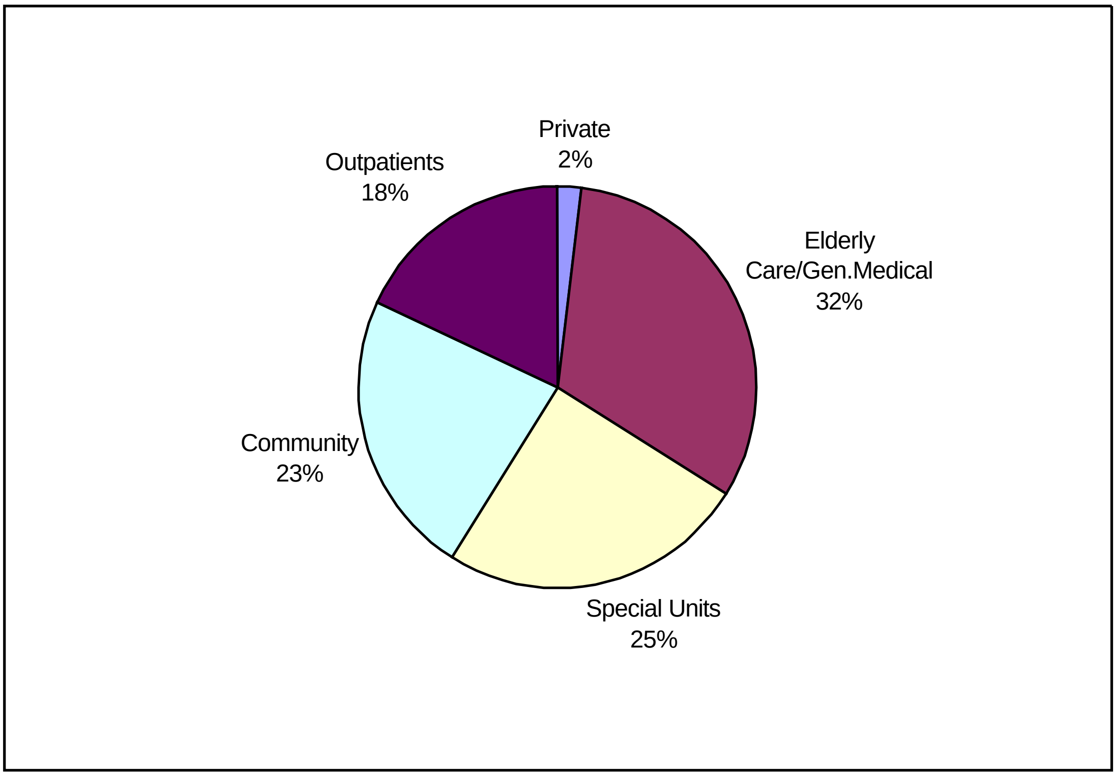


Figure 4.2 Rehabilitation Phase: Locations for Physiotherapy Treatment

4.7.2 Assessment of hemineglect.

Eighty seven per cent of respondents indicated that testing for neglect was carried out by at least one member of the multi-disciplinary team (MDT) during initial patient assessment, the occupational therapist being most frequently identified (30%) as testing for neglect, followed by the doctor (24%), physiotherapist (15%), speech therapist (13%), nurse (11%) and clinical psychologist (5%) in descending order of frequency (2% non response). Of the respondents, 47% stated that a specific test was used, 53% said either that a specific test was not used, or they did not know what was used. When known, specific tests identified as being used by a member of the team (other than the physiotherapist) included: figure or picture copying or drawing (13%), the Rivermead Perceptual Assessment Battery (RPAB) or the Behavioural Inattention Test (BIT) (14%), the Star Cancellation Test (SCT), which is a sub-test of the BIT (8%), the use of letter or line cancellation or line bisection tests (6%). The remaining 6% indicated the use of tests of bilateral simultaneous stimulation (extinction tests).

The vast majority (98%) of respondents said that they themselves identified the presence of hemineglect during routine physiotherapy assessment of the patient, 40% by observation of clinical manifestation of neglect alone (specific examples were not requested), 60% by a combination of observation and specific testing. Of those who used a specific test, drawing and figure or picture copying (e.g. a daisy, clock or house) were most frequently used (56%) followed by bilateral simultaneous stimulation tests for extinction, in tactile or visual mode (20%), then letter, line or star cancellation tests (19%), and finally the BIT (5%). Sixty four per cent of respondents used more than either two or three tests in combination. When a single test was used, it was most commonly either a drawing or copying test, or a bilateral simultaneous stimulation test.

4.7.3 Treatment strategies used to reduce hemineglect

Eighty nine per cent of responders said that they used treatment strategies specifically aimed at reducing hemineglect in stroke patients (11% non response). All physiotherapists who used specific strategies encouraged the patient to look towards, and to touch the affected (neglected) side. These, plus other strategies are listed in Table 4.1 in order of frequency of response for each listed strategy. Strategies commonly used by more than half the respondents included ‘Sitting on/communicating with the patient from /the affected side'; 'Increasing sensory input to the affected side using weight-bearing, touch and stroking'; 'Encouraging the patient to transfer towards the affected side'; 'Encouraging the patient to visually search into neglected hemispace'; 'Encouraging maximum use/movement of affected or unaffected limbs within neglected hemispace'; 'Positioning bedside locker, TV etc. on affected side'; 'Minimisation of environmental stimuli to the unaffected side'; and 'Using a mirror to provide visual feedback'. Around one-third of respondents used visual cues and visual scanning to draw attention to the neglected side, and used inflatable air splints on the affected limbs. Fewer respondents used patient self-verbalisation (24.6%), stimulation using ice over the affected side (16.8%), eye-patching (13.8%) or visual feedback via video recorder (10.2%). A minority (6% or less) used vestibular, mechanical, electrical, optokinetic or auditory stimulation techniques. Also included in Table 4.1 is the actual number of responses to the open question "Which of the listed strategies do you find particularly useful?"

A significant positive relationship ($r=.87$, $p<.01$) was found between percentage frequency of strategies used and their perceived usefulness. In response to the open question "Do you use any other treatment strategies not listed above?" only 25% responded. Of these, the only strategy which was not a variation on those already listed was the comment by 9% of respondents that "education of patients and carers could be considered as a treatment strategy". Knowledge about hemineglect and its treatment had largely been gained post-qualification via in-service training, courses and conferences, by talking to colleagues, and by self-directed study, all in equal measure. Only 39% had gained this knowledge at pre-registration or undergraduate level.

Table 4.1

Treatment strategies aimed at reducing hemineglect, in order of frequency of response.

Rank Order	Treatment Strategy	Percent-age response for strategies used	Number of respondents who found the strategy 'particularly useful'
1	Encouraging the patient to look towards the affected side	100	56
2	Encouraging the patient to touch the affected side	100	62
3	Sitting on/communicating with the patient from /the affected side	92.8	29
4	Increasing sensory input to the affected side using weight-bearing	88	53
5	Increasing sensory input to the affected side using touching/stroking	85.6	56
6	Encouraging the patient to transfer towards the affected side	83.8	53
7	Encouraging the patient to visually search into neglected hemispace	82.6	52
8	Encouraging maximum use/movement of affected or unaffected limbs within neglected hemispace	76.6	20
9	Positioning bedside locker, TV etc. on affected side	75.4	19
10	Minimisation of environmental stimuli to the unaffected side	59.9	13
11	Using a mirror to provide visual feedback	54.5	9
12	Provision of visually stimulating 'cues' or 'anchors' in neglected hemispace	36.5	7
13	Use of specific scanning strategies	34	20
14	Application of inflatable air splints on the affected limbs	31	11
15	Encouraging the patient to verbalise during task activity	24.6	13
16	Increasing sensory input to the affected side using ice	16.8	29
17	Using an eye patch over the non-affected side	13.8	1
18	Using a video monitor to provide visual feedback	10.2	3
19=	Vestibular stimulation to affected side	6	0
19=	Mechanical muscle vibration on affected side	6	2
21	Use of binocular prisms	3.6	0
22	Using a buzzer to direct attention to affected side	2.9	1
23=	Transcutaneous Electrical Nerve Stimulation (TENS) to affected side	0.6	0
23=	Optokinetic stimulation	0.6	0
23=	Music (non-verbal) played through headphones on neglected side	0.6	0
26	Use of hemi-field goggles to reduce visual input to contralesional hemisphere	0	0

4.8 Discussion

The response rate was high, however, because of the sampling procedure, (only members of ACPIN were sampled), the results cannot be generalized to all physiotherapists, but could perhaps be a fair reflection of current practice by experienced senior physiotherapists in the area of stroke rehabilitation.

4.8.1 Assessment of hemineglect

The finding that 13% of respondents stated that neglect was not routinely identified by any member of the MDT during initial clinical assessment is surprising, bearing in mind its potential impact on rehabilitation progress and final outcome (Blanc-Garin, 1994). However, 98% of respondents themselves assessed neglect during physiotherapy assessment, although 40% of these did not use specific tests. Reliance on clinical observation only is subjective, and may fail to detect neglect in patients without obvious clinical manifestations of the disorder. Changes in neglect behaviour may not be adequately monitored by observation alone and may lack objectivity.

Of those physiotherapists who did use specific tests, those most commonly used were drawing, figure and picture copying. Scoring of such testing methods is subjective, not particularly sensitive, and abnormalities in performance have also been found with other cognitive deficits, making such tests less specific (Friedman, 1991). Extinction (reporting of left or right sided stimulation when presented separately, but only ipsilesional stimulus reported with bilateral simultaneous stimulation) may also be indicative of neglect (Feinberg, Haber & Stacey, 1990), and was used in testing by 20% of respondents. However, extinction phenomena may exist in the absence of neglect (Weinstein, 1994).

Nineteen per cent used cancellation tests, including the SCT. The SCT is a sub-test of the BIT (Wilson et al., 1987a), is easy and quick to administer, and has been found to be 70% sensitive (Halligan, Wilson & Cockburn, 1991). The use of a single test may underestimate the presence of neglect, and use of a test battery may be more useful. Only a 5% of respondents themselves used such a battery (the BIT), although batteries such as the RPAB and the BIT were more commonly used by other members of the multi-disciplinary team. Use of a battery rather than a single test may be more sensitive for the identification of neglect (Pizzamiglio et al., 1992b).

4.8.2 Treatment of hemineglect.

Treatment strategies used by between 25%-100% of respondents include those listed in rank order 1-15 (Table 4.1). These all have in common a general aim of drawing attention to the affected side by encouraging the patient to look towards and visually search towards the neglected side, to transfer towards that side, and to maximise movement of limbs on the affected side. Stimulation via touch, weight-bearing, visual feedback, and other environmental stimuli were also used.

These findings are not unexpected, and indeed there is some evidence of effectiveness for some of these strategies when used in a controlled and systematic manner, e.g. the use of visual or motor cues and verbal self-cueing to direct attention towards neglected hemispace (Lennon, 1992; Paolucci et al., 1996b; Riddoch et al., 1995a) and activation of limbs on the contralesional side (Robertson et al., 1998a). Unfortunately, the effects of visual scanning and cueing are disappointingly short term and ineffective in producing long term gains or generalization to tasks not originally trained using scanning and cueing (carry-over) (Halligan et al., 1992b).

Contralesional limb activation techniques, particularly when combined with strategies to improve general levels of attention and arousal (e.g. use of a buzzer), have been found to be effective in reducing neglect and improving everyday function (Robertson et al., 1998a). Incorporation of such techniques into activities of daily living has also been successful (Kalra et al., 1997). However, positioning the patient's locker, chair etc. on the affected side (ranked 9) has not been found effective (Loverro & Reding, 1988). Using video (ranked 18) rather than mirror (ranked 11) visual feedback of performance may be more helpful as the image of the neglected side will now appear on the video monitor screen on the patient's non-neglected side (Tham & Tegner, 1997). The effect of ice stimulation awaits research evidence (ranked 16).

Less commonly used strategies (listed 17, 19-21, 23-26 in rank order in Table 4.1) have all been found to significantly reduce neglect during or for a short time after application, but have only a transitory effect, and none have been shown to generalize to untrained tasks (Robertson, Halligan & Marshall, 1993). These various techniques (including optokinetic, auditory, and vestibular stimulation, and eye-patching, and use of prisms) were infrequently listed by respondents (0-14%). These techniques are relatively new, and require thorough evaluation to establish their clinical value. Cleaves and Inglis (1997) suggest that vestibular stimulation may be particularly useful. The infrequent appearance of such techniques in questionnaire responses may indicate either unfamiliarity with the relevant research literature, or a judgment as to their limitations.

4.8.3 Future Research

The questionnaire did not ask for details of how techniques listed were applied, and future studies could address this issue, as key factors in success of approaches may be use of a specific training focus (i.e. neglect, not perceptual problems in general) and high intensity of training, coupled with incorporation of training techniques into functional activity where possible (with the patient as active participant) to try and overcome problems with carry-over (Calvanio et al., 1993).

4.9 Conclusions

Assessment of neglect by physiotherapists in this study was the norm, although increased use of standardised testing would be of benefit to ensure objective data collection. Some techniques commonly used by respondents for the management of neglect in stroke patients are evidenced-based; however, other techniques used are not. Some less frequently used strategies have demonstrated efficacy in reducing neglect, albeit temporarily, and familiarity with details of these approaches may enhance available rehabilitation techniques, and stimulate further research in the clinical field to benefit the patient.

4.10 Retrospective study critique

Section 4.10 has been added to supplement and reflect upon the preceding paper, as the latter was published several years ago.

4.10.1 Rationale for the study

Physiotherapists are particularly involved in the physical rehabilitation of movement problems in stroke patients (Ashburn, 1997) and there may be failure to take account of factors other than physical problems (Riddoch et al, 1995b). Anderson and Lough (1986) argued for increased emphasis on neuropsychological factors in stroke rehabilitation. As cognitive impairments such as hemineglect occur frequently (sections 2.4 and 2.9.1) and may adversely impact upon functional outcome (sections 2.4 and 2.9.3), physiotherapists need to identify such deficits in order to modify treatment appropriately (Riddoch et al., 1995a). The need for assessment and rehabilitation of hemineglect are also addressed in the recommendations of the National Clinical Guidelines for Stroke (Royal College of Physicians, 2002; 2004). It is clearly important that physiotherapists are aware of and able to use appropriate clinical tests to identify the presence of hemineglect, and to implement effective treatment strategies and techniques that are evidence-based. To this end, there is firstly a need to establish current practice as a baseline from which to progress. This is the first study to investigate assessment and rehabilitation strategies used by physiotherapists, and thus contributes to the body of knowledge in this area.

4.10.2 Limitations of the study

Firstly, the sample was limited to ACPIN members, and as 95% of respondents were in senior positions, it might reasonably be argued that this group were likely to be the more aware and knowledgeable about hemineglect than a larger sample including all levels of seniority and experience. Such a sample could usefully form the basis of future surveys.

Respondents who used clinical observation to identify hemineglect (question 7b) could have been asked to describe behaviours they would consider to be indicative of hemineglect. The tests included in section 7c of the questionnaire were limited to tests for visuo-spatial hemineglect within reaching space. Future surveys might additionally request information about knowledge of the various manifestations of hemineglect and include questions about tests that might be used for these (section 2.5, 2.6 and 2.10). The BIT could be divided into its two components (conventional and behavioural sub-tests; Wilson et al, 1987). In relation to questions in section 8b, it was not possible to analyse the extent to which respondents used the listed strategies, in terms of dosage and timing, neither was it possible to investigate the precise manner in which some of the listed strategies or techniques (e.g. limb activation strategies, or use of visual cues) were applied. Additionally, no information was collected about the theoretical rationale which therapists considered to guide the choice of any techniques used. Finally, information was not requested relating to assessment and management of sustained attention or arousal, considered to be an important aspect of hemineglect by Robertson et al. (1995) (section 1.5.2). Question 10 (relating to the perceived utility of strategies used) could be modified to gain more in depth information. For example, which strategies were considered to be the most useful and why, and on what basis were they chosen? It is also acknowledged that, because this survey was undertaken a number of years ago, the clinical practice of physiotherapists may have since changed, and the findings may therefore be less representative of current practice.

4.10.3 Directions for future study

The survey did not address how the assessment or treatment techniques were applied, nor did it consider the assessment of the different manifestations of the neglect syndrome. There is some inherent difficulty in the use of questionnaires to obtain some of the detailed and in-depth information required to gain comprehensive insight into current practice of physiotherapists, in relation to the assessment and treatment of hemineglect in stroke. In particular, the clinical decision-making process in relation to assessment and treatment of hemineglect is difficult to uncover using a survey method. Therefore a focus group might be a more productive research design to use for future studies, to enable deeper exploration of these issues. Findings from such a series of groups could then be used as a basis for the improved design of a subsequent questionnaire survey. Indeed, qualitative research using focus groups to explore the clinical decision making process used by physiotherapists during assessment of unilateral neglect has recently been undertaken (Plummer, 2004). This Australian study (Plummer, 2004) revealed that there was considerable confusion about how to operationally define unilateral neglect. Experienced physiotherapists concentrated more upon identification of the presence and severity of neglect, rather than identifying specific types of neglect. However, these findings may not be directly transferable to a UK setting.

Finally, whichever assessment tools for hemineglect, for use in the standard clinical setting, are selected by physiotherapists, such tools need to be valid, accessible, inexpensive, and easy to use and interpret. Similarly, treatment strategies, as well as being supported by evidence of efficacy, need to be appropriate for clinical use, and not require expensive or complex equipment. These issues are considered throughout subsequent studies in this thesis.

CHAPTER 5

PRELIMINARY DEVELOPMENT OF AN EVERYDAY FUNCTIONAL TEST BATTERY FOR VISUO-SPATIAL HEMINEGLECT IN ELDERLY STROKE PATIENTS

Some bedside tests for the assessment of visuo-spatial neglect are discussed in relation to their ability to evaluate more functional aspects of neglect. A new test battery, The 'Everyday Test Battery' (ETB) consisting of seven tests, was designed using low-cost, easily available materials, and requiring no specialised equipment. The ETB, fully described here, was piloted with seventeen stroke patients, all with right-sided brain damage and visuo-spatial neglect. Validity, reliability and clinical utility of the ETB was investigated.

This study was presented as a poster at the British Geriatrics Society Spring Conference, Cardiff, April 2001. It was subsequently published as a refereed abstract (Appendix D).

Bailey, M., Riddoch, J. & Crome, P. 2001. Development of an everyday functional test battery for visuo-spatial hemineglect. ***Age and Ageing, 30,*** **Supplement 2, 65.**

Following publication, four more patients were recruited to the study, and this chapter reflects this increase.

5.1 Introduction

Visuo-spatial hemineglect is a perceptual problem commonly found post-stroke (Bailey et al., 2000), especially when there is damage to the territory supplied by the right middle cerebral artery (Mort et al., 2003). Visuo-spatial hemineglect can adversely affect the patient's ability to function normally in their environment (Paolucci et al., 1998) and its assessment is necessary to identify deficits, plan treatment and monitor progress. Presence of hemineglect is an important predictor of poor functional recovery (Jehkonen et al, 2000a).

5.2 Conventional 'bedside' tests for visuo-spatial hemineglect

5.2.1 Pencil-and-paper tasks

There is no one 'gold standard' test for visuo-spatial neglect. Many existing tests developed in the last decade for visual neglect have been based upon lateralized performance on various 'pencil-and-paper' tasks (Appelros et al., 2003). Such tests include cancellation, copying, drawing, and bisection tasks. Cancellation tests require the patient to cancel all targets consisting of shapes (e.g. lines, bells, stars) or letters positioned across an A4 sheet of paper. Omission of targets, particularly contralesionally, is indicative of neglect. Sensitivity of cancellation tasks can be manipulated by increasing the number of target items and by including distractor items that should not be cancelled. For example, the SCT, part of the 'conventional' sub-tests of the BIT (Wilson et al., 1987a) requires the patient to discriminate targets (e.g. small stars) from non-targets, added as background distractor items (e.g large stars, or letters). Line bisection is another commonly used task to assess for neglect.

When asked to bisect a horizontal line drawn on a sheet of paper, subjects with visuo-spatial neglect usually displace their mark to the right side of the true centre. Performance has been found to depend upon line length and position, with larger errors produced with longer lines and lines positioned further to the left (Koyama et al., 1997). However, Koyama and colleagues found that line length had little effect upon performance of patients with severe neglect. Furthermore, some patients with neglect have shown contralesional rather than ipsilesional deviations from the midpoint (Heilman et al., 2003). Comparison of cancellation versus bisection tasks for the assessment of visuo-spatial neglect has shown that cancellation tests were more sensitive for detecting neglect (Ferber and Karnath, 2001), and these authors emphasised that line bisection errors may result from factors other than neglect, such as which hand is used, or the presence of hemianopia. Additionally, Binder et al. (1992) point out that bisection involves a perceptual judgement to compare the relative lengths of each half of the line. As cancellation tasks require subjects to search an array of targets, cancellation and line bisection tasks may thus be assessing different aspects of the neglect syndrome, and this may also contribute to differential performance. Neither type of task reflects functionally realistic performance of patients with visuo-spatial neglect, although use of distractors in cancellation tasks may be helpful in discriminating between subjects with different neglect severity. This is because subjects with mild neglect, who may find all targets, and thus score normally on a cancellation test when no distractors are present, may find the task more attentionally demanding when having to discriminate between targets and distractors, and thus demonstrate an abnormal score.

Various copying and drawing tasks are also commonly used tests, and patients with visuo-spatial neglect may either fail to spontaneously draw left-sided features of a named object (e.g. man, house, daisy), or fail to copy the left-sided features of a drawing presented to them. However, as Heilman et al. (2003) point out, problems with spontaneous drawing may also be due to constructional apraxia, and may not be uniquely related to neglect. They suggest that an alternative test might be to ask the patient to place numbers on a clock face (drawing of a circle). Patients with neglect may either write numbers only on the right side of the clock face, or may place all 12 numbers on that side. However, both copying and drawing tasks involve subjectivity in interpretation and scoring, and some require more demanding graphic skills than cancellation and line bisection tasks (Bailey et al., 2000). Copying and drawing tasks have also been shown to have poor reliability (Hannaford, Gower, Potter, Guest & Fairhurst, 2003). As with other conventional tests, copying and drawing tasks may not reflect everyday activities undertaken by patients.

Considerable variability in performance has been found in the same subject between one test and another (Halligan et al., 1989; Halligan & Marshall, 1992; Robertson & Halligan, 1999). For example, Halligan and Marshall (1992) found that some patients showed visuospatial neglect on both star cancellation and line bisection tasks, while others showed impairment on one or other but not both tests (i.e. double dissociation). Such differential performance may be related to differences in the requirements of the tests, or discrete differences between patients in the manifestation of the clinical syndrome (Kinsella et al., 1995). Therefore, because visuo-spatial neglect may be identified by some tests but not others, a battery of tests, rather than use of just one test, is usually recommended. From a rehabilitation point of view, the conventional pencil and paper ‘bedside’ tests outlined above, though simple and quick to administer, may not assist therapists to identify and understand some of the difficulties experienced by such patients in everyday life. Some difficulties experienced by patients with visuo-spatial neglect, during an in-patient rehabilitation period, may become manifest during activities such as finding objects during various self-care activities, perceiving objects and people around them in the ward, and reading the hospital menu in order to choose their daily meals. Conventional tests described do not reflect such activity. Furthermore, use of these tests implies purchase of published test materials, which may be expensive and not always readily available for use by clinical therapists.

5.3 Functionally-based tests for visuo-spatial hemineglect

5.3.1 The Baking Tray Task

This test was developed by Tham and Tegner (1996) and proposed to be sensitive yet quick to administer. It appears to be more functionally realistic than paper and pencil tasks (see Section 2.6.2). In a series of elderly stroke patients, performance was abnormal in 25% of those with left-sided brain damage and 46% of those with right-sided brain damage (Tham & Tegner, 1996). Scores on this test did not correlate with scores from either two cancellation tasks or a line bisection task. Furthermore, seven patients with right-sided brain damage, who had abnormal scores on the BTT, performed normally on all other neglect tests (cancellation, bisection, drawing and copying), but showed “severe neglect …in daily life.” The authors interpreted this finding as evidence that the BTT was sensitive, and picked up all cases of at least moderately severe neglect. An alternative explanation might be that this task was identifying perceptual deficits in addition to, or other than neglect. Reliability was not tested, and the authors assertion, that the test is “probably relatively insensitive to practice” and thus suitable for repeated testing in single subject designs, was not supported by evidence (Tham & Tegner, 1996). The BTT was evaluated as part of a larger test battery by Bailey et al. (2000) and problems with its use are described (Appendix W).

5.3.2 Use of a Semistructured Scale

Zoccolotti and Judica (1991) developed a battery of tests to enable functional evaluation of neglect by means of tasks similar to activities of everyday life. Four tests were to assess visuo-spatial neglect in near or extrapersonal space, and one test was for personal neglect (utilising common objects). The four tests in extrapersonal space were serving tea, card dealing, description of a scene in three pictures and description of the room in which the patient was sitting. Positive aspects of these tests were that they assessed some everyday activities, also the materials used were ‘real life’ and three dimensional. Thus the tests had face ecological validity. However, one problem with the test is that the scoring used a semistructured scale of 0-3. This necessitated an element of subjectivity in deciding between the descriptors for each score. For example, a score of 3 (normal) is allocated when “no systematic asymmetries in exploration” are found, a score of 2 for “very slight asymmetries”, a score of 1 for “clear contralateral omissions”, and a score of zero for “patient only able to explore a very reduced portion of the contralateral space”. It is clear that differentiating between scores could prove difficult in patients who are close to a boundary score. Use of a more quantitative scoring system would improve objectivity, and be more discriminating between subjects. Finally, the test materials were developed and validated using an Italian sample and although the majority of tests do not appear to be culture-specific, the card dealing instructions are based upon the Italian card game of ‘Scopa’. Therefore some modifications may need to be made for use in UK samples.

5.3.3 Questionnaire measures of neglect

Clinicians who are interested in assessing the more functional aspects of neglect may use questionnaires to identify the types and frequency of everyday neglect behaviour and degree of functional impairment. Questionnaires such as the Subjective Neglect Questionnaire (Towle & Lincoln, 1991a) and the Catherine Bergego Scale (Azouvi et al., 1996) have been developed to identify the frequency and nature of problems experienced in activities of daily life by stroke patients with neglect. The items on the questionnaire may be completed by the patient, and by direct observation of patient by the therapist or carer. Such questionnaires may be useful to enable comparison between patient and carer or therapist’s perception of problems, thus giving an estimate of patient’s anosognosia, since patients with anosognosia for their neglect will tend to rate themselves as having fewer and less severe problems, than ratings given by therapists or carers. They may also help to address the problem found by Appelros et al. (2003), in a small group of subjects, who scored normally on a battery of conventional, pencil-and-paper tests, but who nevertheless exhibited clinical signs of neglect, as judged by therapist report based on ward observations. However, questionnaires are prone to subjectivity in scoring. Furthermore, if questions are not administered to patients verbally, they may be problematic to complete for patients with neglect, as such patients may have reading and writing difficulties associated with their neglect.

5.3.4 The Behavioural Inattention Test

Cermak and Hausser (1989) assert that the BIT was the first published test that attempted to assess functional performance. It was designed specifically to evaluate visuo-spatial neglect in near space (Robertson & Halligan, 1999). It was developed and standardised on 80 stroke patients and 50 age-matched controls by Wilson and colleagues (1987b). This test battery consists of two sets of sub-tests, 'conventional' and 'behavioural'. The conventional sub-tests contain six pencil-and-paper tests, consisting of line cancellation, letter cancellation, star cancellation, line bisection, figure and object copying and representational drawing tasks. These paper-and-pencil tasks are subject to some limitations. The cancellation and line bisection tests are scored objectively by number of targets cancelled, and error from true midline in centimetres respectively, and are thus likely to be more reliable than drawing and copying tasks in which scoring is more subjective. Other limitations of line bisection have been discussed in Section 5.2.1. The letter and star cancellation tests do include distractors, in addition to targets for cancellation, so they may be more sensitive than the line cancellation task, in which there are no distractors, for identifying subjects with less severe neglect. Indeed, the SCT has been found to be one of the most sensitive cancellation tests (Halligan et al., 1989; Marsh & Kersel, 1993). The representational drawing tasks require the patient to draw a clock face with numbers, a man or woman, and a butterfly. The figure and shape copying require the patient to copy drawings of a star, a cube and a daisy, and three geometric shapes, all positioned on the left hand side of a page. Scoring is based on completeness of the respective drawings using a scale of 0 (very poor) to 4 (excellent). Thus the scoring can be open to a degree of subjective interpretation, and indeed Hannaford et al. (2003) found "unsatisfactory" inter-tester reliability (intraclass correlation coefficient below .8) for the representational drawing tests because of ambiguity in interpretation of scoring. According to the test manual (Wilson et al., 1987a), test-retest reliability for the conventional sub-test battery as a whole was analysed using ten subjects, on two separate occasions 15 days apart, yielding a correlation of 0.99. However, it is not clear whether subjects used were patients with or without neglect, or normal controls. Finally, an important limitation of the conventional test battery as a whole is the fact that the tests cannot be easily related to specific difficulties encountered by patients in everyday life. Although the test manual uses an aggregate score for this sub-test battery, with a cut-off score of 129 or below, it is also recommended that if a patient scores below cut-off in one or more individual components, then they should additionally be assessed with the behavioural sub-tests.

The behavioural sub-tests were designed to overcome some of the previous limitations of traditional pencil-and-paper' tasks, by assessing some behavioural strengths and weaknesses of patients with visual neglect, within a functional context. The nine items consist of picture scanning, telephone dialling, menu reading, article reading, telling and setting the time, coin sorting, address and sentence copying, map navigation, and card sorting. Validity was established by analysis of the relationship between total scores on this battery of sub-tests with total scores from the 'conventional' sub-tests for 80 patients. Because the latter consisted of previously standardised and valid tests for visuo-spatial neglect (Wilson et al., 1987b), the strong correlation found of .92 established concurrent, criterion-related validity.

In picture scanning, the patient is shown three large colour photographs, presented one at a time, depicting a meal on a dish (eight items to be identified), a wash basin and toiletries (nine items to be identified), and a large window flanked by various pieces of furniture and mobility aids (15 items to be identified). The patient is asked to name and point to the items in each picture. Telephone dialling uses a real telephone with key-pad, and patients are asked to dial a group of numbers printed on each of three cards. For menu reading, an ‘open-out’ page containing of 18 common food items is arranged in four adjacent columns. Article reading requires the patient to read a short three-column article. Telling and setting the time has three parts. The first requires the patient to read the time from photographs of a digital clock, then from a large cardboard analogue clock face and finally to set the time on the clock face using the moveable cardboard hands. For coin sorting, the patient is presented with an array of 18 coins, three in each of six denominations, and asked to point to all coins named by the tester. Address and sentence copying requires the patient to copy an address and then a sentence, presented separately and opposite the patient’s midline, onto a sheet of white paper. For map navigation, the patient is presented with a large piece of card with a network of pathways connecting nine letters of the alphabet, and asked to use their finger to travel between two letters on the ‘map’ named by the tester. Finally, card sorting requires the patient to point to playing cards named by the tester, and laid out in four columns each containing four cards.

Scoring for each test is based on omissions or errors made, and this is converted, in each case, to a maximum score of nine for each test, if no errors or omissions are made. Thus a total possible score is 81, with a cut-off score of 67 (Wilson et al, 1987a). Scoring does not take into account the location of errors (Cermak & Hausser, 1989), and all errors are counted equally. Article reading and address and sentence copying have a maximum possible number of words that could be omitted of 151, 66, and 86 respectively. However, these tests may be less discriminating than others in the battery, because scoring awards a zero score for more than 30% omission of words for article reading, or more than six omissions for each copying task. This might reflect quite a wide range of neglect behaviour, all allocated the same score of zero, whereas in coin sorting, for example, more than ten omissions would have to be made from a total of 18, in order to score zero.

Although the test components do use some materials which are more relevant to ‘real life’ situations, only three of the nine tests use real everyday three-dimensional materials (a telephone, selection of coins and playing cards) and the other six tests use written or photographic material, and their relevance to ‘real life’ contexts is therefore questionable. Furthermore, although reading and telling the time could be related to functional tasks, the article reading task does not simulate typical reading tasks such as reading a newspaper or book, the digital clock is a picture, and the analogue clock a large cardboard model, neither of which simulate the ‘real thing’. The ‘menu’ consists of a list of foods in large print, arranged in columns, and the ‘map’ is a series of letters connected by straight lines, and, again, these materials are not closely related to a real menu that a patient may come across, or a real map. Despite the use of some real-life materials, pointing to playing cards or coins in an array might not have strong functional relevance. Nevertheless, Hartman-Maeir and Katz (1995) found that seven of the nine behavioural sub-tests (but not article reading or telling the time) were found to discriminate significantly between subjects with and without neglect, thus providing some evidence of validity. Significant relationships were found between performance on four behavioural tests (picture scanning of a room, telephone dialling, telling the time and coin sorting) and performances on five actual similar tasks (correlations between 0.63 and 0.89). However, relationships between four of the behavioural tests (picture scanning plate of food, article reading, address and sentence copying and map navigation) and an activities of daily living checklist (eating, reading, writing and mobility) only showed significant correlations (0.74) for address and sentence copying, indicating that sub-tests of map navigation, picture scanning of food and article reading do not adequately predict 'real life' performance. The test battery is fairly time consuming to administer, therefore patients who fatigue easily, and who have limited attention spans, may have difficulty in completing one or both sections. Although use of standardised test batteries will always be necessary for research purposes, such batteries may be expensive to purchase, require specialist test materials, may be time intensive, or may be difficult to obtain for the everyday clinician.

5.3.5 Summary

The above review of some commonly used existing tests for visuo-spatial neglect has highlighted some concerns that 'conventional' pencil-and-paper tests do not relate to actual performance of patients in everyday situations, and results, though helpful in the diagnosis of neglect, may not assist therapists to identify functional problems of their patients, in order to guide them in designing appropriate therapy programmes. Even 'behavioural' tests designed to provide better ecological validity, may still not be close enough to 'real' life activities to give therapists an indication of the type of problems that may occur due to neglect. Scoring of tests should ideally reflect location of omissions, and should not require subjective interpretation of performance. Finally, tests should be easy and quick to administer by clinical therapists, and use materials that are readily available or cheap to produce.

5.4 Aim of the study

The purpose of this study was to produce a simple battery of tests for visuo-spatial neglect, based on 'real-life' functional activities, and constructed using readily available materials. The battery would be for everyday use by health care practitioners in the clinical setting. This might provide therapists with a more precise description of a patient's capabilities. It is important to detect neglect where present as it can significantly impinge on everyday activities (Jehkonen et al., 2000a). It is also important for clinicians to have access to a reliable and valid assessment tool. Tests were designed to reflect some activities of everyday life, to use material either normally available on a hospital ward, or easy and cheap to produce, and to include a test for far space, in addition to tests for neglect in near space. Administration of the test battery was designed to be simple, and not time consuming.

5.4.1 Screening, validity and reliability issues

A sensitive and standardised screening test was needed to enable selection of subjects with visuo-spatial neglect for the study. The Star Cancellation Test or SCT (Wilson et al., 1987a) was chosen as this screening tool, as it is considered to be a sensitive measure for detecting visual neglect (Marsh & Kersel, 1993). The SCT is a test item taken from the 'conventional' sub-tests of the BIT (Wilson et al., 1987a). In order to assess the concurrent validity of the new, Everyday Test Battery (ETB), it was decided to compare the total score on the new battery with the total score of an existing, validated test battery for visuo-spatial neglect. The nine 'behavioural' sub-tests of the BIT battery were considered to be appropriate for such validation purposes. Finally, test-retest reliability was to be investigated by administering both test batteries on the same day, to minimise any changes in neglect behaviour that may occur over a longer time period. For pragmatic reasons it was only possible to use one tester for administration of both test batteries, who was not blinded to the purpose of the study. All test materials used for the ETB were obtained on the ward where testing took place, or were produced by the tester. All subjects were recruited from and tested at the rehabilitation stroke unit in a community hospital in Stoke-on-Trent.

5.5 Method

5.5.1 Subjects

Subjects were recruited to the study over a 9-month period. Inclusion criteria were: first stroke with right-sided brain damage (judged by CT scan reports), admitted to a 20-bed rehabilitation stroke unit from the acute hospital; scoring below cut-off of 51 on the SCT (Wilson et al, 1987a) and able to communicate and understand instructions sufficiently to follow test instructions. All patients were over 60 years of age.

A total of 98 patients were admitted to the unit during the 9-month period. Thirty-nine patients had right-sided brain damage, and of these, 22 fulfilled the inclusion criteria. All were right-handed, none were independently mobile. Three subjects were discharged, and two died before full testing took place. Thus seventeen right-sided brain damaged stroke patients, nine females and eight males, were recruited to the study, and gave informed consent. Mean age was 73.53 years (range 60-84, sd 6.41), mean time post-stroke 46.82 days (range 15-84, sd 18.71); all 17 patients were able to complete all tests. CT scan results reported that 16 patients had infarcts in the territory of the right middle cerebral artery (including parts of the frontal, parietal, temporal and occipital lobes), one had a haemorrhage in the right basal ganglia.

5.5.2 Materials

5.5.2.1 Screening test

The SCT, used for screening, consisted of a page containing 52 large stars, 10 short words and 13 letters, randomly positioned, with 56 small stars interspersed. Subjects were instructed to cross out (with a black pen) all the small stars across the page. The tester demonstrated by crossing out the two small central stars. Maximum score is 54, 27 right and 27 left. Cut-off score for visual neglect is below 51.

5.5.2.2 Comparator test used for validation purposes

Total scores from the nine behavioural sub-tests of the BIT battery (Wilson et al., 1987a) were used to compare with the performance on the new Everyday Test Battery (ETB), for validation purposes. The construct and predictive validity of the behavioural sub-tests of the BIT has been previously demonstrated (Hartman-Maeir & Katz, 1995) and the sub-tests were designed to reflect aspects of daily life. They consists of: picture scanning, telephone dialling, menu reading, article reading, telling and setting the time, coin sorting, address and sentence copying, map navigation and card sorting. All test materials are printed or in photographic form. Test details and administration are given elsewhere (Wilson et al., 1987a). Maximum score for the behavioural sub-tests of the BIT is 81, with a cut-off score of 67.

5.5.2.3 The Everyday Test Battery

The Everyday Test Battery (ETB) of seven tests was designed to include tests that reflected 'real life' situations, using items or objects with which patients might be expected to be familiar, in addition to a more traditional 'paper-and-pencil' cancellation task. The tests were designed to assess the patient's ability to respond to and report specific visual stimuli in near and far space, securing face and content validity. Scoring was designed to reflect location of omissions, and to avoid the need for subjective interpretation of performance. Justification for the inclusion of each test is given below. The seven tests included were:

1. Cancellation Task – at three levels of difficulty
2. Reading a Hospital Menu
3. Planting Seeds in a Seed Tray
4. Reporting Objects around a Wash Hand-basin
5. Reporting Objects for Making a Cup of Tea
6. Addressing an Envelope
7. Reporting Objects Around the Ward

For all above tests the patient was seated, and centrally positioned in relation to the test materials, and allowed to move their head and eyes but asked not to turn their trunk. This was re-emphasised if there was any sign of trunk rotation. The tester was seated directly facing the patient for tests 1, 2, 3 and 6, and directly behind the patient for tests 4, 5 and 7. Tests 1-6 were performed within reaching space, Test 7 in far space (beyond reaching space). During all testing every patient was seated in their wheelchair. Objects used for the ETB were 'real' and not photographs of objects.

5.5.2.4 Description of tests and justification for inclusion

5.5.2.4.1 Clubs cancellation task

This was the only ‘pencil-and-paper task included, in order to have one test which would be expected to discriminate between mild, moderate and severe neglect, due to the inclusion of increasing numbers of distractors at the ‘moderate’ and ‘difficult’ levels. Clinicians may find it helpful to have some indication of neglect severity when planning treatment. Thus these tests are very similar to other existing cancellation tests, but can be easily produced on a home computer. Furthermore, the author is not aware of any existing published cancellation tests that offer different levels of difficulty in target search.

Symbols of three black shapes (hearts, clubs of small and larger size, and spots) available in Microsoft Word were used in the design. These symbols were chosen as they were likely to be familiar to UK subjects, but were symbols not used in current published tests. These were copied across a sheet of A4 paper, at three levels of difficulty. For the easiest level only the larger clubs symbol was used. This is considered to be ‘easy’ because there are no added distractors, the rows are evenly spaced, only one type of symbol is used, and the total number of items covered the entire page and were all ‘targets’. The central two clubs (highlighted in Figures 5.1-5.3, but not highlighted in the actual presentation), were cancelled by the tester as a demonstration to the patient. Forty-two large club symbols, in six rows, each with seven clubs, were copied across the page. (Figure 5.1).

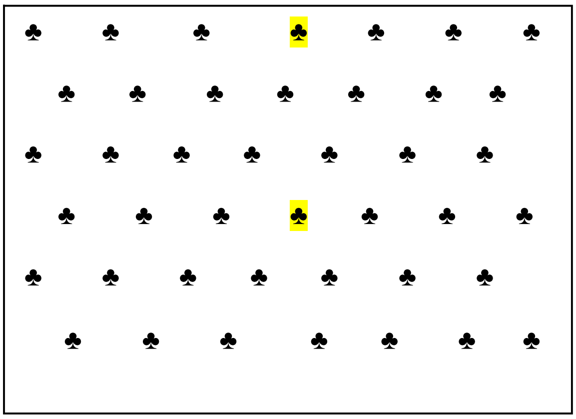


Figure 5.1 Clubs Cancellation Task (easy)

For the second level of difficulty, 26 heart shapes and 23 small club symbols, relatively randomly placed, were added, as distractors, to the 42 large club symbols on a second sheet (Figure 5.2). This was considered to be moderately difficult as one of the added distractors was a different shape, but the second was the same shape, but smaller than the 'target' symbol. This would require a higher level of visual search ability to identify targets in the array.

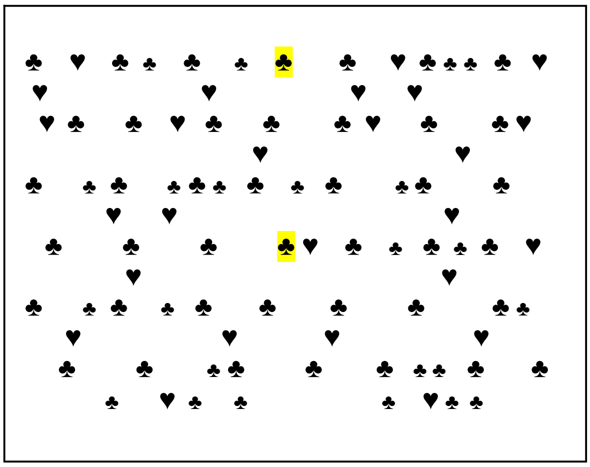


Figure 5.2 Clubs Cancellation Task (moderate)

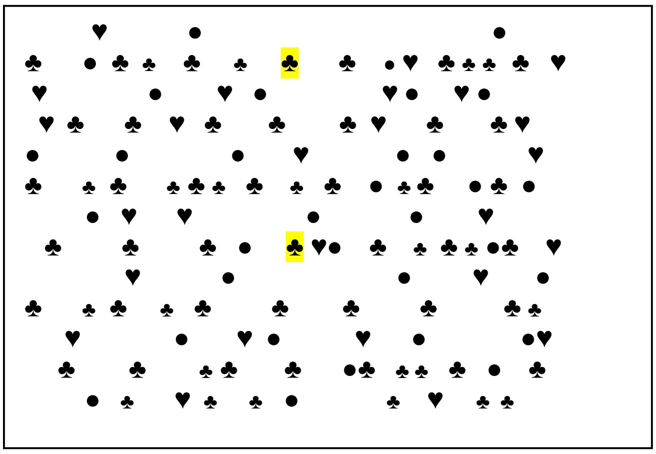


Figure 5.3 Clubs Cancellation Task (difficult)

To the third sheet (Fig.5.3) 33 spots were added as further distractors, which would make the search for targets even more difficult.

Patients were instructed to cross out (with a black pen) all the large club symbols across the page. The tester demonstrated by crossing out the two central large clubs (highlighted in Figures 5.1 to 5.3). Thus maximum score for each level was 40, 20 on each half of the page, giving a total possible maximum score of 120 for this cancellation test.

5.5.2.4.2 Reading a hospital menu

The hospital lunchtime menu actually used on the stroke unit was used for this task (Figure 5.4). Thus the test is similar to the menu reading task of the BIT (behavioural sub-tests) but is considered to be more realistic as it is an actual menu, used daily by all patients to make their meal choices. Patients were asked to read out aloud all the menu choices, including the headings for food choices.

Soup, Sandwiches / Salads		
	Minestrone Soup	
	Turkey Sandwich	(wholemeal)
	Turkey Sandwich	(white)
	Cream Cheese Sandwich	(wholemeal)
	Cream Cheese Sandwich	(white)
	Salad Bowl	
Hot Choice		
	Savoury Minced Lamb	
	Cheese and Onion Quiche	
Vegetables		
	Creamed Potatoes	
	Jacket Potatoes	
	Broccoli Florets	
Sauces		
	Gravy	
Desserts		
	Fruit Scone	
	Strawberry Mousse	
	Mandarins in Juice	

Figure 5.4 Reading a hospital menu

Headings were positioned on the left side of the page, food choices were centrally placed, and bread types to the right side of the page. There were seven words in a left position, 36 central and four in a right position. It is evident that food items are not evenly or equally placed across the page, as they are in the BIT menu-reading task, however, this is likely to more closely reflect the asymmetry of ‘real-world’ menus. Additionally, the fact that more words are located on the left side of the page than on the right means that the score achieved may reflect, to some extent, location of omissions, as patients with neglect would be expected to omit more left-sided words, and thus attain a lower score. The number of correct food words identified by the subject was recorded. Total number of words (naming types of food, including type of bread), thus maximum possible score, was 47. (Errors of word omission included errors of word substitution [Appendix G]).

5.5.2.4.3 Planting seeds in a seed tray

This test was based upon the idea of the Baking Tray Task (Tham & Tegner, 1996) but used materials that might be more meaningful to the patient. Previous evaluation of the Baking Tray Task (Bailey et al., 2000) found that some patients found the idea of such a large ‘baking tray’ unrealistic (even though it was smaller than the original used which was 100cmx75cm). The ‘buns’ were cubes of wood, and some patients had difficulty with the idea of what they had to do following instruction, particularly male subjects (who may have had less experience of ‘baking’). Thus this seed-planting task is considered to be a less ‘gender specific’ test, using materials used in ‘real life’.

Figure 5.5 Planting seeds in a seed tray

A plastic seed-tray, dimensions 40cmx30cm, was filled with potting compost. Subjects were supplied with 16 broad bean seeds in a shallow container, placed centrally in front of them (Figure 5.5). They were instructed to use all the seeds and to ‘plant’ them evenly placed across the tray, by placing them on top of the compost.

The number of seeds ‘planted’ to the left-hand half of the tray was counted. If more than eight seeds were placed on the left side, this was only counted as eight, because at least half the seeds had been ‘planted’ on the contralesional side, and left neglect would not be shown Thus total possible maximum score was 8 which would indicate a normal score whereas less than eight would be due to left-sided omissions, indicating a degree of neglect.

5.5.2.4.4 Reporting objects around a wash hand-basin

This test was based upon the picture task of scanning of a wash hand-basin from the BIT (‘behavioural’ sub-tests). The materials used were real rather than photographic, to improve ecological validity, and all items to be identified were toiletries that would be familiar to subjects. In the original picture-based task, the tap on either side of the basin, the overflow, and the plughole were counted as objects to be named and pointed out. These items might not be immediately obvious as ‘objects’ to be reported by a patient. Furthermore, in the original version, toothbrush and toothpaste were counted as one item rather than two. Such features might affect accuracy in scoring, and were avoided in the design of the current test.

Seven items of toiletry were positioned on the back ledge of a hospital wash hand-basin, three (talc/after-shave, comb, soap tablet) to the left, one (face flannel) centrally, and three (deodorant, toothpaste, toothbrush) to the right (Figure 5.6).

Precise measured positions for these items were not used. However, for consistency, the same sink type and the same items were always used, and items were always laid out as shown in Figure 5.6. Subjects were asked to name and point to the objects they could see which were placed on the wash hand-basin. Scoring was one point for each of the three items on the right, two for the central item and two for each of the three items on the left, giving a total possible maximum score of 11.

Figure 5.6 Reporting objects around a wash hand-basin

5.5.2.4.5 Reporting objects for making a cup of tea

Finding items to make a drink is a common activity of daily life. Therefore, this activity was included in the test battery. Seven items necessary for making a cup of tea were positioned on a hospital bed-table, three on the right side (sugar bowl, teapot, saucer), one centrally (teaspoon) and three (milk jug, tea caddy, cup) on the left side. Precise measured positions for these items were not used. However, for consistency, the same bed-table type and the same items were always used, and items were always laid out as shown in Figure 5.7. Scoring was one point for each of the three items on the right, two for the central item and two for each of the three items on the left, giving a total possible maximum score of 11.

Figure 5.7 Reporting objects for making a cup of tea

5.5.2.4.6 Addressing an envelope

This writing task was considered to be a common activity of daily life. Subjects were asked to write their home address on a standard white 220cmx110cm envelope. The position of the address was judged by the tester to be either left or centrally positioned, possibly with some lines a little to the right (score 3), or to the right (entire address written on the right side) score 2, or far right positioned, score 1 (Figure 5.8). Thus total possible maximum score was 3.

5.5.2.4.7 Reporting objects around the ward

This test, described but not provided with scoring criteria by Stone & Greenwood (1991), was included as it was considered useful to assess whether a patient had difficulties perceiving objects in far space. Subjects were asked to point to and/or name all the objects they could see around them, on both sides, scattered about the hospital ward from far right around to far left. Prior to testing, the position of objects around the ward (beds, tables, chairs etc.) was checked to ensure distribution was approximately the same within each quadrant.

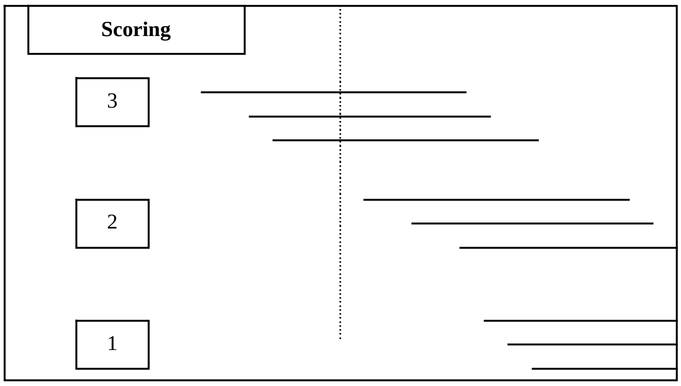


Figure 5.8 Addressing an envelope

The tester stood directly behind the seated subject, and noted which objects were identified by the subject in the six segments shown on Figure 5.9. Each segment represented 30 degrees of a 180-degree semicircle, with the subject seated at the centre. Most main objects in any segment had to be identified to gain full score. As the test always took place in the same ward, the items around the ward were approximately the same for each patient.

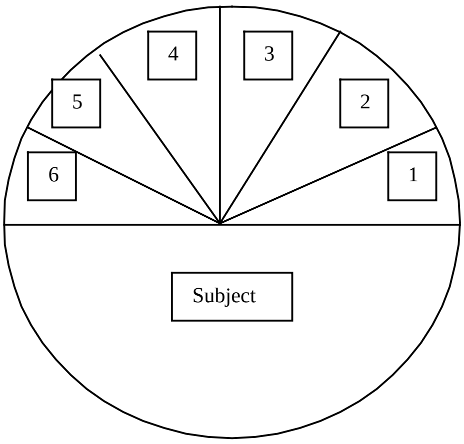


Figure 5.9 Reporting objects around the ward

Scoring was six for the far left segment, five for the next segment and so on, for the six segments, thus giving a total maximum possible score of 21. This scoring reflected location of omissions, as higher scores would be obtained if the patient reported objects in neglected hemispace.

The total score for the Everyday Test Battery is calculated as the sum of all the scores from each sub-test item, including the three separate scores for each of the levels of difficulty of the clubs cancellation task. Thus the maximum possible score is 221.

5.5.3 Procedure

All testing (apart from screening testing) took place on the same part of the day for each patient, either morning or afternoon. The same tester administered all test batteries. An assistant undertook initial screening, using the SCT, during the week prior to administration of the test batteries. Testing took place in a quiet side room, containing a wash hand-basin, with the subject seated at a table, when appropriate. The only exception to this was test Item 7 (reporting objects around a ward) which took place within the actual ward environment. When administering the BIT battery the tester was seated directly facing the patient. For the ETB, and the BIT battery, the patient was seated in their wheelchair, and centrally positioned in relation to the test materials, and allowed to move their head and eyes but asked not to turn their trunk At first sign of any trunk rotation, the patient was reminded not to do so, and in any case, the sitting position, well-supported in a wheelchair, tended to minimise the possibility. The tester was seated directly facing the patient for test Items 1, 2, 3 and 6, and standing directly behind the patient for test Items 4, 5 and 7. Test Items 1-6 were performed within reaching space, test Item 7 in far space (beyond reaching space). Objects used for the ETB were ‘real’ and not photographs of objects.

Either the ETB or the BIT battery (behavioural sub-tests) was tested first, with order of presentation randomised over patients. Following administration of these two test batteries, the ETB was presented for a second time to assess test-retest reliability. A thirty-minute rest period was allowed between administration of each test battery in order to minimise fatigue and enable visits to the bathroom if required. The entire procedure took between two and three hours per patient. All sub-tests in both test batteries were presented in the order 1-7 shown above, for the ETB, and the order in the scoring sheet for the BIT, as follows:

1. Picture Scanning
2. Telephone Dialling
3. Menu Reading
4. Article Reading
5. Telling and Setting the Time
6. Coin Sorting
7. Address and Sentence Copying
8. Map Navigation
9. Card Sorting

5.5.4 Data analysis

Descriptive analysis was computed for the following variables: age, days post-stroke, time taken to complete each of the test batteries, and scores on the SCT, and total scores on each of the test batteries administered. The patients' performance on the ETB battery was used to compare with their performance on the BIT behavioural sub-test battery, also with the SCT, for validation purposes. Total scores for each test for each patient were correlated using Spearman's rank order correlation, as the scores were ordinal. Inter-correlations were computed between the ETB total score (excluding the score of the test item in question so as not to inflate the correlation coefficient (Sim & Wright, 2000)) and each of the sub-tests on the ETB, to assess internal consistency of the sub-tests. Cronbach's alpha was also computed to provide an index of the average intercorrelation of the items within the ETB. A Kappa coefficient was calculated to assess the agreement between neglect severity classified on the basis of BIT scores and that classified on the basis of ETB scores.

Test-retest repeatability for the ETB was assessed using Spearman's rank-order correlation which is a measure degree of association rather than degree of agreement (Sim & Wright, 2000) as it measures relative reliability, or the degree to which individual measurements within a group will maintain their position within the group on repeated measurement. It does not take into account the absolute magnitude of difference between measures. To add to the strength of the analysis, therefore, the Wilcoxon matched-pairs signed-ranks test was applied to the first and second sets of scores from the ETB, and a scatter-plot computed to ensure the line-of-best-fit passed through zero, which would indicate no systematic difference in scores between first and second test. Such analysis still does not provide the actual expected magnitude of difference between test and retest. For this reason, Bland and Altman (1986) have developed an additional method of analysis called the 'limits of agreement'. The limits of agreement give the magnitude of disagreement in the actual units of measurement, thus providing a more clinically useful estimate of test-retest repeatability. Furthermore, graphic presentation of the limits of agreement allows visual interpretation of any systematic bias and random differences between the repeated measures. The bias and 95% limits of agreement were therefore also computed and presented graphically.

5.6 Results

All raw data for the tests are presented in Appendices E, F and G

5.6.1 Screening test and neglect severity of sample

Star Cancellation Test scores (8 23.76 range 6-50, sd 13.03) on initial screening indicated that patients had a range of neglect severity including mild, moderate and severe visuo-spatial hemineglect. If neglect severity is classified arbitrarily by dividing the maximum score into percentage tertiles, 0-33% (actual score between 0 and 18 stars cancelled) of maximum score would indicate severe neglect, 34-67% (actual score between 19 and 36 stars cancelled) would indicate moderate neglect, and 68-94% (actual score between 37 and 50 stars cancelled) would indicate mild neglect. On this basis, six subjects would be classified as having severe neglect, nine with moderate neglect, and two with mild neglect (Table 5.1a). Subject 3 scored only one below cut-off for this test (Table 5.2).

Using these tertile divisions for the BIT and ETB to link with the classification of neglect severity, and comparing both the SCT and the BIT (behavioural sub-tests) with the ETB (Test 1), whilst nine patients showed concurrence of classification between the ETB (Test 1) and either the SCT or the BIT, 8 out of 17 patients would have been classified as one category less severe with the ETB (compared with the BIT or the SCT). Furthermore, one patient (17) would have been classified as severe neglect with the BIT but mild neglect with the ETB first test, although this subject gained a score indicating a classification of moderate neglect on ETB retest (Table 5.1a).

Table 5.1a.

Neglect severity, based on tertile divisions of scores, for the Star Cancellation Test, Behavioural Inattention Test (behavioural sub-tests) and the Everyday Test Battery (first and second administration)

Subject	SCT Neglect Severity	BIT Neglect Severity	ETB (1) Neglect Severity	ETB (2) Neglect Severity
1	Moderate	Severe	Moderate	Moderate
2	Severe	Severe	Severe	Severe
3	Mild	No neglect	Mild	Mild
4	Moderate	Moderate	Moderate	Moderate
5	Severe	Severe	Moderate	Moderate
6	Moderate	Moderate	Mild	Mild
7	Moderate	Mild	Mild	Mild
8	Moderate	Mild	Mild	Mild
9	Moderate	Moderate	Moderate	Moderate
10	Severe	Severe	Moderate	Moderate
11	Severe	Severe	Severe	Severe
12	Severe	Severe	Moderate	Severe
13	Severe	Severe	Severe	Severe
14	Moderate	Moderate	Moderate	Moderate
15	Mild	Moderate	Mild	Mild
16	Moderate	Moderate	Mild	Mild
17	Moderate	Severe	Mild	Moderate

Key:
SCT = Star Cancellation Test (from the BIT, conventional sub-tests)
BIT = Behavioural Inattention Test (behavioural sub-tests)
ETB = Everyday Test Battery

Table 5.1b

Comparison of neglect severity defined by tertile score using the BIT or the ETB (Test 1).

		ETB1			
		Mild	**Moderate**	**Severe**	**Total**
BIT	**Mild**	**3**	**0**	**0**	**3**
	Moderate	**3**	**3**	**0**	**6**
	Severe	**1**	**4**	**3**	**8**
	Total	**7**	**7**	**3**	**17**

Table 5.1b indicates that both tests agree when neglect is mild, but agreement is less close (only around 50% agreement) for moderate or severe neglect, with a tendency for the ETB to classify neglect as moderate and the BIT to classify as severe. Kappa for the data in Table 5.1b was k=.327 (SE .158, p<.028) indicating fair agreement (Landis & Koch, 1977).

5.6.2 Scores on test batteries and time taken to complete

All percentages of maximum scores, and time taken to complete the BIT and the ETB (Test 1 and Test 2) are shown in Table 5.2. The mean raw score on the BIT (out of a maximum score of 81) was 31.82 (range 2-68, sd 21.54), and the mean time for test completion was 52.94 minutes (range 42-70, sd 8.93). Subject 3 scored above the published cut-off score of 67 for this test. The mean raw score on the ETB (Test 1) out of a maximum score of 221, was 126.88 (range 23-200, sd 55.22), and for ETB (Test 2), mean raw score was 122.65 (range 28-192). Average time for test completion of the ETB (Test 1) was 32.94 minutes (range 20-46, sd 7.13), and for ETB (Test 2) was 37.12 minutes (range 20-52, sd 9.29).

Table 5.2.

Percentage (of maximum) scores for the Star Cancellation Test, Behavioural InattentionTest and Everyday Test Battery Test-retest, and time taken for each subject (n=17)

Subject	SCT Score Percentage of Max	BIT Score Percentage Of Max	BIT Time (mins)	ETB Score Test 1 Percentage Of Max	ETB Time (mins)	ETB Score Test 2 Percentage Of Max	ETB Time (mins)
1	39	20	58	44	41	40	50
2	15	6	64	17	45	19	48
3	93	84	58	91	32	87	38
4	57	47	46	57	30	58	38
5	20	32	52	61	33	52	40
6	65	35	49	74	22	77	20
7	41	72	45	71	33	72	35
8	59	78	43	75	30	72	42
9	52	44	66	69	40	62	45
10	30	17	42	59	28	52	25
11	15	9	70	14	46	18	52
12	20	14	45	36	30	32	32
13	11	2	50	10	32	13	30
14	48	56	45	58	30	57	25
15	81	63	65	87	38	86	45
16	37	65	49	83	20	79	30
17	65	25	53	71	30	67	36
Mean	44	39.35	52.94	54.47	32.94	55.47	37.12
Range	11-93	2-84	42-70	10-91	20-46	13-87	20-52
sd	24.14	26.64	8.93	25.21	7.13	23.75	9.29

Key:
SCT = Star Cancellation Test (from the BIT Test, conventional sub-tests)
BIT = Behavioural Inattention Test (behavioural sub-tests)
ETB = Everyday Test Battery
Percentage (of maximum) Scores for all tests are rounded up

Table 5.2 indicates that, compared with scores for Test 1, six patients had higher scores for Test 2 of the ETB and eleven had lower scores. In relation to time taken, although ETB (Test 2) took, on average, some four minutes longer, with 13 of the 17 patients taking longer to complete, this difference was not statistically significant.

5.6.3 Relationships between the Behavioural Inattention Test, the Everyday Test Battery, and the Star Cancellation Test

The BIT and ETB (Test 1) showed strong positive association (Spearman's rho .836, p<.001, 2-tailed). Additionally, the correlation between the SCT and the ETB (Test 1) showed strong positive correlation (Spearman's rho .807, p<.001).

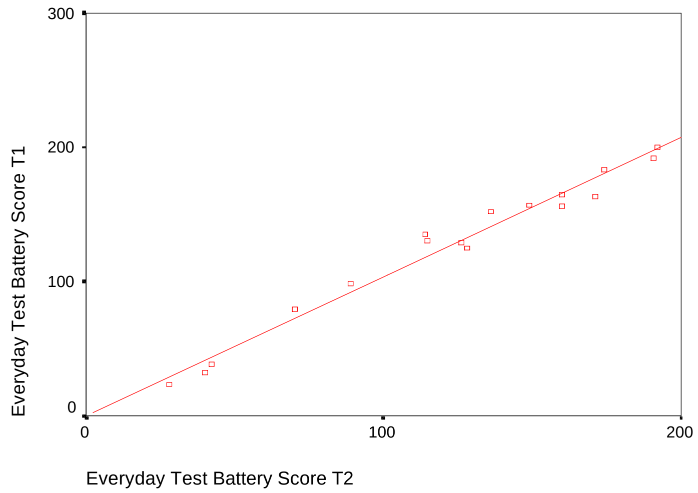


Figure 5.10 Scatterplot to show scores from Everyday Test Battery test 1 versus test 2

The ETB test-retest showed high correlation (Spearman's rho .968, p<.001, 2-tailed), with a mean percentage difference of 8.54% between scores of test 1 and test 2. The minimum percentage difference between ETB Test 1 and ETB Test 2 was 0.52%, the maximum difference was 25%. A scatter plot (Figure 5.10) of Test 1 versus Test 2 scores shows the strength and direction of the association, and that the line passes through zero. There was no significant difference between score totals on test and retest (Z score –1.874, p<.061, 2-tailed).

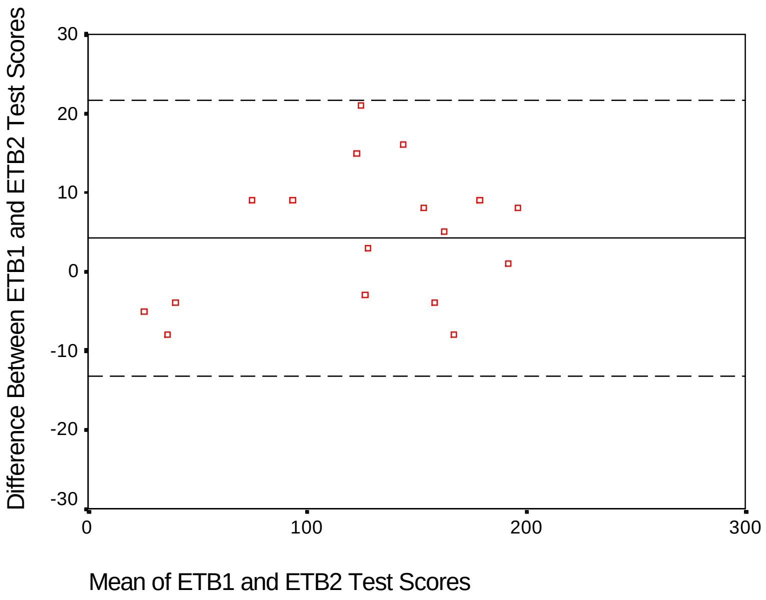


Figure 5.11 Everyday Test Battery (n=17). Bias and 95% limits of agreement for test-retest

The 95% limits of agreement (Bland & Altman, 1986) were from +13.21 to - 21.68 with a small systematic mean bias (mean difference) of 4.24. Figure 5.11 additionally shows that all differences between paired measurements of ETB Test 1 and ETB Test 2 lie between the 95% limits of agreement.

An intercorrelation matrix (Table 5.3) between the scores on the ETB1 (minus the individual score on the test item in question) and the seven sub-tests of the ETB1 (including the three levels of the cancellation task) showed strong, significant ($p<.01$, 2-tailed) correlations with five of the seven sub-tests, but less strong ($p<.05$, 2-tailed) with sub-test 5 'Reporting Objects for Making a Cup of Tea' and sub-test 7 'Reporting Objects Around the Ward', which itself correlated poorly with five of the seven sub-tests. The average intercorrelation of the items within the ETB was given by Cronbach's alpha = .8635, indicating very good internal consistency of test items.

Table 5.3.

Intercorrelation matrix between Everyday Test Battery (test 1) total score (minus item of interest) and sub-tests of the Everyday Test Battery (n=17)

	ETB Test	Clubs Easy	Clubs Medium	Clubs Difficult	Menu Read	Seed Planting	Objects around Wash-basin	Objects Making Cup of Tea	Envelope Address	Objects around Ward
ETB Test	_	.762**	.908**	.830**	.615**	.741**	.608**	.606*	.639**	.544*
Clubs Easy	.785**	_	.787**	.723**	.648**	.547*	.462 NS	.532*	.718**	.469 NS
Clubs Medium	.736**	.787**	_	.900**	.585*	.670**	.611**	.585*	.675**	.463 NS
Clubs Difficult	.713**	.723**	.900**	_	.569*	.682**	.523*	.642**	.587*	.581*
Menu Read	.931**	.648**	.585*	.569*	_	.636**	.422 NS	.499*	.745**	.376 NS
Seed Planting	.683**	.547*	.670**	.682**	.636**	_	.410 NS	.521*	.500*	.447 NS
Objects around Washbasin	.622**	.462 NS	.611**	.523*	.422 NS	.410 NS	._	.640**	.529*	.488*
Objects Making Cup of Tea	.530*	.532*	.585*	.642**	.499*	.521*	.640**	_	.689**	.417 NS
Envelope Address	.718**	.588*	.675**	.587*	.745**	.500*	.529*	.689**	_	.063 NS
Objects around Ward	.509*	.469 NS	.463 NS	.581*	.376 NS	.447 NS	.488*	.417 NS	.063 NS	_

** p<.01, 2-tailed
* p<.05, 2-tailed
NS – not significant

Further analysis was undertaken to investigate some relationships between groups of items from the ETB, the SCT, and the BIT (behavioural sub-tests). First, relationships were examined between the three levels of difficulty of the clubs cancellation test (ETB Item 1) and the SCT used for screening, using percentage of maximum score for each subject for each tests to ensure test comparability. Analysis showed that all correlations between all levels of difficulty of Item 1 and the SCT were strong and positive (Table 5.4) and that the strongest relationship, in terms of level of difficulty, existed between the most difficult level of the Clubs Cancellation Task and the SCT (r_s .811, $p<.01$).

Table 5.4.

Intercorrelations between all levels of difficulty for Everyday Test Battery Item 1 (Clubs CancellationTask) and the Star Cancellation Test

	Clubs Easy	Clubs Moderate	Clubs Difficult	Star Cancellation Test
Clubs Easy	-	.819*	.664*	.604*
Clubs Moderate	.819*	-	.888*	.808*
Clubs Difficult	.664*	.888*	-	.811*
Star Cancellation Test	.604*	.808*	.811*	-

* p<.01, 2-tailed

Table 5.5.

Percentage of total scores for the Clubs Cancellation Tasks (Everyday Test Battery) at three levels of difficulty, and for the Star Cancellation Test and the Behavioural Inattention Test (behavioural sub-tests).

Subjects	ETB Clubs Easy % Score	ETB Clubs Moderate % Score	ETB Clubs Difficult % Score	Star Cancellation Test % Score	BIT Test % Score
1	45	35	23	39	20
2	28	10	8	15	6
3	100	100	95	93	84
4	50	40	38	57	47
5	98	60	48	20	32
6	50	88	88	65	35
7	93	73	25	41	72
8	88	68	70	59	78
9	98	63	50	52	44
10	63	53	60	30	17
11	23	13	15	15	9
12	38	25	15	20	14
13	15	13	10	11	2
14	78	38	30	48	56
15	93	88	93	81	63
16	100	80	70	37	65
17	90	95	60	65	25
Mean	67.35	55.15	46.76	44.0	39.35
Range	15-100	10-100	8-95	11-93	2-84
sd	30.20	29.98	29.43	24.15	26.64

Furthermore, no significant difference (t=.706, p=.491) was found between the percentage score for each subject between the Clubs Cancellation task (difficult) and the SCT (Table 5.5). Table 5.5 also shows that only four subjects (5, 6, 10 and 16) have a greater than 20% difference between scores on the difficult version of the ETB Clubs Cancellation Task, and the SCT.

Table 5.6.

Percentage of total scores for the Everyday Test Battery Items 2-7 (minus the three Clubs Cancellation Tasks), and for the Behavioural InattentionTest (behavioural sub-tests).

Subjects	ETB Items 2-7 only % Score	BIT Test % Score
1	56	20
2	20	6
3	81	84
4	73	47
5	52	32
6	72	35
7	79	72
8	74	78
9	67	44
10	59	17
11	12	9
12	48	14
13	8	2
14	70	56
15	82	63
16	82	65
17	58	25
Mean	59.18	39.35
Range	8-83	2-84
sd	24.39	26.64

Finally, if the scores from all three ETB clubs cancellation tasks are removed, the remaining total percentage scores for the ETB re-calculated (with the total possible score now being (221-120) thus 101), and compared with the percentage scores from the BIT (behavioural sub-tests), Table 5.6 shows that seven subjects (1, 4, 6, 9, 10, 12 and 17) now show more than a 20% difference between ETB and BIT test scores. Furthermore, analysis shows that, although there is a significant and strong relationship between the percentage scores for the ETB Items 2-7 (minus the cancellation tasks), and the BIT ($r_{s.}$.844, $p<.01$), there is also a significant difference ($t = 2.206$, $p<.05$, t_{crit} 2.037, 2-tailed) between percentage scores obtained by each subject in each test battery, with a mean score of 59.18% for the ETB (Items 2-7) compared with a mean score of only 39.35% for the BIT (indicating that the ETB may underestimate neglect severity).

5.7 Discussion

The results of this study show that significant and strong associations were found between the total test scores for the ETB, and both the BIT (behavioural sub-tests), and the SCT, used for initial screening, This provides support for concurrent validity of the ETB. Intercorrelational analysis between individual test items from the ETB with the ETB total score showed that there was good internal consistency of ETB sub-test items, with the exception of item 7 (reporting objects around a ward), indicating very good internal consistency for the test items.

The relationship between first and second administration of the ETB was strong and positive, with a mean difference of only 8.54% between scores of test 1 and test 2, which was not significant. The actual difference between test and retest showed a small systematic mean difference of 4.24 score points. These findings provide strong support for test-retest reliability. The severity of neglect in nine of the seventeen patients was classified at the same level by the ETB and either the BIT (behavioural sub-tests), or the SCT, however for seven other patients, neglect would have been classified as one category less severe, and for one of these, two categories less, using the ETB. On average, the ETB took some 20 minutes less for patients to complete than the BIT battery.

5.7.1 Validity, reliability, and sensitivity.

The results support the concurrent validity, internal item consistency and reliability on test-retest of the ETB. In addition, the relatively short time taken for test completion, and the fact that readily available, inexpensive, and ‘real-life’ materials, were used, these findings indicate that the ETB test battery may be of value in the clinical situation to enable therapists to gain an impression of the some of functional difficulties experienced by patients with visuo-spatial neglect and the degree of visual neglect existing in a patient.

However, the finding that the ETB may have classified some subjects as having less severe neglect than they actually had does raise some concerns about the sensitivity of the ETB in terms of its ability to accurately classify neglect severity. The category differences in neglect severity between the ETB and the SCT may be explained by the fact that the latter, used for initial screening, was administered one week prior to the ETB. Therefore neglect may have undergone some spontaneous recovery during that time, which could explain the less severe neglect in some cases shown on the ETB scores. However, the similar finding using the BIT battery (behavioural sub-tests), which was administered during the same time period as the ETB, suggest that the alternative explanation, that the ETB is less sensitive, is more likely. Alternatively, it is possible that it is the BIT battery (behavioural sub-tests) which may be less accurate in terms of identifying neglect severity, as this test battery has not been previously evaluated for it's discriminative ability. The BIT is not a 'gold standard', and itself may not be particularly sensitive in classifying and differentiating between moderate and severe neglect. Future studies using larger samples, and comparing the ETB with the SCT, administered in the same time period, might help clarify this issue, as the latter test has previously been shown to demonstrate sensitivity for the assessment of visuo-spatial neglect (Marsh & Kersel, 1993).

The finding that the strongest relationship between all the three levels of difficulty of the clubs cancellation tasks (Item 1 ETB) and the SCT was for the most difficult level, also that no significant differences were found between percentage of total scores for this sub-item of the ETB and the SCT, provides support for the validity and discriminative ability of this sub-item, since the SCT has previously been shown to be sensitive for visuo-spatial neglect (Marsh & Kersel, 1993). When all scores from the Clubs Cancellation Tasks were removed, the total percentage score for the remaining Items 2-7 of the ETB still indicated a strong relationship to the total percentage scores on the BIT battery (behavioural sub-tests), signifying concurrent validity. However, the significant difference found between the scores of the ETB (Items 2-7) and the BIT indicates that neglect severity, in some subjects at least, may be underestimated if the ETB is used. This interpretation is based upon the assumption that the BIT battery (behavioural sub-tests), is sensitive for the assessment of neglect severity; such an assumption would require further investigation.

Although the most sensitive items have been shown to be the Clubs Cancellation Tasks, these items are not so functionally-based. Of those more functionally-based items (2-7), the most sensitive appears to be Item 3 (seed planting), and shows the strongest relationship (r_s=.741) with the ETB total score. Item 7 (reporting objects around the ward) appears to be the least sensitive item in the ETB (Items 2-7), with a relationship of r_s=.544. Despite this weak relationship, no subject achieved a maximum score on this item. The lower internal consistency found for Item 7 may indicate that it is assessing a different construct (i.e. visual neglect in far as opposed to near space).

While the ETB may be useful for ongoing assessment of effectiveness of rehabilitation, it is not suggested, however, that this test is used for research purposes, as full validation and standardization have not been undertaken, and the subject sample used was small. Nevertheless, there is good agreement between test and retest scores, at least when the same tester is used, with a mean percentage difference of only 8.54% between test and retest. The limits of agreement suggest that a clinician might, 95% of the time, expect a maximum difference in score between test and retest on the same day of 13 more or 22 less for the total score. This represents a small range of percentage difference, within the context of the maximum possible score for the test, which is 221.

The battery has face validity, (all sub-tests require the patient to search to both sides of visual space), as neglect is characterised by a failure to respond to stimuli in contralateral space. The high positive correlation between the ETB and the BIT (Behavioural sub-test battery) and the SCT Scoring indicates that the battery as a whole has concurrent validity.

5.7.2 Internal consistency of test items

The intercorrelations between individual test items demonstrate internal consistency, and show that most items appear to be measuring a common underlying construct, this being the orientation of attention towards ipsilesional space demonstrated in neglect patients (Gainotti et al., 1991). Nevertheless, sub-test item 7 (reporting objects around a ward) correlated poorly with all other tests. The possibility that this may have reflected the known dissociation of neglect in near space from neglect in far space, found in some patients (Halligan & Marshall, 1991), is not supported by these results, as 16 of the 17 subjects omitted a number of target objects during this test, in addition to omission of target objects in near space. Only Subject 3 showed a tendency for dissociation, because she scored 10 out of 21 for item 7, but achieved above cut-off on the BIT, only one point below cut-off in the Star Cancellation Test, and 91% and 87% of maximum score respectively for first and second administration of the ETB. Guariglia and Antonucci (1992) do suggest that such dissociation is rare. An alternative explanation for the lack of association between this Item 7 and the other sub-tests of the ETB may be that that Item 7 is not sufficiently standardised in it's current form. It relied upon objects being observed and reported by patients, but as testing occurred on different days for each subject, objects of greater or lesser salience may have been present in the ward on different occasions. Pizzamiglio et al. (1992b) noted that "most, if not all, standard tests of unilateral neglect consider only stimulus material placed in the space within hand reach of the patient". In their brief description of this test, Stone and Greenwood (1991), suggested that an item assessing visual neglect in far space should be included in any battery, to enable therapists to gain a fuller picture of the patient's ability to orient to environmental stimuli. Unfortunately, they gave no indication of scoring procedure. Future versions of this test might be more accurate if a set number of standard objects were placed in each ‘segment’ of far space. However, this might limit clinical utility, as the test would require artificial manipulation of the usual ward environment.

5.7.3 Individual test items

The cancellation tasks (test Item 1) were included to give the therapist some idea of the effects of increasing amount of distractors during searching activity. This may help identify patients with more severe neglect. Such behaviour relates to an attentional interpretation of hemineglect, as the number of targets crossed out in this cancellation task usually decreased with increasing number of distractors, an outcome found by others (Kaplan et al., 1991). Twelve of the 17 subjects scored progressively less with increasing levels of difficulty in this task, and of the remaining five, only one scored more on the most difficult task (35 out of 40), compared to the easiest (20 out of 40). The strong relationship found between the ‘difficult’ version of the Clubs Cancellation Task and the Star Cancellation Test, and the lack of any significant difference between the percentage scores on the two tests, provides further support for the validity of this item.

Test item 2 (reading a menu) is the only item that requires the subject to read words. Omission of words, or substitution of part or all of a left-sided word, neglect dyslexia, can occur independently of other forms of visual neglect (Robertson & Halligan, 1999), however, no subject attained a normal or abnormal score, on test and retest, solely on this item. Nevertheless, one subject (14) made only two left omissions the first time, and no omissions on the retest, and one other subject (4) made only three omissions on first attempt and one on second attempt. Because both of these subject had neglect severity classified as ‘moderate’ across all tests (Table 1) these menu-reading scores suggest a possible dissociation between their performance in reading tasks, and the visuo-spatial neglect shown by these two subjects in all other tasks. This possible dissociation between Item 2 and the other tests means that Item 2 (reading a menu) should not be used in isolation to test for presence of neglect or neglect severity. The tester noted that some subjects demonstrated both omissions of left-sided words, and substitution, for example ‘floury’ instead of ‘savoury’, or ‘raspberry’ instead of ‘strawberry’. Details of word substitutions and location of word omissions are shown in Appendix G.

Sub-test item 3, planting seeds in a tray, is very similar in nature to the BTT developed by Tham & Tegner (1996). It was hoped that the idea of planting seeds might overcome some problems found with the BTT in a previous study (Bailey et al., 2000) where some patients found the idea of such a large ‘baking tray’ unrealistic. This was despite the fact that a smaller (75cmx50cm) board was used for the ‘baking tray’, considered to be acceptable, as an A4 size tray had previously been found to be only slightly less sensitive than the original (100cmx75cm) board (Tham & Tegner, 1996). Other problems found by Bailey et al. (2000) were that some subjects had difficulty with the idea of what they had to do following instruction, and attempted to stack the blocks, or place them in circles (also found by Tham & Tegner, 1996). Male subjects may have had less experience of ‘baking’. No subjects in the seed-planting task attempted to stack the seeds or to place them in a circle. Thus the ‘seed planting test’ may be less ‘gender specific’, easier for subjects to follow instructions, and it also uses ‘real life’ materials, rather than cubes of wood which represent ‘buns’ on the’ baking tray’.

Items 2, 4 and 5 in this battery (reading a menu, identifying toiletry objects around a wash basin and tea-making objects around a tray), are similar in nature to the picture scanning and menu reading behavioural sub-test items of the BIT. However, the menu used here was a real menu, and the items to be identified in tests 4 & 5 were real rather than pictorial representations. Addressing an envelope (item 6) is also a functional task. Thus there appears to be better ecological validity of these items, than use of representational material.

Test items 2, 3, 4, 5 and 7 are weighted, with higher scores awarded to identification of left-sided objects or items, thus lower scores are achieved when these are omitted. Although the scoring system described here does not specifically identify laterality of errors, it would be easy for therapists to note, when scoring, on which side of the material errors occurred.

5.7.4 Fatigue effects

The finding that eleven patients scored lower on retest, and that there was an overall very small but systematic average tendency to score 4 less on retest, might indicate a fatigue effect. This might be expected, based on the attentional theory of neglect, in which neglect is at least in part attributed to defective levels of attention and arousal (Robertson, 1999). Thus, a requirement to sustain attention over a longer time period might prove difficult for the patient with neglect. A fatigue effect has been found by others (Fleet & Heilman, 1986; Halligan, Marshall & Wade, 1993). The decision to administer all tests to each subject during an approximately three-hour period was a pragmatic one, and is a procedural problem in this study, when assessing patients in the acute stage with prolonged testing procedures. It would perhaps be better to have a longer time gap between tests to minimise fatigue

5.7.5 Time taken for test administration

The BIT took almost twice as long as the ETB to administer, with the former taking, on average 53 minutes, the latter taking, on average, 33 minutes. Wilson et al. (1987b) state that the BIT takes “ between 10 and 15 minutes”, however their patients were, on average, younger, with a mean age of 54.29 years. Cermak and Hausser (1989) suggested that the entire BIT could “usually be completed in one hour”, although they do not provide evidence to support this assertion. The average time of around 33 minutes to administer the ETB is likely to be more clinically realistic and feasible than the 53 minutes taken to administer the BIT.

5.7.6 Limitations of the study

Only one subject (subject 3) scored above cut-off on the BIT, and also scored only one below cut-off on the SCT. She may therefore not have suffered from visual neglect, and perhaps should have been excluded from the study. She scored close to maximum on all sub-test items of the ETB, and only on item 7 (reporting objects around a ward) did she score poorly, only achieving 10 out of a possible 21. This might indicate that she had a dissociation between visual neglect in far as opposed to near space.

Test items 6 and 7 (addressing an envelope, and reporting objects around the ward) do involve a degree of subjectivity in scoring and would be improved by better objectivity in the scoring procedure. Additionally, Item 7 could be improved by standardization of the nature, number and location of objects, which could be pre-positioned in each segment in far space, around the ward, although this would be more difficult to arrange in the standard clinical situation. The rather low sensitivity for Item 5 (reporting objects for making a cup of tea) might be because the task was inherently easier than some other tasks. It might be better to standardise the colour of objects, as it could be argued that the more brightly coloured cup and lid of the tea caddy might have greater visual 'salience' than the darker colours of the other objects on the tray. Further testing is required to test this idea.

The ETB contains no test for personal neglect, however, a functionally-based, easy to administer, and standardised test for this already exists (Zocccolotti & Judica, 1991). The ETB has not been standardised, as it would need to be if it were to be used for research or diagnostic purposes, on a large sample of elderly stroke patients both with and without visual neglect. Thus no cut-off score has been established. Future development of this test would also need to consider the varying score totals in sub-sections, as sub-tests with different scores would thus contribute different weightings to any total score. Finally, the ETB has only been administered by one tester, who was not blinded to the purpose of the study. To strengthen the clinical utility of the ETB, this study would need to be repeated using several testers, blinded to study purpose, to establish inter-tester forms of reliability.

5.8 Conclusions

The ETB demonstrated clinical ease of use, face and concurrent validity, internal consistency of individual test items, and test-retest reliability, in this small sample. The small size of the sample is recognised, and it is unlikely to be truly representative of a larger population. Additionally, only subjects with right-sided brain damage were included, further limiting any generalisability. Scores on the standardised tests, both at initial screening using the SCT, and results of the BIT Test, indicated that the sample represented patients with a range of neglect severity. However, the discriminative capacity of the ETB for accurately classifying degree of neglect severity may be questionable, and requires further study. Although for research or diagnostic purposes existing tests or test batteries, (Wilson et al., 1987a) standardised on large samples, would be more appropriate, the ETB is offered as a useful test for healthcare practitioners in the clinical setting, for assessment and monitoring purposes. The ETB gives some indication of the impact of visuo-spatial hemineglect upon everyday activities and function. Additionally, and perhaps most usefully, the tests were constructed using techniques or materials that would be readily available on any rehabilitation ward or out-patient therapy department. The test battery is simple to administer and would take minimal time for the training of inexperienced personnel in its use.

CHAPTER 6

TEST-RETEST STABILITY OF THREE TESTS FOR UNILATERAL VISUAL NEGLECT IN PATIENTS WITH STROKE: STAR CANCELLATION, LINE BISECTION AND THE BAKING TRAY TASK.

Tools used to measure change due to the effects of rehabilitation must be reliable on repeat testing, to ensure that any change is likely to be due to intervention, rather than to measurement error due to instability of the measurement tool. Three tests chosen to measure change over time in a subsequent rehabilitation study (Chapter 7) were assessed for test-retest stability in a large group of elderly patients post-stroke, 85 with neglect and 83 without neglect. The tests were the Star Cancellation Test, Line Bisection, and the Baking Tray Task.

This Chapter is presented as a published paper:

Bailey, M.J., Riddoch, M.J., & Crome, P. (2004). Test-retest stability of three tests for unilateral visual neglect in patients with stroke: Star Cancellation, Line Bisection, and the Baking Tray Task. *Neuropsychological Rehabilitation, 14*(4): 403-419.

The remainder of this chapter presents the full paper exactly as it was published, but using numbered sections for consistency of presentation. Raw data are in H to M.

Abstract

Unilateral visual neglect, an attentional disorder, might show variability on repeated testing. This study investigated test-retest stability, in elderly patients post-stroke, 85 with and 83 without neglect. Subjects repeated three common clinical tests for neglect within the hour; the Star Cancellation Test (SCT), Line Bisection (LB) and the Baking Tray Task (BTT). Data analysis indicated good to excellent test repeatability in subjects without neglect. For subjects with neglect, intraclass correlation analysis gave coefficients of .89, .97, and .87 for the SCT, LB, and BTT, respectively, indicating good to excellent agreement. However, analysis of this group, using the 95% limits of agreement, indicated poorer stability, with maximum test-retest differences of: 15 more or 11 less stars cancelled on the SCT, 3cm for LB, and five ‘buns’ on one side of the ‘tray’ for the BTT. Limits of agreement analysis of sub-groups demonstrated better test-retest stability for the SCT, and a trend for this in the LB, in subjects with more severe neglect. Clinically, limits of agreement analysis is useful, providing indication of the maximum difference, in the units of the test, which may be expected on retest. We suggest that, if SCT, LB or BTT are used as outcome measures, subjects with severe unilateral visual neglect are likely to show better stability on repeated testing. This may be especially relevant for single-case design when stability of baseline measurement is of particular importance.

6.1 Introduction

Unilateral visual neglect is a common perceptual deficit found after stroke (Bowen et al., 1999). It is characterised by a failure to direct attention to stimuli, commonly when they are located on the patient's contralesional side (Robertson & Halligan, 1999). Neglect is more severe and longer lasting following right as opposed to left-sided brain damage (Halligan & Marshall, 1994a). Neglect behaviour can be elicited by a wide variety of tests, and because of the heterogenous nature of the syndrome, a battery of tests, rather than use of one single test, has been recommended (Agrell et al., 1997).

For clinical purposes, tests should be sufficiently simple to allow bedside administration. Any test should also provide reliable data, particularly when used for research purposes, when tests may be used both for screening for neglect and as an outcome measure to assess any effect of treatment. Unilateral visual neglect is commonly assessed using cancellation tests or line bisection (Ferber & Karnath, 2001). As neglect is considered to be a disorder of attention (Kinsbourne, 1994), and attention is likely to vary over time, tests for neglect may not provide stable measurements when repeated.

6.2 Reliability and stability

Reliability is the degree to which repeated measures vary for individuals. Stability is an aspect of reliability that represents the extent to which the phenomenon being measured remains consistent during repeated testing (Bruton, Conway & Holgate, 2000), and is determined by a single rater taking repeated measures over time (Sim &

Wright, 2000). In assessing agreement between serial measures, one has to consider stability both of the measures themselves, and of the underlying phenomenon being measured. Psychological measures may be quite labile, and any variability between first and subsequent measurement may be attributable either to measurement error of the examiner, or to inconsistency in performance of the subject. It is important to distinguish the reliability of measurement from the stability of the parameter being measured. When testing for neglect, inconsistency in subject performance is likely to occur because the manifestations of an attentional disorder might be expected to be inherently variable (Halligan et al., 1993). Finally, there will always be a possibility of random or chance error on repeated testing.

The use of correlation coefficients, such as Pearson's r, Spearman's rho or Kendall's tau, are not considered to be the most appropriate methods for assessing repeatability of performance on clinical testing. This is because they measure degree of association rather than degree of agreement (Sim & Wright, 2000). In other words, they measure relative reliability, or the degree to which individual measurements within a group will maintain their position within the group on repeated measurement. They do not take into account the absolute magnitude of difference between measures. For this reason, the intraclass correlation coefficient or ICC (Shrout & Fleiss, 1979) is considered to be a better measure, because it accounts for absolute as well as relative reliability (Domholdt, 1993). Nevertheless, despite these advantages of the ICC for analysis of performance repeatability, such analysis still does not provide the actual expected magnitude of difference between test and retest. For this reason, Bland and Altman (1986) have developed an additional method of analysis called the 'limits of agreement'. The limits of agreement give the magnitude of disagreement in the actual units of measurement, thus providing a more clinically useful estimate of test-retest repeatability than sole use of an ICC value. Furthermore, graphic presentation of the limits of agreement allows visual interpretation of any systematic bias and random differences between the repeated measures.

Reliability of assessment tools used in rehabilitation is important to make sure that any error involved in measurement is minimal in relation to actual change in what is being measured (Rankin & Stokes, 1998). In clinical practice it is important to know if any change measured is due to an intervention rather than measurement error (which itself could be due to rater or measurement tool inconsistency, or the subject's performance).

The three tests for unilateral visual neglect described below have been used in both single-subject design (Robertson et al., 1998a) and group comparison studies (Robertson et al., 1997b). An important characteristic of data for single-subject design analysis during initial baseline phase is that of stability of the data. This allows more confidence to be placed in the effect of any intervention, when data during the treatment phase show clear changes in magnitude of trend or level, compared with the baseline phase. Group comparisons also need to use measures with demonstrated repeatability, to allow valid inferences to be made about effects of intervention.

6.3 Common tests for unilateral visual neglect

Three commonly used tests are the Star Cancellation Test (SCT) and Line Bisection (LB), both from the conventional sub-tests of the Behavioural Inattention Test (Wilson et al., 1987a), and the Baking Tray Task (BTT; Tham & Tegner, 1996).

The SCT involves cancellation of small stars randomly placed on an A4 sheet of paper additionally containing distractors (large stars and letters). LB requires the subject to bisect lines drawn on an A4 sheet of paper. For the BTT, subjects are asked to place ‘buns’ (wooden cubes) across a ‘baking tray’ (wooden board), as evenly and symmetrically as possible. Subjects with neglect fail to cancel stars, particularly on the contralesional side of the page, and the perceived midpoint is displaced ipsilesionally during line bisection (Halligan et al., 1989). During the BTT, subjects tended to skew the distribution of ‘buns’ to the ipsilesional side (Tham & Tegner, 1996). To improve the utility of the SCT, Friedman (1992) proposed the use of a laterality index, which is calculated from the ratio of stars cancelled on the left side of the page, to the total number of stars cancelled. This index has been used to provide a clinically useful measure of the lateralized extent and severity of omissions in contralateral space (Bailey et al., 2000; Marsh & Kersel, 1993; Samuelsson, Hjelmquist, Naver, & Blomstrand, 1992), and as a useful predictor of functional outcome (Friedman, 1992).

The SCT has been extensively used for both screening (e.g. Edwards & Humphreys, 1999; Robertson et al., 1998a) and for measurement of outcome (e.g. Brunila et al., 2002; Rorsman et al., 1999; Yates et al., 2000). Line bisection has been used for screening (e.g. Robertson & North, 1993) and as an outcome measure (e.g. Samuel et al., 2000), and the BTT has also been used for screening (e.g. Ferber & Karnath, 2001) and outcome (e.g. Robertson et al., 1995; Tham et al., 2001).

6.3.1 Reliability of Star Cancellation Test, Line Bisection and the Baking Tray Task

There are few studies examining reliability of the SCT and LB. Wilson et al. (1987a) examined inter-rater reliability on 13 subjects, using two testers, and found a significant correlation (.99) between testers. Test-retest reliability was also investigated on two separate occasions, with a mean interval of 15 days, using an even smaller sample of only 10 subjects. This also produced a significant correlation of .99. Although not specifically stated in the manual, the assumption is that the reported correlations reflect overall scores from the entire test battery of the Behavioural Inattention Test conventional sub-tests (no figures are given for individual sub-tests). Wilson and colleagues do not state what type of correlation coefficient was used to assess reliability. Additionally, the sample sizes were too small for inferences to be made, and characteristics of the samples used to test reliability were not provided, although samples were recruited from a larger group of 80 patients with unilateral brain damage due to stroke. The mean age of this initial group was 56 years, which may not reflect clinical reality, where average age of stroke patients is likely to be much higher. Three-quarters of all first strokes occur in people over 65 years of age, with 50% of these being in people aged 75 and over (Blais, 1994). Furthermore, it is not clear if the small sample used for reliability testing included patients with neglect.

Only one study (Levy et al., 1995), has evaluated repeatability of the SCT (as part of a larger test battery) using one tester, over the shorter time period of one day, usually between 2pm and 5pm, in a sample of 41 acute and convalescent patients with stroke, mean age 76 years. They used Cohen's Kappa to estimate test stability and achieved a k value of 0.6 (substantial agreement) for the SCT. It is hard to justify their use of kappa, a statistic normally used to indicate agreement when nominal data are collected, as the SCT yields interval data. No indication was given about the actual differences in stars cancelled between test and retest. On second administration, the SCT was modified by changing the distractor words. Furthermore, it is unclear whether their sample represented only subjects with neglect.

Reports of reliability of line bisection are also limited. Kinsella et al. (1995) found only moderate correlation (r =.64) on test-retest (test intervals being between 5 and 7 days apart) in a group of 40 subjects with right-sided brain damage, based on average bisection error of 20 lines, ranging from 10-20cm in length, on a sheet of A4 paper. It was not clear how many subjects in the group had neglect. Again, such correlational analysis may be inappropriate to test reliability because the r value indicates only the strength and direction of association, and is not an index of agreement.

Test-retest repeatability of the BTT has not previously been reported. Although its originators maintained that the test was a “simple and yet sensitive test” (Tham & Tegner 1996), suitable for single case and longitudinal studies, they did not report repeatability testing.

There is a clear need to establish the repeatability of these three commonly used clinical tests for unilateral visual neglect. Given some of the limitations of the methods of statistical analysis used in earlier studies, the intraclass correlation coefficient (Shrout & Fleiss, 1979), and the 95% limits of agreement (Bland & Altman, 1986) were both used to analyse data in the present study. This combination of analyses has been recommended for reliability studies (Bruton et al., 2000; Rankin

& Stokes, 1998). The 95% limits of agreement reflect the 'total measurement error' (bias and random error together). Bias conveys the extent of any systematic tendency for scores to increase or decrease between test and retest, in other words, the systematic error. For this study, the bias was calculated by subtracting the second (retest) score from the first test score such that a positive bias indicates that the first score is greater than the second, whereas a negative bias indicates that the second score is greater than the first. The limits of agreement represents the test-retest differences for 95% of the sample (Bland & Altman, 1986), indicating random error.

The purpose of this study is to establish whether the three tests for unilateral visual neglect, SCT, LB and BTT, show adequate repeatability over a short period.

6.4 Methods

6.4.1 Subjects

All elderly patients with stroke (almost all over the age of 60 years) consecutively admitted to a rehabilitation stroke unit, over a two-year period, were approached for testing (n = 226). Patients who were able to understand (by responding appropriately to test instructions) and, on two occasions, complete the Star Cancellation, Line Bisection and Baking Tray tests for unilateral visual neglect, were included in the study. Fifty-eight patients were unsuitable for testing due to communication or cognitive problems. The side of brain damage was confirmed by CT scan. Details of the sample are provided in Table 6.1.

6.4.2 Testing procedure

The tester sat opposite the subject, with a small table between them, on which the sheet of paper (for the SCT and LB) or the wooden board (for the BTT) was placed, the centre of the paper, or board, being aligned with the subject's vertical body midline. Subjects were allowed to move their heads but not the stimulus material. No time limit was imposed. Individual test instructions were standardised, and were repeated, if necessary, only once.

Table 6.1.

Demographic characteristics of the patient sample

	Male	Female	Age/yrs (mean & range)	Time Post-stroke/days (mean & range)	Left-sided brain damage	Right-sided brain damage
Unilateral visual neglect present	44	41	74.8 (61-90)	29.3 (7-71)	20	65
Unilateral visual neglect absent	49	34	73.1 (59-90)	27.4 (3-69)	49	34
Not testable	25	33	76.7 (58-89)	32.9 (8-89)	43	15

Subjects were asked to indicate when they had completed each test. All testing took place between 10.00am and 11.00am. Tests were presented in random order, using the

Latin Square technique (Shaughnessy & Zechmeisser, 1990), and all tests were repeated within the hour.

6.4.3 Tests and scoring

The SCT consisted of a page containing 52 large stars, 10 short words and 13 letters, randomly positioned, with 56 small stars interspersed. Subjects were instructed to cross out (with a black pen) all the small stars across the page. The tester demonstrated by crossing out the two central stars. Maximum correct score is 54 (27 left, 27 right).

The LB test consisted of three horizontal black lines, 20cm long, one to the right, one central and one to the left side of a sheet of white paper (21cm x 30cm). The patient was asked to find and mark the centre of each line in turn. Errors away from true midline were measured and an average error score in centimetres calculated, with leftward errors being given a negative sign, rightward errors a positive sign.

For the BTT, the equipment used was a piece of white-board (75cmx50cm) which was the ‘baking tray’ and sixteen 3.5cm cubes of brown wood (the ‘buns’). Subjects were asked to “place the blocks as symmetrically as possible as if they were ‘buns’ being placed on a baking tray to be put in the oven”. All 16 cubes had to be used and subjects were reminded if any were omitted. The number of cubes in each half of the board was counted. The score used was the number of ‘buns’ on the left side of the board. Thus, ‘buns’ placed on the left side of the board could range from zero to 16.

Cut-off scores to establish presence of unilateral visual neglect were: 51 or less stars cancelled for SCT, more than 1.4cm error to left or to right for LB (Wilson et al., 1987a), and ‘buns’ more skewed than 7 left:9 right, or 9 left:7 right (Tham & Tegner, 1996).

North Staffordshire Local Research Ethics Committee gave approval for the study, and all patients suitable for testing gave informed consent.

6.4.4 Data analysis

Presence of unilateral visual neglect was assumed if either the first or second, or both test and retest scores were below cut-off. For subjects with neglect, for each test, only subjects scoring below cut-off were included in analysis for that test. In order to avoid arbitrary definitions of severity of neglect by scores, scores from each test were divided into upper, middle and lower tertiles, which approximated to mild, moderate and severe neglect respectively. Paired data obtained from all three tests for neglect was interval-type, allowing data to be subsequently analysed using both ICC and limits of agreement.

Sub-group analysis using the limits of agreement was additionally computed for upper, middle and lower tertiles, for the SCT and LB. For the BTT, 44% of the subjects placed zero ‘buns’ on one side of the tray, and all 16 ‘buns’ on the other side, on test and retest. Thus scores of these subjects, in two of the three tertiles, were exactly the same, and tertile analysis did not seem meaningful.

Both the ICC and limits of agreement assume normality of distribution, which would not be satisfied for the group of subjects without neglect, on SCT and BTT, as, by definition, their normal scores (between 51 and 54, and between 7 and 9 respectively) would provide sets of data with very limited range and variability. Data from the LB test would be expected to show normal distribution, as continuous data were obtained, normal scores being between zero and 1.4cm. Therefore, data from the non-neglect group, for SCT and BTT, will be presented descriptively, and inferential analysis will only be presented for the LB test data.

The ICC chosen for all analyses was the ICC (1,k), where k = 1 for SCT and BTT, and k = 3 for LB, as the mean of three measures, for each subject, was calculated. This model was considered the most appropriate for determining reliability using only one rater, and it also gives the most conservative results (Rankin & Stokes, 1998). Additionally, it enables some degree of generalization to other raters (Shrout & Fleiss, 1979). The ICC produces a reliability index ranging between 0 and 1, where closer to 1 represents higher reliability (Bruton et al., 2000). The boundaries used were those given by Portney and Watkins (1993) with below .7 indicating moderate to poor reliability, .7 - .9 indicating good reliability, and above .9 indicating excellent reliability. Statistical Package for Social Sciences (SPSS) version 10.0 was used for ICC analysis and to produce the limits of agreement (LoA) plots.

6.5 Results

6.5.1 Test-retest repeatability in subjects without neglect

All 83 subjects scored between 51 and 54 on SCT, less than 1.4cm error in either direction for LB, and no more skewed than 7/9 or 9/7 ratio of ‘buns’ on the ‘baking tray'. For the SCT there was either total agreement or only a difference of between one and two stars cancelled between first and second test for 95% of subjects, with only 5% of subjects cancelling three stars different between tests. For the BTT, 90% of test-retest scores were the same, on the same side of the 'tray'. Ten per cent were one or two 'buns' different between first and second test. For the LB test, the ICC (1,3) was .76, 95% CI .63-.85, (p<.001), indicating good agreement between test and retest.

6.5.2 Test-retest repeatability in subjects with neglect

6.5.2.1 Results of intraclass correlation coefficients.

From a total of 85 subjects, 63 scored below cut-off on the SCT, 54 on LB, and 71 on the BTT. For the SCT, the ICC (1,1) for test-retest was .89, 95% CI .83-.93 (p <.001). For LB, the ICC (1,3) was .97, 95% CI .94-.98 (p<.001). For the BTT, the ICC (1,1) was .87, 95% CI .81-.92 (p <.001). All results indicate good to excellent agreement between test and retest.

6.5.2.2 Results of bias and limits of agreement.

The 95% limits of agreement (Figure 6.1) for all 63 subjects on the SCT was from –15 to +11 (bias was –2.2). For the upper tertile, the 95% limits of agreement was from –16 to + 11 (bias was –2.3), for the middle tertile between –21 and +12 (bias was –4.5), and for the lower tertile, from –6 to +6 (bias was 0.14). Only two subjects, from the lower tertile, had identical scores on test and retest.

The 95% limits of agreement (Figure 6.2) for all 54 subjects on LB was from –2.7 to +3.0 (bias was 0.13). For the upper tertile, the 95% limits of agreement was from –2.9

to + 3.2 (bias was 0.15), for the middle tertile from -2.8 to +2.9 (bias was 0.1), and for the lower tertile, from –2.7 to +2.9 (bias was 0.14). Only one subject, from the lower tertile, had an identical score on test and retest. During LB, as found in a previous study (Kinsella et al., 1995), some subjects were noted to simply bisect lines with reference to the centre of the page, not taking into account the position of the line on the page.

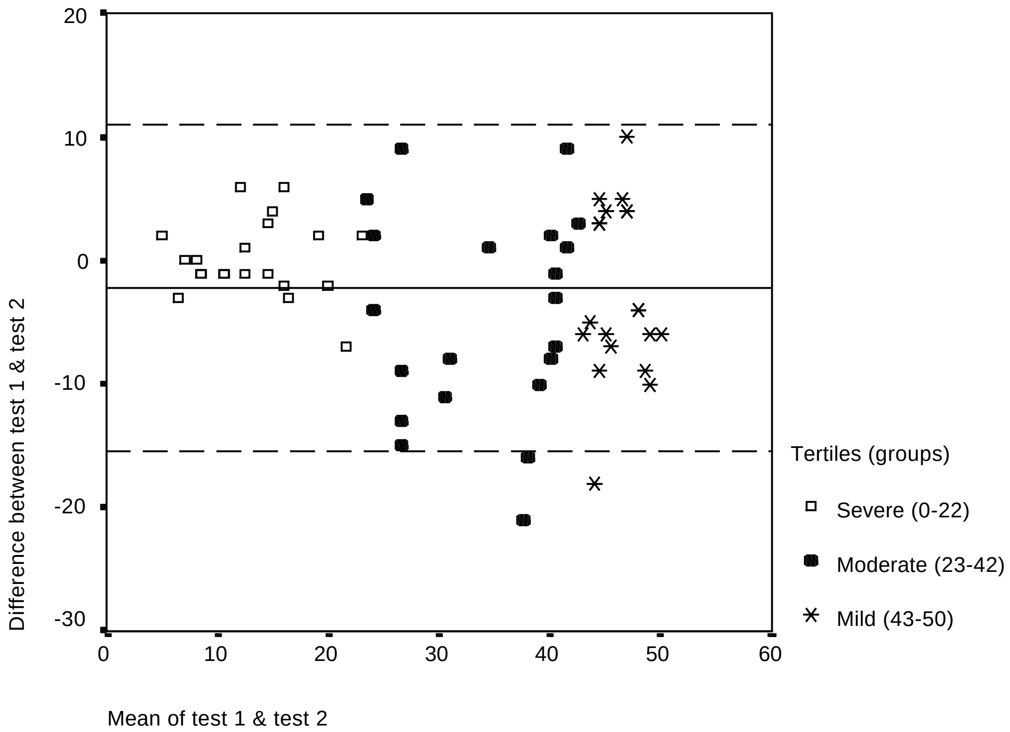


Figure 6.1. Bias and 95% limits of agreement for Star Cancellation Test for subjects with unilateral visual neglect (n = 63). Tertiles (groups) refers to the range of number of stars cancelled for each tertile. Possible range is 0-54.

The 95% limits of agreement (Figure 6.3) for all 71 subjects on the BTT was from –5 to +5 (bias was –0.21). Of these, 31 subjects produced identical scores on test and retest of either zero or 16 ‘buns’ on the left side of the ‘tray’. This sub-group included

15 subjects who were in the lower tertile for the SCT, only 4 being in the upper tertile for the SCT. Of the remaining 40 subjects in this group, only seven scored the same on test and retest, and the 95% limits of agreement was from –7 to +7 (bias was –0.37). Therefore only 53.5% of all subjects had identical test-retest scores.

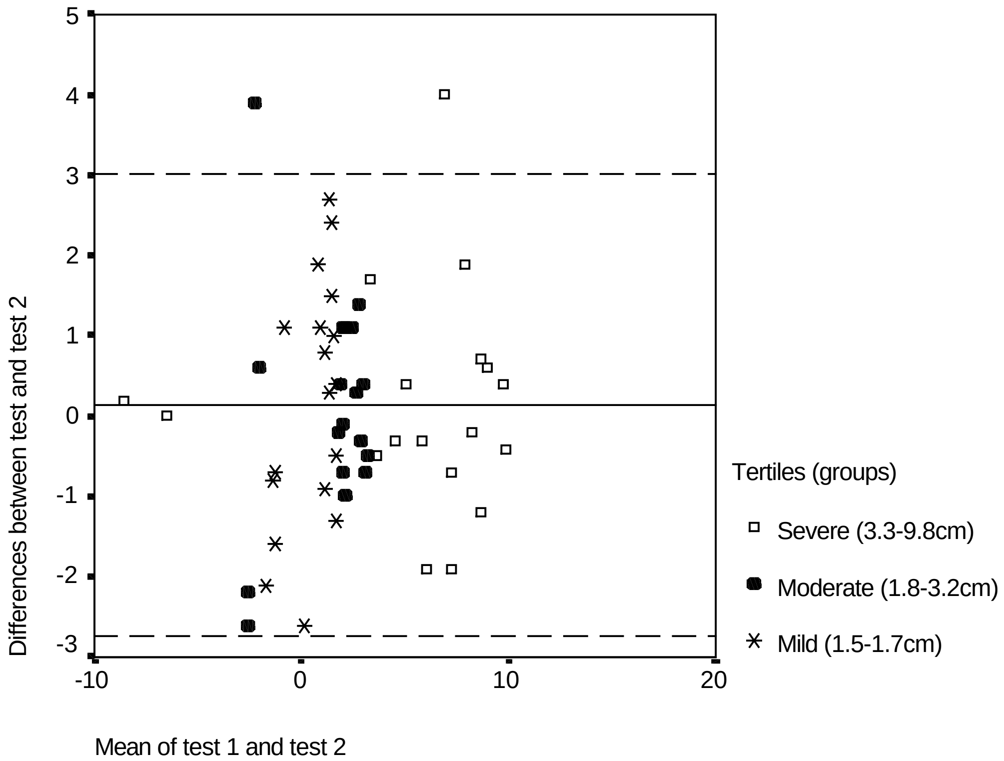


Figure 6.2. **Bias and 95% limits of agreement for Line Bisection Test for subjects with unilateral visual neglect (n = 54). Tertiles (groups) refers to the range of bisection error for each tertile. Possible range is 0-10cm.**

6.5.3 Dissociations between the three tests.

Of the 85 subjects with neglect, 49 scored below cut-off in all three tests, none in the SCT only, six in LB only, and 14 in BTT only. Two scored below cut-off in both SCT and LB, seven in both SCT and BTT, and seven in both LB and BTT.

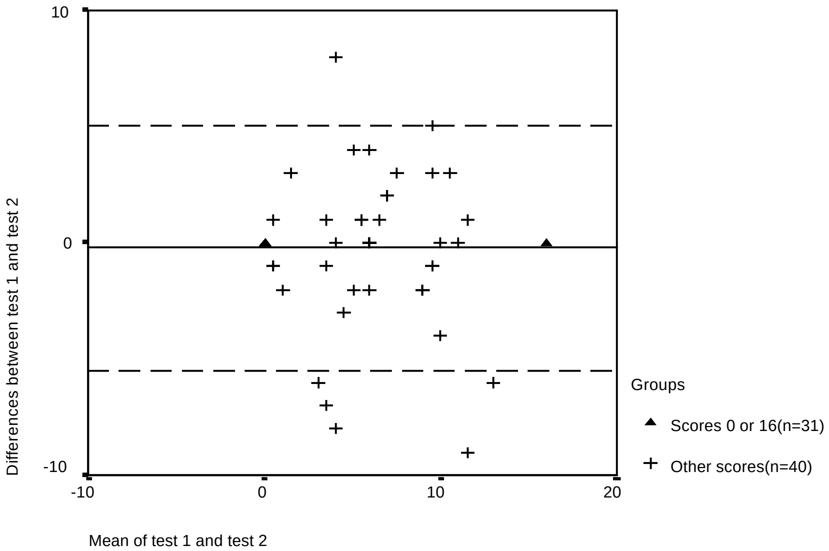


Figure 6.3. Bias and 95% limits of agreement for Baking Tray Task for subjects with unilateral visual neglect (n = 71). Groups refers to one group with either zero or 16 'buns' placed on the left side of the 'baking tray', the other group with scores other than zero or 16.

6.6 Discussion

The findings from the group of patients without neglect indicate that not all scores from the first and second test were equal, but the reliability appeared very good for SCT and LB, although there was less evidence of reliability for the BTT. For the group of patients with neglect, results from the ICC analysis indicate overall good to excellent levels of reliability for all three tests. The range of data (i.e. variance of scores) used to calculate the ICC will influence its magnitude, independently of the actual agreement between paired measures (Sim & Wright, 2000). Thus if the range increases, the within-subject (error) variance will represent proportionately less of the total variance, and the correlation coefficient will increase, and vice versa. Inclusion of a large number of subjects, with a wide range of neglect severity, as in this study, is likely to provide a wide range of test scores, and thus a high value obtained for ICC analysis. This highlights the fact that ICC data must always be interpreted with some caution, taking into account the characteristics of the sample.

The results of the limits of agreement analysis give a slightly different picture, indicating better test-retest reliability for lower tertile sub-groups (those with more severe neglect), clearly shown for the SCT (Figure 6.1) and a similar trend for LB (Figure 6.2). The scores shown in Figure 6.3 for the BTT showing no difference between test and retest, may reflect test stability for those subjects with severe neglect, but may also indicate that a ‘floor effect’ has occurred. Results from the limits of agreement analysis are likely to be of more clinical value than ICC results alone, as they additionally provide an estimate of measurement error in the actual units of measurement, as well as an estimate of any systematic bias on re-test that might be anticipated.

Due to the short time differences between test and retest for each subject, variations in performance would not be due to factors such as spontaneous recovery, or learned strategies during rehabilitation (Levy, Blizzard, Halligan & Stone, 1995), and are more likely to be related to variations in attentional level over time, which could also account for the small variations in test-retest scores for patients without neglect. Unsystematic (random or chance) error may also account for some differences between test-and retest. This might impact particularly upon cancellation tasks, which involve searching for targets, as there will exist a probability of finding any target on any one trial. Thus variability in scores may reflect such error even if the actual neglect behaviour remains stable.

The decision to retest within one hour was to try to minimise the impact of factors such as potentially distracting changes in the ward environment (e.g. related to people or activities), or fluctuations in subjects' level of alertness, or fatigue, at different time periods during the day, which may have influenced subject performance. However, it is acknowledged that repeated testing by clinicians may well take place at time intervals longer than one hour. Future studies could usefully repeat testing on more than two occasions over longer time periods, and between days. This might better reflect clinical reality and would give a more meaningful picture of fluctuations in neglect performance over time, not attributable to natural recovery. Nevertheless, despite the attempt to control for such factors, it remains a possibility that, even over such a short time period, problems such as fatigue, anxiety, distraction, and loss of concentration may all have influenced stability of performance on test-retest in this study. These problems may have interacted with and thus affected attentional capacity.

6.6.1 Differential performance across the three tests

Double dissociations (neglect present on one test but not others at the same time) found for all three tests, first reported by Halligan and Marshall (1992) are consistent with previous findings (Bailey et al., 2000). This reinforces the notion that unilateral visual neglect is not a single entity and requires a range of tests to be used to maximise the possibility of its identification. Differential test performance may be partly explained by the different demands of each task. For example, the SCT uses visual search, line bisection requires a judgement about relative length, and the BTT involves spatial judgements. The tests may also be assessing different aspects of the neglect syndrome. Indeed, although line bisection is a very commonly used clinical test for neglect, Ferber and Karnath (2001) suggest that as factors other than spatial neglect may lead to bisection error, results using this test must be interpreted with caution. Whereas cancellation tasks require the subject to visually search across a stimulus array, line bisection calls upon a different perceptual skill - the ability to compare line length. Thus, as these authors point out, errors made in line bisection are not specific to patients with neglect, although such behaviour may be associated with neglect. Conversely, they reported that line bisection missed 40% of their patient sample who had "well-defined severe spatial neglect". As six subjects in the current study scored below cut-off solely in line bisection, it is possible that these were incorrectly identified as having neglect.

The classification of subjects as presenting with neglect or not was undertaken using the tests under investigation for repeatability. This was done for pragmatic reasons, but is a limitation of the current study. Future studies could avoid this confounding design factor if they used screening tests to identify the presence of neglect which were different from the tests to be used in the actual study.

6.6.2 Stability of the Star Cancellation Test in subjects with neglect

For the SCT, the bias shows a small systematic tendency for more stars (two on average) to be cancelled on retest. This systematic bias might be due to a small practice effect. The overall limits of agreement indicate that for 95% of cases, there is likely to be, on retest, a maximum difference of 15 more or 11 less stars cancelled. Decrease in score on retest might indicate fatigue in some patients, or a reduction in attentional levels due to some external distraction. Conversely, increase in score in some patients might reflect a learning effect, although no feedback on performance was given. It is also possible that repetition of the activity may have increased arousal levels, thus improving performance. The findings from sub-group analysis by tertile indicate poor agreement between test and retest for the upper and middle tertile, representing subjects with mild or moderate neglect. However, there appears to be better agreement and minimal systematic bias for the lower tertile, representing subjects with more severe neglect. Here a difference of plus or minus 6 stars cancelled between test and retest indicates better stability. This pattern is demonstrated in Figure 6.1.

6.6.3 Stability of the Line Bisection Test in subjects with neglect

For the LB test, for the whole group, and for each tertile (Figure 6.2), the limits of agreement indicate a difference of no more than 3cm between test and retest for 95% of cases. There was minimal systematic bias. The possibility of a patient with neglect scoring up to 3cm differently between test and retest indicates poor stability in test performance. Again, possible reasons discussed above for performance instability in SCT may also apply here. These findings suggest that in any studies of intervention to ameliorate neglect, improvements measured by reductions in line bisection error would need to be greater that 3cm to provide strong evidence that change was due to the intervention and not to measurement error linked with instability of the measurement. In patients with severe neglect, such error would be likely to form a smaller percentage of error, as these patients could be expected to bisect with larger ipsilesional errors than patients with less severe neglect (Koyama et al., 1997).

6.6.4 Stability of the Baking Tray Task in subjects with neglect

For the BTT, for the whole group, the limits of agreement indicate that for 95% of cases, on retest, a patient might place five ‘buns’ more, or less, on one side of the ‘tray’. There was minimal systematic bias. Thus use of this test to indicate change due to intervention, would need to be interpreted with some caution, due to poor test-retest stability, at least for subjects with mild to moderate neglect. As with LB, the test appears to involve a perceptual judgement about symmetry, although attentional aspects of neglect may also be accessed during the test activity. However there was complete stability of performance in all those subjects who positioned all ‘buns’ on only one side of their tray. Of these the majority also scored poorly (middle to lower tertiles) in the SCT, suggesting these subjects had more severe neglect. Such complete apparent stability may also be due to the BTT showing ‘floor’ effects.

6.6.5 Validity of relating tertile division of scores to neglect severity

Although no data relating to the SCT was found in previous studies, to support the assumption that data analysis by tertile from this sample (Table 2) might reflect neglect severity, some studies have reported magnitude of line bisection error related to neglect severity.

Table 6.2.

Descriptive statistics from subjects with unilateral visual neglect (mean of test and retest scores) for star cancellation and line bisection based on division of data into tertiles.

	Star Cancellation Test (total number of stars cancelled) n=63	**Line Bisection (error from true midline/cms) n=54**
Lower Tertile (severe neglect)	8 13.21 range 0-22 sd 5.08 n=21	8 7.04 range 3.3-9.8 sd 1.97 n=18
Middle Tertile (moderate neglect)	8 34.04 range 23-42 sd 7.04 n=21	8 2.40 range 1.8-3.2 sd 0.45 n=18
Upper Tertile (mild neglect)	8 46.11 range 43-50 sd 2.04 n=21	8 1.35 range 0.85-1.75 sd 0.27 n=18

Friedman (1990), using bisection of a single centrally positioned 20cm line, in a large group of elderly acute stroke patients, considered bisection error of 0.7-1.5cm to indicate mild neglect, and above 1.5cm to be more severe, although no ‘moderate’ category was included. Using average data from eight bisections of centrally positioned 20cm lines, Koyama et al. (1997) defined mild neglect as ‘small’ to 3.3cm error, moderate neglect as 3.3-5.5cm error, and severe neglect as more than 5.5cm error. Such results are comparable with findings from this study (Table 6.2), and provide some support for the assumption.

6.7 Conclusions

The results of this study demonstrate the different persepectives on the data shown by ICC and limits of agreement analysis. Additional use of limits of agreement analysis allows the strength of agreement to be interpreted within a clinical context. The SCT, LB and BTT are all simple to administer and score. However, although the ICC findings indicate very good reliability for all three tests, the limits of agreement analysis shows that if these tests are to be used to assess unilateral visual neglect, subjects with severe neglect are likely to show greater stability on repeat testing than those with mild or moderate neglect. Repeat testing using SCT, LB or the BTT in subjects with mild or moderate neglect may be difficult to interpret, because small changes in performance may reflect measurement error due to test-retest instability, rather than any real change occurring as a result of an intervention. Stability of baseline measures is particularly important in single-case experimental design, and these results suggest that subjects with more severe neglect are more likely to show such test-retest stability, at least in two of the three tests investigated here. This study indicates that, while these tests may be both appropriate and useful for screening patients and for initial assessment, if used for repeated testing, the results must be interpreted with caution, particularly in subjects with mild to moderate neglect.

6.8 Implication of findings for single case experimental design study (Chapter 7) – supplementary material

Based upon these findings, the Star Cancellation Test, Line Bisection, and the Baking Tray Task, were considered to be appropriate tests to be used for repeated measures for each subject in the single case series, to assess visual neglect. Due to the necessity to use repeated testing in the single case series, subjects with moderate to severe visual neglect were considered most suitable for inclusion, as test-retest stability has been shown in the above study to be better for this patient group.

N.B. The ‘unpublished study’ (referred to in the following Chapter 7, Section 7.6.3.1), was subsequently published, and is in fact the study presented here in Chapter 6. This reliability study ultimately used a larger sample of patients than the 57 referred to in the footnote (p.224), and also included a control sample.

CHAPTER 7

EFFECTIVENESS OF TWO STRATEGIES FOR THE TREATMENT OF VISUAL NEGLECT IN ELDERLY STROKE PATIENTS

Two strategies for the rehabilitation of visual neglect are evaluated using a series of single subject experimental designs. Five patients received a scanning and cueing approach, and two received a contralesional limb activation approach. Both approaches reduced aspects of visual neglect in some subjects, although no evidence was found of improvements in functional ability which were directly related to the treatment regime. Findings from a series of five further patients is added after the presentation of the published paper.

This Chapter is presented as a published paper:

Bailey, M.J., Riddoch, M.J., and Crome, P.(2002). Treatment of visual neglect in elderly patients with stroke: a single-subject series using either a scanning and cueing approach or a left-limb activation strategy. ***Physical Therapy, 82*** **(8), 782-797.**

This chapter presents the full paper exactly as it was published, but using numbered sections for consistency of presentation.

Prior to presentation of the published paper, the pilot study will be briefly presented. Following presentation of the published paper, findings are added from a further series of five patients, using one or other of the two treatment approaches.

7.1 Pilot study

Brief details of the pilot study were not included in the published paper due to constraints of word limit, and are therefore included here. Following granting of ethical approval (Appendix V), six patients admitted to the stroke rehabilitation unit over a 12-month period, who fulfilled the inclusion criteria (below cut-off in all three tests of SCT, LB and BTT – see section 7.6.2), all with cerebral infarction involving the territory of the right middle cerebral artery, were recruited to the pilot study (Table 7.1). A single-subject experimental design was used, with first baseline (A1), treatment (B) and second baseline (A2) phases, each lasting approximately 3-4 weeks.

Table 7.1

Subject details, timing of phases in ABA design, and treatment (pilot study).

Subject	Sex	Age (yrs)	Days post-stroke (start of A1 phase)	Days post-stroke (start of B phase)	Days post-stroke (start of A2 phase)	Treatment Strategy Used during B phase
01	Male	77	17	38	64	Scanning and cueing
02	Male	66	34	53	83	Scanning and cueing
03	Female	78	21	44	65	Scanning and cueing
04	Male	73	18	51	74	Scanning and cueing
05	Male	77	24	47	96	Limb activation
06	Male	72	25	49	77	Limb activation

All tests for neglect and for sensation, stroke severity and function used in the pilot study are listed in Table 7.2. In addition, rationale for inclusion of the seven tests for unilateral neglect, and scoring and administration of all tests for neglect used in the pilot study are given in Bailey et al. (2000) see Appendix W.

Table 7.2

Tests used to assess unilateral neglect and function during screening and across phases (pilot study)

Test	Purpose of test	Used for screening	Used to assess progress over time	Frequency of collection of data over time
Star Cancellation Test[1]	UVN	Yes	Yes	Minimum 10 per phase
Line Bisection Test[2]	UVN	Yes	Yes	Minimum 10 per phase
Baking Tray Task[3]	UVN	Yes	Yes	Minimum 10 per phase
Copy-a-daisy[4]	UVN	No	Yes	Minimum 10 per phase
Draw-a-clock[5]	Representational neglect	No	Yes	Minimum 10 per phase
Utilisation of common objects test[6]	Personal neglect	No	Yes	Minimum 10 per phase
Exploratory-motor task[7]	Motor exploration of contralesional space	No	Yes	Minimum 10 per phase
Nottingham Sensory Assessment scales[8]	Light touch	No	Yes	Minimum 3 per phase
Nottingham Sensory Assessment scales[8]	Proprioception	No	Yes	Minimum 3 per phase
Rivermead Mobility Index[9]	Mobility in bed, transfers & walking	No	Yes	Minimum 3 per phase
Barthel Index[10]	Activities of daily living	No	Yes	Minimum 3 per phase
Canadian Neurological Scale[11]	Stroke severity	No	Yes	Minimum 3 per phase

1 Wilson et al, 1987. 2 Friedman, 1990. 3 Tham & Tegner, 1996. 4 Wilson et al, 1987. 5 Wilson et al, 1987. 6 Zoccolotti & Judica, 1991.7 Maeshima et al, 1997. 8 Lincoln et al, 1998. 9 Collen et al, 1991. 10 Mahoney & Barthel 1965. 11 Cote et al, 1989.

Preliminary analysis of the data from these subjects, using visual inspection alone, indicated improvement in unilateral neglect in at least one of the tests, which occurred at the onset of the treatment phase, and was maintained during the second baseline phase. There was a great deal of variation between patients in the scores for sensation and function, some patients showing little change over time, others showing improvement over time. However, few or no changes occurred in the stroke severity scores over time for any patient.

Following evaluation of this battery of tests for unilateral neglect (Bailey et al., 2000) the decision was made to retain the Star Cancellation and to use the Line Bisection tests (both from the Behavioural Inattention Test battery, Wilson et al., 1987a) and the Baking Tray Task (Tham & Tegner, 1996), for the screening and ongoing measurement of visuospatial neglect. The 'Copy-a-Daisy', 'Draw-a-clock', the 'Exploratory-Motor' task, and the 'Utilisation of Common Objects' test for personal neglect were omitted. Thus only visuospatial neglect was to be monitored, to enable better focus on this particular manifestation of neglect, and also because of problems of test validity and sensitivity of the other tests for neglect (Bailey et al., 2000). Test-retest reliability of the three tests chosen to measure visuospatial neglect was confirmed, for patients with moderate to severe neglect, and findings are discussed in Chapter 6. Other tests for sensation, function and stroke severity were retained, as they have previously been shown to be valid and reliable for use with elderly stroke patients (see section 7.6.3.2). Two other changes were made, following piloting, to strengthen the validity of the main study design. Firstly, it was recognized that blinding would reduce the possibility of researcher bias, if an independent assessor, blind to study purpose, and to phase (A or B), were to take all of the measurements. Therefore, application was submitted for a research grant for £5,000, subsequently approved (North Staffordshire Medical Institute, Stoke-on-Trent, UK), which enabled employment of an independent assessor. Secondly, it was decided to randomly allocate patients to varying lengths of baseline (two, three or four weeks) to control some threats to internal validity. No other changes were made as a result of the pilot study, and the main study is reported in the remainder of this chapter.

Abstract

Background and Purpose. The presence of unilateral visual neglect (UVN) may adversely affect functional recovery, and rehabilitation strategies that are practical for use in clinical settings are needed. The purpose of this study was to evaluate the use of 2 approaches to reduce UVN in people who have had strokes. ***Subjects.*** Seven elderly patients with stroke and severe left UVN, aged 60 to 85 years, were recruited from a stroke rehabilitation unit. ***Methods.*** A nonconcurrent, multiple-baselines-across-subjects approach, with an A-B-A treatment-withdrawal single-subject experimental design, was used. Five subjects received a scanning and cueing approach, and 2 subjects received a contralesional limb activation approach, for 10 one-hour sessions. In the former approach, active scanning to the left was encouraged by the therapist, using visual and verbal cues and a mental imagery technique, during reading and copying tasks and simple board games. In the latter approach, functional and goal-oriented left upper-limb activities in neglected hemispace were encouraged. Unilateral visual neglect was examined by a masked (blinded) examiner throughout all phases using the Star Cancellation Test, the Line Bisection Test, and the Baking Tray Task. Data were analyzed using visual and inferential statistical techniques. ***Results.*** Both subjects who received limb activation and 3 of the 5 subjects who received scanning and cueing showed a reduction in UVN in one or more tests. This improvement was maintained during the withdrawal phase. ***Discussion and Conclusion.*** Both approaches had a positive effect of reducing aspects of UVN in some subjects relative to no-treatment baselines. However, causality cannot be assured in the absence of controls. The approaches are practical for use in rehabilitation settings. These procedures warrant further replication across subjects, settings, and therapists.

7.2 Introduction

Unilateral visual neglect (UVN), a common perceptual deficit found after stroke (Bowen et al, 1999), manifests as an inability to direct attention to stimuli when they are located on the side contralateral to the lesion (Robertson & Halligan, 1999). Unilateral visual neglect is a component of the "hemineglect syndrome," which can include manifestations of neglect other than visual (e.g. motor, sensory). Hemineglect is more severe and longer lasting following right-sided as opposed to left-sided brain damage (Halligan & Marshall, 1994b), which has been attributed to the right hemisphere playing a primary role in spatial attention (Posner & Peterson, 1990). The presence of UVN may adversely affect functional recovery (Katz et al., 1999), and it is associated with rehabilitation taking longer and being less complete than in patients without UVN (Cherney et al., 2001).

Treatments thought to ameliorate UVN involving artificial manipulation of proprioceptive or visual input have been referred to in detail elsewhere (Bailey & Riddoch, 1999). However, using such techniques, reduction of visual neglect has only been demonstrated during or immediately following such treatment sessions, and long-term carryover has not been demonstrated. Additionally, such treatments may require specialized equipment and technical support, and they do not easily lend themselves to application in real-life clinical situations. Robertson and colleagues (1995) found that sustained attention training appeared to be effective. The training involved the trainer first giving direct verbal feedback to the subject to attend to the task, progressing to the subject being required to provide his or her own verbal feedback to attend. However, the self-alerting procedures they used often required a degree of insight, memory, and cooperation from their subjects, which many elderly patients who have had strokes may not possess. Other strategies, which may be more practical for use in rehabilitation settings, include the use of scanning and cueing (Antonucci et al., 1995; Paolucci et al., 1996b; Pizzamiglio et al., 1992a) and limb activation (Brown, Walker, Gray & Findlay, 1999; Robertson et al., 1998a; Wilson et al., 2000). Scanning encourages the subject's attention to be directed to neglected hemispace, and cueing, provided by the trainer or internally self-generated by the subject, facilitates such direction of attention.

In our study, we examined 2 different treatment approaches for patients with UVN, one using a scanning and cueing strategy and one using a left-limb activation (LLA) strategy. We used a series of single-system designs.

7.3 The use of cues and visual scanning to direct attention to left hemispace

Gordon and colleagues (1985) contended that merely telling a patient to attend to the left visual field is ineffective in remediating faulty scanning habits. More systematic attempts to rehabilitate visual neglect by visual scanning training have been described (Bergego et al, 1997; Gordon et al., 1985; Wagenaar et al., 1992; Webster et al., 1984; Weinberg et al., 1979). Typically, training involves visual scanning of rows of lights across a board using slow and systematic searches from left to right, with use of visual and verbal cues to direct attention to the left side of the board. Reduction of visual neglect has not been a consistent research finding across different studies, and there has been little or no generalization to untrained tasks (Robertson et al., 1990).

Some researchers have successfully used cueing to reduce visual neglect immediately after a training session. Ladavas, Menghini & Umilta (1994) trained 12 elderly patients with stroke and stable UVN for 30 hours using computer-generated left-sided visual cues. There was no randomization, and there were only 4 subjects in each of the control and experimental groups, with no masking (blinding) of outcome. Riddoch et al. (1995c) used a left-sided colored sticker and the explicit reporting of this visual cue to reduce visual neglect in a single subject during a reading and copying task. Despite the negative results of some studies (Robertson et al., 1990), other studies (Antonucci et al., 1995; Pizzamiglio et al., 1992a) have shown that a combination of cueing and scanning methods reduced visual neglect, with generalization to some functional activities. These methods also were used by Paolucci and co-workers (1996b), who found improvement in activities of daily living in 2 groups of subjects with stroke and stable UVN. Improvements were "time-locked" to the period of specific, targeted training for neglect. They randomly assigned 23 elderly patients with stroke and stable UVN to immediate (mean age-68 years, SD=7.19) and delayed (mean age=70 years, SD=5.46) treatment groups. Forty hours of scanning and cueing training reduced visual neglect and improved function in both groups, compared with the subjects' performance during a “general cognitive” intervention. Function was assessed by the Barthel Index (BI) (Mahoney & Barthel, 1965) for activities of daily living and the Rivermead Mobility Index (RMI) (Collen, Wade, Robb & Bradshaw, 1991) for mobility in bed activities, transfers, standing, and walking. No information was given by Paolucci and colleagues as to which particular tasks in these batteries showed improvements in response to the specific treatment intervention. In general, no follow-up data have been reported following cueing studies, although Lennon (1994) successfully trained one patient with severe UVN to avoid left-sided collisions in the gymnasium by use of colored markers on edges to be avoided. Unfortunately, the patient required further retraining within his home environment. This retraining was successful, and eventually he did not need the visual cues.

7.4 Effects of contralesional limb activation on hemineglect

In patients with right-hemisphere brain damage, motor responses are usually made using the right arm because most people are right-hand dominant and the left arm may be paralyzed. Kinsbourne (1987) proposed that visual neglect results from an attentional imbalance rather then an attentional deficit, with the right hemisphere being dominant for spatial attention. In addition, he argued that activation of one hemisphere would tend to inhibit the activity of the other hemisphere. Because the right arm is controlled by the intact left hemisphere, using this arm may exacerbate visual neglect, because activation of the left hemisphere (by right arm use) would tend to further inhibit the already damaged right hemisphere. Conversely, LLA would lead to increased activity in the right hemisphere. Hemispheric activation has been used to account for the reduction in visual neglect found in several studies (Brown et al., 1999; Robertson et al., 1992, 1998a; Robertson & North, 1992, 1993, 1994; Wilson et al., 2000) where even quite small active movements of the left upper limb have reduced visual neglect on the left side of the subject in single cases. Robertson and North (1992) found that LLA on the left side, rather than the limb acting as a visual cue, was important in the reduction of visual neglect. In contrast, Cubelli, Paganelli, Achilli and Pedrizzi (1999) repeated the study by Robertson and North (1994) using a group design, rather than a single-subject design. Cubelli and colleagues (1999) found that only 1 of 10 patients, the only patient with no proprioceptive loss had reduced omissions in both a reading task and a cancellation task. A randomized controlled trial by Kalra and colleagues (1997) showed that LLA, or "spatio-motor cueing," combined with emphasis on functional activity, reduced visual neglect and length of hospital stay in a group of 25 elderly patients with stroke compared with a comparable control group of 25 patients who received more conventional therapy, in this case therapy based on the Bobath approach.

The hemispheric activation explanation has been challenged by the results from a study by Ladavas et al. (1997) who used a control group. They found that passive movement of the left index finger in left space (with vision of the hand reflected in a mirror that inverted right and left space) reduced visual neglect. This finding supported a proprioceptive, as opposed to visuospatial, cueing explanation. More recently, Samuel et al. (2000) used LLA combined with use of the left arm as a "visual anchor" (subjects were trained to look at and move their left arm if they were unable to find the target in an exercise) during activity for a total of 18 hours during the 2-week treatment phases of an ABAB design. The 2 subjects had reduction in their visual neglect, as well as improved functional ability, which had not improved with previous scanning training.

Many limb activation studies have included a "neglect alert device," worn by the subject during different activities and therapies. This device buzzes at intervals and must be switched off by the subject, using the left arm, thus encouraging activation of the left limb (Brown et al., 1999). Other researchers (Wilson et al., 2000) have required the subject to tap in response to a command with the hand or fingers. Some authors (Brown et al., 1999; Cubelli et al., 1999; Robertson & North, 1992, 1993, 1994) have tested for visual neglect along with LLA. In other studies (Kalra et al., 1997; Robertson et al., 1992; Wilson et al., 2000) limb activation was not implemented during testing.

7.5 Studies that may lend themselves to the clinical situation

In many studies (Bergego et al., 1997; Gordon et al., 1985; Ladavas et al., 1994; Robertson et al., 1990; Wagenaar et al., 1992) there was use of complex or specialized computer-based equipment for scanning and cueing. In our view, the use of such equipment limits the practical application of scanning and cueing. In other studies (Brown et al., 1999; Ladavas et al., 1997; Riddoch et al., 1995c; Robertson & North, 1992, 1993, 1994; Robertson et al., 1992; 1995; Wagenaar et al., 1992; Webster et al., 1984), researchers used interventions that took place in more strictly controlled laboratory situations.

A number of researchers (Antonucci et al., 1995; Fanthome et al., 1995; Niemeier, 1998; Paolucci et al., 1996b; Pizzamiglio et al., 1992a) exploring rehabilitation of visual neglect used scanning and cueing techniques that may be more applicable to clinical settings. Strategies used in all of these studies (in addition to the computer-based scanning training included by some researchers (Antonucci et al., 1995; Paolucci et al., 1996b; Pizzamiglio et al., 1992a) involved searching for and describing objects in pictures, particularly in the left visual field; reading and copying activities; using left-sided cues, and the use of simple games and pencil-and-paper tasks. Visual imagery, consisting of asking patients to imagine their eyes as beams from a lighthouse (Niemeier, 1998) might be clinically useful to reinforce patients' direction of attention. This compensatory strategy encourages them to generate cues (the mental image of the "lighthouse beam scanning the horizon") for themselves.

However, measurements of outcome in this study (Niemeier, 1998) were not obtained by masked observers, and some of the measures used had no demonstrated validity or reliability. Reduction of visual neglect was maintained for 5 months posttreatment in 7 of the 13 patients followed up by Pizzamiglio and colleagues (1992a), however, no control group was used for comparison. Other researchers (Antonucci et al., 1995; Paolucci et al., 1996b) repeated and improved upon the Paolucci et al. (1992) study by randomly assigning subjects to experimental and control groups. However, maintenance of positive effects was not assessed after the subjects' steady improvement that occurred during the 8-week treatment period.

Several limb activation strategies have been used in rehabilitation settings (Kalra et al., 1997; Robertson et al., 1992; Samuel et al., 2000; Wilson et al., 2000). The length of time for which treatment benefit lasted was assessed immediately after treatment at the end of the second baseline phase and at 12 weeks after treatment in 2 studies (Kalra et al., 1997; Wilson et al., 2000). Some researchers have demonstrated improvements in activities not directly used during training (Robertson et al., 1998; Wilson et al., 2000) including activities of daily living (Samuel et al., 2000) which were maintained at 1-month follow-up. Some findings, we believe, must be interpreted with caution. For instance, in some studies (Samuel et al., 2000; Wilson et al., 2000) there was no evidence of masking of the individuals who took the outcome measurements, and in other studies (Wilson et al., 2000) the reliability of the measurements was questionable. Kalra and colleagues (1997) gave no details of the limb activation approach used, precluding study replication. A further problem is that only 3 of the clinically based rehabilitation studies (Antonucci et al., 1995; Fanthome et al., 1995; Kalra et al., 1997) included participants who were, on average, over 70 years of age, an age group that is more likely to reflect those who have had stroke and UVN.

Some researchers (Brown et al., 1999; Robertson et al., 1992; Samuel et al., 2000) have used subjects who were capable of only minimal upper-limb use and no isolated finger movements. Limb activation strategies, however, can be used only when there is an assumption of at least residual voluntary control of the left upper (or lower) limb and thus may not be appropriate for patients with no such recovery. For these patients, the use of scanning and cueing strategies may be the only approach possible. In addition, use of a "neglect alert" electronic device, as an adjunct to limb activation, may be difficult in some hospital situations and may not be readily available or acceptable for routine use.

More clinical trials are needed to investigate the effectiveness of techniques likely to reduce UVN. This need is particularly pressing because of the high incidence of UVN and the link with poor prognostic outcome, particularly following right-sided brain damage (Bailey et al., 2000). We believe a variety of strategies may be used to overcome some of the shortcomings discussed. The person obtaining outcome measurements should be masked. To reduce the effects of confounding variables such as history and maturation, subjects should be randomly assigned to different baseline time periods. We also believe the strategies chosen for each approach should be clinically applicable and should use simple, low-cost, and easily available equipment. In our study, we attempted to address these issues via use of a series of single-subject designs to investigate whether scanning and cueing (for patients with no or only minimal recovery of upper-limb function following stroke) or an LLA strategy (for patients with some spared upper-limb voluntary activity) would reduce UVN in selected elderly patients with stroke.

7.6 Method

7.6.1 Experimental design

We considered a single-subject experimental design to be appropriate for subjects in a rehabilitation setting due to the heterogeneity of the visual neglect syndrome and other features of stroke, such as movement ability and level of sensation, which can be confounding variables in group studies (Riddoch & Lennon, 1994). Seven patients were studied. A nonconcurrent, multiple-baseline-across-subjects design was chosen (Zhan & Ottenbacher, 2001) because it was not possible for us to obtain more than one subject suitable for study at any one time. Varying the length of the first baseline phase (A1) controls for some threats to internal validity because of factors such as history, maturation, and the possibility of spontaneous recovery and is also appropriate when withdrawal of the intervention might not result in the outcome behaviour returning to baseline levels (Backman, Harris, Chisholme & Monette, 1997) perhaps because of a permanent change in behaviour due to the intervention. A second baseline (withdrawal) phase (A2) was included to establish whether any changes would be maintained. Ideally, baseline (A1) data should show stability so that a treatment effect, shown by a change in level, trend, or variability during the intervention (B) phase, would be clearly visible. In our study, the intervention (B) and second baseline/withdrawal (A2) phases each lasted approximately 3 weeks. We believe that this duration enabled sufficient data to be collected in each phase. A minimum of 10 data points per phase is recommended (Ottenbacher, 1986) to be collected to enable subsequent statistical analysis. Subjects were randomly assigned to a 2-, 3-, or 4-week baseline phase (A1) as they became available for evaluation. In this way, subjects 1, 4, and 6 were assigned to a 4-week baseline phase; subjects 2 and 3 were assigned to a 3-week baseline phase; and subjects 5 and 7 were assigned to a 2-week baseline phase. All subjects continued to receive their usual occupational therapy and physical therapy on the ward throughout all phases, which consisted of approximately 30 minutes each weekday for each type of therapy. The therapists were aware of the presence of visual neglect in all subjects, and although treatment focused on this problem was not given to the subjects, all subjects were encouraged to look toward their neglected side during activities such as dressing, self-care, and physical rehabilitation exercises.

7.6.2 Subjects

Subjects were all patients between 60 and 85 years of age who were admitted from an acute care hospital to a stroke rehabilitation unit over a 12-month period. Inclusion criteria were: right-sided brain damage (determined by CT scan results), first stroke, moderate to severe left-sided UVN on screening, and cognition and physical ability sufficient to allow inclusion in the testing and treatment program. Subject details are shown in Table 7.3. Subjects who had minimal or no left upper-limb voluntary movement were treated using the scanning/cueing approach. Subjects with some left upper-limb voluntary control (at least enough to lift the arm and place it on a table in front of them) and at least minimal voluntary finger movement were treated using the LLA approach. It must be emphasized that the aim was not to compare these two approaches, but to separately evaluate the efficacy of each approach in the clinical setting.

Table 7.3.

Subject Details and Timing of Commencement of Phases in ABA Single-Subject Design

Subj. No.	Sex	Age (y)	CT Scan Result	Days Post-stroke (Start of A1 Phase)	Days Post-stroke (Start of B Phase)	Days Post-stroke (Start of A2 Phase)
1	Female	79	Right posterior frontal and basal ganglia infarct	31	61	82
2	Female	72	Large infarct in right middle cerebral artery territory	46	68	91
3	Male	85	Right temporo-parieto-occipital infarct	42	62	90
4	Female	78	Right parieto-occipital infarct	25	55	69
5	Female	78	Large infarct in right middle cerebral artery territory and basal ganglia	19	65	89
6	Male	72	Large infarct in right middle cerebral artery territory	20	48	76
7	Female	60	Right parietal infarct	13	26	33

7.6.3 Screening and testing procedures

Testing was always carried out at the same time in the morning, prior to training, so any changes in behavior resulting from training that could be measured needed to last at least 24 hours. For logistical reasons, the same person undertaking the training, which normally occurred on alternate weekdays, assessed the first 2 subjects (subjects 1 and 2). To reduce the possibility of observer bias, all testing sessions for UVN for these 2 subjects were videotaped and later independently analyzed in an effort to ensure that test administration was standardized. For all other subjects, testing and training were carried out by 2 different individuals, and the assessor was masked to which phase of the single-subject design was in effect in each test session. Testing for UVN was normally undertaken daily or on alternate days during weekdays throughout all study phases (depending on subject availability). Other tests (for stroke severity, sensation, and function) were carried out weekly throughout all phases.

7.6.3.1 Tests for unilateral visual neglect

The initial screening of suitable patients involved the same 3 standardized tests for UVN that would be used in the study. These tests were the Line Bisection Test (LBT) and Star Cancellation Test (SCT), both from the Behavioural Inattention Test battery (Wilson et al., 1987a) and the Baking Tray Task (BTT) (Tham & Tegner, 1996). The LBT and SCT have been shown to have concurrent validity (Wilson et al., 1987a) (Pearson r=.92) when the test scores were compared with scores from the behavioural battery subtests of the Behavioural Inattention Test (Wilson et al., 1987a) and intrarater and interrater reliability (Wilson et al., 1987a) (Pearson r=.99) based on scores from 80 patients with stroke (54 with right brain damage and 26 with left brain damage). Marsh and Kersel (1993) considered the SCT to be particularly responsive for visual neglect. The BTT was recently developed and was described by Tham and Tegner (1996) as a quick, yet sensitive, test that may not be subject to practice effects and therefore could be useful for repeated measurements. In an unpublished study,* we have demonstrated test-retest reliability for all 3 tests for UVN. Several tests were

* For a sample of 57 elderly patients with stroke and UVN, intraclass correlation coefficients for the SCT, LBT, and BTT were .96, .94, and .87, respectively, indicating good to excellent reliability.

chosen for UVN because of the heterogeneity of the syndrome (Robertson & Halligan, 1999) and to enable "capture" of a wider range of lateralized performance deficits.

The SCT consists of a page containing 52 large stars, 10 short words, and 13 letters, randomly positioned, with 56 small stars interspersed among them. Subjects were instructed to cross out (with a black pen) all of the small stars across the page. The tester demonstrated the procedure by crossing out the 2 central stars. The maximum correct score is 54 (27 left, 27 right). The LBT consists of 3 horizontal black lines, 20 cm long, one to the right, one central, and one to the left side of a sheet of white paper (21 × 30 cm). Subjects were asked to find and mark the center of each line in turn. Errors away from true midline were measured, and an average error score (in centimeters) was calculated, with leftward errors being given a negative sign and rightward errors being given a positive sign. For the BTT, the equipment used was a white board (75 × 50 cm), which was the "baking tray," and sixteen 3.5-cm cubes of brown wood (the "buns"). Subjects were asked to "place the blocks as symmetrically as possible as if they were ‘buns’ being placed on a baking tray to be put in the oven." All 16 cubes had to be used, and subjects were reminded if any were omitted. For ease of data analysis and to give a laterality index, the BTT ratio of "buns" placed on the left side of the "baking tray" to the total of 16 was calculated, thus giving a potential range of scores of 0 to 1, with a score of 0.5 indicating normal symmetry.

For the purposes of our study, patients with moderate to severe visual neglect were included because they were more likely to show change in response to treatment (Fanthome et al., 1995;Weinberg et al., 1979). Screening cutoff scores for inclusion, therefore, were more strict than those originally recommended (Tham & Tegner, 1996; Wilson et al., 1987a) being set at fewer than 20 stars cancelled, a mean line bisection error of more than 2.5 cm, and a ratio of 0.25 or less for the BTT (which equates to 4 "buns" or less placed on the left side of the tray). Further details for the SCT, LB and the BTT are given in N to P.

7.6.3.2 Tests for sensation, function, and stroke severity.

Both position sense and light touch for affected upper and lower limbs were tested, with the subjects blindfolded, using the Nottingham Sensory Assessment scales (Lincoln, Jackson & Adams, 1998). The Nottingham Sensory Assessment scales have a total maximum possible score of 24 for position sense and 20 for light touch (full details are given by Lincoln et al., 1998). Mobility in bed, transfers, and walking was assessed using the RMI (Collen et al., 1991) (maximum mobility score=15), and activities of daily living were assessed using the BI (Mahoney & Barthel, 1965) (maximum functional score=100). These 2 tests were chosen to reflect different aspects of everyday function. Stroke severity was monitored with the Canadian Neurological Scale (Cote et al., 1989) (maximum score=11.5, with lower scores indicating more severe symptoms). Criteria and scoring details are given in Appendices Q to U. All of these tests for sensation, function, and stroke severity have been validated for use in elderly patients with stroke and have demonstrated good to excellent reliability (kappa>.6) in patients (studies included subjects with stroke over 60 years of age) (Collen et al., 1991; Collin, Wade, Davies & Horne, 1988; Lincoln et al., 1998; Cote et al., 1989; D’Olhaberriague, Litvan, Mitsias & Mansbach, 1996; Wolfe, Taub, Woodrow & Burney, 1996).

7.6.4 Procedures.

Testing procedures were not directly used for intervention, nor were intervention procedures implemented during testing. A minimum of 10 data points per phase were normally collected for all 3 tests for UVN. Fewer data points were collected for the other tests. Intervention, given during the B phases, always took place during the morning and occurred, when possible, on alternate weekdays for a minimum of 10 sessions, each lasting for 1 hour. All testing and interventions took place in a quiet area on the ward. The subjects were seated for all activities. We designed the interventions to be clinically feasible in terms of time spent, equipment available, and activities performed.

7.6.4.1 *Instructions given to all subjects.*

During the first treatment session of the intervention (B) phase, the problem of UVN was thoroughly explained to the subjects. Manifestations (omission of objects on the left during visual search or words or letters on the left during reading) were demonstrated to the subjects during activities such as reading, copying, drawing, and finding named objects in pictures or in the surrounding ward.

7.6.4.2 Intervention using scanning and cueing techniques.

Because the subjects in this study had no voluntary left upper-limb movement, the right (unaffected) upper limb was used, where necessary. The following strategies were applied:

- Subjects were encouraged to actively scan from left to right of the visual field so that they could correctly respond in reading, copying, drawing, or description tasks. Scanning was to the sides of the table for near-space activities and to the sides of the room or ward for far-space activities.

- Left-sided visual cues were used (attention being drawn to the left arm or to a red shiny ribbon placed on the left) to help the subjects to actively make a left start in visual search tasks.
- All activities progressed from simple to complex over the course of the intervention phase (e.g. reading only one line on a page, then reading 2 lines, then 3 lines, and so on) in terms of stimuli presented for reading, copying, drawing, and finding objects within the visual field.
- Activities progressed in terms of complexity, with addition of distracting material, only when the preceding tasks had been successfully achieved.
- The subjects were given feedback about performance success in each task, and praise was given for each correct response.

Some tasks (i.e., reading and copying tasks using newspaper headlines and handwritten sentences, copying of line drawings on a dot matrix, and description of scenes in pictures) were based on those used in previous studies (Antonucci et al., 1995; Paolucci et al., 1996b; Pizzamiglio et al, 1992a). The following tasks were undertaken:

- During the first treatment, the subjects were shown a simple line drawing of a lighthouse and told "Imagine you are a lighthouse like this one. Imagine your eyes are like the lights inside the top, sweeping all the way to the left and right of the horizon to guide the ships at sea to safety. Use your 'lighthouse beam' to sweep and scan across the table top/book/newspaper/around the ward. Especially remember to sweep your beam and scan to the left side." Over the period of the intervention phase, the subjects were encouraged to self-cue, using this lighthouse strategy (Niemeier, 1998) especially if they were having difficulty in finding objects on the left of their midline.

- Both visual and verbal cues were used to facilitate attention to the left, and the subjects were verbally cued where necessary by the therapist ("look for the red ribbon," "find your left arm," "remember to sweep that lighthouse beam of your eyes all around to the left to find what you are looking for," or, during picture description, "can you find anything else?"). The therapist gave tactile cues by tapping on the subjects' left arm (if they had sufficient sensation to appreciate the stimulus).
- Reading and copying tasks made use of books, magazines, and newspapers. Subjects also were asked to copy line drawings of various objects, presented on the left side of a white board (75 × 50 cm) placed on a table in front of them, onto the right side of the board. About 15 minutes per session was devoted to these activities.
- Copying of line drawings on a dot matrix also was used. Two identical dot matrices (black dots on a sheet of white A4 paper, varying from 4 to 20 points) were used; on the left, some dots (progressively increasing in number) were connected by solid lines. Subjects were asked to copy this line drawing onto the right matrix. A cross indicated the starting point. About 10 minutes per session was devoted to this activity.
- Color pictures from magazines were used as stimuli, and the subjects were asked to describe the scene in the picture or to find various named objects in the picture. Pictures were progressed from simple to complex in terms of number, size and

complexity of items, and amount of distracting information. About 20 minutes per session was devoted to this activity.

- Subjects were asked to identify and describe various items they could see around the ward. About 5 minutes per session was devoted to this activity.
- Simple board games (eg, Snakes and Ladders, Scrabble,[†] Dominoes, finding words embedded in word puzzles), placed and played progressively into left-sided space, were used to encourage scanning to the left. About 10 minutes per session was devoted to this activity.

7.6.4.3 Intervention using left limb activation techniques.

Subjects were told that research showed that moving the left limb (preferably the upper limb, but also the lower limb) on the left side of their body space had been shown to reduce visual neglect and to possibly improve function. They were told that this approach would be adopted in the intervention sessions. The following activities took place:

- Subjects were asked to concentrate on moving only their left upper limb during the sessions and not to additionally use their right upper limb.
- Where possible, activities involved voluntary active movement of the left upper and lower limbs. If a subject was unable to actively achieve a particular functional goal, then the therapist assisted the action.
- Subjects were taught to activate their left arm (e.g. by tapping their hand or fingers on an adjacent left surface, as described by Wilson et al. (2000) prior to and while performing activities that involved directing attention to the neglected hemispace,

[†]JW Spear & Sons PLC, subsidiary of Mattel (UK) Ltd, Mattel House, Vanwall Business Park, Vanwall Rd, Maidenhead, Berkshire, SL6 4UB, United Kingdom.

such as the playing of simple board games (e.g. Scrabble, Dominoes, Snakes and Ladders) or word games. About 15 minutes per session was devoted to this activity.

- Activities chosen were functional and goal oriented where possible and included activities such as combing the hair, shaving (for men), applying makeup (women), putting on upper-body garments, picking items out of a basket and placing them on the table in front of the subject, undoing tops and caps of containers (any necessary steadying done by the therapist to ensure only left upper-limb use), pouring out a drink, and drinking from a beaker or cup. Variously sized and shaped objects were used. About 30 minutes per session was devoted to this activity.
- Subjects also used a cloth, held in the left hand, to rub off words, letters, drawings, and so on made on the left side of the white board by the therapist. About 15 minutes per session was devoted to this activity.

Subjects 1 through 5 received the scanning and cueing approach, and subjects 6 and 7 received the LLA approach. All subjects were given written and verbal explanations about the study, and all subjects gave written informed consent before taking part in the study.

7.6.5 Data analysis

7.6.5.1 *Tests for unilateral visual neglect.*

A combination of visual and statistical analysis was used, as visual inspection alone, cannot be used to test an hypothesis and weak treatment effects may be overlooked (Bobrovitz & Ottenbacher, 1998). Successive observations in a time series tend to be correlated (Zhan & Ottenbacher, 2001); therefore, all of the UVN data series were examined for serial dependency using the method described by Ottenbacher (1986). Where autocorrelations were found in any phase for any test, the C-statistic method (Tryon, 1982) was used for subsequent data analysis for that test for the subject in question to look for significant differences between phases ($p<.05$). When serial dependency was not found, standard inferential analysis proceeded (using SPSS software[‡]). The Kruskal-Wallis test for differences was applied across the 3 phases, and if the result was significant ($p<.05$), the Mann-Whitney test was used for post hoc testing (Domholdt, 1993) of where the differences lay. A Bonferroni adjustment was used to set the alpha level at .025 for post hoc comparisons of the A1 and B phases and the B and A2 phases to compensate for the alpha-level inflation that occurs in multiple tests. The following null hypothesis was used for each subject's set of data: there will be no difference between first baseline and intervention (A1 to B) phases or between the intervention and second baseline (B to A2) phases for the SCT, LBT, and BTT tests for UVN ($p<.05$). Graphs of the raw data were generated (Carr & Burkholder, 1998) using Microsoft Excel.[§] These graphs showed celeration and trend lines for each phase, computed using the split-middle technique (Zhan & Ottenbacher, 2001) enabling further visual inspection. It should be emphasized that (1) only 9 of a possible total of 21 graphs are presented here to illustrate the only instances of reduction of visual neglect and (2) of these 9 graphs, 7 graphs display data from only 3 subjects.

[‡] SPSS Inc, 233 S Wacker Dr, Chicago, IL 60606.
[§] Microsoft Corp, One Microsoft Way, Redmond, WA 98052.

7.6.5.2 Tests for stroke severity, function, mobility, and sensation.

Because there were only 3 data points for each of these tests per phase, insufficient for subsequent inferential analysis, the data will be presented descriptively. Tests of sensation, function, mobility, or stroke severity were examined to determine whether any score change coincided with phase change (ie, between the A1 and B phases and the B and A2 phases).

7.7 Results

Over a 12-month period, 141 patients were admitted to the unit; 29 patients (21%) (all with left-sided brain damage and communication problems) were not testable. Of the remaining 112 patients, 64 (57%) had right-sided brain damage; 39 (61%) of the patients with right-sided brain damage had UVN. From this group of 39 patients, a total of only 7 patients (Table 7.4) fulfilled the inclusion criteria during the course of the study. Data, including mean and range for each phase for each of the 3 tests for UVN, for each subject, are shown in Table 7.4. Results of all statistical tests performed on the time series data for UVN tests are presented in Tables 7.5 to 7.7. The range of scores for tests of severity, function, mobility, and sensation for each phase, for each subject, are shown in Table 7.8. Results in the remainder of this section will be summarized on a case-by-case basis.

Table 7.4.
Time series data for each phase for the three tests for unilateral visual neglect[a]

Subj.	SCT			LBT			BTT		
No.	A1	B	A2	A1	B	A2	A1	B	A2
1									
8	21.90	32.60	37.20	2.03	2.02	2.02	0.06	0.13	0.21
Range	13-34	15-46	28-45	0.80-4.20	0.90-3.70	0.80-3.50	0-0.56	0-0.31	0-0.37
2									
8	19.30	29.60	38.70	-0.37	1.29	0.80	0.12	0.43	0.40
Range	8-35	19-48	28-53	-3.70-+2.40	0-3.40	-0.90-+1.90	0-0.50	0-0.88	0-0.75
3									
8	8.64	23.18	36.58	9.64	6.97	2.98	0	0.01	0.09
Range	5-12	9-48	23-47	9.20-10	0.30-10	1-5.80	0-0	0-0.13	0-0.50
4									
8	15.30	21	21.50	5.49	6.02	6.61	0	0.01	0.07
Range	11-21	10-34	10-32	4.40-6.90	0.90-8.80	3.40-7.70	0-0	0-0.13	0-0.38
5									
8	8.53	10.91	7.80	7.36	7.20	7.04	0	0.03	0.06
Range	8-11	6-14	3-11	5.20-8.80	6.10-8.30	5.30-8.20	0-0	0-0.19	0-0.31
6									
8	16.73	36.67	41.73	6.24	3.83	4.41	0.12	0.47	0.48
Range	11-36	19-48	31-51	5.40-7.80	1.70-6.60	0.34-6.70	0-0.38	0.31-0.63	0.25-0.63
7									
8	13.29	43.71	52	7.43	5.79	4.35	0.36	0.58	0.54
Range	8-23	26-52	51-53	3.60-9	-0.40-+7.30	2.20-6.50	0-0.75	0.19-0.81	0.44-0.63

[a]SCT=Star Cancellation Test score (maximum score=54)
LBT=Line Bisection Test score deviation error from true centre (in centimetres)
BTT=Baking Tray Task ratio "buns" placed on left: total of 16 "buns"
(0.5 shows equal number of "buns" placed on left and right sides of board)
A1=first baseline phase; B=intervention phase; A2=second baseline phase

Table 7.5.

Statistical analysis results for Star Cancellation Test for all subjects[a]

Subj. No.	**Kruskal-Wallis across phases (*p*<.05)**	**Mann-Whitney *Post Hoc* Test Between A1 and B Phases (*p*<.025)**	**Mann-Whitney *Post Hoc* Test Between B and A2 Phases (*p*<.025)**
1	*p*=.012*	*p*=.024*	*p*=.587
2	*p*=.001*	*p*=.017*	*p*=.041
3	*p*<.001*	*p*<.001*	*p*=.006*
4	*p*=.104		
5	Not applicable**	NS (*z*=1.183)**	NS (*z*=0.897)**
6	*p*<.001*	*p*<.0001*	*p*=.195
7	Not applicable**	*z*=3.63** (*P*<.05)*	Too few data points

[a]If the Kruskal-Wallis Test result is nonsignificant, further *post hoc* testing is unnecessary. Asterisk indicates a significant difference at the stated p value. Double asterisk indicates serial dependency in data and analysis by C statistic. For significance at $p<.05$, z must be >1.64. NS=not significant, A1=first baseline phase, B=intervention phase, A2=second baseline phase.

Table 7.6.

Statistical analysis results for Line Bisection Test for all subjects[a]

Subj.No.	**Kruskal-Wallis Test Across Phases (*p*<.05)**	**Mann-Whitney *Post Hoc* Test Between A1 and B Phases (*p*<.025)**	**Mann-Whitney *Post Hoc* Test Between B and A2 Phases (*p*<.025)**
1	*p*=.707		
2	*p*=.086		
3	Not applicable**	*p*<.01* (*z*=4.065)	*p*<.01* (*z*=4.026)
4	*p*=.041*	*p*=.098	*p*=.934
5	*p*=.651		
6	*p*=.003*	*p*=.003*	*p*=.406
7	Not applicable**	NS (*z*=-1.32)	Too few data points

[a] If the Kruskal-Wallis Test result is nonsignificant, further *post hoc* testing is unnecessary. Asterisk indicates a significant difference at the stated p value. Double asterisk indicates serial dependency in data and analysis by C statistic. For significance at $p<.05$, z must be >1.64. NS=not significant, A1=first baseline phase, B=intervention phase, A2=second baseline phase.

Table 7.7.

Statistical analysis results for Baking Tray Task for all subjects[a]

Subject No.	Kruskal-Wallis Test Across Phases (p<.05)	Mann-Whitney *Post Hoc* Test Between A1 and B Phases (p<.025)	Mann-Whitney *Post Hoc* Test Between B and A2 Phases (p<.025)
1	p=.03*	p=.051	p=.245
2	p=.015*	p=.010*	p=.761
3	p=.362		
4	p=.023*	p=.340	p=.071
5	p=.441		
6	p<.001*	p=.003*	p=.406
7	Not applicable**	NS (z=1.057)	Too few data points

[a] If the Kruskal-Wallis Test result is nonsignificant, further *post hoc* testing is unnecessary. Asterisk indicates a significant difference at the stated p value. Double asterisk indicates serial dependency in data and analysis by C statistic. For significance at p<.05, z must be >1.64. NS=not significant, A1=first baseline phase, B=intervention phase, A2=second baseline phase.

7.7.1 Subjects receiving scanning and cueing training (subjects 1-5)

Subject 1 (Table 7.3) had severe left-sided motor and sensory loss, was only occasionally continent, and fell to the left during unsupported sitting. She had left homonymous hemianopia; severe reading impairment; and severe visuospatial neglect, with eyes and head usually turned to the right. She was lethargic and drowsy, with flat affect throughout most testing and treatment sessions. She was assigned to a 4-week baseline phase. Intervention was commenced at 61 days post-stroke. Ten treatment sessions were conducted. The SCT score was the only one to show a change between the A1 and B phases (Table 7.5). This change is illustrated in Figure 7.1, which shows an increase in level between the A1 and B phases and a change in slope and trend between the B and A2 phases, indicating that the improvement was maintained or slightly increased. Although there were some small changes in motor, sensory, and functional scores (Table 7.8), none of these were coincident with any phase change and/or related to the timing of the intervention.

Table 7.8.

Score range (minimum-maximum) for stroke severity, function, mobility and sensation for each phase of each single case[a]

Subjects	Canadian Neurological Scale Score 0-11.5	Barthel Index Score 0-100	Rivermead Mobility Index Score 0-15	Position Sense Score 0-24	Light Touch Score 0-20
1					
A1	3.5-7.0	0.0-15.0	0.0-0.0	0.0-3.0	0.0-1.0
B	7.0-7.0	15.0-15.0	0.0-1.0	3.0-3.0	1.0-1.0
A2	7.0-7.0	15.0-15.0	1.0-1.0	3.0-3.0	1.0-1.0
2					
A1	6.5-6.5	20.0-20.0	1.0-1.0	4.0-4.0	4.0-4.0
B	6.5-6.5	20.0-25.0	1.0-1.0	4.0-4.0	4.0-4.0
A2	6.5-6.5	25.0-30.0	1.0-1.0	4.0-4.0	4.0-4.0
3					
A1	7.0-7.0	5.0-15.0	1.0-1.0	11.0-14.0	11.0-14.0
B	7.0-7.0	15.0-20.0	1.0-1.0	14.0-16.0	14.0-17.0
A2	7.0-7.0	20.0-20.0	1.0-1.0	16.0-16.0	17.0-17.0
4					
A1	7.0-7.0	10.0-25.0	1.0-0.0	10.0-12.0	10.0-12.0
B	7.0-7.5	25.0-25.0	0.0-0.0	12.0-12.0	11.0-11.0
A2	8.0-8.5	25.0-30.0	1.0-3.0	14.0-15.0	14.0-15.0
5					
A1	5.0-6.5	15.0-20.0	0.0-0.0	4.0-5.0	3.0-4.0
B	5.0-6.5	20.0-20.0	0.0-0.0	3.0-4.0	4.0-4.0
A2	5.0-5.0	20.0-20.0	0.0-0.0	4.0-4.0	4.0-4.0
6					
A1	8.5-9.5	20.0-30.0	1.0-2.0	13.0-13.0	14.0-14.0
B	9.5-9.5	45.0-60.0	2.0-6.0	13.0-13.0	14.0-17.0
A2	9.5-9.5	85.0-90.0	8.0-9.0	13.0-13.0	14.0-14.0
7					
A1	9.5-9.5	55.0-60.0	4.0-5.0	16.0-16.0	16.0-16.0
B	9.5-9.5	60.0-75.0	5.0-6.0	16.0-16.0	16.0-16.0
A2	9.5	75.0	6.0	16.0	16.0

[a] A1=first baseline phase, B=intervention phase, A2=second baseline phase.

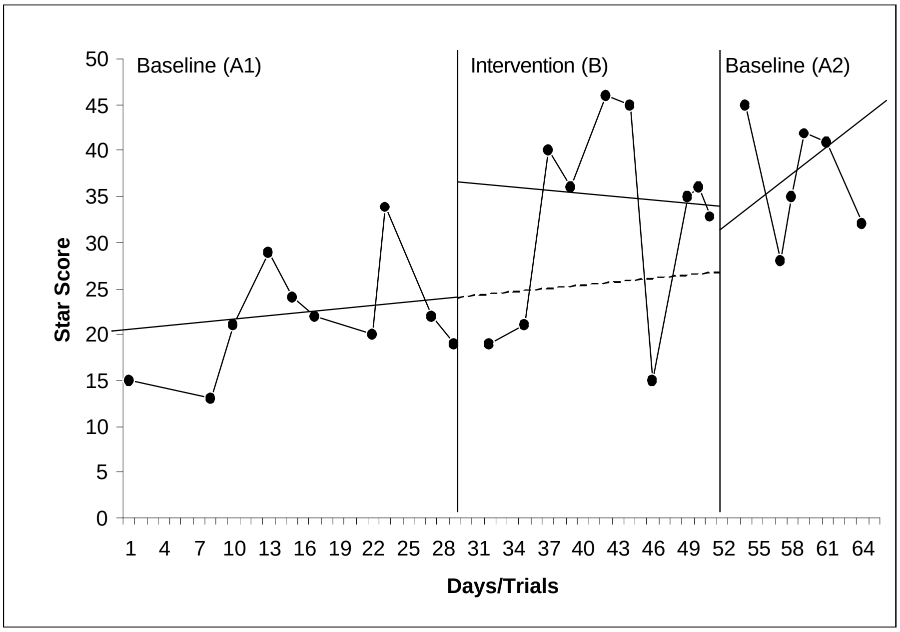


Figure 7.1. Scanning and cueing approach: Subject 1. Star Cancellation Test (SCT) scores across phases showing celeration line in A1 (first baseline) phase continued into B (intervention) phase and trend lines in B and A2 (second baseline) phases.

Subject 2 (Table 7.3) had severe left-sided motor and sensory loss, with the upper limb more affected than the lower limb and with minimal sensation and active movement in the left lower limb. She was occasionally incontinent and was able to maintain unsupported sitting. She had left homonymous hemianopia; mild reading impairment, and severe UVN (Table 7.4), with eyes and head usually turned to the right. She was usually alert but sometimes drowsy, occasionally losing concentration. She was assigned to a 3-week baseline phase. Intervention was commenced at 68 days post-stroke. Ten treatment sessions were conducted. The SCT and BTT showed a change only between the A1 and B phases (Tables 7.5 and 7.7). These changes are illustrated in Figures 7.2 and 7.3.

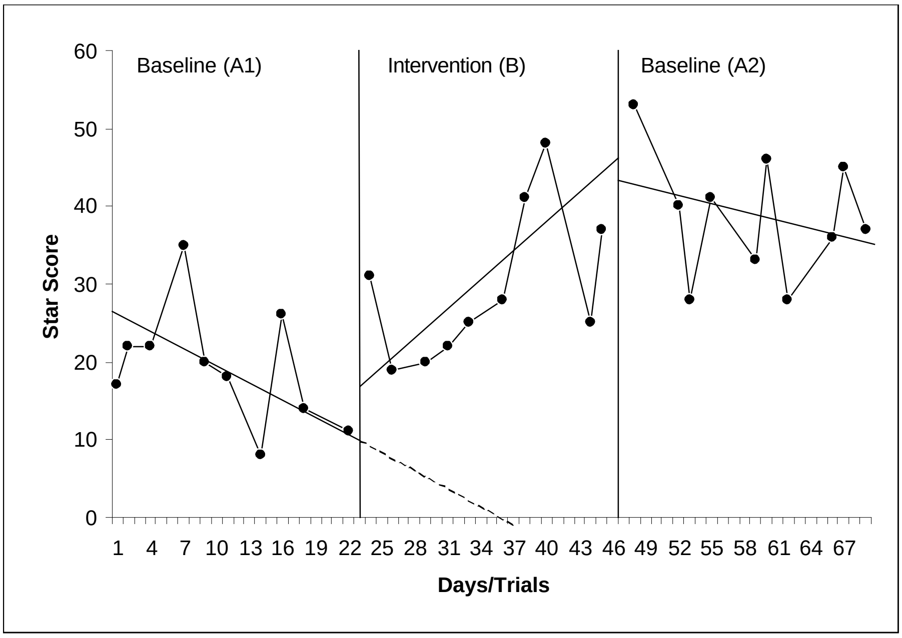


Figure 7.2. Scanning and cueing approach: Subject 2. Star Cancellation Test (SCT) scores across phases showing celeration line in A1 (first baseline) phase continued into B (intervention) phase and trend lines in B and A2 (second baseline) phases.

Figure 7.2 shows improvement in SCT scores during the intervention phase, with changes in slope, trend and level, and the improvement was maintained during the A2 phase. The changes in trend lines for the BTT (Figure 7.3) indicate better symmetry and less variability in "bun" placement during the B phase, which was partly maintained during the A2 phase. Small changes in BI scores were due to improvements in continence (Table 7.8) and were not related to the timing of the intervention. The subject reported that she was now able to find medications and refreshments placed on the table in front of her or to her left, which previously she had missed.

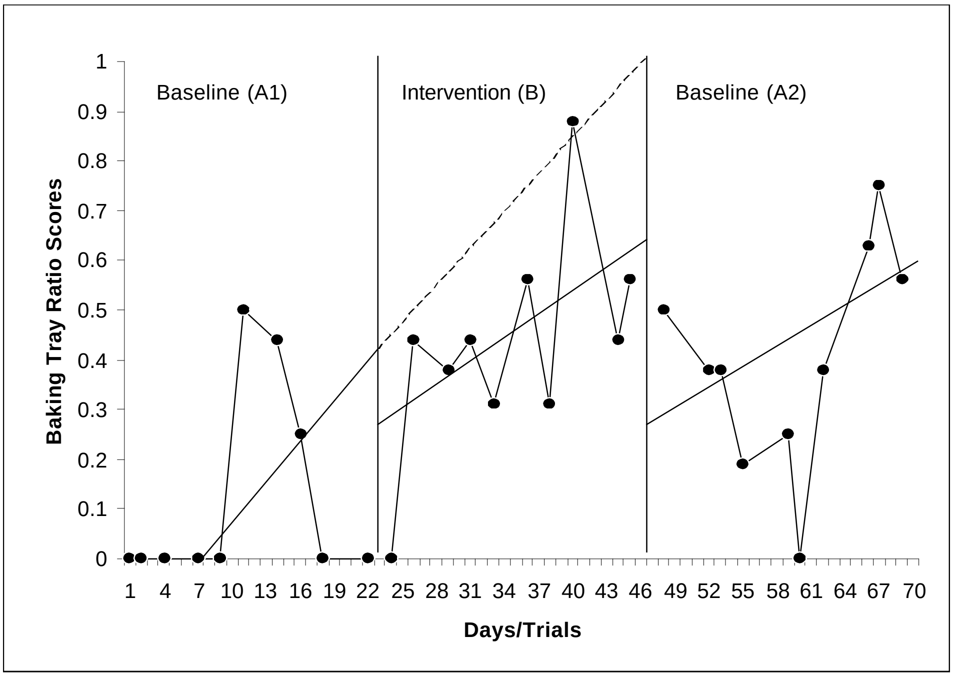


Figure 7.3. Scanning and cueing approach: Subject 2. Baking Tray Task (BTT) scores across phases showing celeration line in A1 (first baseline) phase continued into B (intervention) phase and trend lines in B and A2 (second baseline) phases (ratio score of 0.5=normal symmetry).

Subject 3 (Table 7.3) had moderate left-sided motor loss, which was worse in the upper limb than in the lower limb, and mild left-side sensory loss; was incontinent; and had good sitting balance. He had a severe hearing deficit and used a hearing aid. He had moderate reading impairment and severe UVN (Table 7.4), with eyes and head turned to the right. He was frequently drowsy but was more alert during testing and treatment sessions. He was assigned to a 3-week baseline phase. Intervention commenced at 62 days post-stroke. Ten treatment sessions took place. He showed improvement in SCT scores and reduction in line bisection error between the A1 and B phases and between the B and A2 phases (Tables 7.5 and 7.6). These changes are illustrated in Figures 7.4 and 7.5.

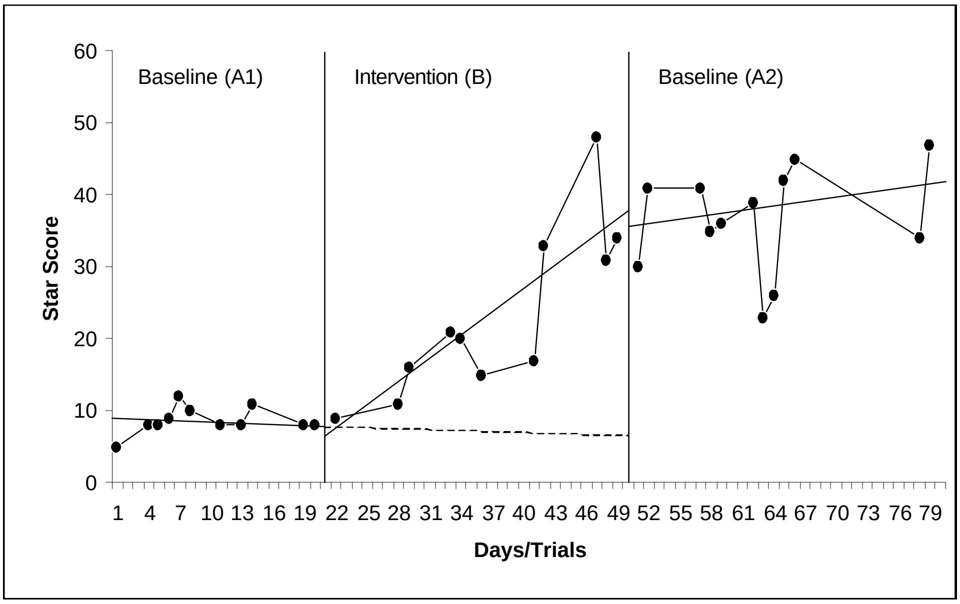


Figure 7.4. Scanning and cueing approach: Subject 3. Star Cancellation Test (SCT) scores across phases showing celeration line in A1 (first baseline) phase continued into B (intervention) phase and trend lines in B and A2 (second baseline) phases.

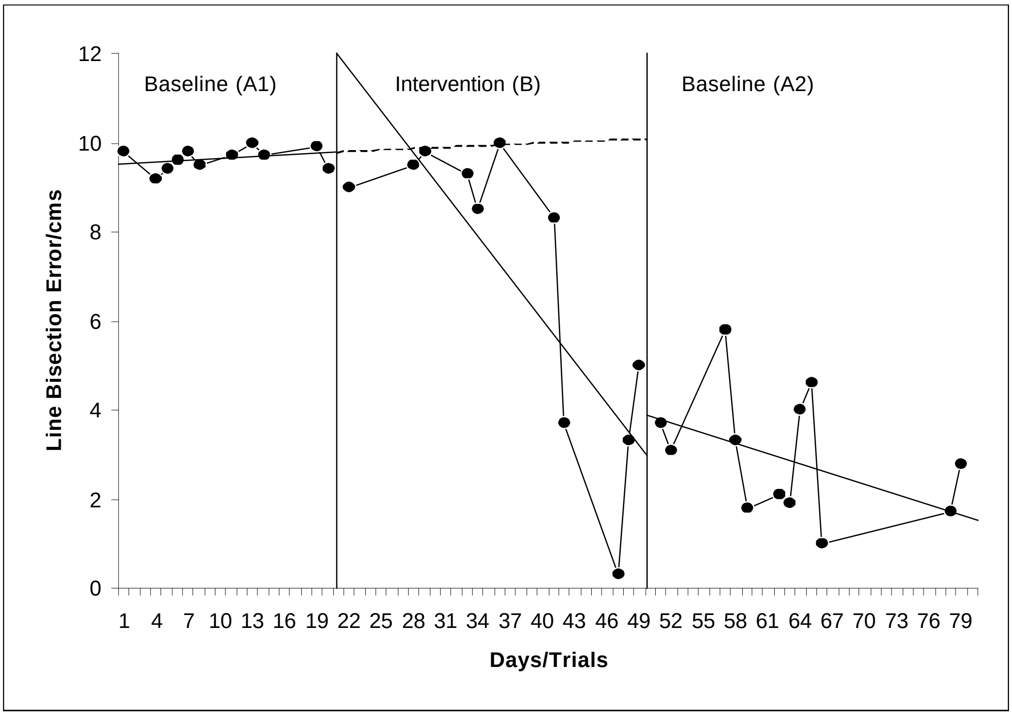


Figure 7.5. Scanning and cueing approach: Subject 3. Line Bisection Test (LBT) scores across phases showing celeration line in A1 (first baseline) phase continued into B (intervention) phase and trend lines in B and A2 (second baseline) phases.

Figure 7.4 shows changes in trend and slope for the SCT between the A1 and B phases, with a leveling off of the trend line in the A2 phase. This indicated large improvement coinciding with treatment, which was maintained during the A2 phase. Figure 7.5 shows a sharp decrease in line bisection error during the B phase, with continued but less dramatic improvement during the A2 phase. The small changes in BI scores were due to improvements in his ability to transfer (Table 7.8) and were not related to the timing of the intervention. However, there were small changes in both position sense and touch during the B phase, which were maintained during the A2 phase (Table 7.8).

Subject 4 (Table 7.3) was incontinent and had moderate left-sided motor and sensory loss, with some sparing of sensation and fair active movement in the left lower limb. She had good sitting balance. She had severe left UVN (Table 7.4) and severe reading impairment. She was frequently drowsy during testing and treatment sessions, frequently needing to be aroused during testing in order to complete tasks. She was assigned to a 4-week baseline phase. Intervention commenced at 55 days post-stroke. Ten treatment sessions were conducted. No changes in score in any tests for UVN between phases were found (Tables 7.5, 7.6 and 7.7). There were minor changes in motor control, function, mobility, and sensation (Table 7.8), none of which were related to the timing of the intervention.

Subject 5 (Table 7.3) had left-sided hemiplegia, with severe motor and sensory loss. She was incontinent and very drowsy during all testing and treatment sessions, such that she required frequent rousing to complete any task. She was unable to sit without support. She had severe left-sided UVN (Table 7.4), with head and eyes deviated to the right. She was assigned to a 2-week baseline phase; however, the baseline phase turned out to be much longer than planned due to a period of patient illness. Intervention commenced at 65 days post-stroke, and 10 treatment sessions were conducted. No changes in score in any tests for UVN between phases were found (Tables 7.5, 7.6 and 7.7). There was a small change in her BI scores (Table 7.8) due to improvement in continence, but this change was not related to any phase change.

7.7.2 Subjects receiving limb activation training (subjects 6 and 7)

Subject 6 (Table 7.3) had left-sided moderate hemiplegia, with left homonymous hemianopia. He had some reduced sensation; position sense worse than light touch, with sensory extinction; and moderate active control of his left upper and lower limbs. He was incontinent, was able to transfer with supervision, and was able to walk with the help of one person. He had severe left-sided UVN (Table 7.4) omitted left parts of garments during dressing, and had severe reading impairment. He was alert and cooperative. He was assigned to a 4-week baseline phase. Intervention started at 48 days post-stroke. Ten treatment sessions were conducted. He showed improvements only between the A1 and B phases for all 3 tests for UVN (Tables 7.5, 7.6 and 7.7). Figure 7.6 shows continual improvement in SCT scores throughout the B phase, and improvement was maintained during the A2 phase. Figure 7.7 shows a general trend of reduction in line bisection error, with a small trend of increasing errors during the A2 phase. Figure 7.8 shows a clear trend for improved symmetry (a score of 0.5 indicates symmetry), with more "buns" being placed on the left, the change being coincident with the intervention, and the improvement partly maintained during the A2 phase.

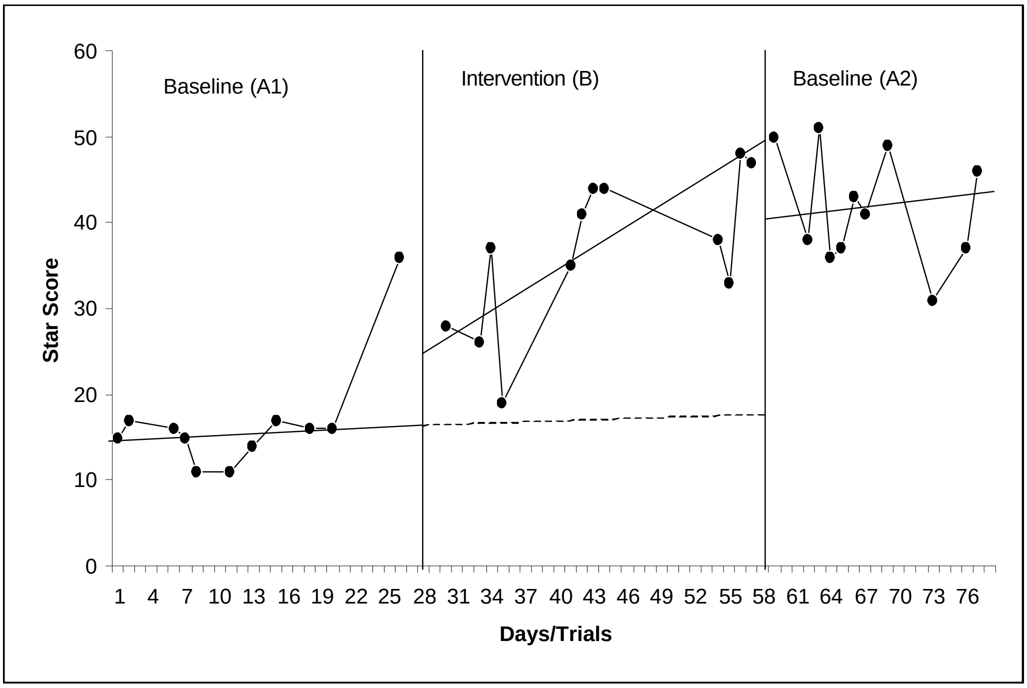


Figure 7.6. Limb activation approach: Subject 6. Star Cancellation Test (SCT) scores across phases showing celeration line in A1 (first baseline) phase continued into B (intervention) phase and trend lines in B and A2 (second baseline) phases.

However, the graphs show, for all 3 tests, that there were indications of improvements in scores at the end of the baseline (A1) phase, before intervention began. Table 7.8 shows that, although there were changes in scores in severity, function, mobility, and sensation, only changes in the BI and the light touch scores were coincident with the change from the A1 phase to the B phase. The increase in BI scores from 30 to 45 was due to improvements in continence, dressing ability, and balance (ability to transfer with help).

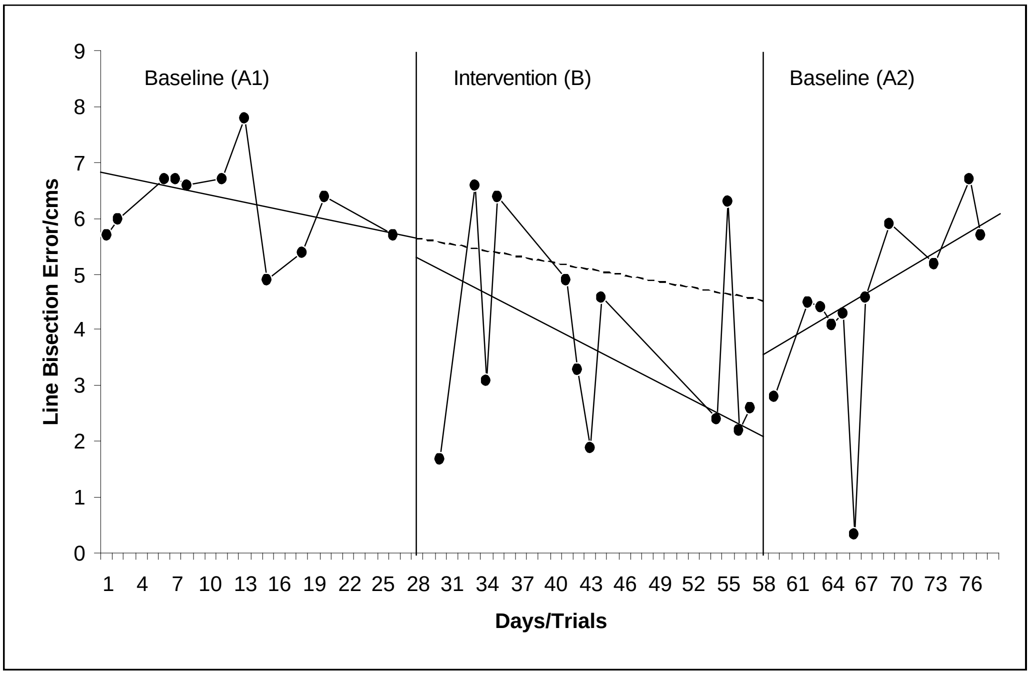


Figure 7.7. Limb activation approach: Subject 6. Line Bisection Test (LBT) error scores across phases showing celeration line in A1 (first baseline) phase continued into B (intervention) phase and trend lines in B and A2 (second baseline) phases.

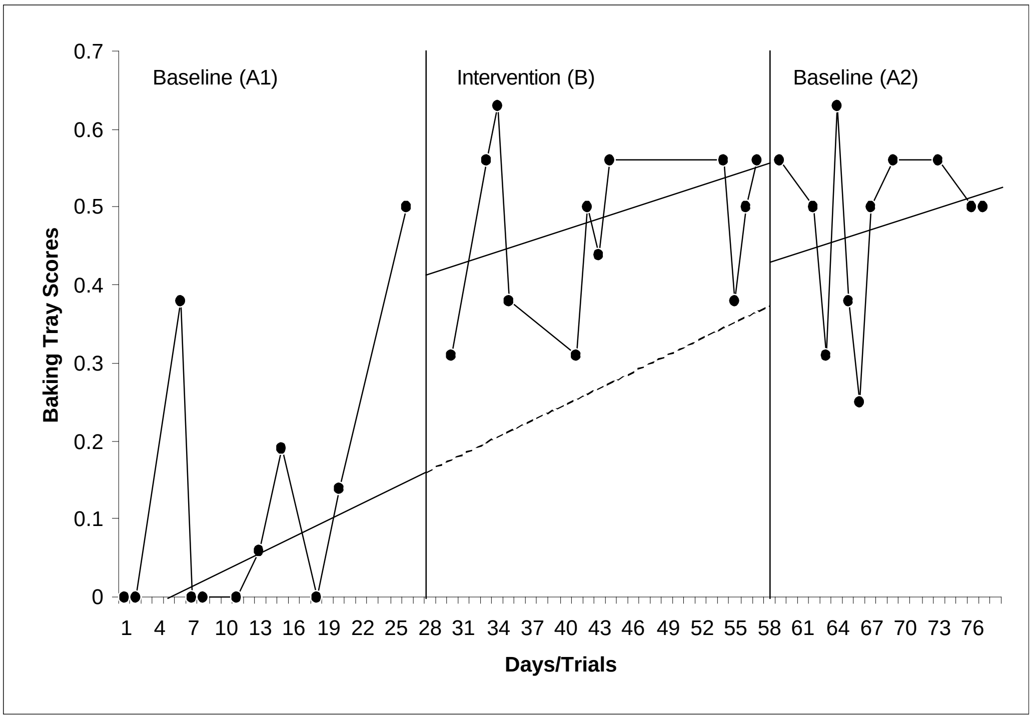


Figure 7.8. Limb activation approach: Subject 6. Baking Tray Task (BTT) scores across phases showing celeration line in A1 (first baseline) phase continued into B (intervention) phase, and trend lines in B and A2 (second baseline) phases (ratio score of 0.5=normal symmetry).

Improvements continued during the A2 phase. Light touch appreciation improved from 14 to 17 in the forearm and hand during the B phase, and improvement was maintained during the A2 phase. He reported that he was now able to find medications and refreshments placed on the table in front of him or to his left, which previously he had missed.

Subject 7 (Table 7.3) had left-sided, mild hemiplegia, with left hemianopia and severe left UVN, with head and eyes deviated to the right.

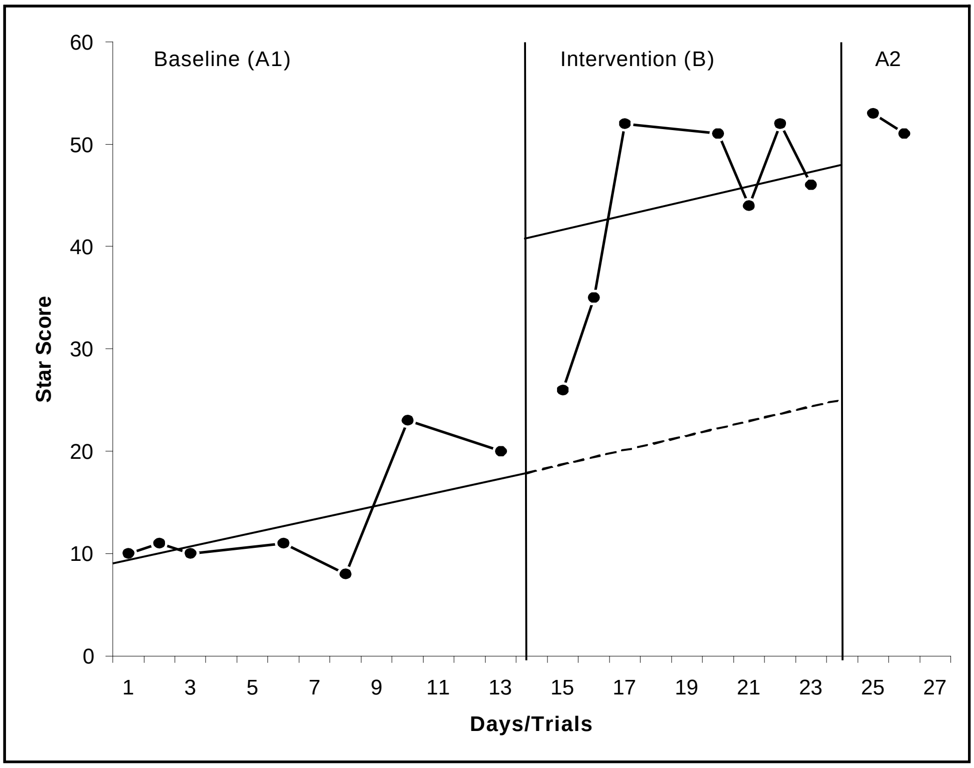


Figure 7.9. Limb activation approach: Subject 7. Star Cancellation Test (SCT) scores across phases showing celeration line in A1 (first baseline) phase continued into B (intervention) phase and trend line in B phase.

.She had good sensation and only mild left-sided weakness, with some incoordination. She was able to stand and walk but required assistance with mobility and self-care activities due to balance problems. She was continent and alert. She was assigned to a

2-week baseline phase. Intervention commenced at 26 days post-stroke. Seven test sessions were conducted during the A1 phase, and 7 intervention and testing sessions were conducted during the B phase. Only 2 testing sessions were completed during the A2 phase because the subject was discharged home. She showed improvement in SCT scores between the A1 and B phases (Table 7.5). Figure 7.9 shows that this improvement occurred during, and was coincident with, the intervention phase. Table 7.8 indicates that, although there were some changes in function and mobility scores (BI and RMI), these were not coincident with change from the A1 phase to the B phase. She reported that she was now able to find medications and refreshments placed on the table in front of her or to her left, which previously she had missed.

7.8 Discussion

Our results indicate that both subjects who were treated using the limb activation approach and 3 of the 5 subjects who were taught scanning and cueing strategies demonstrated reduction in UVN ($p<.05$) between the baseline and intervention phases in one or more of the 3 tests. This finding allows the null hypothesis to be rejected in these cases. However, in the absence of true control (although some control was provided by the use of no-treatment baseline phases), alternative explanations to the intervention causing reduction of visual neglect (e.g. spontaneous recovery) also should be considered. Two subjects showed no improvements in any of the tests for UVN and no change in sensation, stroke severity, function, or mobility relating to any change of phase. These 2 subjects had extremely low levels of arousal and were usually drowsy during both testing and treatment sessions. Unilateral visual neglect is strongly related to self-maintained arousal (Robertson et al., 1997a) and this may explain the failure of these 2 subjects to respond. Unless sustained attention can be maintained or improved (e.g. by use of a "neglect alert" device (Robertson et al., 1998b), patients are unlikely to respond to specific treatment that focuses on improving the ability to orient attention contralesionally.

7.8.1 Impact on visual neglect

Of the 5 subjects who did improve, all showed improvements in SCT scores between the baseline and intervention phases. In addition, 2 subjects (subjects 3 and 6) showed reduction in error on the LBT, and 2 subjects (subjects 2 and 6) had better symmetry in BTT scores between the baseline and intervention phases. Improvements found during intervention for these 5 subjects were generally maintained during the second baseline phase (Figures 1-4 and 6-9), which suggests to us a degree of permanent change. Only 1 subject (subject 6) who was alert and well-motivated showed improvement in UVN across all 3 tests, but his LBT scores worsened following withdrawal of treatment. Differential performance within subjects for the LBT and BTT may be because these tests involve complex spatial organizational and perceptual skills, in addition to visual search ability (Robertson & Halligan, 1999). Such tests may have been less susceptible to the type of visual scanning and search training emphasized in our study, which may have had a greater impact on the ability of the subjects to search for and cancel targets, as demonstrated by improved SCT scores. Additional support for the selectivity of the training effect is given by the fact that stroke severity, as measured by the Canadian Neurological Scale, was relatively stable within each subject across time (Table 7.8), a finding also noted by Paolucci and colleagues (1996b).

7.8.2 Possibility of spontaneous recovery

One subject (subject 7) had intervention only 26 days post-stroke, another subject (subject 6) showed slight improvements prior to intervention, and a third subject (subject 3) showed continued improvement in SCT and LBT scores between the intervention and second baseline phases. Thus, spontaneous recovery cannot be entirely ruled out. However, random assignment of subjects to differing baseline phase lengths should have reduced this possibility. In addition, Zoccolotti et al. (1989) established stability of visual neglect at 1 month post-stroke.

7.8.3 Possible mechanisms explaining improvement

7.8.3.1 Scanning and cueing.

Frontal lesions are thought to involve a defect in voluntary orienting, whereas parietal lesions involve a defect in automatic orienting (Berger & Posner, 2000). Such loss of automatic orienting, but the possibility of preserved voluntary orienting ability toward contralateral space, may assist in the rehabilitation of visual neglect (Gainotti, 1996). The reduction in UVN shown by 3 subjects (subjects 1-3) indicates that practice and repetition of activity that directed attention to the neglected hemispace may have encouraged these subjects to use spared voluntary orienting mechanisms. Incorporation of a self-alerting procedure using visual imagery (Niemeier, 1998) may have further encouraged leftward orienting in these 3 subjects. The 2 subjects who did not respond (subjects 4 and 5) may have had insufficient levels of alertness to enable them to effectively use this procedure.

7.8.3.2 Limb activation.

Reduction of visual neglect by LLA has been explained by 2 theories. One theory is that such use activates the lesioned hemisphere and thus improves attentional control toward contralesional space (Kinsbourne, 1987). Left limb activation, therefore, can be seen to act as a motor stimulus that activates the right hemisphere. A second theory is that left-limb movement activates a left personal space system and that this system modifies the abnormal spatial bias toward the ipsilesional side (Karnath, Niemeier & Dichgans, 1998; Ladavas et al., 1997). We believe that the limb activation approach used in this study was more functionally based than the approaches used in many previous studies, including the use of finger tapping (Wilson et al., 2000) or turning off a buzzer activated at random intervals (Robertson et al., 1998).

7.8.4 Generalization of training effect to nontrained tasks.

Contrary to previous findings (Paolucci et al., 1996b) only 2 subjects showed changed scores (coincident with intervention) on some tests of function (subject 3 showed improvements in touch and position sense, and subject 6 showed improvements in touch and BI scores). This problem of lack of generalization to functional activity has been noted previously (Robertson & Halligan, 1999) suggesting that scanning and cueing training should be incorporated into functional activities where possible, thus facilitating transfer. Some improvements in BI scores and sensation may be related to treatment and may be explained either by the subject’s improved ability to pay attention to the left, due to visual scanning training, or by position sense cueing using LLA. Touch discrimination apparently may improve when the patient pays attention and, conversely, may appear more impaired when the patient is distracted. The functional outcome measures chosen may not have been sufficiently sensitive to demonstrate any small changes in function that may have been related to a reduction in visual neglect (Bowen & Cross, 2000) and outcome measures addressing this problem are needed. As found previously (Robertson et al., 1998a; Wilson et al., 2000) increased use of the left limb was observed for subjects 6 and 7 following the training phase.

Unfortunately, some subjects who showed reduced visual neglect on formal testing still demonstrated visual neglect behavior in some everyday situations, as also found by Bergego et al. (1997). For example, they were unaware of a person approaching on their neglected side. This finding illustrates the continued inability to orient automatically, even though there may be improvements in the capacity to orient voluntarily. Even if visual neglect seems resolved in classic tests, the inability to elicit a leftward response in other, perhaps noisier, situations where there may be increased attentional demands may be due to continued failure to inhibit right-sided bias for novel objects (Bartolomeo, 2000). Nevertheless, 3 subjects (subjects 2, 6, and 7) reported that they were now able to find medications and refreshments placed on their table in front of them or to their left, which previously they had missed.

Our study was not designed to compare the relative effectiveness of the 2 approaches, and there is some evidence that each approach reduced aspects of visual neglect in some subjects. It may be that a combination of the approaches would produce an additive effect in alert and motivated patients with sufficient upper-limb function. This possibility warrants further investigation. There is no way of knowing how much, if any, practice each subject did outside of training sessions, although it is possible that those who were more alert might have undertaken more practice. This practice effect may have contributed to differential effects on outcome. In clinical practice, maximization of training could be achieved by involving other health care professionals, as well as relatives or friends of the patient, in the use of one or other of the treatment approaches used in our study. Although external validity of the data obtained in this study is strengthened by replication across subjects, Hersen and Barlow (1976) have recommended 3 replications, in addition to the original demonstration of treatment effectiveness, in order to provide sufficient evidence. In the absence of control, it is also difficult to make causal statements and to show effectiveness of a treatment.

7.9 Conclusions

Both the scanning and cueing strategy and the LLA strategy appear to have reduced visual neglect, in at least 1 of the 3 tests, in 5 of the 7 subjects in this study, although inferences of causality must be viewed cautiously due to lack of a traditional control group (although a degree of control was provided by the use of no-treatment baseline phases) and the possibility of spontaneous recovery. In addition, we studied a small number of subjects. The design of this study precludes any judgment of relative efficacy of the 2 approaches. Some subjects appeared to be able to learn to voluntarily scan and pay attention to left-sided objects, although this ability did not seem to affect their automatic deficit in orienting. The strategies used appeared most successful in the more alert subjects, who were better able to cooperate. There was minimal evidence of generalization of reduction of visual neglect to nontrained tasks. The strategies used did not require complex or expensive equipment, and they would be easy to apply in the clinical setting by therapists or trained therapist assistants. The time allocated for these activities also was clinically feasible.

7.10 Material supplementary to published paper – five further patients

Because only two subjects suitable for limb activation training had been recruited in the published study, it was considered important to continue recruitment to enable data to be collected from a larger number of patients.

7.10.1 Method

The experimental design was as previously described in section 7.6.1. Full details of all tests used for stroke severity (CNS), function (BI), mobility (RMI) and sensation (Nottingham Sensory Assessment Scales for light touch, and proprioception) are located in Appendices Q to U. Subjects 8 and 10 were assigned to a 4-week baseline phase; subjects 11 and 12 were assigned to a 3-week baseline phase, and subject 9 was assigned to a 2-week baseline phase. The five subjects were between 64 and 79 years of age and were admitted from an acute care hospital to a stroke rehabilitation unit over a 14-month period. Subject details are shown in Table 7.9. Subjects 8 and 10 received the scanning and cueing approach, and subjects 9, 11 and 12 received the LLA approach. All subjects gave written informed consent before taking part in the study. Data analysis was as described in section 7.6.5 and, once again, the only graphs presented here are those which illustrate a significant reduction of neglect between the first baseline and the intervention phases. However, each of the five subjects is represented in at least one of the 11 graphs included (Figures 7.10 to 7.20).

7.10.2 Results

Over a 14-month period (following immediately on from the 12-month period of study which included the 7 patients previously described in the published paper), 168 patients were admitted to the unit; it was not possible to test 37 patients (22%), in most instances this was due to communication problems resulting from left-sided brain damage; a few cases with right-sided brain damage were excluded due to reasons of confusion, illness and frailty, and refusal to be tested. Of the remaining 131 patients, 66 (50%) had right-sided brain damage and 38 (58%) of these had UVN. From this group of 38 patients, a total of only 5 patients (Table 7.9) fulfilled the specified inclusion criteria (first stroke and UVN on all three screening tests – see section 7.6.2).

Table 7.9.

Subject details and timing of commencement of phases in ABA Single Subject Design (subjects 8-12).

Subject	Gender	Age/ yrs	CT Scan Result	Days post-stroke (start A1 phase)	Days post-stroke (start B phase)	Days post-stroke (start A2 phase)
8	Male	73	Right tempero-occipital (large) and frontal infarcts (small)	22	52	68
9	Male	79	Right tempero-parietal and basal ganglia infarcts	20	33	49
10	Female	68	Right posterior parieto-occipital infarct	27	59	77
11	Male	73	Right frontal subcortical infarct	18	38	59
12	Male	64	Right parietal cortical infarct	18	42	65

Data including mean and range for each phase for each of the three tests for UVN, for each subject, are presented in Table 7.10.

Table 7.10.

Time series data for each phase for the three tests for unilateral visual neglect[a] (subjects 8-12)

Subject Number	**SCT A1**	**B**	**A2**	**LB A1**	**B**	**A2**	**BTT A1**	**B**	**A2**
8									
8	9.28	43.83	33.12	7.19	4.15	5.12	0	0.09	0.01
Range	7-12	27-53	20-52	6.4-8.5	2.6-6.8	2.9-6.6	0-0	0-0.31	0.0-0.19
9									
8	24	51.8	53.4	1.24	1.07	0.99	0.06	0.07	0.27
Range	22-31	48-54	50-54	0.3-2.5	0.3-1.7	-0.3-+1.8	0.0-0.56	0.0-0.31	0-0.63
10									
8	17.54	40.36	44.75	8.95	8.32	5.67	0.04	0.15	0.14
Range	8-29	29-53	35-53	6.0-9.9	7.2-9.4	4.5-7.2	0.0-0.25	0.0-0.81	0.0-0.94
11									
8	21.27	32.38	34.64	2.57	1.38	1.16	0	0.29	0.44
Range	12-26	26-40	27-38	1.3-3.9	0.8-2.2	-0.2-+2.3	0.0-0.0	0.0-0.56	0.0-0.81
12									
8	12.64	20.85	35.71	2.46	2.84	0.63	0.19	0.21	0.16
Range	8-17	11-32	18-53	0.2-4.1	1.3-5.7	-0.8-+1.9	0.0-0.44	0.0-0.75	0.0-0.44

[a]SCT = Star Cancellation Test Star Score (maximum score 54)
LB = Line Bisection Test score deviation error from true centre (cms)
BTT = Baking Tray Task ratio ‘buns’ placed on left: total of 16 buns
(0.5 shows equal number of ‘buns’ placed on left and right side of board)
A1=first baseline phase; B=intervention phase; A2=second baseline phase
Results of all statistical tests performed on the time series data for UVN tests are presented in Tables 7.11 to 7.13.

Table 7.11.

Statistical analysis results for Star Cancellation Test for subjects 8-12[a]

Subjects	**Kruskal-Wallis across phases (p<.05)**	**Mann-Whitney (*post hoc test*) between A1 and B phases (p<.025)**	**Mann-Whitney (*post hoc test*) between B and A2 phases (p<.025)**
8	Not applicable**	p<.05* (z=2.428)	p<.05* (z=-2.530)
9	p<.001*	p< .001* (z=-4.227)	NS
10	p<.001*	p<.001* (z=-4.396)	NS (z=-1.804
11	p<.001*	p<.001* (z=-4.069)	NS (z=-1.134)
12	p<.001*	p=.003* (z=-2.936)	p<.001* (z=-3.255)

[a]If the Kruskal-Wallis test is non-significant, further *post hoc* testing is unnecessary. Asterisk
indicates a significant difference at the stated p value.
Double asterisk indicates serial dependency in data and analysis by C statistic.
For significance at p<.05, z must be >1.64. NS=not significant.
A1=first baseline phase, B=intervention phase, A2=second baseline phase.

Table 7.12.

Statistical analysis results for Line Bisection Test for subjects 8-12[a]

Subjects	**Kruskal-Wallis across phases (p<.05)**	**Mann-Whitney (*post hoc test*) between A1 and B phases (p<.025)**	**Mann-Whitney *(post hoc test*) between B and A2 phases (p<.025)**
8	p<.001*	p<.001* (z=-4.346)	p<.01* (z=-2.564)
9	NS	NS (z=-.556)	NS (z=-.362)
10	p<.001*	p<.017* (z=-2.382)	p<.001* (z=-3.917)
11	P<.001*	p<.001* (z=-3.368)	NS (z=-.523)
12	Not applicable**	NS (z=.001)	p<.05* (z=2.91)

[a]If the Kruskal-Wallis test is non-significant, further *post hoc* testing is unnecessary.
Asterisk indicates a significant difference at the stated p value.
Double asterisk indicates serial dependency in data and analysis by C statistic.
For significance at p<.05, z must be >1.64. NS=not significant.
A1=first baseline phase, B=intervention phase, A2=second baseline phase.

Table 7.13.

Statistical analysis results for Baking Tray Task for subjects 8-12[a]

Subjects	**Kruskal-Wallis across phases (p<.05)**	**Mann-Whitney (*post hoc test*) between A1 and B phases (p<.025)**	**Mann-Whitney (*post hoc test*) between B and A2 phases (p<.025)**
8	p<.001*	p<.001* (z=-3.272)	p<.001* (z=-3.344)
9	p= .001*	NS (z=-.834)	p= .001* (z=-3.225)
10	NS		
11	p<.002*	p=.012* (z=-2.514)	NS (z=-1.105)
12	NS		

[a]If the Kruskal-Wallis test is non-significant, further *post hoc* testing is unnecessary.
Asterisk indicates a significant difference at the stated p value.
Double asterisk indicates serial dependency in data and analysis by C statistic.
For significance at p<.05, z must be >1.64. NS=not significant.
A1=first baseline phase, B=intervention phase, A2=second baseline phase.

The range of scores for tests of severity, function, mobility, and sensation for each phase, for each subject, are shown in Table 7.14. Results in the remainder of this section will be summarized on a case-by-case basis.

7.10.2.1 Subjects receiving scanning and cueing training (subjects 8 and 10)

Subject 8 (Table 7.9) had a left sided hemiplegia with severe sensory and motor loss. He had no sensation, including proprioception, on the left side, although touch on the left side of his face was preserved. He had minimal voluntary ability to flex his left hip and knee, sufficient to allow him to tap his left foot a little on the floor whilst sitting, and minimal shoulder girdle activity in his left arm. Any voluntary movement on the left side was accompanied by increased muscle tone. He had a left homonymous hemianopia, and severe left visuospatial neglect and reading impairment, with no spontaneous direction of his attention to the left when addressed from that side. He hesitantly explored the space on his left side with his right hand. He had good sitting balance but required the help of two people during all transfers (e.g. from wheelchair to bed).

Table 17.14.

Score range (minimum to maximum) for stroke severity, function, mobility and sensation, for each phase for subjects 8-12 [a],

Subjects	Canadian Neurological Scale Score 0-11.5	Barthel Index Score 0-100	Rivermead Mobility Index Score 0-15	Proprioception Score 0-24	Light Touch Score 0-20
8	5.5-6.5	20.0-25.0	1.0-1.0	0.0-0.0	1.0-2.0
A1	7.0-7.5	25.0-25.0	1.0-1.0	6.0-12.0	3.0-4.0
B	7.5-7.5	25.0-30.0	1.0-1.0	12.0-13.0	4.0-6.0
A2					
9					
A1	9.0-9.0	70.0-70.0	6.0-6.0	14.0-14.0	16.0-16.0
B	9.0-9.0	70.0-75.0	6.0-7.0	14.0-14.0	16.0-17.0
A2	9.0-9.0	85.0-85.0	8.0-8.0	16.0-16.0	15.0-16.0
10					
A1	7.5-7.5	30.0-35.0	1.0-2.0	11.0-13.0	12.0-16.0
B	7.5-8.5	35.0-35.0	3.0-4.0	12.0-13.0	16.0-19.0
A2	8.5-8.5	35.0-35.0	4.0-4.0	12.0-13.0	16.0-16.0
11					
A1	8.0-8.0	25.0-25.0	3.0-3.0	10.0-10.0	11.0-11.0
B	8.5-8.5	30.0-30.0	4.0-5.0	8.0-9.0	12.0-12.0
A2	8.5-8.5	40.0-40.0	6.0-6.0	10.0-11.0	11.0-12.0
12					
A1	9.0-9.5	20.0-20.0	0.0-2.0	0.0-0.0	2.0-2.0
B	9.5-9.5	20.0-35.0	3.0-5.0	4.0-11.0	5.0-11.0
A2	9.5-9.5	35.0-45.0	5.0-5.0	10.0-11.0	10.0-10.0

[a] A1=first baseline phase, B=intervention phase, A2=second baseline phase

He was mostly continent for both bowels and bladder, with occasional accidents. He was generally alert during all treatment sessions, and appeared to have some awareness of his stroke-related and neglect-related problems. He was assigned to a 4-week baseline phase. Intervention commenced at 51 days post-stroke. Ten treatment sessions took place. He showed improvement in SCT scores and BTT symmetry, and a reduction in line bisection errors between the A1 and B phases; however, between B and A2 phases, there was a decrease in mean star score, a reduction in symmetry of 'bun' placement, and an increase in mean line bisection error (Tables 7.10 to 7.13).

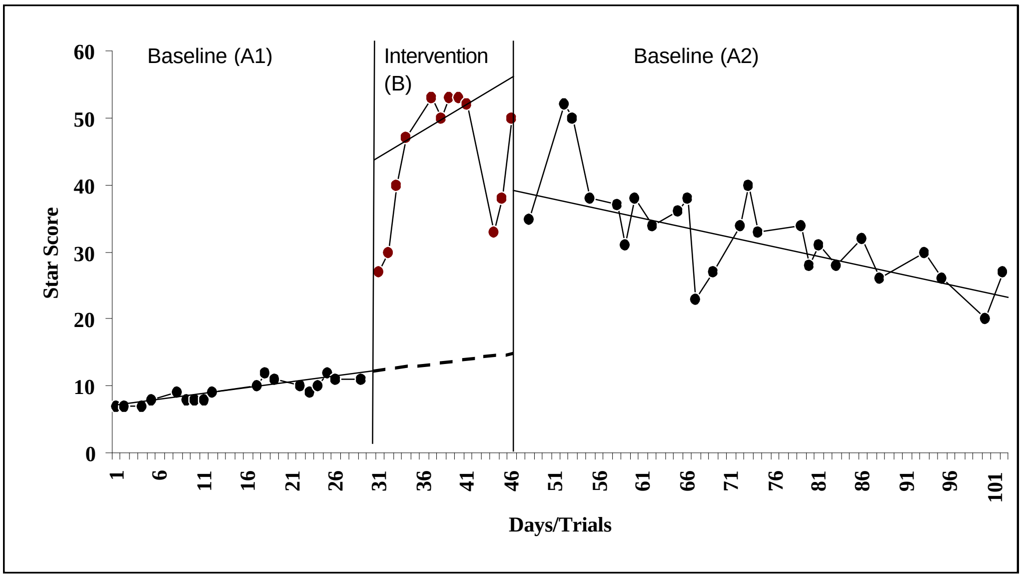


Figure 7.10. Scanning and cueing approach: Subject 8. Star Cancellation Test (SCT) scores across phases showing celeration line in A1 (first baseline) continued into B (intervention) phase and trend lines in B and A2 (second baseline) phases.

These changes are illustrated in Figures 7.10 to 7.12. Figure 7.10 shows changes in both slope and level for SCT between A1 and B phases, and changes in trend, slope and level between B and A2 phases. These changes indicate large improvement coinciding with treatment, which, although maintained for a around 10 days after withdrawal of treatment, then gradually deteriorated over time during the A2 phase, although not returning to baseline levels.

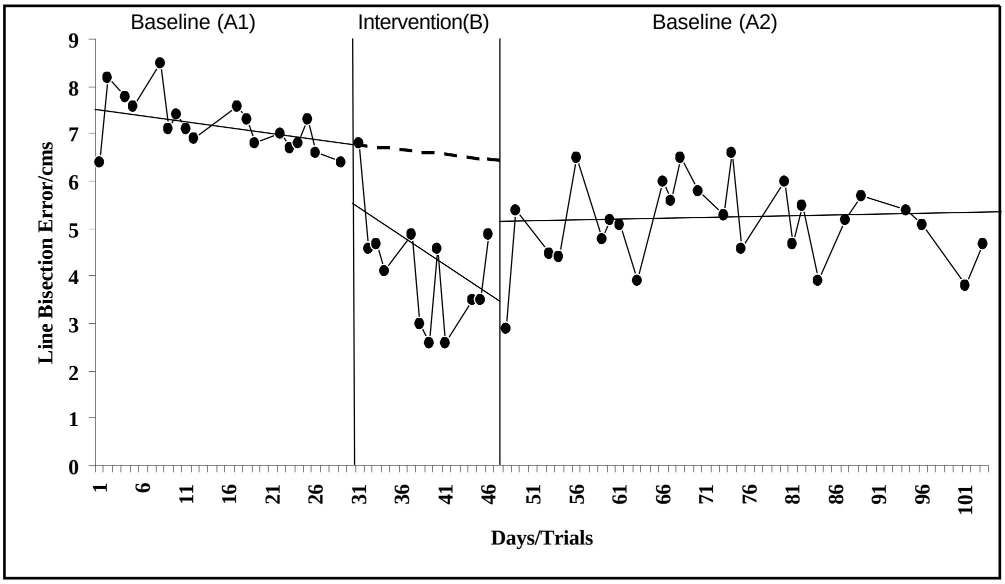


Figure 7.11. Scanning and cueing approach: Subject 8. Line Bisection (LB) error scores across phases showing celeration line in A1 (first baseline) continued into B (intervention) phase and trend lines in B and A2 (second baseline) phases.

Figure 7.11 shows a change in level and slope between A1 and B phases, and further changes in level, slope and trend between B and A2 phases. These changes indicate a large improvement in line bisection error coinciding with treatment. However, when treatment ceased, the bisection error showed a small increase, then remained at this level throughout the A2 phase.

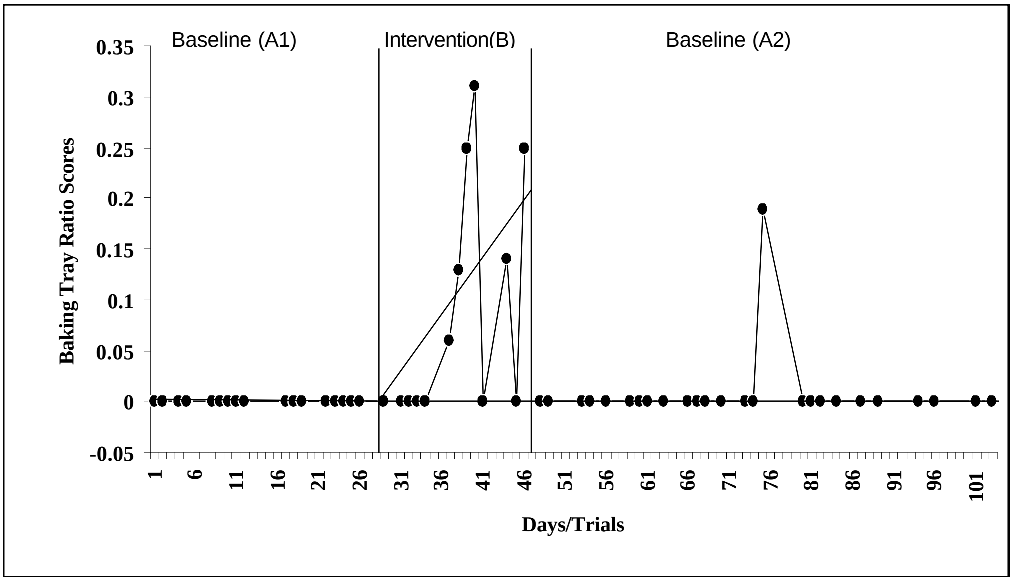


Figure 7.12. Scanning and cueing approach: Subject 8. Baking Tray Task (BTT) ratio scores across phases showing celeration line in A1 (first baseline) continued into B (intervention) phase and trend lines in B and A2 (second baseline) phases. (Ratio score of 0.5 = normal symmetry)

Figure 7.12 shows a change in slope and trend between the A1 and B phases, and a further change in trend and level between B and A2 phases. The scores during both baseline phases are, with one exception, at floor level, and indicate that all 'buns' were placed on the right side of the 'tray'. These changes indicate clear improvement in symmetry of 'bun' placement during the treatment phase, albeit not exactly coincident with the start of treatment. However, total symmetry (equal number of 'buns' on each side of the tray) was never achieved. When treatment ceased, the measurements returned to baseline levels, apart from one isolated occasion, indicating that, once again, all 'buns' were being placed on the right side of the 'baking tray'. With regard to changes in test scores for sensation, function and stroke severity, the following were recorded for subject 8: there was no change over time in the RMI, the score of 1 being consistently achieved for maintenance of sitting balance; there was gradual improvement in the BI scores due to improvements in bowel and bladder control, and gradual improvement in CNS scores due to small increases in voluntary movements in hip, knee, then foot, and finally, minimal finger and wrist movement, none of these being related to the timing of the intervention. The only changes which were coincident with the start of treatment were those in sensation; during baseline A1 phase, light touch was only felt on both sides of the face, but during the intervention B phase light touch was perceived and correctly located on both sides of the trunk and hip on some, but not all, occasions. During second baseline A2, light touch was additionally perceived on the elbow and shoulder area on both sides, and correctly located on some but not all occasions. For proprioception, there was a large improvement between A1 and B phases, from a zero score, to a score of 6, which showed that the patient was able to indicate that a joint had been (passively) moved although he was unable to correctly state the direction of movement (joints included all major ones in the left lower limb and the elbow and shoulder of the left upper limb). These changes were related to the timing of the intervention, and were maintained during the second baseline A2 phase.

Subject 10 (Table 7.9) had a mild to moderate severity left hemiplegia with good voluntary movement of her left leg, good sitting balance, was able to stand and balance unaided, but was unable to walk unaided. Her left arm had some voluntary movement and she was able to lift it above her head although the limb tended to adopt a pattern of massed flexion during this and any upper limb activity. She was unable to selectively move her wrist, hand or fingers on the left. Sensation on the left was present but reduced throughout to light touch, and she was able to identify movement and its direction in her left lower limb but was less accurate in her upper limb. She was continent for bowels but catheterised for bladder. She was alert and cooperative, and had severe visuospatial neglect and reading impairment. She was assigned to a 4-week baseline phase. Intervention commenced at 59 days post-stroke. Ten treatment sessions were conducted. Differences were found in SCT scores between A1 and B phases, for line bisection errors between A1 and B and between B and A2 phases, and no changes in BTT score (Tables 7.10 to 7.13). These changes are illustrated in Figures 7.13 and 7.14.

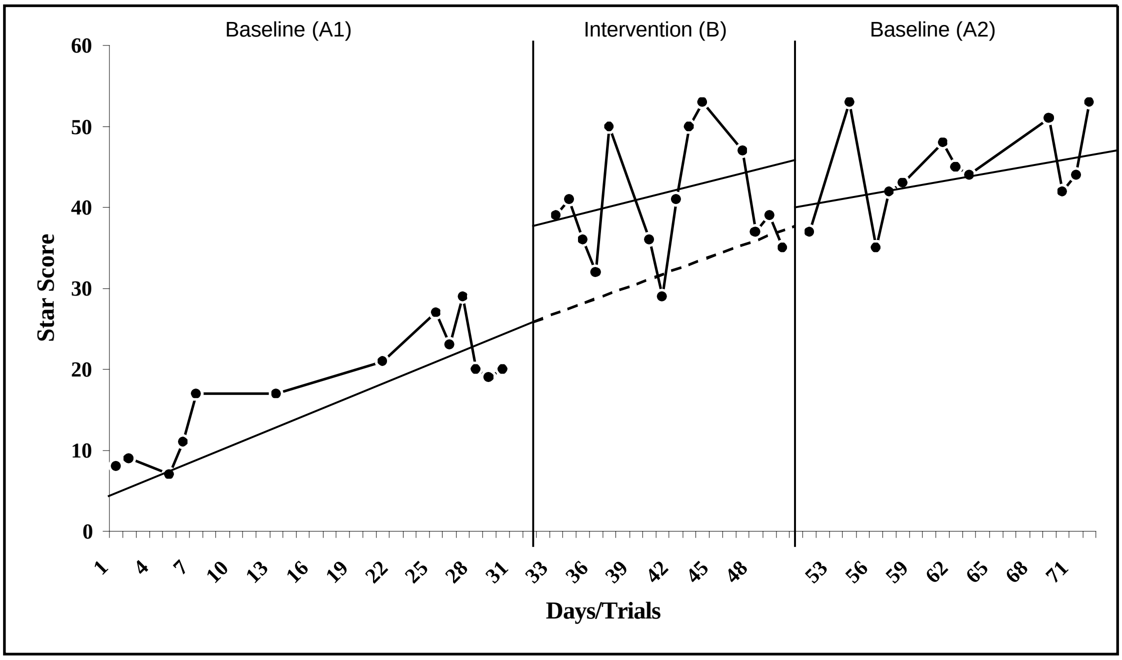


Figure 7.13. Scanning and cueing approach: Subject 10. Star Cancellation Test (SCT). scores across phases showing celeration line in A1 (first baseline) continued into B (intervention) phase and trend lines in B and A2 (second baseline phases.

Figure 7.13 shows changes in level between A1 and B phases. This indicates an increase in star score, which was coincident with the onset of treatment, and maintenance of the improvement during the second baseline phase.

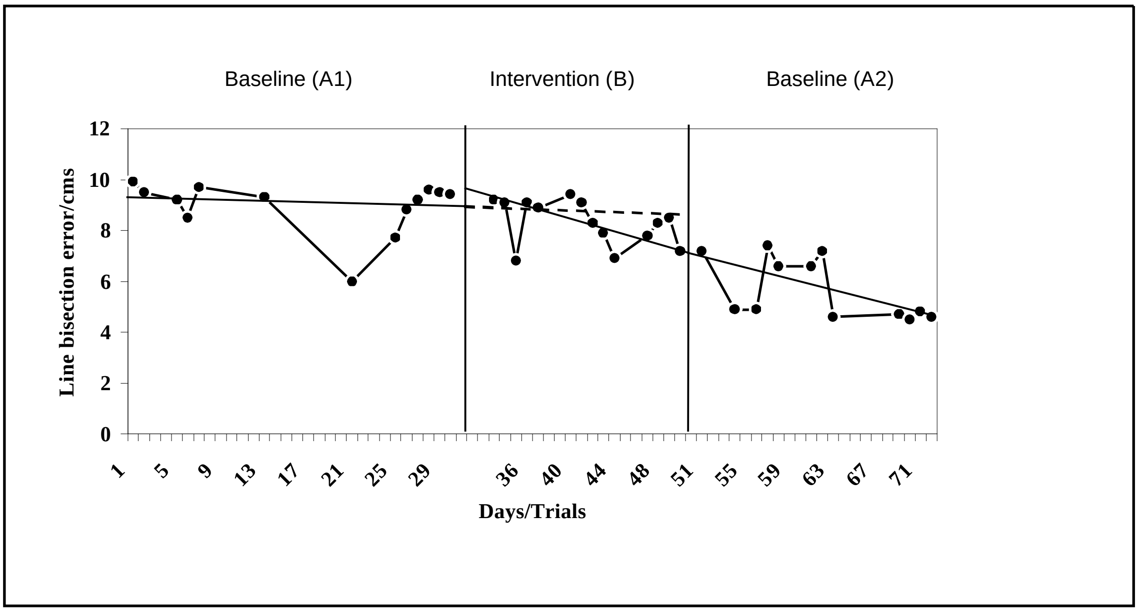


Figure 7.14. Scanning and cueing approach: Subject 10. Line Bisection (LB) error scores across phases showing celeration line in A1 (first baseline) continued into B (intervention) phase and trend lines in B and A2 (second baseline) phases.

Figure 7.14 shows changes in slope between A1 and B phases. This indicates a reduction in line bisection error between A1 and B phases, an improvement which continued during the A2 phase. There were small changes in function and mobility (Table 7.14); for the RMI, standing balance improved during first baseline, and the ability to go from sitting to standing was achieved during the intervention phase; for the BI the only improvement was during first baseline due to removal of the catheter and urinary continence established. The CNS score improved during the intervention phase due to some increase in voluntary control of proximal left limb joints. There were no changes of note in sensation (Table 7.14), and the score of 19 (maximum score 20) for light touch appreciation was recorded on only one occasion during second baseline.

7.10.2.2 Subjects receiving limb activation training (subjects 9, 11 and 12)

Subject 9 (Table 7.9) had a mild to moderate severity left hemiplegia with good movement and sensation on his affected side such that he was able to get from lying in bed into his chair with no help, but required the support of one therapist whilst walking indoors. He was able to use his left arm and hand for self-care activities such as dressing, using a knife and fork (with large handles), combing his hair and drinking from a cup, but had insufficient fine hand and finger control to pick up small objects with his fingers. He was able to feel and locate light touch on his left side and to correctly indicate direction of movement on his left side (hip, knee, ankle, foot, and shoulder) and that a movement had taken place (but not its direction) in his left fingers, hand, wrist and elbow. He was fully continent. He showed extinction to touch on the left side. He was alert during all treatment sessions. He had moderate to severe visuospatial neglect on initial screening. He was assigned to a 2-week baseline phase. Intervention commenced at 33 days post-stroke. Ten treatment sessions were conducted. The only differences in scores for UVN were found were those in the SCT (between A1 and B phases only) and for the BTT, but only between B and A2 phases (Tables 7.10 to 7.13).

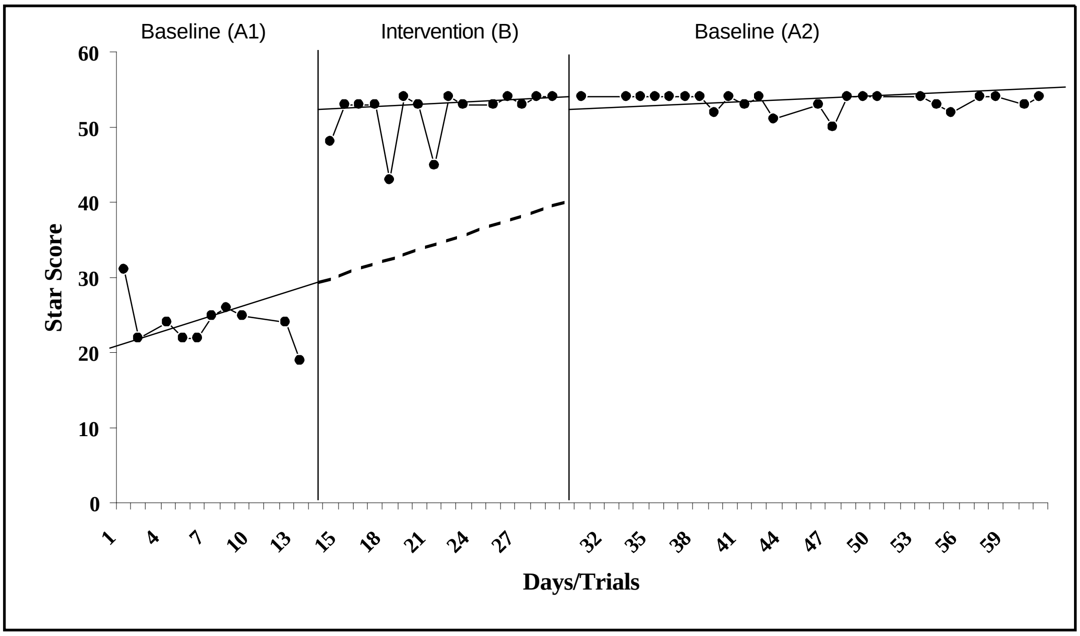


Figure 7.15. Limb activation approach: Subject 9. Star Cancellation Test (SCT) scores across phases showing celeration line in A1 (first baseline) continued into B (intervention) phase and trend lines in B and A2 (second baseline) phases.

Figure 7.15 shows changes in slope, level and trend between A1 and B phases, but no change in the trend line between B and A2 phases. This indicates a large increase in star score, coincident with the onset of treatment. The improvement was maintained and reached maximum (normal) scores during most measurement periods throughout the treatment and second baseline phases. Improvement in scores for function and mobility started during the B phase and continued during the A2 phase. This subject's BI and RMI scores improved a little over time as his function and mobility improved. The BI scores reflected the patient's independence in feeding and cutting up food during the B phase, and the added ability to cope with stairs and dressing unaided during the second baseline phase. The RMI scores showed that during the B phase, the patient became able to walk indoors unaided, and progressed to ability to go up and down four steps unaided during the second baseline phase. There was no measurable change in scores for stroke severity (CNS) or sensation (light touch or proprioception) during any of the three phases.

Subject 11 (Table 7.9) had a left sided hemiplegia with sufficient voluntary movement on his left side to enable him to turn in bed, get from lying to sitting, balance in sitting and get from sitting to standing. He was unable to maintain standing balance and could not transfer independently, tending to push towards his affected side during both activities. He had sufficient voluntary movement in his left upper limb to enable him to be independent in personal toilet and to feed with help. He had very poor ability to pick up objects with his affected hand, but was able to do so with effort, and clumsily. He had some appreciation of light touch on his left side and also could indicate that a movement had taken place in any joint of his left upper or lower limb, but not the direction of the movement. He had homonymous hemianopia, and severe left visuospatial neglect with eyes and head deviated towards the right. Although alert and cooperative, he seemed unrealistic about his problems, stating that he could dress unaided and was continent (neither being true). He had a short attention span and was easily distracted from the task in hand. He had almost no reading impairment and was able to read the newspaper with few errors. He was assigned to a 3-week baseline phase. Intervention commenced at 38 days post-stroke. Ten treatment sessions were conducted. Differences were found in SCT scores between A1 and B phases, for line bisection errors between A1 and B and between B and A2 phases, and for BTT scores between A1 and B phases (Tables 7.10 to 7.13). These changes are illustrated in Figures 7.16 to 7.18.

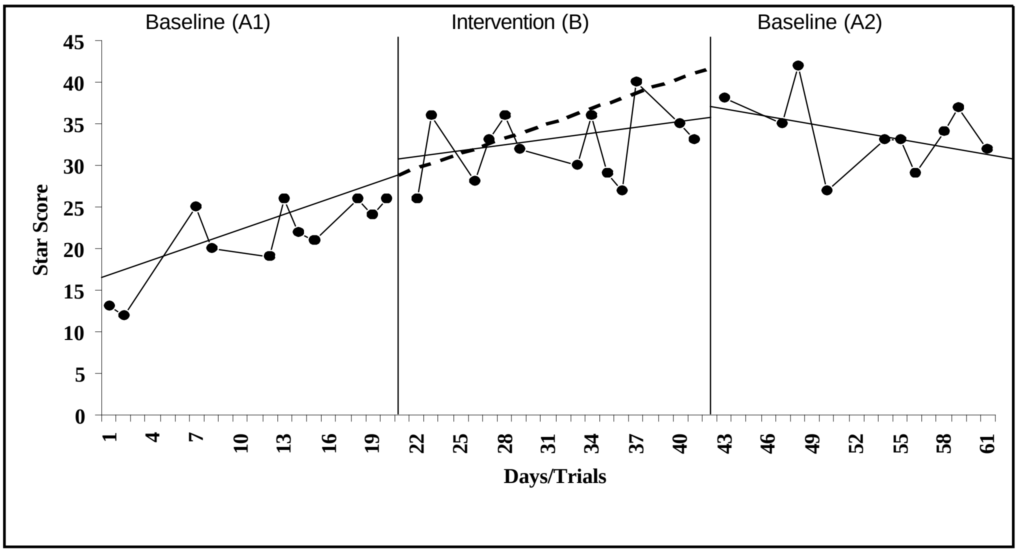


Figure 7.16. Limb activation approach: Subject 11. Star Cancellation Test (SCT) scores across phases showing celeration line in A1 (first baseline) continued into B (intervention) phase and trend lines in B and A2 (second baseline) phases.

Figure 7.16 shows minimal changes in level and slope between A1 and B phases, then a change in trend between B and A2 phases. This indicates an increase in star score which was comparable across the first baseline and intervention phases, although the increase was not tied to onset of intervention. The improvement was just maintained but not increased during second baseline.

Figure 7.17 shows changes in level and slope between A1, B and A2 phases, and also a change in trend between B and A2 phases. This indicates a reduction in line bisection error during the intervention phase, which coincided with treatment, and a further reduction during the second baseline phase, but with a trend to increase during that phase.

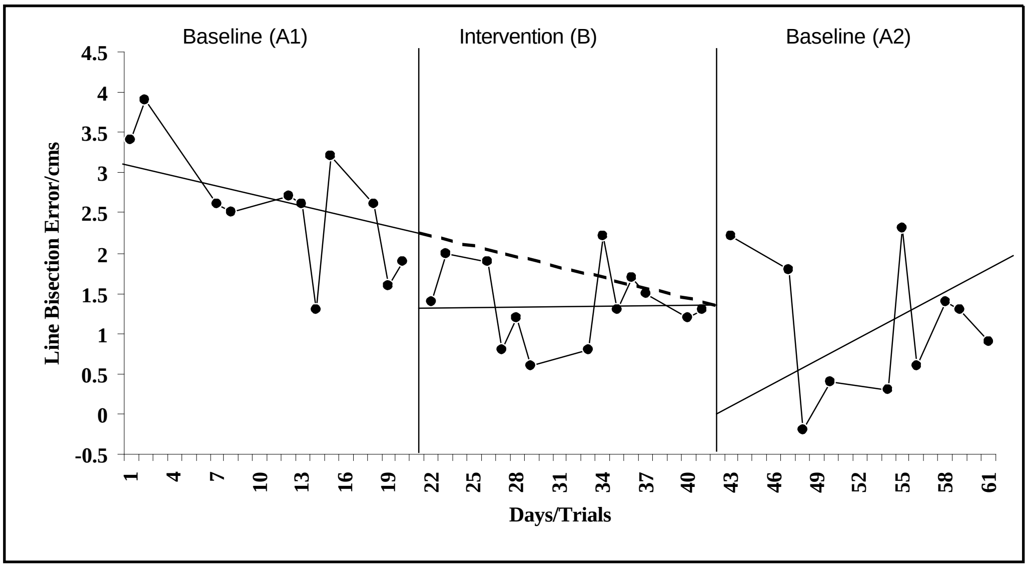


Figure 7.17. Limb activation approach: Subject 11. Line Bisection (LB) error scores across phases showing celeration line in A1 (first baseline) continued into B (intervention) phase and trend lines in B and A2 (second baseline) phases.

Figure 7.18 shows a completely stable baseline, with all 'buns' placed on the right side of the tray, followed by a change in trend and slope between A1 and B phases, and a change in level between B and A2 phases. This indicates improved symmetry in the placement of 'buns' on the 'baking tray' which coincided with treatment, and this improvement was maintained during the second baseline phase. In terms of changes in stroke severity, function, mobility and sensation (Table 7.14), CNS scores remained almost constant, BI scores improved over time between A1 and B phases due to improvements in ability to transfer from bed to chair, and in A2 phase due to improvement in urinary continence. RMI scores improved between A1, B and A2 phases due to improvements in standing balance, with less tendency to fall or push

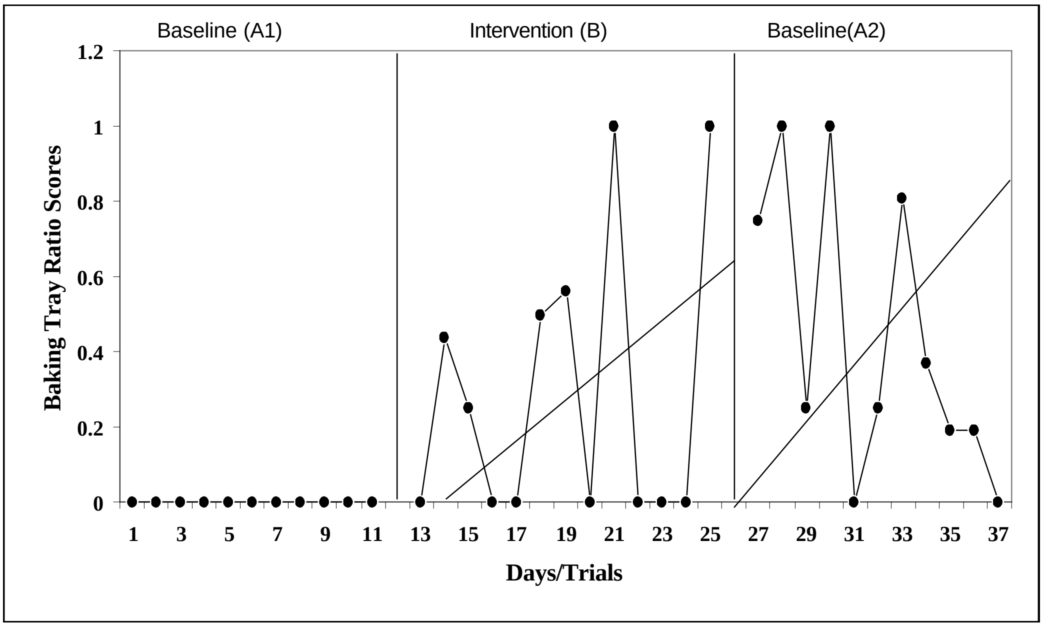


Figure 7.18. Limb activation approach: Subject 11. Baking Tray Task (BTT) ratio scores across phases showing celeration line in A1 (first baseline) continued into B (intervention) phase and trend lines in B and A2 (second baseline) phases. (Ratio score of 0.5 = normal symmetry)

himself over to the left, and improved ability to transfer from bed to chair (in which he achieved independence) respectively. Changes in sensation were minimal and not related to any particular phase.

Subject 12 (Table 7.9) had a left sided hemiplegia of moderate severity who had fair voluntary movement of his left side, but was unable to balance in sitting, go from sitting to standing or transfer from bed to chair due to his poor posture and balance and a tendency to fall or to push towards his affected side. His left upper limb movement was better proximally than distally and allowed him to use a knife and fork with help, to pick up objects rather clumsily with his left hand (although fine manipulative skills were poor), and to undertake personal toilet unaided. He had absence of sensation over his entire left side, except for touch on his face. He was able to read well, only missing the odd word on the left. Although able to move his left arm he tended to let it drop down and 'dangle' over the left side of his wheelchair. He was alert and cooperative, but had a very poor short-term memory (e.g. he never remembered the researcher's name). He missed food on the left side of the plate, and showed severe visuospatial neglect. He was assigned to a 3-week baseline phase. Intervention commenced at 42 days post-stroke. Ten treatment sessions were conducted. There were differences in SCT score and line bisection errors between A1 and B phases. There were no differences in BTT scores (Tables 7.10 to 7.13).

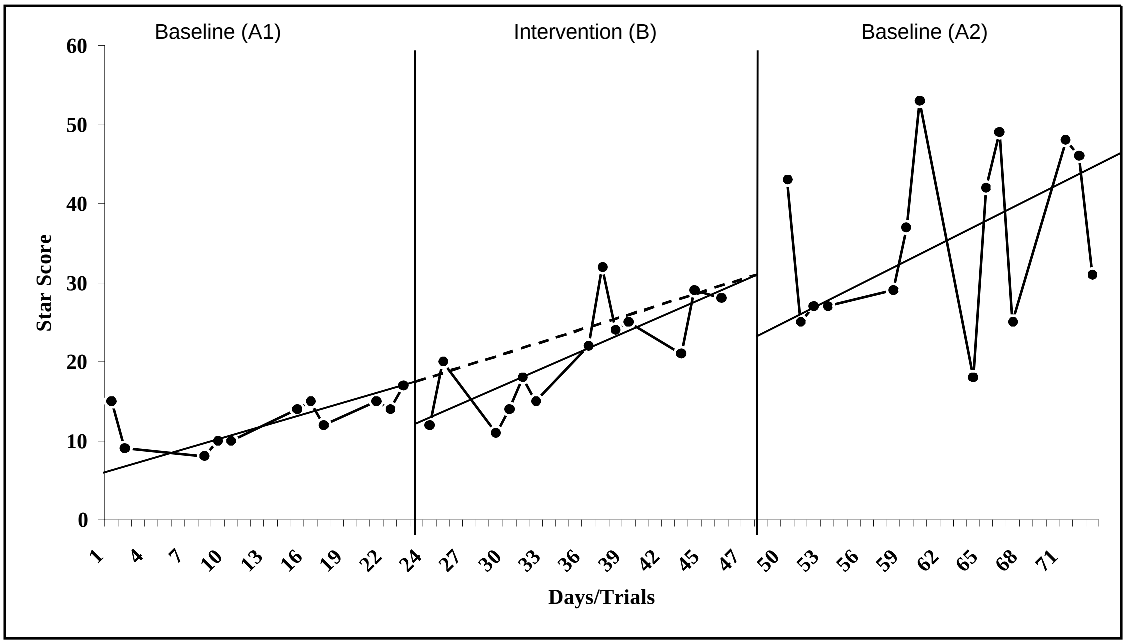


Figure 7.19. Limb activation approach: Subject 12. Star Cancellation Test (SCT). scores across phases showing celeration line in A1 (first baseline) continued into B (intervention) phase and trend lines in B and A2 (second baseline) phases.

Figure 7.19 shows a general increase in star scores over the three phases, with a slightly increased rate of change during the treatment phase. Improvements continued during the second baseline phase.

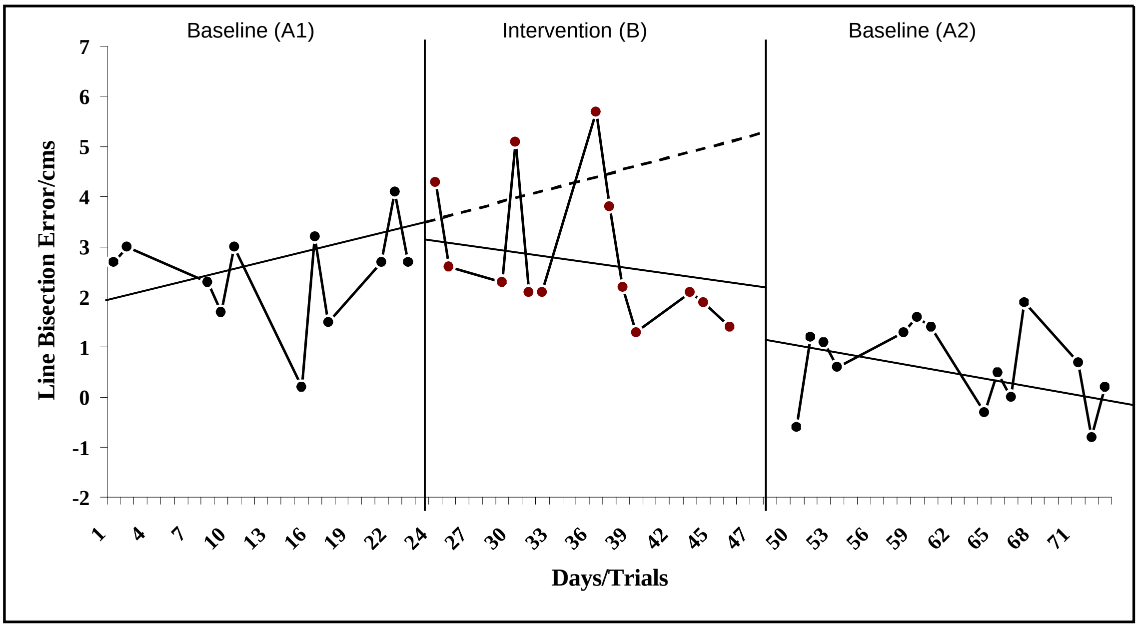


Figure 7.20. Limb activation approach: Subject 12. Line Bisection (LB) error scores across phases showing celeration line in A1 (first baseline) continued into B (intervention) phase and trend lines in B and A2 (second baseline) phases.

Figure 7.20 shows a small change in level and a change in trend (for a reduction in bisection error) between A1 and B phases, and a small change in level between B and A2 phases. However, no significant difference was found between A1 and B phases (Table 7.12), and the difference found between B and A2 phases shows a large decrease in line bisection error occurring during second baseline. Some changes were noted in function, mobility and sensation between the phases, but no change in stroke severity except for a small improvement in distal upper limb strength during first baseline (Table 7.14). There were quite large changes in function (Table 7.14); the BI showed improvement during the intervention phase due to ability to transfer from bed to chair and on and off the toilet with help, and a further improvement during second baseline due to ability to walk on the level with help; the RMI also showed improvement during the first baseline due to ability to sit and stand unsupported, and during the intervention phase due to ability to turn in bed, and go from lying to sitting and sitting to standing without help; these abilities were maintained during second baseline when the patient still needed help during transfers and walking, for safety reasons, as he tended to fall to the left. Large changes were recorded for sensation during the intervention phase only, which were maintained during second baseline. Light touch improved, to include appreciation of touch location on left upper and lower limbs and trunk. Proprioception improved to include the ability to mirror direction of movement of left upper and lower limb proximal joints, and to indicate movement but not direction for left upper and lower limb distal joints, except for the hand.

7.10.3 Discussion

In general, the findings related to these five additional patients support and augment the previous findings, and therefore, discussion of these latter findings will be confined to the specific results from each subject, but should be viewed within the context of the previous discussion in section 7.8.

These results indicate that both subjects who were taught scanning and cueing strategies and all three who were treated using the limb activation approach demonstrated reduction in UVN ($p<.05$) between first baseline (A1) and intervention (B) phases in one or more of the three tests. This again allows the null hypothesis to be rejected, and provides further evidence that either of the strategies used may be effective in reducing UVN. Nevertheless, despite the care that was taken to control for the effects of spontaneous recovery by the use of no-treatment baseline phases, randomized allocation of patients to varying lengths of first baseline, and the single blinding of all outcome measures, spontaneous recovery remains a possible alternative explanation for the findings, as all patients commenced treatment between 5 to 8 weeks post-stroke. Stineman and Granger (1991) found that 8-9 weeks post-stroke was the average peak time for recovery of UVN. However, Zoccolotti et al. (1989) considered that visual neglect, if still present, would be relatively stable at 4-weeks post-stroke, and Stone et al. (1992) stated that UVN recovers most quickly in the first 10 days post-stroke. Furthermore, stability of baseline measurement, and large and significant improvements in any measure of UVN which coincided with the onset of treatment adds strength to the interpretation of a treatment effect being responsible for change, rather than spontaneous recovery. This was the case for some measures of UVN for some subjects, which will be addressed below.

7.10.3.1 Impact on visual neglect

All subjects showed significant improvement in star cancellation between A1 and B phases (comparable with the findings in section 7.7). This might reflect the higher sensitivity of the SCT in the assessment of UVN severity (Bailey et al., 2000). Subjects 8, 10 and 11 showed significant reduction in line bisection error between these two phases, and subjects 8, and 11 also showed improved symmetry in the BTT between A1 and B phases. Discrepancy between tests used to measure recovery of UVN has previously been found (Sacher et al., 2004), with increased recovery shown when subjects performed cancellation as opposed to bisection tasks. Such differential test performance suggests that the tests do not measure the same thing (Binder et al., 1992), and that the treatments given to the subjects in the current study may have exerted differential beneficial effects. Star cancellation may make greater demands on visual search than Line Bisection (O’Neill & McMillan, 2004), and it could be that both scanning and cueing, and limb activation strategies used here may have specifically improved visual search.

As found previously (section 7.7), most improvements were maintained during the second baseline phase, suggesting either that a degree of permanent change had occurred, or that spontaneous recovery, once begun, was continuing. The one exception to this finding was subject 8, who showed significant worsening of neglect on all three measures during the second baseline phase, during which measurement of UVN took place for a longer time period than for other subjects, extending until some 4 months post stroke. This shows that there was no permanent change in his UVN, following the improvement during intervention; this lack of carry-over does add strength to the interpretation that a treatment effect had occurred, as his UVN worsened on withdrawal of treatment (although not entirely returning to pre-intervention levels).

Once again, there was relative stability of stroke severity (measured by the CNS) for all subjects across all phases (Table 7.14) and this adds support to the notion of selectivity of the training effect, found by others (Paolucci et al., 1996b). Unlike two of the patients in the published study, all of these five patients were generally alert and cooperative and so may have been better able to respond to and benefit from treatment. Calvanio et al. (1993) emphasise that patients with neglect who are also ‘hypoactive and appear apathetic’ can present huge barriers to effective training for neglect. Subject 11 had a degree of anosognosia for aspects of his stroke; cognitive impairments such as anosognosia, are likely to restrict trainability (Calvanio et al., 1993). On the other hand, subject 8 appeared to have some insight into his neglect-related difficulties, and this may have enhanced his capacity to benefit from treatment.

7.10.3.2 Further consideration on the use of scanning and cueing strategies

The adult brain is able to show experience-dependent changes in neural circuits (Robertson & Murre, 1999). If similar changes occur in the damaged brain, rehabilitation can be directed towards the design of appropriately planned experiences which will facilitate and guide such recovery (Robertson & Manly, 2002). If a treatment effect has taken place in this study, and any experience-dependent changes in neural circuitry have occurred these changes might be related to the impact of repetitive and specific training upon the two patients who were taught scanning and cueing strategies, such that these patients may have developed an ability to compensate for their difficulties, which they were then able to maintain following withdrawal of specific treatment. Once again, the incorporation of visual imagery using the 'Lighthouse Strategy' may have encouraged patients to self-alert, outside of 'face-to-face' treatment sessions, and provided opportunities for further repetition and practice in directing attention to objects on their left side. Positive treatment effects were found using this strategy in a recent study (Niemeier, 2002) however there were design limitations, which have been addressed in this current study (see also section 3.4.4). The ability of a patient to 'self-alert' when not in direct contact with a therapist may also be beneficial in improving general attentional levels, considered by Robertson and colleagues (1997) to be an important factor in the reduction of spatial neglect.

7.10.3.3 Further considerations on the use of limb activation

Movement of the left limb in left hemispace has again been used therapeutically to ameliorate neglect in a very recent study (Maddicks et al., 2003). The data support the theory that contralesional limb movement activates both personal and extrapersonal spatial sectors, resulting in activation of motor circuits in the damaged right hemisphere, which in turn reduces neglect (Robertson et al., 2002). Robertson and Manly (2002) suggested that such a ‘right hemisphere activation effect’ enhances the ability of the right hemisphere to compete with the intact left hemisphere, and that such an effect is additionally modulated by the location of the motor act (i.e. in left hemispace).

7.10.3.4 Generalization of training effect to non-trained tasks

In agreement with the findings of Paolucci et al. (1996b) all five subjects showed some improvement, during the intervention phase, in one or more untrained tasks. All improvements were maintained during the second baseline phase. Subject 8 showed considerably improved sensation. Subject 9 improved in his ability to cut up food, subject 10 in her ability to go from sitting to standing, and subject 11 in his standing balance and ability to transfer unaided. Subject 12 showed the most improvement in all areas. His ability to go from lying to sitting and to transfer unaided continued to improve after treatment withdrawal as he became able to walk unaided. His sensation, both the ability to identify timing and location of light touch and to locate and identify the direction of limb movement, improved dramatically during the treatment phase and was maintained after treatment withdrawal. It is not possible to conclude that any of these changes were due to generalization of a treatment effect, as the outcome measures for stroke severity, function, mobility and sensation were only monitored approximately three times during each phase. Explanations for the improvements could be due to spontaneous recovery (although there were no or only minimal changes within subjects in CNS scores for stroke severity across time), alone, or in addition to the effects of routine therapy treatment (which continued throughout the study). However, an alternative explanation is that there was some generalization, of the effect of the treatment for neglect, to functional and sensory ability in these patients. Indeed studies reviewed by Vallar et al. (1997b) have shown that amelioration of UVN has been related to improved sensory and motor performance on the affected side of the body. Smania and Anglioti (1995) showed that severe sensory loss was reduced when attention was directed by the patient towards the anaesthetic side. Halligan and Marshall (2002) emphasise that primary sensory and motor deficits may co-occur with impairments of higher cognitive processes such as neglect, implying that in the absence of attention being directed towards the affected limb, there may appear to be a primary deficit. Thus the improvements in movement and sensation found in this study might be related, at least in part, to increased attention being directed by the patient towards the contralesional side of their body. Robertson et al. (2002) and O'Neill and McMillan (2004) also found improvements in left-sided motor function following limb activation training, which they posited were due to increased attention to the left side which in turn increased the probability of left sided movement. Interestingly, Van der Lee et al. (1999) found that forced use of the affected upper extremity in stroke patients was most effective, and indeed 'clinically relevant' with a sub-group of seven chronic stroke patients with hemineglect. Thus use of contralesional limb activation techniques might be valuable in both reducing neglect and improving limb function.

Significant improvements in UVN, using scanning and cueing strategies, have been demonstrated by previous workers (Antonucci et al., 1995; Paolucci et al., 1996b). They additionally found generalization to non-trained tasks. The current study only used ten treatment sessions per patient (Antonucci and Paolucci using 40), which may have been insufficient to enable such clear evidence of transfer of training. However, in the current climate of the NHS, it may be clinically unrealistic, in terms of costs incurred, to provide treatment sessions equal in length and intensity to those used by Antonucci et al. (1995) or Paolucci et al. (1996b).

Once again, some subjects, who showed reduction of neglect on formal testing, still demonstrated neglect behaviour in some everyday situations, showing the continued difficulty in automatic as opposed to voluntary orienting of attention (Gainotti, 1996). Indeed, Bartolomeo (2000) found that some patients with ‘recovered’ UVN still showed some clinical evidence of the disorder during performance of tasks which demanded greater attentional resources, and he concluded that these patients were not able to effectively use compensatory strategies. However, anecdotally, nursing staff on the ward where the current study took place remarked to the occupational therapist, who noted the comment in her records (during the time of the intervention phase) that subject 12 had stopped leaving food on the left side of his plate, was finding objects more easily which were placed on his left side, and was using his left arm more than previously.

Combining the two approaches in the hope that an additive effect might occur has indeed been investigated by Brunila et al. (2002). However, as the combined therapy, albeit successful, was not compared with one or the other approaches used alone, it is not possible to hypothesise about any putative additive effect (see also section 3.4.2).

7.10.4 Final Conclusions and recommendations

As previously found (section 7.8) both scanning and cueing and limb activation strategies may have reduced UVN. Evidence is provided by the significant reductions found in one or more tests for UVN, between first baseline and intervention phases. These reductions related to the time of onset of treatment, or close to this, for 10 out of the total of 12 patients in this entire study, with results from subject 8 providing the most convincing evidence across all three tests. Moreover, subject 8 did not commence treatment until almost eight weeks post-stroke, when any effects of spontaneous recovery might reasonably be expected to have occurred. Nevertheless, it is still not possible to be sure that it was the specific treatment that reduced neglect rather than spontaneous recovery being responsible for the changes. Neither is it possible to compare relative efficacy of the two approaches, although the only patients who showed no reduction in neglect were subjects 4 and 5, who received scanning and cueing training, but who both were hypoactive, drowsy, and appeared apathetic. Such patients are less likely to benefit from treatment.

All subjects in this study had moderate to severe neglect, and such patients are more likely to show change. In addition, Bailey, Riddoch and Crome (2004) have shown that patients with moderate to severe neglect are more likely to show baseline test-retest stability of measurement of UVN. Although patients with less severe neglect might show treatment benefits, such patients are less likely to have persisting neglect

(Jehkonen et al, 2000a). Thus if patients are investigated in the chronic stage post-stroke, and have persisting neglect, this is likely to be moderate to severe.

The techniques of scanning and cueing, and limb activation, could be realistically used in the clinical environment, because there would be minimal cost of equipment and human resources, including time, simplicity of equipment, and ease of use of these techniques by therapists or by trained assistants. It would be interesting to repeat the study using patients who were in the chronic rather than the acute phase post-stroke, as this would minimise the possibility of spontaneous recovery being an explanation for the findings. Use of a randomized controlled design would also enable inferences of causality to be strengthened. On the other hand, it is less easy, logistically, to find stroke patients who are in the chronic stage, as many may have been discharged home, and so be less accessible for recruitment. Finally, large randomised controlled trials usually require cooperation, in the process of patient recruitment, on a multi-centre basis, to enable sufficient numbers to be included in a study. This is costly and time consuming, but must be part of the process of investigation of efficacy of rehabilitation strategies for visuospatial neglect. Single case experimental designs at least obviate the difficulties of recruiting large numbers of patients, and additionally allow more detailed analysis of each patient, taking into account the heterogeneity of stroke and unilateral visual neglect. Such variability in individual presentation may become lost in the data reduction necessarily occurring during analysis of outcome in large-scale studies.

It is difficult to interpret the findings of this study in terms of the clinical significance, or otherwise, of changes measured using the three tests for UVN. Whether or not large increases in stars cancelled, or large reductions in line bisection error, or much improved symmetry in the placement of ‘buns’ on the ‘baking tray’, also manifest in clinically useful changes in everyday neglect behaviour, is not possible to estimate. Although tests for sensation and function were used, the results do not allow inferences to be made about the effects or otherwise of neglect reduction upon such functional abilities, and any possible links discussed are therefore speculative. Future studies might usefully apply outcome measures such as the Catherine Bergego Scale (Azouvi et al., 2003; also see section 2.10.4), which evaluates the functional consequences of unilateral neglect. However, this would require careful planning for use in single case design, as the scale requires acute and thorough observation of the patient by the therapist over time; such observation would need to be undertaken by a person blinded to the study purpose. This suggestion therefore implies the need for extra resources, in terms of extra time, staffing, and costs.

Finally, to improve external validity, this single case experimental design study should be replicated in different locations and with different therapists (Todman & Dugard, 2001). Until then, the results of this study cannot be generalized outside the setting in which they occurred which was that of a stroke rehabilitation unit, or to patients different from those included in the trial, who were all elderly, in the acute stage post-stroke, and with right-sided brain damage, and moderate to severe visuospatial neglect.

CHAPTER 8

CLINICAL ASSESSMENT AND REHABILITATION OF UNLATERAL NEGELCT IN STROKE PATIENTS: OVERALL FINDINGS.

The findings of previous chapters in the thesis are summarized here. They include some ways in which physiotherapists assess and treat unilateral visual neglect, provide a test battery to assess visual neglect in the clinical situation, present findings of a reliability study for three common tests for neglect, and offer two different treatment protocols which may ameliorate neglect and would be appropriate for use by therapists. The contribution of the thesis as a whole to theory and practice is outlined. Recommendations for clinical practice are offered. Limitations of the studies in the thesis are presented, in terms of generalizability of findings, and subject characteristics of patients in a single case series. Directions for future research are suggested.

8.1 Chapter summaries

8.1.1 Chapter 1

Stroke is a common disabling condition, and perceptual deficits such as unilateral neglect frequently accompany stroke, especially when the damage is located in the right side of the brain. Unilateral neglect has been reported to occur in sensory, representational, and motor modalities, and may also occur in different parts of space (Robertson & Halligan, 1999). Dissociations of unilateral neglect, either in modality or in spatial domain, have been described (Mesulam, 1999). Neglect may frequently co-occur with other clinical features, such as extinction to bilateral simultaneous stimulation, visual field defects, and anosognosia, although all such features have also been reported to occur independently of unilateral neglect (Karnath et al., 2003).

Various explanations have been put forward to account for the occurrence of neglect, the primary ones being attentional, intentional, and representational accounts. No single explanation seems sufficient to accommodate all observations relating to neglect behaviour, however neglect is commonly viewed as an action-intention impairment (Gore et al., 2002) and reflects the role of the parietal lobe in perception and action (Husain et al., 2000).

Because unilateral neglect can have a negative impact upon the rehabilitation of stroke patients, and adversely affect their functional outcome (Cherney et al., 2001), it is clearly important that therapists are able not only to assess the common presentations of the neglect syndrome, but also to apply effective rehabilitation strategies to reduce the impairment (Royal College of Physicians, 2002; 2004).

8.1.2 Chapter 2

Unilateral neglect is particularly associated with lesions in the posterior parietal cortex, but may also involve frontal areas, and subcortical structures including thalamus and basal ganglia. These cortical and subcortical areas are considered to comprise an attentional network. Persistent, severe neglect is related to extensive lesions (Maguire & Ogden, 2002). More recent imaging techniques, such as fMRI, may help further elucidate the precise anatomical correlates of various types of neglect. Neglect is more frequent, severe, and longer lasting in right as opposed to left sided lesions (Bowen et al., 1999), and although neglect may recover spontaneously, it may persist for much longer periods, and so should be assessed and monitored not only immediately post-stroke, but over a longer time period during the acute and chronic phases (Appelros et al., 2004). A deficit of a general ability to sustain attention, in addition to the specific directional attentional deficits of neglect, have been proposed to help explain the persistence of clinically significant neglect (Robertson, 2001).

Patients with neglect are less likely to make a good functional recovery than patients without neglect, are more likely to have a longer hospital stay, and less likely to be able to live independently (Paolucci et al., 2001). However, most studies which examine the impact of neglect upon functional outcome, focus on patients with visuo-spatial neglect in near space, and the impact upon ADL of visual neglect in far space, and other modalities of neglect in near and far space, have not been investigated with the same rigour.

Valid tests are required to identify the various types of neglect with which a patient may present, in order that rehabilitation may be appropriate and targeted, and best use may be made of limited resources. Due to the multi-modal nature of neglect, a battery of tests is recommended for the identification and ongoing assessment of the various types of the disorder, rather than use of any single test. Such a battery should include tests such as the Star Cancellation Test and Line Bisection for visuo-spatial neglect (Wilson et al., 1987a), the adapted 'comb-and-razor' test for personal neglect (Beschin & Robertson, 1997), and the exploratory-motor task for directional motor neglect (Maeshima et al., 1997a). To assess visuo-spatial neglect in far space, cancellation and/or bisection tasks can be projected onto a screen positioned at a distance from the patient, who may use a 'light pen' (Robertson & Halligan, 1999); alternatively, patients may be asked to describe the visual environment outside of their 'reaching space'. Use of questionnaires such as the Catherine Bergego Scale (Azouvi et al, 1996) are helpful not only to evaluate the everyday consequences of neglect, but also to assess the degree of denial by the patient of their difficulties. Finally, because a deficit in general arousal levels may accompany the lateralised attentional deficit of neglect, and this may manifest as a tendency to lose concentration easily during therapy, then assessment of this aspect may also be useful, and tests such as the 'Elevator Counting Task' from the 'Test of Everyday Attention' (Robertson, Ward, Ridgeway & Nimmo-Smith, 1994) could be used.

8.1.3 Chapter 3

There may be considered to be two main routes to the rehabilitation of unilateral neglect. One approach uses systematic instruction and structured experience to manipulate the functioning of attentional systems involved in neglect behaviour, and includes scanning and cueing strategies, contralesional limb activation techniques, and the maintenance of general levels of arousal. Scanning and cueing to encourage left visual search have been used to reduce neglect (Antonucci et al., 1995) and additionally to improve function (Paolucci et al., 1996b; Rusconi et al., 2002), and such training would be straightforward for therapists to apply in the clinical situation. The use of mental imagery using the ‘Lighthouse Strategy’ (Niemeier, 1998, 2002; Niemeier et al., 2001) has shown some promise when used to assist the patient to mentally pay attention to the neglected hemispace during activities. This strategy could easily be incorporated during the practice of functional activity by the patient as an adjunct to the use of scanning and cueing strategies. Contralesional limb activation within contralesional hemispace has been shown to reduce neglect and to improve functional outcome in a number of single case design (e.g. Robertson & North, 1992, 1993, 1994; Robertson & Hawkins, 1999) Wilson et al., 2000) and group studies (e.g. Kalra et al., 1997; Robertson et al., 2002). Some studies (Maddicks et al., 2003; Robertson et al., 1998b) have additionally used a ‘neglect alert’ device to prompt the patient to use their contralesional limb, and additionally to enhance their general level of arousal. Both scanning and cueing strategies, and limb activation approaches lend themselves to clinical application for the rehabilitation of unilateral neglect. However, study replication is needed, using a well-controlled single case experimental design in a case series, to explore if these techniques are effective in reducing specified types of neglect in elderly stroke patients, as this group are most likely to reflect clinical reality. This design, in contrast to group studies, additionally allows individual response to treatment to be carefully evaluated.

The other approach involves the artificial manipulation of various sensory inputs, considered to temporarily correct the presumed distortion of perception of egocentric space occurring in neglect patients. Such techniques include caloric vestibular stimulation, neck muscle vibration, optokinetic stimulation and the use of prism glasses. Although strategies based upon this second approach have reliably been found to ameliorate neglect, most do not last beyond the period of stimulation, and may be impractical for rehabilitation in the clinical setting. However, two approaches, namely neck muscle vibration (Schindler et al., 2002) and the adaptive effect of prism glasses (Frassinetti et al., 2002) have recently been found to reduce neglect for several weeks post-stimulation and to have some positive impact upon functional ability. Nevertheless, further study is required to replicate these findings in larger groups of patients.

8.1.4 Chapter 4

In order to develop appropriate rehabilitation strategies for unilateral neglect, therapists must have a sound knowledge of how to identify and assess the disorder. No previous studies were found which addressed this topic, and the survey presented in this chapter provides new information about how physiotherapists in particular assess unilateral neglect and what strategies they use to try and reduce neglect during rehabilitation. This study addressed the first aim of the thesis.

A national survey using a random sample of physiotherapists, who were members of ACPIN, and practicing in the UK, was undertaken to establish how they assessed and treated unilateral neglect. Observation was the most frequently reported method for assessing neglect and this finding is consistent with recent research (Plummer, 2004). The most commonly used specific tests were drawing and copying tasks, found to have poor sensitivity, validity (Bailey et al., 2000. Appendix W), and reliability (Hannaford et al., 2003).

The majority of respondents used specific strategies to reduce unilateral neglect, principally by encouraging the patient to pay attention to the neglected side, to look and to perform transfers towards that side, the use of visual and verbal cues, and encouraging the patient to move the affected side. There is some evidence of the efficacy of such approaches, but only if they are used in a systematic manner, and repeated over relatively long periods of time (Paolucci et al., 1996b). Other approaches, using manipulation of various sensory inputs, such as the use of prism glasses, muscle vibration and vestibular and optokinetic stimulation, were infrequently listed by respondents and may indicate lack of awareness of recent research in the field. The majority of respondents gained knowledge about the assessment and treatment of unilateral neglect post-graduation, implying a need for this important topic to be introduced at undergraduate level, and re-visited post-graduation as part of continuing professional development.

8.1.5 Chapter 5

Currently available test batteries for unilateral neglect may not relate well to the performance of patients in everyday situations, may include tests that do not closely reflect ‘real life’ activities, and may be expensive to purchase, or be difficult for therapists to obtain in the clinical situation. The study reported in this chapter, which addressed the second thesis aim, addressed some of the limitations of existing test batteries, and provided a new test battery, constructed using inexpensive and readily available ‘real life’ materials. The Everyday Test Battery provides improved ecological validity relative to existing test batteries (such as the Behavioural Inattention Test, Wilson et al., 1987a) and gives therapists a better idea of some of the functional difficulties experienced by stroke patients who have unilateral neglect. A number of the tests in this new battery can be considered to be activity-level measures of neglect, which may be of more clinical value to therapists than use only of measures at the level of impairment (Wenman et al., 2003). Evidence is provided to demonstrate the validity and reliability of the new test battery, which includes a test for visuo-spatial neglect in far space as well as tests within reaching space.

8.1.6 Chapter 6

Three frequently utilised tests for visuo-spatial neglect in reaching space are the Star Cancellation Task and the Line Bisection Test (Wilson et al., 1987a), and the Baking Tray Task (Tham & Tegner, 1996). Following preliminary evaluation (Bailey et al., 2000 see Appendix W), these tests were considered for use in the subsequent rehabilitation study, in which patients with visuo-spatial neglect were to be included.

Prior to use, it was necessary to assess the test-retest reliability of these three tests, thus fulfilling the third aim of this thesis. This study contributes new information, as there has been no previous rigorous investigation of the reliability of these three tests, despite their frequent use as progress and outcome measures in rehabilitation studies (e.g. Wenman et al., 2003).

The findings provided evidence of good test-retest reliability for patients with and without visuo-spatial neglect. However, the highest degree of reliability in the neglect group was for those patients with moderate to severe neglect. Indeed, for patients with mild neglect, there was a large degree of instability in test-retest scores, probably due to the wide fluctuations in attention over even short periods of time of this group. Actual differences in the absolute score that might be expected between test and retest are also provided, for patients with different severity of neglect; and this information provides new information, and should assist future research studies in terms of interpretation of score change over time. Because the best stability of scores was found for patients with moderate to severe visuo-spatial neglect, this information was used to design the inclusion criteria for the subsequent rehabilitation study reported in Chapter 7.

8.1.7 Chapter 7

As outlined in section 8.1.4, studies of unilateral neglect using cognitive rehabilitation have provided some evidence of efficacy. Indeed, a Cochrane systematic review and meta-analysis of 15 randomised and controlled trials (Bowen et al., 2003) has supported the finding that impairment of negle ct can be reduced using such cognitive techniques, including scanning and cueing and contralesional limb activation. However, because the impact upon the level of activity was unclear, Bowen et al. (2003) recommended that future studies should include activity level outcome measures. Additionally, the Cochrane review did not include single case experimental design studies. Because the neglect population is not homogenous, due to the existence of, and dissociations of, various manifestations of neglect (Bailey et al., 2000, Appendix W), also the variable co-occurrence of other motor, sensory, cognitive and perceptual problems (Buxbaum et al., 2004), the use of single case experimental design can assist researchers to investigate effectiveness of therapy in different individuals. In particular, therapy which can be delivered in a 'real life setting' over an extended period of time. Providing sufficient data points in each phase are collected, both descriptive and inferential analyses may be used, and the design can be further strengthened by the use of randomization to baseline time periods, and by blinding measurement of outcome.

The above points were considered in the design of a series of twelve single experimental case studies, using an ABA design, and the study reported in Chapter 7 addressed the fourth and final aim of this thesis. The study provided some promising evidence for the effects of both scanning and cueing, and limb activation strategies upon unilateral visual neglect. The assessment tools utilised, which were valid and reliable, were chosen to evaluate both the impairment level (neglect, and also sensation) and activity level (function and mobility). Only patients with visuo-spatial neglect within reaching space were included, this being the most common manifestation of the disorder (Buxbaum et al., 2004); also because the strategies planned for therapy relied largely upon activities in the visuo-spatial domain, thus making the treatment specific for the deficit, in order to maximise its potential effect (Pierce & Buxbaum, 2002).

The findings showed that 10 out of the 12 patients showed reduction in neglect occurring around the onset of treatment, whether treatment was using scanning and cueing or limb activation strategies, evidenced by a significant change in score in one or more of the three tests for unilateral visual neglect. Most patients maintained the improvement during the second baseline (treatment withdrawal) phase, indicating either that a treatment effect was maintained, or that spontaneous recovery was continuing, However, three of the ten showed significant improvement in scores across all three tests, one of whom showed significant worsening of scores on all three tests following treatment withdrawal, another showed worsening of line bisection error following treatment withdrawal. Such worsening following treatment withdrawal supports a treatment effect. Furthermore, in those nine patients who showed continued improvement (usually in SCT score) during the second baseline phase, only one showed a greater average improvement in this phase compared with the treatment phase; in the remainder, the average size of the improvement was much smaller. This provides additional evidence that a treatment effect had occurred, which was maintained when treatment was withdrawn. All ten patients showed significant improvement in SCT scores between first baseline and treatment phases, five also showed significant reductions in line bisection error, three of whom additionally showed improved BTT. Two patients, both of whom received scanning and cueing training, showed no improvement over time in any test, and both of these patients had very low levels of arousal, being frequently drowsy during testing and treatment sessions. There was no intention to compare relative efficacy of the two treatment approaches, and each of the protocols appeared to be effective in reducing neglect.

At the level of measurement of activity, as opposed to impairment, it is not possible to be certain that the treatments for neglect generalised to any improvements in function, because spontaneous recovery is an alternative explanation (although no changes in stroke severity occurred between first baseline and treatment phases for 10 of the 12 patients). Also, measurement took place on only three occasions during each phase, thus only descriptive analysis is possible. Nevertheless, five of the 12 patients showed some improvements during the intervention phase in one or both outcome measures related to function and mobility, and two patients additionally showed improved sensation, an impairment level measure.

8.2 Contribution of the thesis to theory and practice

The review of literature emphasizes the need for therapist to be more cognizant of the presence of hemineglect in stroke patients, due to its common occurrence and potential adverse impact upon rehabilitation and functional outcome. The review evaluates the literature in the field, and provides summary conclusions which will be of value to therapists, in terms of guiding them in their selection of appropriate tests for hemineglect, and in the application of clinically useful and effective rehabilitation strategies. The review also highlights the existence of forms of neglect other than the most common manifestation of visual neglect in reaching space; this provides important information for therapists, because testing and rehabilitation strategies must take such factors into account.

The thesis presents the findings of the first survey to be undertaken in the U.K. investigating the testing and rehabilitation of hemineglect by physiotherapists. The survey highlights the need for therapists to use standardized tests to assess hemineglect, which have demonstrated validity and reliability, and to be aware of recent research published in the field of rehabilitation of hemineglect to enable them to undertake evidence-based practice.

The development of the ETB, with its demonstrated validity and reliability, provides therapists with the first ecologically valid battery of tests for visual neglect in near and far space, which can be constructed using easily available and inexpensive materials. Most tests in the battery offer assessment at the level of activity, which may be of more clinical value to therapists than many existing ‘pencil and paper’ tests which measure only at the level of impairment.

New knowledge is provided by this work in the subject area of test-retest reliability, investigating three tests for visual neglect in reaching space. The tests chosen are very commonly used in rehabilitation research, despite the lack of information regarding test-retest reliability, which is of fundamental importance to ensure that changes in neglect behaviour are due to treatment effects and not to variability in testing outcomes. The finding that test-retest reliability reached acceptable levels only in patients with severe neglect should help therapists and others to interpret rehabilitation research into hemineglect in a more valid way.

Finally, the thesis provides good evidence of the efficacy of scanning and cueing also of limb activation strategies for the rehabilitation of hemineglect in elderly patients with acute stroke, using a large series of single subject designs. It presents a detailed protocol for each strategy, which could be easily used by therapists or therapy assistants in the standard clinical situation. The design used for this series has removed, or minimized many threats to internal validity, present in a number of previous n=1 studies, which increases the validity of the current findings. Such experimental designs are important as a possible precursor to larger randomized trials, and can help inform the design of the latter.

The paper presented in Appendix W adds to the body of knowledge related to assessment of hemineglect, and provides further data on the rate of occurrence of four manifestations of neglect in reaching space, based on a large sample of elderly stroke patients, in a rehabilitation setting, and using cut-off scores obtained from a large age-matched control sample. In addition, it is the first study to provide data about relative test sensitivity for several commonly used clinical tests for hemineglect, and it makes recommendations about appropriate tests for use in the clinical situation.

8.3 Recommendations for clinical practice

- Because of the relatively high incidence of unilateral neglect in stroke patients, particularly those with right-sided brain damage, and the fact that the presence of neglect is likely to impact adversely upon functional outcome (section 2.9.1), it is important that therapists routinely use valid and reliable assessment tools to identify its presence as soon as possible post-stroke. They should also continue to monitor the progress of neglect, using these tools, at regular intervals during in-patient stay and post-discharge if possible. The Star Cancellation Tests is recommended for its sensitivity as a quick screening test for neglect to use prior to more extensive testing.

- Due to the different subtypes found to occur as part of the neglect syndrome, and the frequent dissociations of such manifestations, (section 1.4), therapists should use a battery of tests, rather than a single test, to identify neglect and monitor progress. Such a battery should ideally include tests for perceptual and motor forms of neglect, in personal, peripersonal and far space. Because patients who demonstrate denial of manifestations of stroke (e.g. weakness, neglect) have a poorer prognosis than those without such anosognosia, it may also be useful to additionally employ a questionnaire measure such as the Catherine Bergego Scale (Azouvi et al., 1996). This has the advantage of assessing the functional consequences of neglect, and also allows some estimate to be made of patients' denial of their problems. Appropriate assessment of neglect by therapists would also comply with the recommendations of the National Clinical Guidelines for Stroke (2002), see section 1.2.
- Because neglect is a disorder of attention, fluctuating levels of attention in such patients may lead to considerable variation in tests scores, even when measured on the same day (section 6.7). Patients with moderate to severe neglect are more likely to show stability of measurement on repeated testing. Thus interpretation of score improvements as being due to the effects of rehabilitation must be made with some caution, as small changes may merely be due to fluctuations over time in levels of attention.

- Therapists may not always have access to published, standardised tests batteries to assess neglect, and the Everyday Test Battery developed here could be used by therapists in the clinical situation to give an impression of the functional difficulties experienced by patients with visuo-spatial neglect, and it can easily be produced using inexpensive and readily available materials.
- If the presence of unilateral neglect has been identified by therapists, it is recommended that they implement a treatment regime incorporating particular strategies, such as scanning and cueing or limb activation protocols, described here, in order to try and ameliorate neglect. Where possible, treatment should be as functionally based as possible in order for maximum generalization to occur to activities which are functionally relevant for any individual patient. The protocols described here could be easily modified to suit individual needs. Furthermore, they can be undertaken using easily available and inexpensive equipment, and could be applied by therapy assistants following minimal training. In patients with sufficient upper limb voluntary movement, the limb activation protocol would be the treatment of choice, as it would give additional opportunity for the patient to use their upper limb during functional activity. Patients with very low levels of arousal are less likely to respond to treatment, and this must be taken into account when treatment priorities are being decided. Appropriate rehabilitation of neglect by therapists would also comply with the recommendations of the most recent National Clinical Guidelines for Stroke which specify that

> “Patients with a persisting, disabling impairment should receive therapy for their neglect/inattention using techniques such as cueing, scanning, (and) limb activation…..”.
>
> (Royal College of Physicians, 2004, Section 4.2.1, p57)

8.4 Limitations of the research

8.4.1 Generalizability of findings

The survey study in Chapter 4 was conducted using a sample of physiotherapists who were members of the special interest group, ACPIN, thus findings cannot be applied to physiotherapists in general, although the results might reasonably be assumed to generalize to senior physiotherapists, experienced in stroke management, as these were the majority represented in the sample.

For use as a research or diagnostic tool, and in order to establish appropriate cut-off scores, the Everyday Test Battery, piloted in Chapter 5, would need to be standardised on a large sample of stroke patients with and without neglect and a sample of matched normal control subjects. However, the ETB remains of potential value in the clinical setting to evaluate neglect behaviour at a functional level, and to monitor progress.

Information about test-retest stability for three tests for visuo-spatial neglect in reaching space was presented, based upon findings from one tester. Therefore, results cannot be generalized to situations where more than one tester is used. Nevertheless, the findings presented in Chapter 6 are based upon large samples of elderly stroke patients with and without neglect, and should therefore prove to be robust for situations where only one tester is used.

Single case experimental design is useful as a first step in evaluation of therapy effectiveness before more strictly controlled designs, using larger numbers of participants, such as randomized controlled trials, are undertaken (Wenman et al., 2003). Nevertheless, it is important to investigate individual patient response to treatment, which is not possible with group studies; furthermore, use of RCTs is problematic due to the heterogeneity of a stroke population (Riddoch et al., 1995). Therefore a series of well-controlled single case experimental design studies, as presented in Chapter 7, are of value. Results cannot be generalized outwith the context within which this series occurred.

8.4.2 Subject characteristics in single case series

For pragmatic reasons, the elderly stroke patients included in the series of studies presented in Chapter 7 were all in the acute stage post-stroke. Therefore, spontaneous recovery will always be an alternative explanation for any improvements occurring. Every effort was made to control for this event, by way of randomization to time period of first baseline phase (Backman et al., 1997; Zhan & Ottenbacher, 2001), and blinded measurement of outcome to reduce the possibility of researcher bias. In addition, careful visual inspection of each series of data was undertaken (Bobrovitz & Ottenbacher, 1998) to establish that any improvement occurred around the time of commencement of the intervention, following reasonable stability of data points during the first baseline phase.

8.5 Direction for future research

Further investigation is needed to gain insight into current practice of physiotherapists in the assessment and management of the various manifestations of neglect, and the rationale for their choice of assessment tools and treatment strategies. Qualitative approaches using interviews, or focus groups, as recently used in Australia (Plummer, 2004) might be helpful, and could form the basis for questionnaire design for a UK national survey, to sample a wider range of physiotherapists than just those who are members of a special interest group.

There is a need for future research to continue to develop valid and standardised outcome measures for use in single case experimental designs, and subsequently randomized controlled trials, to evaluate real life performance of patients with neglect at the activity level. The preliminary development of the ETB is a step in this direction.

Variability of repeated performance on tests for neglect provides a challenge for researchers in terms of valid interpretation of studies investigating incidence of efficacy of various treatments, or incidence of various manifestations. It would be useful to establish if similar variations, demonstrated in this thesis for three tests in the visuo-spatial modality in reaching space, also occur in other standardised tests for manifestations of neglect in motor modalities, and in spatial domains of personal and far space. Test-retest variability shown in this study further highlights the need for collection of an adequate number of data points per phase in single case experimental design, in order to strengthen validity of interpretation of trends in the data. Future studies examining test reliability should consider using analysis which incorporates limits of agreement analysis, as used in this study, in addition to the more traditional use of ICC analysis, in order that results can be interpreted within a clinical context

The protocols described in Chapter 7 for the rehabilitation of unilateral visual neglect require repetition in different settings, and with different therapists to improve external validity (Todman & Dugard, 2001). It would be of additional value to replicate the studies using stroke patients who are in the chronic stage, for example six months or more post-stroke, to reduce the possibility of spontaneous recovery being an explanation for any treatment effect. However, it is acknowledged that such a population, perhaps being community-based, might be less accessible for research purposes than patients in hospital during the acute stages post-stroke. Finally, it would be helpful in future studies to include assessment of the functional impact of unilateral neglect. This would have resource implications, because additional time would be needed to repeatedly observe and score everyday functional behaviour, using, for example the Catherine Bergego Scale (Azouvi et al., 1996). Longer time phases for baseline and withdrawal would also be needed for measurement of function/ADL, as these parameters are unlikely to demonstrate measurable change over short time periods.

8.6 Conclusions

Emphasis has been given throughout this thesis to approaches to assessment and rehabilitation strategies for unilateral neglect that are clinically realistic, can be easily accessed and administered by therapists, and may be undertaken using inexpensive and readily available materials. Assessment of neglect can be complicated by its many manifestations, both across modalities and within spatial domains. Whilst clinical observation of neglect behaviour is valuable, therapists need to be familiar with a range of assessment tools in order to identify and quantify neglect more objectively and to enable them to instigate appropriate treatment strategies and monitor progress. Findings in this thesis show that, even when standardised tests are used, the results must be interpreted with caution, due to inherent variability which occurs in neglect behaviour due to fluctuations in attentional level. The Everyday Test Battery is offered as a useful test which therapists may use in the clinical situation to gain some insight into functional difficulties and to monitor progress of patients with neglect.

Two different rehabilitation protocols, which applied either scanning and cueing, or contralesional limb activation strategies, are provided which may reduce neglect, at least at the level of impairment. These protocols could be easily applied clinically by therapists, therapy assistants, and perhaps carers. Further study is required to establish whether or not such strategies will improve functional ability. Patients with low levels of general arousal, who appear drowsy, and who may tend to 'nod-off' during assessment and/or treatment, may not benefit from these rehabilitation strategies. Such patients may need additional strategies to be incorporated to improve their general levels of alertness in order that they may benefit maximally from rehabilitation. Both scanning and cueing, and limb activation protocols were used systematically but within a clinically realistic time frame, and utilised functionally based activities, which would maximise the possibility of transfer of any training effect to similar activities.

Appendices and References

Citation	Population	Setting	Measures of Hemineglect	Results at Given Time Points	Comments
Appelros et al. (2004)	N=37 all RBD consecutively admitted first strokes; mean age 74yrs (33-90) 22f, 15m	Two in-patient rehabilitation wards (Sweden)	PN-Semi-structured Scale[1] PPN-BIT[2] FN-BIT[3] Cut-off scores as originally published Measures taken at 2-4 weeks post-stroke, 6 months and one year	First test -at 2-4/52, PN n=23, mean score 2 PPN-n=36, mean score 1.93 FN n=14, mean score 2 Second test at 6/12 PN n=9, 3 improved, 2 no change, 4 worse (4 died) PPN n=26; mean score 1.3 (6 died) FN n=7; 2 worse; 4 improved, 1 no change (3 died) Third test at 1 yr PN n=10 (2 improved, 2 no change, 6 worse) 1 died PPN n=23; mean score 1.04) 4 died, FN n=7 (4 worse; 3 improved) 1 died	Improvement from baseline to 6/12 significant ($p<.02$) but from 6/12 to 1yr not significant ($p<.681$) PN-65% improvement; PPN-13% improvement; FN-71% improvement (baseline to 6/12) Test for FN[3] adapted from BIT; and no evidence provided for validity or reliability. Limited evidence acknowledged for validity or reliability for test for PN[1] Patients had more severe strokes than average (median NIHSS score 11) Patients with 2nd stroke during study period excluded
Cassidy et al. (1998)	N=250 consecutively admitted; 66 of whom were first stroke with RBD, were assessed for neglect	General medical and geriatric wards at a district general hospital (Scotland)	Unilateral visual neglect – BIT (conventional sub-tests, cut-off score 129) Measured on admission within 7/7 post-stroke, then at monthly intervals for 3/12	First test - On admission n=27 with neglect (median age 73yrs), mean BIT score 56.3 (10-126) At 1/12 follow-up mean BIT score 96.5 (sd 38.3) At 2/12 follow-up mean BIT score 110 (sd 36.7) At 3/12 follow-up 6 still had neglect mean BIT score 121.3 (sd 28.6); 3 no neglect (10 discharged to home or long term care, 8 died)	Recovery from neglect took place throughout the 3/12 period but greatest recovery in the first month No data provided of numbers with neglect at 1/12 or 2/12 follow-up Only visual neglect in peripersonal space measured Higher scores on line cancellation (less severe neglect) related to better recovery of neglect, and vice versa

APPENDIX A

Summary Table of Epidemiological Data of Recovery from Hemineglect

Citation	Population	Setting	Measures of Hemineglect	Results at Given Time Points	Comments
Colombo et al. (1982)	Consecutive admissions with acute unilateral stroke over a 19 month period (total number not stated)	In-patient wards; type of ward not stated (Italy)	Four tests, all for VSN in peripersonal space 1. Pointing to circles (5L, 5R); cut-off failure to point to one or more stimuli contralesionally 2. Pointing to row of 7 children in photograph (3L,3R,1 centre); cut-off failure to point to one or more stimuli contralesionally 3. Reading full-width, two line headline from newspaper; cut-off failure to read 'initial words' 4. Copying 8 drawings (4 geometrical shapes, clock, face, house & daisy); cut-off failure to copy 'left sided details' Measured at admission and 10 months post-stroke	On admission n=43 with neglect (38 RBD, 5 LBD) Only n=22 available for study duration (20 RBD, 2 LBD; 8f, 13m; mean age 67yrs sd 9yrs), so only these included in analysis. First test – 1-27 days post-stroke; All had severe (n=13) or moderate (n=9) neglect -Severe neglect - >half of words omitted or half omitted plus two other tests below cut-off -Moderate neglect – half words omitted, or <half plus three other tests below cut-off Second test - mean 10.3 months post-onset n=15 with neglect, of which 5 severe (no change) 10 others reduced one or two categories (severe/moderate/mild); 7 no neglect (one with LBD)	Persistent severe impairment linked with initially 'severe' neglect; complete recovery only in patients with initially 'moderate' neglect 8 of the 22 still showed 'persistent, disabling neglect', 2 of the 5 still severe had thalamic damage (one exclusively, the other combined with wide parietal damage Tests used for neglect not standardized and no evidence provided for validity or reliability On admission tests 1-4 used but not all patients able to do all tests (of the RBD, 10 did 3, 10 did 4, the LBD only did pointing to circles); at second time point all four tests were given
Denes et al. (1982)	Consecutive admissions with acute unilateral stroke over 17 month period (N=90), 42 lost to study, 48 remained (24 RBD, 24LBD); mean age 61yrs	Geriatric Hospital (Italy)	VSN in peripersonal space - Modified 'Copying Crosses' Test[4] (neglect if more crosses copied ipsilesionally than contralesionally; 9 crosses on L and 9 on R to be copied) Measures taken at 2 months and 6 months post-stroke	First test (average 7-8/52 post stroke) n=13 (8 RBD, 5 LBD) Second test 6/12 later n=9 (7 RBD, 2 LBD)	Only one test used to identify neglect Evidence not provided for validity or reliability of copying test No information provided as to initial severity of neglect or degree of improvement, or lack of it

APPENDIX A

Summary Table of Epidemiological Data of Recovery from Hemineglect

Citation	Population	Setting	Measures of Hemineglect	Results at Given Time Points	Comments
Gialanella & Mattioli (1992)	N=45 RBD first stroke average age 63-69 yrs, 23f, 22m (no further detail given of total population)	In-patient rehabilitation centre (Italy)	EN – Verbal cancellation test PN – touch left hand with right hand (score 0-3) Anosognosia for PN and hemiplegia measured on a scale of 0-3 Measures taken at one month and five months post-stroke	First test – (mean 1/12 post-stroke, sd 9.2); n=21 with neglect (12 with EN, 9 with EN+PN) Second test – (mean 5/12 post-stroke range 3-6 months n=21 (19 with EN, 2 with EN+PN)	PN occurred only in patients who also had EN and anosognosia Increase in numbers with EN at second test not commented upon – may indicate tests-retest variability, or further stroke over study period Evidence for validity and reliability of tests for neglect not provided No information provided as to initial severity of neglect or degree of improvement, or lack of it
Halligan et al. (1992a)	N=675 Chronic stroke patients with first stroke; but final N=190; 92 RBD, 98 LBD (those suitable for inclusion and who remained to follow-up)	Oxford Community Stroke Project from 10 general practices in Oxfordshire (UK)	Visual neglect in peripersonal space - SCT cut-off score 44 Measured only once	First test- n=26 with neglect (14 RBD, 12 LBD); average age 76-79yrs; average time post-stroke 202-230 weeks	Neglect not assessed at acute stage so evolution of neglect over time not investigated but study of note in that that 15% of RBD and 12% of LBD first strokes had visual neglect some 4 years post-stroke Only one test used for visual neglect in peripersonal space
Hier et al (1983)	N=41RBD first stroke; mean age 59yrs (sd 16.&); 22f, 19m	Hospital based but no further details provided (USA)	USN – failure to reproduce elements on left side when copying Rey figure Neglect of left hemispace – failure to attend to left-sided visual and auditory stimuli Tactile extinction Measured on admission then at 2-4 week intervals until recovery or lost to follow-up (mean follow-up 13.5 weeks, sd 18.3)	First test – 7/7 post-stroke: USN – n=35 Neglect of left hemispace n=19 Tactile extinction n=26 Median time for 50% recovery: USN – 8/52 Neglect of hemispace – 9/52 Tactile extinction – 43/52	Authors state little change in neglect symptoms observed after 2 months. No influence of age or gender on recovery Better recovery for smaller lesions and sparing of R frontal lobe Neglect behaviour on tests coded as 'present' or 'absent', thus issue of severity not addressed No data provided for times to complete resolution (or otherwise) of neglect

APPENDIX A

Summary Table of Epidemiological Data of Recovery from Hemineglect

Citation	Population	Setting	Measures of Hemineglect	Results at Given Time Points	Comments
Jehkonen et al. (2000a)	N=57 consecutive admissions with RBD; mean age 63yrs, 20f, 36m	Patients admitted as emergency cases to an acute hospital (Finland)	UVN in peripersonal space: BIT conventional and behavioural sub-tests (cut-offs as per published data) Measured within 10/7 of onset (n=56); at 3/12 (n=53); at 6/12 (n=52); at 1 yr (n=50)	BIT Conventional Sub-Tests: 10/7 – 16/56 (29%) 3/12 – 5/53 (9%) 6/12 – 6/52 (12%) 1yr – 4/50 (8%) BIT Behavioural Sub-Tets: 10/7 – 15/56 (27%) 3/12 – 6/53 (11%) 6/12 – 4/52 (8%) 1yr – 3/50 (6%)	Neglect had resolved in the majority by 3/12 No patients had a second stroke during follow-up Neglect severity and recovery pattern not reported
Katz et al. (1999)	N=40 consecutive admissions with first stroke RBD; mean age 58.6yrs	Specialist rehabilitation hospital receiving patients from all general hospitals in the country (Israel)	BIT conventional sub-tests (cut-off <130) ADL Checklist for neglect – 10 items scored on 3-point scale. Cut-off score not provided Measured at admission and discharge (BIT) also ADL checklist at 6 months follow-up	At admission (mean 34/7 post-stroke sd 10.9) n=19 with neglect: Mean BIT score 85.9 (sd 39.9) Mean ADL neglect 16.2 (sd4.6) At discharge (mean length of stay 118.7 days sd 48.7): Mean BIT score 107.5 (sd 41.5) Mean ADL neglect 12.3 (sd 5.0) At 6/12: Mean ADL checklist 11.7 (sd 4.7)	Majority of recovery took place during hospitalization No detail regarding numbers or neglect severity at follow-up time points ADL checklist subjectively scored and no evidence provided for test reliability BIT not administered at 6/12 follow-up
Kinsella & Ford (1985)	N = 195 consecutive admissions with stroke N=31 suitable (14 RBD, 17 LBD), mean age 62yrs (33-74) patients serially selected (first stroke, less than 75yrs; more than 6 weeks before transfer from acute to rehabilitation facility)	Rehabilitation hospital (Australia)	UVN in peripersonal space: Line cancellation (one or more omissions) Line bisection (>1cm from centre 10cm line) Copying: Rey figure, Maltese cross; flower (left details omitted) Neglect if at least 2 tests abnormal Measures taken at 4, 8, 12 weeks and follow-up 15-18 months post-stroke	First test at 4/52 n=8/31 with neglect Second test at 8/52 n=7 with previous neglect assessed (4 now less severe, 3 resolved completely) Third test at 8/52 none with neglect Fourth test at follow-up 15-18/52 post-stroke none with neglect	Only patients with neglect identified at first test were re-tested Initial severity of neglect not reported

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Summary Table of Epidemiological Data of Recovery from Hemineglect

Citation	Population	Setting	Measures of Hemineglect	Results at Given Time Points	Comments
Mattingley et al. (1994)	N = 13 with left UVN, mostly acute stroke with RBD; 5f, 8m; mean age 64.4yrs (sd 9.7)	Setting not reported, nor patient screening/ for UVN nor selection procedure (Australia)	UVN in peripersonal space: Line Cancellation (>4 omissions) Circle Cancellation (>1 omission) Star Cancellation (>15 omissions) Line Bisection (>3mm leftward error) Attentional bias – face-matching task (.positive asymmetry score) Measured initially and at 12 months	First test at mean 97.7 days post-stroke (range 4-423); mean excluding the 423 was 26.7 days post-stroke. All 13 had abnormal scores on all cancellation tests except Circle Cancellation 11/13 had abnormal line bisection. Line Cancellation omissions - mean 40.5%, range 8-94%, Circle Cancellation omissions mean 23.8%, range 0-75% (8/13 abnormal) Star Cancellation omissions mean 49.8%, range 4-91% Line Bisection mean error 12.7mm Face-matching showed significant rightward bias Second test - 12-month follow-up: Line Cancellation – 2/13 abnormal Circle Cancellation 2/13 abnormal Star Cancellation – 3/13 abnormal Line Bisection – 6/13 abnormal, mean error 3.7mm Face-matching Task - Significant persistent rightward bias	At 12 months, only a small number still had impaired performance on cancellation tasks. although just less than half the group still had abnormal, although much reduced line bisection errors One patient with the lowest scores on first test, implying severe neglect, continued to score low at 12 months In contrast, some 80% of patients still had a persistent rightward attentional bias on face-matching
Stone et al. (1991b)	N = 44 first strokes consecutively admitted, 18 RBD, 26 LBD; mean age 71.2yrs (sd 12.8)	Hospital acute in-patient (UK)	UVN in peripersonal space – 7 items from the BIT: Food on a plate; reading a menu; reading a newspaper article; line cancellation; star cancellation; coin selection; figure copying; (published cut-off scores) FN – pointing to objects around a ward Measured on admission and at 3 months post-stroke	First test – 3/7 post-stroke' neglect present in 13 of 18 testable RBD and in 16/26 testable LBD Second test – 3/12 post-stroke – neglect still present in 9/12 with RBD (1 died), and in 5/14 with LBD (2 died). Neglect had declined in all tests for all patients ($p<.05$)	Neglect equally common in RBD and LBD at 3 days, but was less severe and resolved more frequently in LBD than RBD Validity, reliability and sensitivity of test battery was reported

APPENDIX A

Summary Table of Epidemiological Data of Recovery from Hemineglect

Citation	Population	Setting	Measures of Hemineglect	Results at Given Time Points	Comments
Stone et al. (1992)	N = 171 consecutively admitted first strokes. Ages not reported	Hospital in-patients (UK)	UVN in peripersonal space – 5 items from the BIT: Food on a plate; reading a menu; line cancellation; star cancellation; coin selection; (published cut-off scores). FN – pointing to objects around a ward Above battery called the VNRI and maximum UVN scored 0%, no neglect scored 100% Anosognosia – present or absent Measured at 3 and10 days, 3 and 6 weeks, and 3 and 6 months post-stroke	First test – 3/7 post-stroke n=68 with neglect(34 RBD, 34 LBD), but neglect more severe in RBD (mean VNRI 45% for RBD compared with 68% for LBD) Second test 10/7 post-stroke n=64 (mean VNRI 65% for RBD, 88% for LBD) Third test 3/52 post-stroke n=66 (mean VNRI 70% for RBD, 89% for LBD) Fourth test 6/52 post-stroke n=66 (mean VNRI 73% for RBD, 90% for LBD) Fifth test 3/12 post-stroke n=68 (mean VNRI 78% for RBD, 97% for LBD) Sixth test 6/12 post-stroke N = 62 (mean VNRI 83%for RBD, 96% for LBD)	Neglect recovered most quickly over first 10 days and plateaued at 3 months Number of patients with recovery of neglect at all time points except the first were not reported Many patients had mild or no visual neglect at 3 months, and only 7 patients had a VNRI below 60% All patients showed recovery (significant across all time periods) up to 3 months but greater in LBD than RBD Severity of neglect and anosognosia at 3 days predicted severity of neglect at 3 and 6 months

APPENDIX A

Summary Table of Epidemiological Data of Recovery from Hemineglect

APPENDIX A

Summary Table of Epidemiological Data of Recovery from Hemineglect

Citation	Population	Setting	Measures of Hemineglect	Results at Given Time Points	Comments
Sunderland et al. (1987)	N = 197 first strokes, surviving at 3 weeks post-stroke, with unilateral signs only; 84 RBD, 113 LBD; mean age 70yrs (sd 9) Sample taken from an original group of 449 patients registered in first year of stroke register of patients reported by GPs in a health district	Setting not reported but community implied as all were GP referrals. (Stroke Register covered one health district in Bristol, UK)	UVN in peripersonal space: Copying a cross – neglect defined by omissions or distortions of drawing on contralesional side Raven's Coloured Progressive Matrices – correct responses to left and right recorded; scores to define neglect not reported for copying, cut-off score provided for Raven's test Measured at 3 weeks and 6 months post-stroke. Raven's Matrices also tested at 1 year post-stroke	First test – 3/52 post-stroke, 167 assessed on copying (75 RBD, 92 LBD), and 155 on Raven's (67 RBD, 88 LBD) n=4 RBD with left sided omissions on copying (severe neglect) n=11 below cut-off on Raven's test (7 RBD, 4 LBD) Definite neglect reported total 13% RBD and 3% LBD Second test – 6/12 post-stroke, 150 assessed on copying (69 RBD, 81 LBD) and 134 on Raven's (63 RBD, 71 LBD) Only 1 case of neglect in drawing (not identified at first tests) n=2 on Raven's test Definite neglect reported total 2% RBD, 0% LBD. 4 with neglect at 3/52 were not included here Third test – 1yr post-stroke; 123 assessed on Raven's (56 RBD, 67 LBD). n=2 (1 RBD, 1 LBD) Definite neglect reported total 1% RBD, 1% LBD	Low incidence of neglect may reflect community-based sample (hospital admissions would include more severe strokes) Evidence of validity, reliability and sensitivity for copying task and Raven's Matrices not provided Insensitivity of copying task to identify neglect acknowledged Most recovery between 3 weeks and 6 months post-stroke, although some recovery still occurring up to 1 year post-stroke

Citation	Population	Setting	Measures of Hemineglect	Results at Given Time Points	Comments
Zoccolotti et al. (1989)	N = 104 first strokes with RBD consecutively admitted; mean age 64.8yrs (sd 8.1, range 30-75); 44f, 60m	Rehabilitation Clinic (Italy)	UVN in peripersonal space: 1.Line Cancellation –21 lines (26.7%% showed neglect) 2. Letter Cancellation – letter H's in an array of 104 letters (52% incidence) 3. Sentence reading – 3 setences (41.8%) 4. Wundt-Jastrow Illusion Test – a shape matching task with fans (47.9% incidence) Cut-off scores provided Severity of neglect evauated on a 5-point scale – 1 = no abnormality, 5 = extremely severe deficit (on basis of 'overall response to test battery'.	First (and only) time of testing – five subgroups assessed based on time post-stroke: 2/12 post-stroke; n=34 (20 with no neglect; 7 moderate, 7 very-extremely severe) 3/12 post-stroke; n=17 (7 with no neglect, 3 moderate, 7 very-extremely severe) 4-5/12 post-stroke; n=17 (6 with no neglect, 6 moderate, 5 very-extremely severe) 6-12/12 post-stroke; n=14 (6 with no neglect, 7 moderate, 1 extremely severe) >1yr post-stroke; n=22 (12 with no neglect, 7 moderate, 3 very severe)	There was a progressive reduction in the deficit from the 3/12 sub-group in 3 of the 4 tests Some 20% of patients showed severe or extremely severe neglect many months post-stroke, and even after 1 year This was a cross-sectional rather than a longitudinal study Test 1, 2 and 4 are standardized, test 3 was devised for the research. No evidence is provided for validity or reliability of these tests; cut-off scores for tests based on performance of two age-matched control samples (19 LBD and 21 normal subjects)

Abbreviations used in Table

BIT = Behavioural Inattention Test
EN = Extrapersonal neglect
FN = Far (outside reaching space) neglect
f = female, m=male
LBD = Left-sided brain damage
NIHSS = National Institute of Health Stroke Scale (median score for population-based unselected sample is 6)
PN = Personal neglect
PPN = Peripersonal (within reaching space) neglect
RBD = Right-sided brain damage
SCT = Star Cancellation Test
USN = Unilateral spationa neglect
UVN = Unilateral visual neglect
VNRI = Visual Neglect Recovery Index
VSN = Visuo-spatial neglect

1 Use of Common Objects (Comb and razor/powder compact and spectacles) Test. (Zoccolottit & Judica 1991)
2 Seven sub-tests from BIT (conventional & behavioural sub-tests) used were 'food on a plate' (photograph), reading a menu, reading a newspaper article, line cancellation, star cancellation, coin selection, and figure copying. (Wilson et al. 1987)
3 Pointing at objects located about the ward (cut-off >50 degrees); based on BIT behavioural sub-test photograph of objects in a ward
4 Copying Crosses Test (De Renzi, E., & Faglioni, P. 1976).

APPENDIX A

Summary Table of Epidemiological Data of Recovery from Hemineglect

APPENDIX B

Questionnaire
Physiotherapy for Hemineglect in Adult Stroke Patients

This questionnaire is for those physiotherapists who are currently working, or have recently (during the last year) worked, with adult stroke patients.

Please tick the boxes that apply to you:

1. You are:

a. Currently working with adult stroke patients ☐

b. Not currently, but recently worked with adult stroke patients ☐

c. Not currently working, or not recently worked with adult stroke patients during the last 12 months ☐

If you ticked box c. you do not need to respond to any further questions in this questionnaire. Sorry to have troubled you.

2. Grade/Occupational Group

a. Junior physiotherapist ☐

b. Senior II physiotherapist ☐

c. Senior I physiotherapist ☐

d. Superintendent IV physiotherapist ☐

e. Superintendent III physiotherapist ☐

f. Superintendent II physiotherapist ☐

g. Superintendent I physiotherapist ☐

h. Private Practice ☐

3. How many years have you been qualified?

a. 0-5 ☐

b. 6-11 ☐

c. 12-16 ☐

d. 17-21 ☐

e. 21 and over ☐

4. Which of the following qualifications do you have?
(please tick all that apply)

a. Diploma in Physiotherapy ☐

b. First degree ☐

c. Masters degree ☐

d. MPhil/PhD ☐

5. In which of the following settings do you normally treat stroke patients?
(please tick all that apply)

1. Acute stage

a. General medical wards ☐

b. Stroke Unit ☐

c. Elderly care wards ☐

d. Community hospital-based ☐

e. Community domicillary visits ☐

2. Rehabilitation Phase

a. General medical wards ☐

b. Elderly care wards ☐

c. Stroke Unit ☐

d. Rehabilitation wards ☐

e. Hospital out-patients ☐

f. Community hospital-based ☐

g. Community domicillary visits ☐

h. Private practice ☐

<u>Assessment and Treatment of Hemineglect in Adult Stroke Patients</u>

Please answer the following questions in relation to adult stroke patients only

6a. Is hemineglect routinely identified by at least one member of the Multi-Disciplinary Team?

Yes ☐

No ☐

6b. Which of the following members of the Multi-Disciplinary Team identify the presence of hemineglect? (please tick all that apply)

a. Doctor ☐

b. Physiotherapist ☐

c. Occupational therapist ☐

d. Clinical psychologist ☐

e. Nurse ☐

f. Speech and language therapist ☐

6c. Is a specific test used by the person/people identified in 6b above?

a. Yes ☐

b. No ☐

c. Don't know ☐

6d. If you ticked 'Yes' in 6c. above state the <u>name</u> of the test(s) used (if known)

…………………………………………………………………………….

7a. Do you, as a physiotherapist, identify the presence of hemineglect?

a. Yes ☐

b. No ☐

7b. If you answered 'yes' to 7a above, do you use (tick only one):

a. Observation of clinical manifestations only ☐

b. Specific tests only ☐

c. Both observation and specific tests ☐

7c. If you use a specific test for hemineglect, which of the following do you use? (please tick all that apply)

a. Behavioural Inattention Test (BIT) ☐

b. Star Cancellation Test ☐

c. Letter or line cancellation test ☐

d. Figure or picture copying ☐

e. Drawing tests (e.g. 'draw a clock'; 'draw a daisy') ☐

f. Bilateral simultaneous stimulation tests for extinction (tactile or visual) ☐

8a. If the patient had been identified as having hemineglect, do you then use any treatment strategies specifically aimed at reducing hemineglect?

a. Yes ☐

b. No ☐

8b. If you answered 'yes' to question 8a. above, which of the following strategies do you use? (please tick all that apply)

a. Minimising environmental stimuli on the non-affected side ☐

b. Positioning of bedside locker, TV etc. on the affected side ☐

c. Sitting/talking to the patient from the affected side ☐

d. Encouraging the patient to:

i. Touch the affected side ☐

ii. Look towards the affected side ☐

iii. *Visually search into neglected hemispace* ☐

iv. *Transfer towards the affected side* ☐

e. Increasing sensory stimulation to the affected side using:

i. Touch/massage/stroking ☐

ii. *Weight bearing* ☐

iii. *Ice* ☐

f. Encouraging patient to self-verbalise during task activity ☐

g. Use of specific scanning strategies ☐

h. Encouraging maximum use of affected or unaffected limbs within the neglected hemispace ☐

i. Provision of visually stimulating ‘cues’ or ‘anchors’ in the neglected hemispace ☐

j. TENS stimulation to affected side ☐

k. Vestibular stimulation ☐

l. Mechanical muscle vibration ☐

m. Optokinetic stimulation ☐

n. Use of binocular prisms ☐

o. Eye patching ☐

p. Use of hemifield goggles ☐

q. Use of music played through headphones on the affected side ☐

r. Use of a ‘buzzer’ to direct attention towards neglected hemispace ☐

s. Use of inflatable air splints on the neglected limb(s) ☐

t. Use of visual feedback with:

i. Video feedback ☐

ii. *Mirror* ☐

9. Where did you gain your knowledge regarding hemineglect and its treatment? (please tick all that apply)

a. Pre-registration/undergraduate level ☐

b. Post-registration/postgraduate level:

i. In-service training ☐

ii. Discussion with/learning from colleagues ☐

iii. Taught courses/conferences ☐

iv. *Self-directed study* ☐

10. If you use any of the strategies or techniques listed in question 8b. above, do you find any of them particularly useful?
(please circle the relevant number(s) below, in relation to the list in question 8b)

a
b
c
di
dii
diii
div
ei
eii
eiii
f
g
h
i
j
k
l
m
n
o
p
q
r
s
ti
tii

11. Do you use any other treatment strategies/techniques <u>not</u> previously listed in question 8b above? (please state below)

Thank you very much indeed for your help and time in completing this questionnaire.

APPENDIX C

Questionnaire Results Raw Data

Physiotherapy for Hemineglect in Adult Stroke Patients

Question 1. To Include/Exclude Respondents

Currently working with adult stroke patients	135
Not currently, but recently worked with adult stroke patients	32
Not currently working, or not recently worked with adult stroke patients during the last 12 months	60

Question 2. Grade/Occupational Group

Junior physiotherapist	2
Senior II physiotherapist	17
Senior I physiotherapist	96
Superintendent IV physiotherapist	19
Superintendent III physiotherapist	12
Superintendent II physiotherapist	3
Superintendent I physiotherapist	12
Private Practice	6

Question 3. Years Qualified

0-5	0
6-11	4
12-16	22
17-21	59
21 and over	82

Question 4. Qualifications

Diploma in Physiotherapy	154
First degree	16
Masters degree	9
MPhil/PhD	1

Question 5. Settings for Treatment

Acute stage	
General medical wards	55
Stroke Unit	26
Elderly care wards	62
Community hospital-based	6
Community domicillary visits	18
Rehabilitation Phase	
General medical wards	28
Elderly care wards	25
Stroke Unit	36
Rehabilitation wards	6
Hospital out-patients	30
Community hospital-based	27
Community domicillary visits	12
Private practice	3

Assessment and Treatment of Hemineglect in Adult Stroke Patients

Question 6a. Hemineglect Identified by Multi-Disciplinary Team

Yes	145
No	14
No response	8

Question 6b. Members of the Multi-Disciplinary Team who Identify the Presence of Hemineglect?

Doctor	116
Physiotherapist	73
Occupational therapist	147
Clinical psychologist	27
Nurse	56
Speech and language therapist	62
No response	9

Question 6c. 'Is a specific test used by the person/people identified in 6b above?'

Yes	79
No	28
Don't know	60

Question 6d. Name(s) of the Test(s) Used

Rivermead Perceptual Assessment Battery (RPAB)	18
Star Cancellation Test	16
Letter/line cancellation/line bisection	13
Extinction tests	12
Figure/picture copying	12
Drawing tasks	15
Behavioural Inattention Test (BIT)	12
No response	111

Question 7a. Identification of the Presence of Hemineglect by Physiotherapist

Yes	163
No	4

Question 7b. Identification of Hemineglect by Physiotherapist (method)

Observation of clinical manifestations only	67
Specific tests only	0
Both observation and specific tests	100

Question 7c. Specific Tests used by Physiotherapist

Behavioural Inattention Test (BIT)	16
Star Cancellation Test	23
Letter or line cancellation test	29
Figure or picture copying	66
Drawing tests (e.g. ‘draw a clock’; ‘draw a daisy’)	92
Bilateral simultaneous stimulation tests for extinction (tactile or visual)	55
No response	61

Question 8a. ‘Do you use any treatment strategies specifically aimed at reducing hemineglect?’

Yes	149
No	0
No response	18

Question 8b. Strategies used to Minimize Hemineglect

Minimising environmental stimuli on the non-affected side	100
Positioning of bedside locker, TV etc. on the affected side	126
Sitting/talking to the patient from the affected side	155
Encouraging the patient to:	
Touch the affected side	165
Look towards the affected side	167
Visually search towards neglected hemispace	138
Transfer towards the affected side	140
Increasing sensory stimulation to the affected side using:	
Touch/massage/stroking	143
Weight bearing	147
Ice	28
Encouraging patient to self-verbalise during task activity	41
Use of specific scanning strategies	57
Encouraging maximum use of affected or unaffected limbs within the neglected hemispace	128
Provision of visually stimulating 'cues' or 'anchors' in the neglected hemispace	61
TENS stimulation to affected side	1
Vestibular stimulation	10
Mechanical muscle vibration	10
Optokinetic stimulation	1
Use of binocular prisms	6
Eye patching	23
Use of hemifield goggles	0
Use of music played through headphones on the affected side	1
Use of a 'buzzer' to direct attention towards neglected hemispace	5
Use of inflatable air splints on the neglected limb(s)	52
Use of visual feedback with:	
Video feedback	17
Mirror	91

Question 9. Where Knowledge about Hemineglect was Gained

Pre-registration/undergraduate level	65
Post-registration/postgraduate level:	
In-service training	114
Discussion with/learning from colleagues	134
Taught courses/conferences	128
Self-directed study	113

Question 10. Strategies/Techniques for Treatment of Hemineglect found to be of Particular Utility

Minimising environmental stimuli on the non-affected side	13
Positioning of bedside locker, TV etc. on the affected side	19
Sitting/talking to the patient from the affected side	29
Encouraging the patient to:	
Touch the affected side	62
Look towards the affected side	56
Visually search towards neglected hemispace	52
Transfer towards the affected side	53
Increasing sensory stimulation to the affected side using:	
Touch/massage/stroking	56
Weight bearing	53
Ice	29
Encouraging patient to self-verbalise during task activity	13
Use of specific scanning strategies	20
Encouraging maximum use of affected or unaffected limbs within the neglected hemispace	20
Provision of visually stimulating ‘cues’ or ‘anchors’ in the neglected hemispace	7
TENS stimulation to affected side	0
Vestibular stimulation	0
Mechanical muscle vibration	2
Optokinetic stimulation	0
Use of binocular prisms	0
Eye patching	1
Use of hemifield goggles	0
Use of music played through headphones on the affected side	0
Use of a ‘buzzer’ to direct attention towards neglected hemispace	1
Use of inflatable air splints on the neglected limb(s)	11
Use of visual feedback with:	
Video feedback	3
Mirror	9

Question 11. Other Strategies used by Physiotherapists not Previously Listed

Use of modified Proprioceptive Neuromuscular Facilitation (PNF)	2
‘Correct’ handling	11
Bilateral limb activities	9
Weight-bearing in different ‘postural sets’	8
Education of patients and carers	24
No response	126

APPENDIX D

ABSTRACT

(linked with Chapter 5)

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DEVELOPMENT OF AN EVERYDAY FUNCTIONAL TEST BATTERY FOR VISUO-SPATIAL HEMINEGLECT

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EARLY VERSUS LATE MORTALITY IN VERY ELDERLY END-STAGE RENAL DISEASE PATIENTS STARTING DIALYSIS

S. MUNSHI, N. VIJAYKUMAR, A. PATEL, T.C.N. LO AND G. WARWICK

Subject	Sex	Age	CVA	Post stroke/days	SCT Score	Location CVA	BIT Score	BIT(mins)	ETB score test1	ETB1 Time (mins)	ETB Score test2	ETB2 Time (mins)	mean t1/t2	diff t1-t2	absolute diff t1-t2	% difference
1	F	79	R	26	21	R par occ	16	58	98	41	89	50	93.5	9	9	9.18
2	F	78	R	45	8	R fron par	5	64	38	45	42	48	40	-4	4	10.53
3	F	72	R	52	50	R par occ	68	58	200	32	189	38	194.5	11	8	4.00
4	M	76	R	30	31	R par & bg	38	46	125	30	128	38	126.5	-3	3	2.40
5	M	76	R	38	11	R post fron	26	52	135	33	114	40	124.5	21	21	15.56
6	F	73	R	56	35	R bg haem	28	49	163	22	171	20	167	-8	8	4.91
7	F	72	R	48	22	R mca	58	45	156	33	160	35	158	-4	4	2.56
8	F	74	R	38	32	R par-occ	63	43	165	30	160	42	162.5	5	5	3.03
9	F	84	R	84	28	R post fron & bg	36	66	152	40	136	45	144	16	16	10.53
10	M	73	R	40	16	R mca	14	42	130	28	115	25	122.5	15	15	11.54
11	M	84	R	45	8	Rmca	7	70	32	46	40	52	36	-8	8	25.00
12	F	60	R	15	11	R par	11	45	79	30	70	32	74.5	9	9	11.39
13	M	61	R	32	6	Rmca	2	50	23	32	28	30	25.5	-5	5	21.74
14	M	74	R	37	26	R fron par	45	45	129	30	126	25	127.5	3	3	2.33
15	F	68	R	81	44	R par occ	51	65	192	38	191	45	191.5	1	1	0.52
16	M	73	R	59	20	R fron par	53	49	183	20	174	30	178.5	9	9	4.92
17	M	73	R	70	35	R occ temp	20	53	157	30	149	36	153	8	8	5.10

Age	
Mean	**73.53**
Median	73
Mode	73
sd	**6.414**
Minimum	**60**
Maximum	**84**
Count	17

Days Post Stroke	
Mean	**46.824**
Median	45
Mode	45
sd	**18.712**
Minimum	**15**
Maximum	**84**
Count	17

BIT Time (mins)	
Mean	**52.941**
Median	50
Mode	45
sd	**8.934**
Minimum	**42**
Maximum	**70**
Count	17

ETB 1 Time (mins)		ETB 2 Time (mins)	
Mean	**32.941**	**Mean**	**37.117**
Median	32	Median	38
Mode	30	Mode	38
sd	**7.128**	**sd**	**9.292**
Minimum	**20**	**Minimum**	**20**
Maximum	**46**	**Maximum**	**52**
Count	17	Count	17

SCT Score	
Mean	**23.76**
Median	22
Mode	8
sd	**13.03**
Min	**6**
Max	**50**
Count	17

BIT Score	
Mean	**31.824**
Median	28
Mode	#N/A
sd	**21.544**
Min	**2**
Max	**68**
Count	17

ETB1 Score		ETB2 Score		Difference ETB1-ETB2		Absolute Difference ETB1-ETB2	
Mean	**126.882**	**Mean**	**122.647**	**Mean**	**4.235**	**Mean**	**8**
Median	135	Median	128	Median	5	Median	8
Mode	#N/A	Mode	160	Mode	9	Mode	8
sd	**55.218**	**sd**	**52.732**	**sd**	**8.722**	**sd**	**5.208**
Min	**23**	**Min**	**28**	**Min**	**-8**	**Min**	**1**
Max	**200**	**Max**	**192**	**Max**	**21**	**Max**	**21**
Count	17	Count	17	Count	17	Count	17
				2sd	**17.443**		

% Difference ETB1-ETB2	
Mean	**8.543**
Median	5.096
Mode	10.526
sd	**7.01**
Min	**0.521**
Max	**25**
Count	17

Key:
ETB1 = Everyday Test Battery Test 1
ETB2 = Everyday Test Battery Test 2
BIT = Behavioural Inattention Test
SCT = Star Cancellation Test

APPENDIX E. Raw Data (n=17) and Descriptive Statistics for Demographic Data, Scores for Star Cancellation Test, Behavioural Inattention Test, Everyday Test Battery, and Time Taken.

Everyday Test BatteryTest 1

	Clubs	Cancellation	Task							
Max score	**40**	**40**	**40**	**47**	**8**	**11**	**11**	**3**	**21**	**221**
Subject	**Easy**	**Medium**	**Difficult**	**Menu**	**Seeds**	**Washbasin**	**Tea**	**Envelope**	**Ward**	**Total**
13	6	5	4	2	0	2	2	1	1	23
11	9	5	6	0	0	5	3	1	3	32
2	11	4	3	4	4	2	3	1	6	38
12	15	10	6	27	0	7	7	2	5	79
1	18	14	9	27	0	7	7	1	15	98
4	20	16	15	44	6	5	7	2	10	125
14	31	15	12	45	2	5	11	3	5	129
10	25	21	24	29	3	5	11	2	10	130
5	39	24	19	37	0	3	5	2	6	135
9	39	25	20	39	7	5	9	2	6	152
7	37	29	10	45	6	11	9	3	6	156
17	36	38	24	35	4	5	7	2	6	157
6	20	35	35	38	8	7	11	3	6	163
8	35	27	28	46	7	5	5	2	10	165
16	40	32	28	40	8	9	11	2	13	183
15	37	35	37	40	6	11	11	2	13	192
3	40	40	38	43	6	11	9	3	10	200

Everyday Test Battery Test 2

	Clubs	Cancellation	Task							
Max score	**40**	**40**	**40**	**47**	**8**	**11**	**11**	**3**	**21**	**221**
Subject number	**Easy**	**Medium**	**Difficult**	**Menu**	**Seeds**	**Washbasin**	**Tea**	**Envelope**	**Ward**	**Total**
13	10	4	4	4	0	1	3	1	1	28
11	14	10	2	0	0	5	5	1	3	40
2	10	6	5	6	0	5	3	1	6	42
12	18	7	3	22	0	5	7	2	6	70
1	21	12	5	20	0	5	7	1	18	89
5	35	28	18	22	0	3	3	2	3	114
10	28	22	12	27	0	9	9	2	6	115
14	28	16	10	47	0	7	9	3	6	126
4	29	17	6	46	8	7	7	2	6	128
9	38	20	22	37	0	5	5	3	6	136
17	34	30	24	34	0	5	11	3	8	149
7	40	31	27	39	0	7	7	3	6	160
8	33	29	20	42	6	7	10	3	10	160
6	36	32	32	34	6	7	11	3	10	171
16	38	32	25	41	8	5	11	2	12	174
3	40	39	31	43	8	6	9	3	10	189
15	37	35	36	44	6	9	11	3	10	191

(N.B. Total scores are presented in ascending order)

APPENDIX F. Raw Scores for all Subjects (n=17) for Everyday Test Battery Test 1 and Test 2 (in ascending order of total scores)

	Everyday Test Battery Menu Reading (Item 2 of the battery)				
Subject	**Errors of Omission (retest score in brackets)**				**Errors of Substitution**
Number	**Left-sided/7**	**Central/36**	**Right-sided/4**	**Total omissions/47**	**Description**
1	7(7)	11(18)	2(2)	20(27)	wholemeal' read as 'oatmeal': 'strawberry' read as 'merry'
2	7(7)	36(34)	0(0)	43(41)	
3	4(4)	0(0)	0(0)	4(4)	
4	3(1)	0(0)	0(0)	3(1)	
5	3(7)	7(18)	0(0)	10(25)	mandarins' read as 'sardines'
6	7(7)	2(6)	0(0)	9(13)	
7	1(5)	1(3)	0(0)	2(8)	
8	1(3)	0(2)	0(0)	1(5)	
9	7(7)	1(3)	0(0)	8(10)	
10	7(7)	11(13)	0(0)	18(20)	
11	7(7)	36(36)	4(4)	47(47)	
12	7(7)	10(18)	3(0)	20(25)	
13	7(7)	36(36)	2(0)	45(43)	
14	2(0)	0(0)	0(0)	2(0)	
15	5(3)	2(0)	0(0)	7(3)	
16	6(5)	1(1)	0(0)	7(6)	
17	6(7)	6(6)	0(0)	12(13)	strawberry' read as 'raspberry': 'savoury' read as 'floury'

APPENDIX G. Everyday Test Battery - Menu Reading (Test Item 2). Errors of Omission and Substitution on Test 1 (and Test 2)

APPENDIX H.

Test-retest Stability of Three Tests for Unilateral Visual Neglect. Raw Data from Patients without Neglect

Repeated Measures for SCT, LB (from BIT) and BTT taken same day I hour apart (10am-11.00am) over a 2-yr period

Subjects	CVA	Gender	Age	Days post	SCT1	SCT2	xLB1/cm	xLB2/cm	BTT1	BTT2
1	R	m	67	12	51	54	-0.6	-0.4	7,9	9,7
2	L	m	77	35	52	54	-0.6	-0.8	8,8	8,8
3	L	f	69	20	54	54	-0.7	0.1	8,8	8,8
4	R	m	71	22	51	51	0.7	0.4	8,8	8,8
5	L	m	88	22	52	54	0.3	-0.4	7,9	9,7
6	L	m	68	26	54	54	-0.4	-0.2	7,9	9,7
7	R	f	79	22	53	51	-0.1	1.5	8,8	8,8
8	L	f	73	25	53	51	0.1	0.5	9,7	9,7
9	L	f	75	35	54	53	-0.7	-0.2	9,7	9,7
10	R	m	84	20	53	51	-0.5	-0.2	8,8	8,8
11	R	m	77	17	54	53	0.1	0.2	8,8	7,9
12	L	m	71	27	54	54	-0.5	-0.8	8,8	8,8
13	L	f	78	38	52	54	-0.8	-0.7	7,9	9,7
14	L	m	75	30	53	54	0.6	0	7,9	7,9
15	L	f	62	69	51	53	0.4	0.4	9,7	7,9
16	L	m	75	29	53	54	-0.6	-0.1	9,7	9,7
17	R	m	82	20	54	54	-0.5	-0.6	8,8	8,8
18	L	m	75	14	52	54	-0.3	-0.4	8,8	9,7
19	R	f	82	17	53	53	-1.1	-1.1	8,8	8,8
20	L	m	72	20	52	54	-0.9	-0.6	7,9	9,7
21	L	m	75	14	54	53	0.2	0	9,7	8,8
22	R	f	73	13	54	54	-1.3	-0.3	7,9	7,9
23	L	m	79	13	53	51	-0.6	0.2	8,8	9,7
24	R	f	65	10	53	54	-0.6	-0.2	9,7	8,8
25	L	m	71	8	54	54	-0.7	-0.8	8,8	8,8
26	L	m	77	11	51	53	-0.4	0.9	9,7	8,8
27	L	m	63	50	53	54	0.3	0	9,7	9,7
28	L	f	68	19	54	54	-0.2	-0.2	9,7	8,8
29	R	m	84	18	54	54	0	-0.3	8,8	8,8
30	R	m	69	26	53	54	-0.7	-0.6	8,8	8,8
31	L	m	68	18	54	53	-0.6	-0.1	8,8	8,8
32	L	m	79	18	54	54	-0.4	-0.4	8,8	8,8
33	L	f	84	19	52	54	0.4	0.1	8,8	8,8
34	L	m	90	32	51	53	0	0	8,8	8,8
35	L	m	64	7	53	54	-1	-0.8	7,9	9,7
36	L	m	68	25	51	53	0	0	8,8	8,8
37	R	f	72	24	54	54	1	0.5	8,8	8,8
38	L	m	65	21	54	54	0.4	0.8	8,8	8,8
39	R	f	64	27	53	53	0.9	1	8,8	7,9
40	L	m	63	42	52	54	-0.3	-0.5	7,9	8,8
41	R	m	67	26	54	54	0.2	0.5	8,8	8,8
42	L	m	70	21	54	54	-0.8	-1.3	8,8	8,8
43	L	f	78	37	52	54	0.1	-0.2	7,9	8,8
44	L	m	78	18	54	54	-1.1	-0.4	9,7	8,8
45	L	f	66	44	54	53	-0.4	-1	7,9	9,7
46	R	f	79	29	54	54	0.1	0.3	7,9	7,9
47	R	m	75	27	53	53	1.2	0.7	9,7	8,8
48	L	m	87	31	54	54	-0.8	-0.3	7,9	9,7
49	L	m	79	11	51	54	0.1	0	9,7	9,7
50	R	m	77	34	54	54	-0.1	0.4	7,9	8,8
51	R	f	74	3	51	54	0.6	1.1	8,8	8,8
52	L	f	79	51	51	53	0	0	8,8	9,7
53	L	f	51	21	51	51	-0.2	0.8	9,7	8,8
54	R	f	79	11	54	54	-0.7	-1.1	7,9	8,8
55	R	m	78	10	54	54	-0.1	0.6	9,7	8,8
56	L	f	90	7	54	54	-0.6	-0.3	8,8	8,8
57	R	f	73	34	52	54	0.9	0.4	7,9	8,8
58	R	m	83	17	53	54	1.1	0.7	8,8	8,8
59	R	m	76	34	53	54	0.3	0.1	9,7	8,8
60	L	m	65	27	54	54	-1	-0.4	8,8	7,9
61	R	f	81	54	53	52	0.5	-0.3	8,8	8,8
62	R	m	76	18	54	54	0.2	0	8,8	8,8
63	L	m	62	46	54	54	0	-0.7	9,7	8,8
64	R	f	65	42	54	54	0	0.06	9,7	9,7
65	L	f	66	53	53	52	-0.9	-0.5	8,8	8,8
66	R	f	73	37	53	53	0	-0.5	8,8	8,8
67	R	m	71	59	54	51	-0.1	-0.5	8,8	8,8
68	L	f	75	28	54	54	-0.4	-0.8	8,8	8,8
69	L	m	76	21	54	54	0.3	-0.1	9,7	8,8
70	R	f	86	48	53	53	0.8	1.8	8,8	8,8
71	R	m	60	26	54	54	0.7	-0.1	8,8	8,8
72	L	m	59	58	54	54	0.6	-0.1	9,7	8,8
73	L	m	63	22	54	54	0.3	0.6	7,9	7,9
74	L	m	59	45	51	53	-0.8	-1.3	7,9	8,8
75	R	f	75	69	54	54	1.3	0	9,7	8,8
76	R	m	78	11	54	54	0.7	0.1	7,9	7,9
77	R	f	77	27	52	54	0.1	0.4	8,8	8,8
78	L	f	79	21	51	53	-0.5	0	9,7	8,8
79	L	f	62	38	54	54	0	0.1	9,7	8,8
80	R	f	73	37	54	54	-0.4	-0.8	8,8	8,8
81	L	f	87	10	54	54	-0.4	-0.8	8,8	8,8
82	L	m	60	32	53	54	0.5	0.6	8,8	9,7
83	L	m	56	48	53	54	0.3	0.4	9,7	9,7

Key: SCT = Star Cancellation; LB = Line Bisection; BTT = Baking Tray Task

Age		*Days post stroke*	
Mean	**73.0602**	**Mean**	**27.4458**
Median	75	Median	25
Mode	79	Mode	27
sd	**8.20373**	**sd**	**14.452**
Range	39	Range	66
Minimur	**51**	**Minimur**	**3**
Maximui	**90**	**Maximui**	**69**
Count	83	Count	83

N=83, 34 females, 49 males, 49 with L cva, 34 with R cva

APPENDIX I.

Test-retest Stability of Three Tests for Unilateral Visual neglect. Raw Data from Neglect Patients

Repeated Measures for SCT, LB (from BIT) and BTT taken same day I hour apart (10am-11.00am) over a 2-yr period

Subjects	CVA	Gender	Age	D/post	SCT1	SCT2	xLB1/cm	xLB2/cm	BTT1	BTT2
1	R	f	79	37	24	22	1.5	1.2	0,16	0,16
2	R	m	63	36	42	41	1.2	1	6,10	5,11
3	L	f	76	60	54	53	-1.6	-0.9	16,0	16,0
4	R	f	67	43	52	54	2.7	0.3	7,9	3,13
5	R	f	72	48	22	26	-0.6	-0.9	3,13	4,12
6	R	f	73	53	52	52	0.2	1.1	7,9	8,8
7	R	f	75	27	52	54	2.1	1.1	3,13	0,16
8	L	f	74	45	17	13	-8.5	-8.7	16,0	16,0
9	R	m	84	42	5	8	9.3	8.7	0,16	0,16
10	R	f	86	71	19	13	8.1	8.3	0,16	0,16
11	R	m	90	41	47	43	1	1.3	0,16	0,16
12	R	m	73	26	35	53	2.7	0	1,15	0,16
13	R	m	86	31	40	46	-0.3	-4.2	7,9	8,8
14	R	f	78	25	14	15	4.4	4.7	0,16	0,16
15	L	m	75	24	52	54	0.2	0.4	16,0	16,0
16	R	m	76	28	10	11	1.4	1.9	0,16	0,16
17	R	m	80	22	35	34	0.5	1	6,10	6,10
18	R	f	77	18	53	53	0.2	0.6	6,10	6,10
19	R	m	73	20	15	17	5.7	6	0,16	0,16
20	R	m	76	17	19	21	3	1.9	0,16	2,14
21	R	m	74	16	54	54	0.7	1.6	0,16	0,16
22	L	m	79	18	44	54	0.3	-0.1	16,10	8,8
23	R	m	77	20	47	53	-0.8	0.5	8,8	6,10
24	L	m	89	13	41	39	-0.6	-0.2	10,6	10,6
25	R	f	76	16	51	52	1.9	1.5	8,8	8,8
26	R	f	90	32	42	48	0.4	1.2	6,10	6,10
27	R	f	90	9	42	49	2.8	2.5	0,16	0,16
28	L	f	84	11	49	48	-1.1	-0.5	8,8	9,7
29	R	m	67	12	46	50	0.7	0.8	9,7	10,6
30	R	m	84	23	25	23	5.1	7	0,16	0,16
31	L	f	86	12	25	36	0	-0.6	9,7	8,8
32	L	f	73	21	54	54	-3.7	-1.5	12,4	7,9
33	R	f	78	19	8	8	6.9	7.6	0,16	0,16
34	R	m	61	28	6	4	9.6	10	0,16	0,16
35	R	f	61	26	10	11	9	8.3	10,6	16,0
36	R	m	69	8	50	45	1.8	-0.1	7,9	8,8
37	R	f	63	19	41	46	2.1	1.7	7,9	8,8
38	L	m	75	51	44	53	-2.8	-0.7	16,0	16,0
39	R	f	76	49	49	45	-0.3	-1.4	8,8	0,16
40	L	f	73	45	36	44	1.6	2.6	0,16	7,9
41	R	m	76	53	53	53	-1.2	1.4	7,9	6,10
42	R	f	76	23	40	41	4.2	2.5	5,11	7,9
43	R	f	66	10	52	54	0.5	0.1	4,12	6,10
44	R	m	62	37	46	43	0.6	1.2	9,7	10,6
45	R	m	73	25	13	12	3.4	3.9	0,16	0,16
46	R	m	62	17	46	43	1.5	0.4	9,7	8,8
47	R	f	90	27	8	9	3.5	2.1	0,16	0,16
48	R	m	69	14	27	48	1.2	1.2	0,16	0,16
49	L	f	77	46	46	50	-1.8	-1	8,8	8,8
50	R	f	68	24	54	54	0.1	0	0,16	6,10
51	R	f	68	28	8	9	9.9	9.5	0,16	1,15
52	R	m	79	40	51	46	1.5	0.7	8,8	6,10
53	R	m	65	18	15	9	2.7	3	0,16	1,15
54	R	m	64	24	47	42	1.3	0.6	6,10	6,10
55	L	f	81	13	53	52	0	0.8	7,9	16,0
56	R	m	80	34	52	53	0.3	0.7	4,12	3,13
57	L	m	74	21	52	53	-0.5	0.2	9,7	8,8
58	R	f	75	54	53	52	1.9	2	7,9	7,9
59	L	f	83	40	49	45	-1.7	-2.3	4,12	4,12
60	R	m	76	38	27	35	3.2	2.8	0,16	8,8
61	R	f	74	37	46	43	1.7	1.9	6,10	5,11
62	L	m	83	22	54	54	-6.5	-6.5	8,8	9,7
63	R	f	68	7	44	41	0.3	0.7	9,7	6,10
64	L	m	80	18	51	52	-0.2	0.3	11,5	11,5
65	R	m	73	22	7	7	6.3	8.2	0,16	0,16
66	R	m	72	24	20	18	2.2	0.7	0,16	0,16
67	R	f	76	26	20	33	8.8	6.9	0,16	0,16
68	R	m	67	32	26	21	2.9	3.4	0,16	0,16
69	L	m	67	25	40	49	-1	0.2	11,5	8,8
70	R	m	78	26	30	46	1.4 ?		8,8	10,6
71	R	m	73	31	22	31	1.1	0.2	0,16	0,16
72	L	f	62	25	15	18	0.4	0.6	12,4	11,5
73	R	f	64	32	37	44	1.6	2.3	0,16	0,16
74	R	f	87	40	34	44	1	2.3	8,8	4,12
75	R	f	85	21	18	25	8.9	4.9	0,16	0,16
76	L	f	72	26	49	44	-2.1	-0.5	16,0	16,0
77	R	m	61	26	46	52	2.5	1.4	0,16	0,16
78	L	f	73	18	19	34	-0.4	-0.4	12,4	9,7
79	R	m	69	34	54	53	2.7	3.4	7,9	9,7
80	R	m	79	30	31	22	1.2	0.5	0,16	0,16
81	R	m	66	57	39	42	1.2	1.2	8,8	12,4
82	R	f	77	46	52	42	2.7	1.6	8,8	10,6
83	R	f	77	36	16	13	-3.9	-1.3	3,13	6,10
84	R	m	71	47	46	37	5.2	4.8	0,16	0,16
85	R	m	85	32	12	13	8	9.2	0,16	0,16

Key: SCT = Star Cancellation Test; LB = Line Bisection; BTT = Baking Tray Task

	Age		*Days post stroke*
Mean	74.8353	Mean	29.2706
Median	75	Median	26
Mode	76	Mode	26
sd	7.62491	sd	13.2893
Range	29	Range	64
Minimur	61	Minimu	7
Maximur	90	Maximu	71
Count	85	Count	85

N= 85, 41 females, 44 males, 20 with L cva, 65 with R cva

APPENDIX J.

Test-retest Stability of Three Tests for Unilateral Visual Neglect.
Patients Unable to be Tested due to Communication, Cognitive or other Problems.

Subjects	Gender	CVA	Age	Days post	Reason for non test
1	M	L	77	74	Aphasic
2	M	L	75	40	Dysphasia/confusion
3	F	L	82	71	Dysphasia/confusion
4	F	L	81	47	Aphasic
5	M	L	84	22	Receptive dysphasia
6	F	L	84	20	Unable to comprehend instructions
7	M	L	71	22	Aphasic
8	F	L	71	16	Confused+language probs
9	M	L	80	30	Communication probs
10	F	L	81	39	Dementia
11	M	L	86	19	Blind
12	F	L	82	39	Aphasia
13	M	L	71	35	Dysphasia/confusion
14	F	L	73	17	Dysphasic
15	F	L	79	47	Confused+language probs
16	M	L	87	27	Dysphasic
17	F	L	86	17	Unable to understand instructions
18	F	R	84	19	Refused to complete tests
19	M	L	77	19	Non English speaker
20	F	L	83	43	Eyesight too poor
21	M	L	69	43	Eyesight too poor
22	M	L	75	11	Unable to understand instructions
23	F	L	73	23	Unable to understand instructions
24	F	L	72	13	Unable to understand instructions
25	F	L	82	25	Unable to understand instructions
26	F	L	62	30	Some comprehension problem
27	F	L	60	23	No English also dysphasic
28	F	L	79	47	Unable to understand instructions
29	M	L	58	66	Unable to understand instructions
30	M	R	82	27	Unable to rouse enough to test
31	F	R	69	31	Poor English and understanding
32	F	L	83	23	Confused and aggressive
33	F	L	77	37	Poor comprehension and eyesight
34	M	L	89	11	Some dysphasia, didn't want to continue
35	F	L	76	36	Difficulty understanding; poor vision
36	F	L	72	29	Aphasic can't understand
37	M	L	85	13	Difficulty understanding instructions
38	M	R	68	33	Unwell; did not wish to proceed
39	F	R	73	28	Frail, unwell, did not wish to proceed
40	M	R	75	57	Visual probs, couldn't see line
41	F	R	84	23	Confused
42	F	L	84	12	Poor understanding
43	F	R	79	8	Confused and didn't want to continue
44	M	L	69	59	Poor comprehension
45	M	R	76	36	Poor English (German speaker)
46	M	R	79	34	Poor comprehension
47	F	R	80	39	Refused to complete tests
48	F	L	75	89	Unable to understand instructions
49	M	L	71	45	Too ill to test
50	M	R	77	20	Difficulty understanding instructions
51	F	R	87	30	Confused
52	F	L	74	30	Difficulty understanding instructions
53	F	L	82	32	Refused to complete
54	M	L	64	34	Unable to follow commands
55	F	R	85	87	Unable to understand instructions
56	M	L	60	20	Unable to understand instructions
57	M	L	62	26	Unable to understand
58	F	R	85	18	Eyesight too poor

Age		**Days post stroke**	
Mean	76.6552	Mean	32.94828
Median	77	Median	30
Mode	82	Mode	30
sd	7.60783	sd	18.02087
Range	31	Range	81
Minimum	58	Minimum	8
Maximum	89	Maximum	89
Count	58	Count	58

N = 58, 33 females, 25 males, 43 with L cva, 15 with R cva

APPENDIX K.

Test-retest Star Cancellation Test Neglect Patients.
Raw Data in Tertile Divisions (Upper, Middle and Lower); Limits of Agreement Calculations

Subjects	SCT1	SCT2	Mean(sort)	Tertiles	Difference T1 to T2
1	47	53	50	1	-6
2	46	52	49	1	-6
3	44	54	49	1	-10
4	44	53	48.5	1	-9
5	46	50	48	1	-4
6	46	50	48	1	-4
7	52	42	47	1	10
8	49	45	47	1	4
9	49	45	47	1	4
10	49	44	46.5	1	5
11	42	49	45.5	1	-7
12	47	43	45	1	4
13	42	48	45	1	-6
14	47	42	44.5	1	5
15	46	43	44.5	1	3
16	46	43	44.5	1	3
17	46	43	44.5	1	3
18	40	49	44.5	1	-9
19	35	53	44	1	-18
20	41	46	43.5	1	-5
21	40	46	43	1	-6
22	44	41	42.5	2	3
23	46	37	41.5	2	9
24	42	41	41.5	2	1
25	40	41	40.5	2	-1
26	39	42	40.5	2	-3
27	37	44	40.5	2	-7
28	41	39	40	2	2
29	36	44	40	2	-8
30	34	44	39	2	-10
31	30	46	38	2	-16
32	27	48	37.5	2	-21
33	35	34	34.5	2	1
34	27	35	31	2	-8
35	*25*	*36*	30.5	2	-11
36	31	22	26.5	2	9
37	22	31	26.5	2	-9
38	20	33	26.5	2	-13
39	19	34	26.5	2	-15
40	25	23	24	2	2
41	22	26	24	2	-4
42	26	21	23.5	2	5
43	24	22	23	3	2
44	18	25	21.5	3	-7
45	19	21	20	3	-2
46	20	18	19	3	2
47	15	18	16.5	3	-3
48	19	13	16	3	6
49	15	17	16	3	-2
50	17	13	15	3	4
51	16	13	14.5	3	3
52	14	15	14.5	3	-1
53	13	12	12.5	3	1
54	12	13	12.5	3	-1
55	15	9	12	3	6
56	10	11	10.5	3	-1
57	10	11	10.5	3	-1
58	8	9	8.5	3	-1
59	8	9	8.5	3	-1
60	8	8	8	3	0
61	7	7	7	3	0
62	5	8	6.5	3	-3
63	6	4	5	3	2

Key: SCT1 = Star Cancellation Test 1; SCT2 = Star Cancellation Test 2
N.B. Data sorted by Mean of Test 1 and Test 2 to enable Tertile Division

Diffs sorted by mean			*Diff Upper tertile sort mean*				*Diff mid tertile sort mean*			*Diff lower tertile sort mean*		
Mean	**-2.22222**	**bias**	**Mean**	**-2.33333**	**bias**		**Mean**	**-4.45619**	**bias**	**Mean**	**0.142857**	**bias**
		2sd			**2sd**				**2sd**			**2sd**
sd	**6.651326**	**13.30265**	**sd**	**6.879922**		**13.75984496**	**sd**	**8.310349**	**16.6207**	**sd**	**3.086838**	**6.173677**
		LoA			**LoA**				**LoA**			**LoA**
		-15.5247				**-16.09314**			**-21.0969**			**-6.03082**
		11.08065				**11.42654**			**12.14451**			**6.316534**
Minimum	-21		Minimum	-18			Minimum	-21		Minimum	-7	
Maximum	10		Maximum	10			Maximum	9		Maximum	6	
Count	63		Count	21			Count	21		Count	21	

APPENDIX L.

Test-retest Line Bisection Neglect Patients.
Raw Data in Tertile Divisions (Upper, Middle and Lower); Limits of Agreement Calculations

Subjects	LB1	LB2	LB1 actual error	LB2 actual error	Mean (sort) actual error	Tertiles	Difference T1 to T2
1	-0.3	-1.4	0.3	1.4	0.85	1	1.1
2	1.5	0.4	1.5	0.4	0.95	1	1.1
3	1.8	-0.1	1.8	0.1	0.95	1	1.9
4	1.5	0.7	1.5	0.7	1.1	1	0.8
5	0.7	1.6	0.7	1.6	1.15	1	-0.9
6	-1.6	-0.9	1.6	0.9	1.25	1	-0.7
7	-1.2	1.4	1.2	1.4	1.3	1	-2.6
8	-2.1	-0.5	2.1	0.5	1.3	1	-1.6
9	1.5	1.2	1.5	1.2	1.35	1	0.3
10	2.7	0	2.7	0	1.35	1	2.7
11	-1.8	-1	1.8	1	1.4	1	-0.8
12	2.2	0.7	2.2	0.7	1.45	1	1.5
13	2.7	0.3	2.7	0.3	1.5	1	2.4
14	2.1	1.1	2.1	1.1	1.6	1	1
15	1.4	1.9	1.4	1.9	1.65	1	-0.5
16	1	2.3	1	2.3	1.65	1	-1.3
17	1.9	1.5	1.9	1.5	1.7	1	0.4
18	-2.8	-0.7	2.8	0.7	1.75	1	-2.1
19	1.7	1.9	1.7	1.9	1.8	2	-0.2
20	2.1	1.7	2.1	1.7	1.9	2	0.4
21	1.9	2	1.9	2	1.95	2	-0.1
22	1.6	2.3	1.6	2.3	1.95	2	-0.7
23	2.5	1.4	2.5	1.4	1.95	2	1.1
24	-1.7	-2.3	1.7	2.3	2	2	0.6
25	1.6	2.6	1.6	2.6	2.1	2	-1
26	2.7	1.6	2.7	1.6	2.15	2	1.1
27	-0.3	-4.2	0.3	4.2	2.25	2	3.9
28	3	1.9	3	1.9	2.45	2	1.1
29	-3.7	-1.5	3.7	1.5	2.6	2	-2.2
30	-3.9	-1.3	3.9	1.3	2.6	2	-2.6
31	2.8	2.5	2.8	2.5	2.65	2	0.3
32	3.5	2.1	3.5	2.1	2.8	2	1.4
33	2.7	3	2.7	3	2.85	2	-0.3
34	3.2	2.8	3.2	2.8	3	2	0.4
35	2.7	3.4	2.7	3.4	3.05	2	-0.7
36	2.9	3.4	2.9	3.4	3.15	2	-0.5
37	4.2	2.5	4.2	2.5	3.35	3	1.7
38	3.4	3.9	3.4	3.9	3.65	3	-0.5
39	4.4	4.7	4.4	4.7	4.55	3	-0.3
40	5.2	4.8	5.2	4.8	5	3	0.4
41	5.7	6	5.7	6	5.85	3	-0.3
42	5.1	7	5.1	7	6.05	3	-1.9
43	-6.5	-6.5	6.5	6.5	6.5	3	0
44	8.9	4.9	8.9	4.9	6.9	3	4
45	6.9	7.6	6.9	7.6	7.25	3	-0.7
46	6.3	8.2	6.3	8.2	7.25	3	-1.9
47	8.8	6.9	8.8	6.9	7.85	3	1.9
48	8.1	8.3	8.1	8.3	8.2	3	-0.2
49	-8.5	-8.7	8.5	8.7	8.6	3	0.2
50	8	9.2	8	9.2	8.6	3	-1.2
51	9	8.3	9	8.3	8.65	3	0.7
52	9.3	8.7	9.3	8.7	9	3	0.6
53	9.9	9.5	9.9	9.5	9.7	3	0.4
54	9.6	10	9.6	10	9.8	3	-0.4

Key: LB1 = Line Bisection Test 1; LB2 = Line Bisection Test 2
N.B. Data sorted by Mean of Test 1 and Test 2 to enable Tertile Division

Diffs all UVN n=54

Mean	**0.133333**	**Bias**
		2sd
sd	**1.433428**	**2.866857**
		LoA
		-2.73352
		3.00019
Range	6.6	
Minimum	-2.6	
Maximum	4	
Count	54	

Diffs Upper tertile sort by mean (actual) error

Mean	**0.15**	**Bias**	
		2sd	
sd	**1.542057449**		**3.084114898**
		LoA	
			-2.934114898
			3.234114898
Range	5.3		
Minimum	-2.6		
Maximum	2.7		
Count	18		

Diffs Mid tertile sort by mean (actual) error

Mean	**0.111111**	**Bias**
		2sd
sd	**1.441359**	**2.8827184**
		LoA
		-2.771607
		2.9938295
Range	6.5	
Minimum	-2.6	
Maximum	3.9	
Count	18	

Diffs lower tertile sort by mean (actual) error

Mean	**0.138888889**	**Bias**
		2sd
Standard Deviation	**1.39627188**	**2.792544**
		LOA
		-2.65365
		2.931433
Range	5.9	
Minimum	-1.9	
Maximum	4	
Count	18	

APPENDIX M.

Test-retest Baking Tray Task Neglect Patients Raw Data. Limits of Agreement Calculations

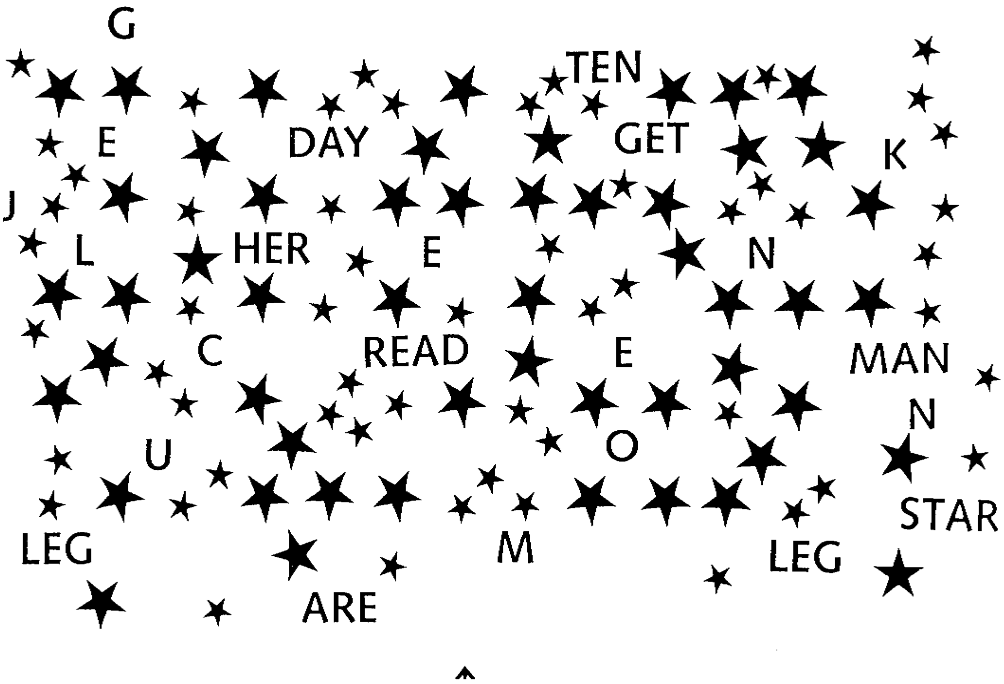
Subjects	Buns 1	Buns2	Groups	Buns on L1	Buns on L2	Mean	Diff
1	8,8	6,10	1	8	6	7	2
2	8,8	10,6	1	8	10	9	-2
3	8,8	10,6	1	8	10	9	-2
4	8,8	4,12	1	8	4	6	4
5	8,8	12,4	1	8	12	10	-4
6	8,8	0,16	1	8	0	4	8
7	9,7	10,6	1	9	10	9.5	-1
8	7,9	6,10	1	7	6	6.5	1
9	9,7	10,6	1	9	10	9.5	-1
10	9,7	6,10	1	9	6	7.5	3
11	7,9	3,13	1	7	3	5	4
12	*7,9*	*16,0*	1	*7*	*16*	11.5	-9
13	6,10	6,10	1	6	6	6	0
14	6,10	6,10	1	6	6	6	0
15	8,8	6,10	1	8	6	7	2
16	10,6	10,6	1	10	10	10	0
17	6,10	6,10	1	6	6	6	0
18	6,10	6,10	1	6	6	6	0
19	6,10	5,11	1	6	5	5.5	1
20	6,10	5,11	1	6	5	5.5	1
21	10,6	16,0	1	10	16	13	-6
22	11,5	8,8	1	11	8	9.5	3
23	5,11	7,9	1	5	7	6	-2
24	11,5	11,5	1	11	11	11	0
25	12,4	7,9	1	12	7	9.5	5
26	12,4	9,7	1	12	9	10.5	3
27	4,12	6,10	1	4	6	5	-2
28	12,4	11,5	1	12	11	11.5	1
29	4,12	4,12	1	4	4	4	0
30	4,12	3,13	1	4	3	3.5	1
31	3,13	6,10	1	3	6	4.5	-3
32	3,13	4,12	1	3	4	3.5	-1
33	3,13	0,16	1	3	0	1.5	3
34	1,15	0,16	1	1	0	0.5	1
35	0,16	8,8	1	0	8	4	-8
36	0,16	7,9	1	0	7	3.5	-7
37	*0,16*	*6,10*	1	*0*	*6*	3	-6
38	0,16	2,14	1	0	2	1	-2
39	0,16	1,15	1	0	1	0.5	-1
40	0,16	1,15	1	0	1	0.5	-1
41	0,16	0,16	2	0	0	0	0
42	16,0	16,0	2	16	16	16	0
43	16,0	16,0	2	16	16	16	0
44	0,16	0,16	2	0	0	0	0
45	0,16	0,16	2	0	0	0	0
46	0,16	0,16	2	0	0	0	0
47	0,16	0,16	2	0	0	0	0
48	16,0	16,0	2	16	16	16	0
49	0,16	0,16	2	0	0	0	0
50	0,16	0,16	2	0	0	0	0
51	0,16	0,16	2	0	0	0	0
52	0,16	0,16	2	0	0	0	0
53	0,16	0,16	2	0	0	0	0
54	0,16	0,16	2	0	0	0	0
55	0,16	0,16	2	0	0	0	0
56	16,0	16,0	2	16	16	16	0
57	0,16	0,16	2	0	0	0	0
58	0,16	0,16	2	0	0	0	0
59	0,16	0,16	2	0	0	0	0
60	0,16	0,16	2	0	0	0	0
61	0,16	0,16	2	0	0	0	0
62	0,16	0,16	2	0	0	0	0
63	0,16	0,16	2	0	0	0	0
64	0,16	0,16	2	0	0	0	0
65	0,16	0,16	2	0	0	0	0
66	0,16	0,16	2	0	0	0	0
67	16,0	16,0	2	16	16	16	0
68	0,16	0,16	2	0	0	0	0
69	0,16	0,16	2	0	0	0	0
70	0,16	0,16	2	0	0	0	0
71	0,16	0,16	2	0	0	0	0

Key: BTT1 = Baking Tray Task Test 1; BTT2 = Baking Tray Task Test 2
Group 1 = subjects not scoring zero or 16 'buns' on one side; Group 2 = subjects with either zero or 16 'buns' on one side

Differences (all)			**Diffs BTT Test1 and Test 2 n=40 Group 1**		
Mean	**-0.21127**	**Bias**	**Mean**	**-0.375**	**Bias**
		2sd			**2sd**
sd	**2.629044**	**5.258**	**sd**	**3.5132533**	**7.0265066**
		LoA			**LoA**
		-5.047			**-7.4015066**
		5.469			**6.6515066**
Minimum	-9		Minimum	-9	
Maximum	8		Maximum	8	
Count	71		Count	40	

APPENDIX N

Star Cancellation Test
[from the Behavioural Inattention Test, Wilson et al, (1987a)]



The Star Cancellation Test (not actual size; actual size is A4)

Description:

Subjects are presented with an A4 sheet of white paper containing 52 large stars, 13 randomly positioned letters and 10 short words, interspersed with 56 smaller stars.

Instructions:

"*This page contains stars of different sizes. Look at the page carefully - this is a small star. Every time you see a small star, cross it out like this*." (Illustrate by crossing out the two small stars immediately above the central arrow on the stimulus sheet.) "*I would like you to go through this page and cross out all the small stars without missing any of them*."

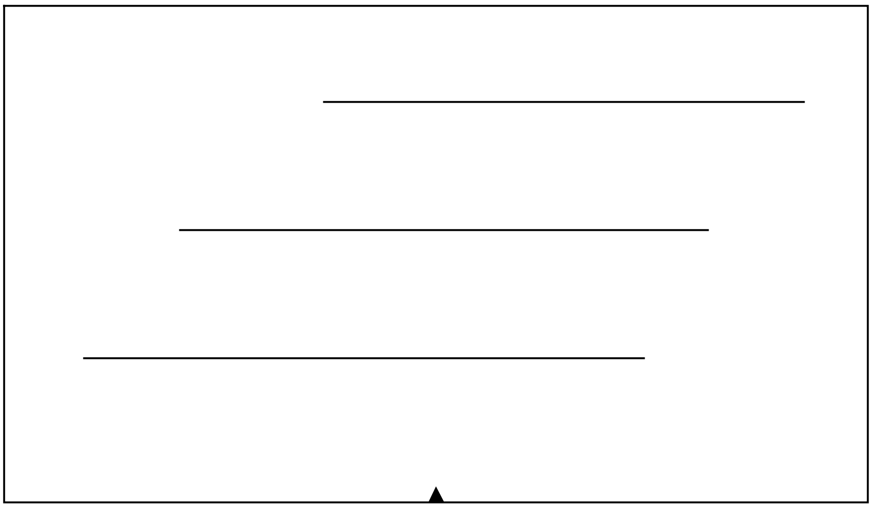
Scoring:

The total number of small stars cancelled is noted. The response sheet can be further divided into six sections by the scoring template for further analysis of omissions. Total number of stars is 54 (27 left, 27 right).

Cut-off score: based on a sample of 50 normal subjects (mean age 58.2yrs, sd 13.5) was 51, so less than 51 indicates neglect.

APPENDIX O

Line Bisection Test
[From the Behavioural Inattention Test (Wilson et al, 1987a)]



Figure….The Line Bisection Test (not actual size; actual size is A4)

Description:

Ensure patient is sitting symmetrically and is well-supported.
The test sheet of A4 (21cmx30cm) white paper consists of three horizontal black lines, each 20cm long, one to the right, one central and one to the left side of the sheet.
Place the sheet containing the 3 lines on the table in front of the patient, positioned in their mid-sagittal plane (using the arrow).

Instructions:

“ *Can you see these three lines on the page*?” (indicate the extent of each one)
“*I want you to judge where you think the middle/centre/halfway point is for each separate line, and put a pen mark on that point for each line in turn*”

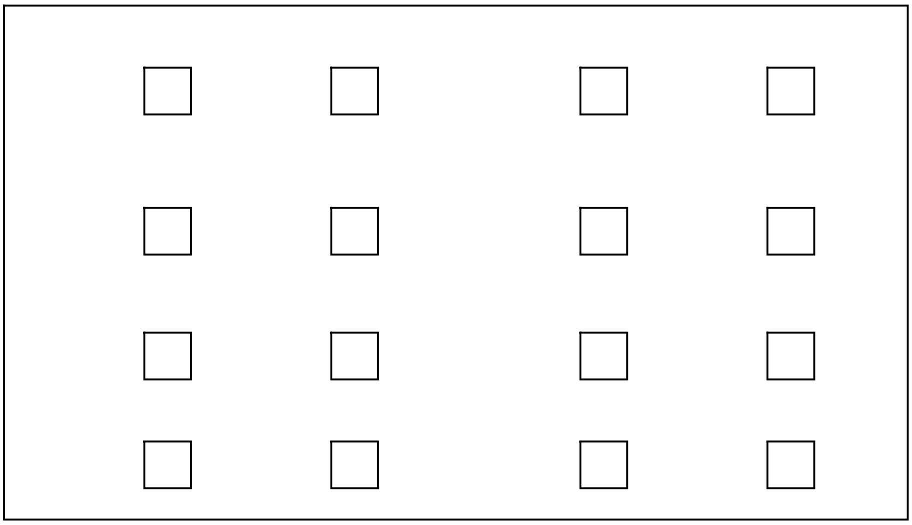
Scoring:

Errors away from true midline are measured and an average error score in centimetres is calculated; leftward errors are given a negative sign, and rightward errors a positive sign.

Cut-off score: based on a sample of 50 normal subjects (mean age 58.2yrs, sd 13.5) was an error greater than 1.4cm to left or to right, indicating neglect.

APPENDIX P

Baking Tray Task for Extrapersonal Neglect
(Tham & Tegner, 1996).



Figure…… The Baking Tray Task (not actual size)

Description:

Piece of whiteboard 75cm x 50cm (the 'baking tray'), placed centrally on a table in front of the patient, and sixteen 3.5 cm cubes of brown wood (the 'buns'), placed in a central pile just proximal to the board.

Instructions:

"*Place the blocks as symmetrically as possible as if they were buns being placed on a baking tray to be put in the oven*". All cubes must be used and the subject reminded if any are omitted.

Scoring: Count number of cubes in each half. If a cube straddles the midline, a score of ½ is counted for each half field. The ratio of 'buns' placed on the left side of the tray to the total of 16 is calculated, giving a potential range of scores of 0 to 1, with a score of 0.5 indicating normal symmetry, a score of 0 indicating all 'buns' are on the right side, a score of 1 indicating all buns are on the left side of the 'tray'.

Cut-off: score: Normals (based on 30 controls mean age 52.8 yrs, SD 12.1, range 39-82)- no more skewed than 7 in one half field and 9 in the other; so cut-off would be 6 or less 'buns' on one side of the 'tray.

APPENDIX Q

Canadian Neurological Scale.
(Cote et al, 1989)

<u>Mentation</u>

Level of Consciousness	Alert	3.0
	Drowsy	1.5
Orientation	Oriented	1.0
	Disoriented/NA	0.0
Speech	Normal	1.0
	Expressive deficit	0.5
	Receptive deficit	0.0

<u>Motor Function: weakness (no comprehension deficit)</u>

Face	None	0.5
	Present	0.0
Arm, proximal	None	1.5
	Mild	1.0
	Significant	0.5
	Total	0.0
Arm, distal	None	1.5
	Mild	1.0
	Significant	0.5
	Total	0.0
Leg, proximal	None	1.5
	Mild	1.0
	Significant	0.5
	Total	0.0
Leg, distal	None	1.5
	Mild	1.0
	Significant	0.5
	Total	0.0

(Total Score 11.5, omit final section)

<u>Motor Response *(separate section for pts with comprehension deficit, instead of above section))*</u>

Face	Symmetrical	0.5
	Asymmetrical	0.0
Arms	Equal	1.5
	Unequal	0.0
Legs	Equal	1.5
	Unequal	0.0

APPENDIX R

Test for Light Touch (Nottingham Sensory Assessment Scale).
(Lincoln et al., 1998)

Using a piece of **cotton wool**, the patient's arm and leg are touched briefly in random order (each part 3 times) and the patient asked to say "yes" when they feel the touch and to say where they are being touched.

The following areas are tested, and each is also compared to the good side ("*does it feel the same*?")

TEST FACE, HAND, WRIST, ANKLE AND FOOT FIRST
If hand and wrist both score 2 give 2's for elbow, shoulder and trunk
If ankle and foot both score 2's give 2's for hip and knee

Face	**Ankle**
Hand	**Foot**
Wrist	Knee
Elbow	Hip
Shoulder	
Trunk	

Scoring:

Normal = **2** (feel it, locate it and say same as good side)
Impaired = **1** (correct on some but not all)
Absent = **0** (fails to identify the test sensation on three occasions)
Unable to test = 9

APPENDIX S

Test for Proprioception (Nottingham Sensory Assessment scale) (Lincoln et al., 1998)

All three aspects of movement are tested: appreciation of movement, its direction and accurate joint position are assessed simultaneously. The limb on the affected side of the body is supported and moved by the examiner in various directions but movement is only at one joint at a time. The patient is asked to mirror the change of movement with the other limb. Three practice movements are allowed before the blindfolding. The reverse procedure, supporting and moving the unaffected arm, is attempted if there is a good recovery of movement in the affected limb. Patient is blindfolded.

The upper limb is tested in sitting and the lower in supine lying

If hand and wrist score 3 give 3's for elbow, shoulder and trunk

If ankle and foot score 3 give 3's for knee and hip

Hand	**Ankle**
Wrist	**Foot**
Elbow	Knee
Shoulder	Hip

Scoring:

0 = Absent	**(no appreciation of movement taking place**
1 = Some appreciation	**(pt indicates on each occasion that a movement takes place but the direction is incorrect)**
2 = Direction of mvt sense	**(Pt able to appreciate and mirror the direction of the test mvt each time, but inaccurate in its new position)**
3 = Jt position sense	**(Accurately mirrors test mvt to within 10 degs of new pos)**
9 = Unable to test	

APPENDIX T

The Barthel Index (Original Version)
(Mahoney and Barthel, 1965)

		With Help	Independent
1.	Feeding (if food needs to be cut up=help)	(5)	(10)
2.	Moving from wheelchair to bed & return (includes sitting up in bed)	(5-10)	(15)
3.	Personal toilet (wash face, comb hair, shave, clean teeth)	(0)	(5)
4.	Getting on & off toilet (handling clothes, wipe, flush)	(5)	(10)
5.	Bathing self	(0)	(5)
6.	Walking on level surface	(10)	(15)
	(or if unable to walk, propel wheelchair) *score only if unable to walk	(0*)	(5*)
7.	Ascend and descend stairs	(5)	(10)
8.	Dressing (includes tying shoes, fastening fasteners)	(5)	(10)
9.	Controlling bowels	(5)	(10)
10.	Controlling bladder	(5)	(10)

Scores for each category are in brackets. See over page for definition and discussion of scoring. **Maximum score is 100** (patient able to feed, dress, get out of chair and bed, bath/shower, go up and down stairs, walk at least 50 yards; he may not be able to live alone; he may not be able to cook, keep house, and meet the public, but he is able to get along without attendant care).

APPENDIX T

Definition and Discussion of Scoring

1. **Feeding**

10 = Independent. Pt can feed himself from a tray or table when someone put the food within his reach. He may use an assistive device if needed, cut up food, use condiments, etc. Must accomplish in reasonable time.

5 = Some help necessary

2. **Chair to bed transfers**

15 = Independent in all phases of activity. If W/C can safely approach bed, lock brakes, lift footrests, move safely to bed, lie down, sit up on side of bed, change position of W/C if necessary, to transfer back into it safely, and return to W/C

10 = Either some minimal help is needed or pt needs reminding or supervising for safety on one or more parts.

5 = Pt can come to a sitting position without the help of a second person but needs to be lifted out of bed, or transfers with a great deal of help.

3. **Personal Toilet**

5 = Can wash hands & face, comb hair, clean teeth, shave, put on make-up, but need not braid or style hair.

4. **On and Off Toilet**

10 = Able to get on and off, fasten and unfasten clothes, prevent soiling of clothes, use paper, without help. May use wall bar for help. If bedpan, must place on chair, use and empty and clean it!

5 = Needs help because of imbalance, handling clothes or toilet paper

5. **Bathing Self**

5 = Bath or shower and do all steps involved without presence of another

6. **Walking on a level surface**

15 = Can walk at least 50 yards with no help or supervision. May use assistive device except rollator.

10 = Needs help in any of above but can walk 50 yards with a little help.

6a. Propelling a W/C (if pt cannot walk)

5 = Manoevre chair to table, bed, toilet etc and push it at least 50 yards

7. **Stairs**

10 = Able to go up and down a flight. May use walking aid if needed, and carry it if he does use one.

5 = Needs help or supervision with any part

8. **Dressing and Undressing**

10 = Able to put on and remove and fasten all clothing, tie shoes. Special clothing may be used

5 = Needs help but must do at least half of work himself in reasonable time

9. **Continence Bowels**

10 = Full control, no accidents

5 = Occasional accidents

10. **Continence Bladder**

10 = Day and night no accidents

5 = Occasional accidents or can't get to toilet in time or wait for bedpan. Needs help with any external device.

A score of **0** is given in all above when pt unable to meet criteria as defined.

APPENDIX U

The Rivermead Mobility Index
(Collen et al, 1991)

	Score	*Comment*
1.Turning over in bed *Do you turn over from your back to your side without help?*	Yes=1 No=0	
2.Lying to sitting *From lying in bed, do you get up to sit on the edge of the bed on your own?*	Yes=1 No=0	
3.Sitting balance *Do you sit on the edge of the bed without holding on for 10 seconds?*	Yes=1 No=0	
4.Sitting to standing *Do you stand up (from any chair) in less than 15 secs, and stand there for 15 secs (using hands, and with an aid if necessary)?*	Yes=1 No=0	
5.Standing unsupported *Observe pt doing this for 10 secs.*	Yes=1 Unable=0	
6.Transfer *Do you manage to move eg. from bed to chair and back without any help?*	Independently=1 No/needs help=0	
7.Walking inside, with an aid if needed *Do you walk 10m, with an aid or furniture if necessary, but with no standby help?*	Yes=1 No-0	
8.Stairs *Do you manage a flight of stairs without help?*	Yes=1 No=0	
9.Walking outside (even ground) *Do you walk around outside, on pavements without help?*	On my own=1 No/with help=0	
10.Walking inside, with no aid *Do you walk 10m inside with no caliper, splint, aid or use of furniture, and no standby help?*	Yes=1 No=0	

APPENDIX U

The Rivermead Mobility Index (continued)

	Score	***Comments***
11.Picking off floor *If you drop something on the floor, do you manage to walk 5m, pick it up, and then walk back?*	Yes=1 No=0	
12.Walking outside (uneven ground) *Do you walk over uneven ground (grass, gravel, dirt, snow, ice, etc.) without help?*	On my own=1 No/with help=0	
13.Bathing *Do you get in/out of bath or shower unsupervised and wash self?*	Yes=1 No=0	
14.Up and down four steps *Do you manage to go uo and down four steps with no rail and without help, but using an aid if necessary?*	Yes=1 No=0	
15.Running *Do you run 10m without limping in 4 secs (fast walk is acceptable)*	Yes=1 No=0	

Total score possible is 15. Pt is asked above questions, and *observed for item 5.*

APPENDIX V

ETHICS APPROVAL

1. Departmental Research Ethics Committee (DREC) for Survey Study
2. Local Research Ethics Committee (LREC. Project 689)
3. Local Research Ethics Committee (LREC. Project 1090)

KEELE UNIVERSITY DEPARTMENT OF PHYSIOTHERAPY STUDIES

STUDENT APPLICATION TO DEPARTMENTAL RESEARCH ETHICS COMMITTEE FOR APPROVAL OF PROPOSED RESEARCH INVOLVING HUMAN SUBJECTS

KEELE UNIVERSITY DEPARTMENT OF PHYSIOTHERAPY STUDIES
STUDENT APPLICATION TO DEPARTMENTAL RESEARCH ETHICS COMMITTEE FOR
APPROVAL OF PROPOSED RESEARCH INVOLVING HUMAN SUBJECTS

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PLEASE REPLY TO: RESEARCH ETHICS COMMITTEE, NURSES HOME, ROYAL INFIRMARY, HARTSHILL, STOKE-ON-TRENT, ST4 7PS

[redacted]

73 PRNT 1247

APPENDIX W

PUBLICATION

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Evaluation of a test battery for hemineglect in elderly stroke patients for use by therapists in clinical practice

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Hemineglect is not a single entity, and the syndrome has a number of sensory and motor manifestations. The purpose of this study was a) to measure performance of healthy elderly subjects on a battery of validated tests for hemineglect in order to establish appropriate cut-off scores and b) to assess performance of a large sample of elderly stroke patients in a rehabilitation unit, using the same battery. Tests were selected to identify rate of occurrence of hemineglect in visuo-spatial, representational, pre-motor and personal modalities. The battery was administered to 107 patients with right or left sided brain damage and 43 age-matched controls. Results showed that 39.2% of the patient sample (78.6% of which had right-sided brain damage), were 'neglecters', scoring below cut-off in one or more tests. Star Cancellation and Line Bisection showed the highest relative sensitivity for visuo-spatial neglect (76.4%). The 'Baking Tray Task', the 'Exploratory Motor Task', and utilisation of common objects test for personal neglect are additionally suggested for use in the clinical situation. 'Copying a Daisy' and clock-drawing are not recommended due to low sensitivity and subjectivity in scoring respectively.

Keywords: Hemineglect/neglect, stroke, elderly, directional hypokinesia, tests

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1. Introduction

Hemineglect manifests as an inability to either pay attention or respond to stimuli located in "selective parts of space" [41], commonly objects or people on the patient's contralesional side. It is not attributable to a primary sensory or motor deficit, since many patients with neglect do not have concomitant sensory and motor deficits [41]. The prevalence of hemineglect is extremely variable and depends on the nature and timing of tests used, patient selection, and side of the lesion. Bowen and colleagues [9] found frequencies ranging from 12% to 100% in 30 studies that prospectively recruited patients with right-sided brain damage, and frequencies of 0% to 76% in the 17 studies that recruited patients with left-sided brain damage. The presence of hemineglect may adversely affect patients' ability to gain maximal benefit from therapeutic rehabilitation [12,28,37]. Hemineglect has been found to be more severe and longer lasting following right-sided brain damage [21]. This is consistent with the right hemisphere being dominant for spatial attention [10, 40].

It is widely accepted that neglect can manifest in a number of sensory (input) and motor (output) modalities, occurring in personal space, reaching space, and beyond reaching space [35]. Input or perceptual types of neglect, considered to be disorders of inattention, include visuo-spatial and representational (mental imagery) manifestations. In contrast, output modalities are considered to be disorders of action and intention [25], and include two types. Motor neglect is the failure to use the affected limb despite minimal or no paralysis. Directional hypokinesia is a reduced ability to move into contralesional space, even when the unaffected limb is used [42]. Many aspects of neglect can be observed clinically [41]. For example, when the head and eyes are deviated to the ipsilesional side, objects and people on the contralesional side may be ignored.

Formal quantitative testing is necessary to identify the severity and type of neglect. Testing may help the clinician to select appropriate treatment strategies and monitor the effectiveness of rehabilitation for neglect.

Since neglect is multi-modal and multi-faceted, no single test can be used for comprehensive diagnosis. For precision in diagnosis a battery that includes tests for several different modalities of neglect is recommended. Any battery should include tests that are: (1) validated; (2) sensitive; (3) simple to administer in the clinical situation; (4) easy to score and interpret; and, (5) should not require complex or specialised equipment.

2. Test batteries

One of the most well known test batteries is the Behavioural Inattention Test or BIT [48]. This consists of six 'conventional' pencil-and-paper tests (line crossing, letter and star cancellation, figure and shape copying, line bisection and representational drawing), and nine 'behavioural' tests (picture scanning, telephone dialling, menu-reading, telling and setting the time, coin sorting, address and sentence copying, map navigation and card sorting). This battery was developed specifically to measure visuo-spatial neglect in reaching space [41]. The BIT was validated on 50 controls and 80 stroke patients, including patients with left and right-sided brain damage. The average age of patients and controls was between 54 and 58 years. This age-range does not closely reflect the average age of a typical stroke population, as three-quarters of all first strokes occur in people over 65 years of age [13], 50% of all first strokes being in those aged over 75 years [8]. The 'behavioural' sub-tests of the BIT were included to enable the clinician to assess more functionally relevant activities, and have been shown to relate to actual functional performance [23]. However, administration of the entire BIT can be time consuming (the full test can take around 45 minutes), and patients, particularly elderly patients, in the acute stage post-stroke, may be unable to concentrate sufficiently.

Because of the time needed to administer the full BIT, a shorter version has been validated [45], and the test sample used had an average age of 72 years. This modified battery may be more appropriate than the original BIT for use with elderly patients, although it is still restricted to testing neglect in the visuo-spatial modality. The Star Cancellation Test, used in the modified battery, was found to be the most sensitive.

Black and co-workers [7] evaluated a 'bedside battery' of five tests (line drawing, line bisection, line and letter cancellation and visual picture search) on 42 elderly stroke patients and 22 age-matched controls (precise age was not given). In this study line bisection was found to be the most sensitive test. Again, the tests in this battery are confined to the evaluation of visuo-spatial neglect in reaching space. Furthermore, as Pizzamiglio et al. [39] point out, cancellation and drawing tasks, also line bisection, require a motor response into contralesional space in addition to visual search [36].

Thus batteries including such tests do not clearly distinguish motor from perceptual forms of neglect. Tests which can distinguish these aspects are based on subjects making a motor response to a stimulus, by reaching across into neglected hemispace with the unaffected upper limb, in a situation where a visual response to the stimulus is not required. Tests include a pulley system for line bisection [6], a mirror system [46], or the more simple to administer exploratory-motor task [32].

Some test batteries have included tests for other modalities of neglect. Zocolotti and Judica [49] developed a battery which can be used for the functional evaluation of neglect in personal (e.g. asymmetry in using a comb, razor etc.) and reaching space (e.g. card dealing, serving tea and description of objects in a picture). This battery can be criticised because, although some tasks are restricted to the visual modality (description of objects in a picture), other tasks, for example serving tea, additionally require a motor response into contralesional space.

Pizzamiglio et al. [39] combined the six 'conventional' sub-tests of the BIT with a test for personal neglect [49], and a task with no motor requirements, the Wundt-Jastrow area illusion test [34], in which a verbal response only is accepted. This battery was used on a large sample of right brain damaged subjects, mean age 59 years. However, not all of the subjects tested had suffered a stroke, and so results may not be comparable with studies on neglect in stroke patients.

Kinsella and colleagues [30] used a battery combining standard shape and circle cancellation tasks, line bisection, spatial imagery tasks (for representational neglect) including clock drawing and a tactile maze, and tests for bilateral simultaneous extinction in visual, tactile and auditory modes. They applied the battery to 22 stroke patients with neglect, 18 without neglect, all with right-sided brain damage, and 20 age-matched controls. Average age of all groups was below 70 years. Thus the sample was not representative, either in terms of the average age of a typical stroke population, or in representing both right and left-sided damage.

None of the above batteries have included a sample combining a large number of elderly stroke patients over 70 years old, with both right and left sided brain damage, which might reflect clinical reality for many therapists. Moreover, although several batteries include tests that evaluate types of neglect in addition to visuo-spatial manifestations, none have included tests that might differentiate visual neglect from a reduced ability to move into contralesional space (known as directional hypokinesia or pre-motor neglect). It may be important to distinguish different modalities of neglect, in order to design appropriate rehabilitation strategies to target specific problems. Therefore an 'ideal' test battery should include a range of validated tests suitable for identifying most of the major manifestations of neglect (visuo-spatial, representational, and directional hypokinesia), also neglect occurring in personal and reaching space. There are currently no validated tests for neglect of far (beyond reaching) space [41], although a bedside test has been described [43], nor for motor (as opposed to pre-motor) neglect, although, again, a bedside test has been described [3].

The purpose of this study was a) to measure performance of healthy elderly subjects on a battery of tests for hemineglect in order to establish appropriate cut-off scores and b) to assess performance of a large sample of elderly acute stroke patients using the same battery. A battery of seven tests was administered to elderly stroke patients with right and left sided brain damage, and to a sample of age-matched controls. The battery included validated tests for visuo-spatial neglect within extrapersonal or reaching space, directional hypokinesia (inability or slowness to move the non-affected hand across into contralesional space), representational neglect, and personal neglect. No validated test for motor neglect, or neglect in far space, is currently available, and thus could not be included. An additional aim was to evaluate the clinical usefulness of the test battery in relation to test sensitivity, and simplicity of application in the clinical situation.

3. Rationale for choice of tests

The tests included were:

- The Star Cancellation Test (visuo-spatial neglect)
- Line Bisection (visuo-spatial neglect)
- Copy-a-Daisy (visuo-spatial neglect)
- The Baking Tray Task (visuo-spatial neglect)
- Draw-a-Clock (representational neglect)
- Exploratory Motor Task (directional hypokinesia or pre-motor neglect)
- Personal Neglect Test (personal neglect)

The Star Cancellation Test (SCT), copying-a-daisy, line bisection [24] and the Baking Tray Task or BTT [47] were all chosen to assess visuo-spatial neglect. The decision to include several tests for visuo-spatial neglect within reaching space was because double dissociations (neglect present on one test but not others) have been shown to occur in this restricted modality. However, the first study [19] to demonstrate this phenomenon for line bisection and Star Cancellation included a sample of only six stroke patients. The SCT and copy-a-daisy are both sub-tests of the BIT. The SCT is considered to be particularly sensitive [22, 33]. The 'Baking Tray Task' (BTT) was recently developed, and is described [47] as a quick yet sensitive test, which may not be subject to practice effects and, therefore, could be useful for repeated measurements. Drawing a clock-face from memory is considered to test for representational neglect [1,30]. Drawing a clock and copying a daisy were included because they are popular in the clinical setting [2]. Directional hypokinesia, reflecting absent or reduced motor exploration in contralesional hemispace, was assessed using the exploratory motor (EM) task [32]. Personal neglect was assessed by the 'utilizing common objects test' [49]. Further evaluation of the recently advocated BTT and EM task will also be provided.

4. Materials and methods

4.1. Subjects

4.1.1. Patient sample

One hundred and fifty three elderly stroke patients, admitted consecutively to a rehabilitation stroke unit from the acute stroke unit during a 12-month period, were screened for inclusion in the study. The side of the lesion was determined by CT scan in all cases. Forty six patients were unable to be tested (eight were too ill, eight were confused, seven were blind or had vision too poor for adequately seeing the test materials, and 23 had severe aphasia and were unable to understand test instructions). The excluded group consisted of 23 men and 23 women, 10 with right sided brain damage (RBD), 34 with left sided brain damage (LBD) and two with bilateral damage.

One hundred and seven patients were suitable for testing and all agreed to participate. There were 56 men and 51 women, of whom 61 had RBD and 46 had LBD. Mean age was 75.2 years (sd 7.1, range 60–91). All were tested within 9 weeks post-stroke ($\overline{x}$ 22.3 days, sd 11.9, range 3–61).

4.1.2. Control sample

Forty-three normal elderly control subjects (13 men and 30 women) were recruited to the same study in order to establish cut-off scores for each test. Control subjects were all spouses of patients in the study. The sample was one of convenience, as only spouses who happened to be visiting the hospital during the time the researcher was undertaking patient testing, and who agreed to participate, were included. Of all those approached, only one subject, a male, did not wish to participate. The mean age of this group was 75.19 years (sd 6.87, range 65–89).

The study received ethical approval from the Local Research Ethics Committee (North Staffordshire Hospitals). All patients and normal subjects were given written and verbal explanations about the study and all gave verbal informed consent before taking part.

4.2. Test administration and scoring methods

All testing of patients and normal subjects took place in a quiet side room on the stroke unit. Administration of the entire battery took approximately 20 minutes per subject. The same clinician administered all the tests, using standardised instructions. The order of test presentation was randomised. None of the tests stipulated a time limit. The paper-and-pencil tests (SCT, line bisection, clock drawing and daisy copying) were on separate sheets of A4 white paper. Each stimulus sheet had a centralised arrow to allow it to be positioned on a table in front of the subject, at a viewing distance of approximately 45 cm, central to their body midline. The clinician was seated directly in front of the subject. Subjects were allowed to move their head and eyes but not the sheet of paper.

4.3. The Star Cancellation Test

This consisted of a page containing 52 large stars, 10 short words and 13 letters, randomly positioned, with 56 small stars interspersed. Subjects were instructed to cross out, with a black pen, all the small stars across the page. The tester demonstrated an example by crossing out the two central stars. The maximum possible number of stars for the patient to cross was 54 (27 left and 27 right). The total actually crossed was counted and a Laterality Index [16] or star ratio was also calculated from the ratio of stars cancelled on the left side of the page to total number of stars cancelled. Scores between 0 and 0.46 indicated left-sided neglect, and 0.54–1 indicated right-sided neglect.

4.4. The Line Bisection Test

Rather than using only one single line for bisection, Friedman [14] recommended use of multiple lines. For line bisection (LB), each subject in this study was asked to bisect a centrally positioned black horizontal line 20 cm long and 0.15 cm wide, one at a time, on 24 separate pages. Subjects were instructed to "put a pen mark on the line, where you think the centre or middle of the line would be". The distance away from the true midline of the mark made by subject, in centimetres, across all 24 lines, was averaged to obtain a mean error score. Bisections to the right of true midline were counted as positive, and those to the left as negative.

4.5. Copy-a-Daisy

The subject was presented with a drawing of a daisy flower positioned on the left side of a sheet of paper for normal subjects and patients with RBD, and positioned on the right side for patients with LBD. They were instructed to copy the daisy as well as they could onto the blank half of the sheet. Scoring used a scale of 1-4 based on the BIT [48] to reflect lateralised omissions. Scoring was as follows:

4 = a complete and normal drawing

3 = a drawing with some omissions in detail but not clearly lateralised

2 = lateralised omissions of petals and/or leaf on one side

1 = major lateralised omissions (e.g. only one side of the flower and leaf drawn, maybe less).

4.6. The Baking Tray Task

The equipment used was a piece of whiteboard (75 cm × 50 cm), which was the 'baking tray', and sixteen 3.5 cm cubes of brown wood, which were the 'buns'. The baking tray was a little smaller than the original (100 cm × 75 cm) tray size, but was considered adequate. Tham and Tegner [47] found that using an A4 sized tray was only slightly less sensitive. The tray used in this study was considerably larger than A4 size, but was deemed a more practical size than the original. Subjects were asked to "place the blocks as symmetrically as possible as if they were buns being placed on a baking tray to be put in the oven". All 16 cubes had to be used and subjects were reminded if any were omitted. The number of cubes in each half of the board was counted. If a cube sat astride the midline, a score of 1/2 was counted for each half area. For ease of data analysis, the BTT ratio, of 'buns' placed on the left side of the board to the total of 16, was calculated.

4.7. Draw-a-Clock

The subject was presented with a blank sheet of paper and asked to draw from memory a large clock face with all the numbers. Scoring was based on the BIT [48] but the range was expanded from 1–3 to 1–4 in order to increase sensitivity, as follows:

4 = a normally drawn, symmetrical clock face with no omissions

3 = a symmetrical drawing with some omissions or numbers omitted or reversed

2 = an incomplete drawing with more numbers on the one side than the other

1 = numbers only drawn on one side of the clock-face, even though a whole circle may have been drawn.

4.8. Exploratory Motor Task

The EM task was modified from that used by Maeshima and co-workers [32] who used a board (47 cm × 34 cm), and marbles. Equipment used here was the same board used for the BTT and the same 16 cubes. The task was carried out with the subject blindfolded. The 16 cubes were spaced out evenly on the board with four in the top right quarter, four in the top left quarter, four in the bottom right quarter and four in the bottom left quarter. Subjects were not informed about the number or position of blocks. Subjects were instructed to "pick up the blocks on the board in front of you one by one and move them off the board to one side without sweeping" (right side for normal subjects and patients with RBD, left side for patients with LBD). When the patient thought they had removed all the cubes from the board, they had to say "finished". Cubes left on the board were regarded as errors, considered to demonstrate directional hypokinesia (patients were unable to make sufficient movements into neglected hemispace in order to manually find all the cubes).

4.9. Personal Neglect

To assess for personal neglect (PN), subjects were presented with 3 objects, one at a time: (1) comb; (2) razor (for men), powder compact (for women); and (3) spectacles for both. Subjects were asked "show me how you use . . ." to demonstrate how they would use each object. Scoring used an observational scale of 0–3 used by Zoccolotti and Judica [49] which assessed the extent to which the subject demonstrated neglect for the contralesional side of the head. Scoring was as follows:

0 = normal (subject combs/shaves/powders etc. on both sides of face/head without obvious asymmetries, or at least performance can be explained in terms of their arm weakness)

1 = slight deficit (subject uses object on both sides but completes affected side only after an obvious hesitation; puts on spectacles incorrectly but corrects).

2 = medium deficit (subject does activity only on non-affected side of face or head and clearly omits opposite side; spectacles are put on incorrectly but lenses are centred on the eyes)

3 = severe deficit (subject does activity only on extreme non-affected side; puts on spectacles incorrectly on affected side and lenses are not centred on the eyes)

Each of the three objects is scored on the 3-point scale. Thus a maximum abnormal score would be 9 (score of 3 for each object).

5. Data analysis

Descriptive statistics (means, standard deviations, ranges and percentages) were used to describe performance. Differences between groups were compared using Student's t-test (unrelated) or chi-square analysis. An alpha level of 0.01 (two-tailed) was chosen. Spearman's correlation was used to compare age and test performance with an alpha level of 0.01 (one-tailed) chosen due to the number of comparisons.

6. Results

6.1. Performance of the control group and derivation of cut-off scores

The performance of the 43 normal elderly control subjects was as follows:

Table 1
Comparative data between non-neglecters and neglecters (patient group)

	Non-neglecters ($n = 65$, 60.8%)	Neglecters ($n = 42$, 39.2%)
Mean age (years)	75.3 (sd 7.7, range 60–91)	75.2 (sd 6.2, range 64–87)
Mean days post-stroke	21.2 (sd 11.3, range 3–58)	23.9 (sd 12.6, range 4–61)
Ratio Male : Female	33 : 32 (50.8% : 49.2%)	23 : 19 (54.8% : 45.2%)
Ratio RBD : LBD*	28 : 37 (43.1% : 56.9%)	33 : 9 (78.6% : 21.4%)

*RBD = right-sided brain damage, LBD = left-sided brain damage.

SCT – No control subject in this study cancelled less than 51 stars out of a maximum of 54 stars. This cut-off equated with that given by Wilson and colleagues [48].

LB – No control made an error greater than 0.98cm to the right or 0.95cm to the left of the true midpoint; thus a cut-off score of 1cm to right or left was used, and was comparable to previous findings [14,48].

Clock-Drawing and Daisy-Copying – No control scored less than 3; a score of less than 3 was deemed abnormal.

BTT – No controls placed 'buns' more asymmetrically than 7 on one side and 9 on the other, similar to the findings of Tham and Tegner [47]. Therefore, if 'buns' were more skewed than a 7 : 9 ratio, performance was considered abnormal.

EM – Controls made no errors, as found by Maeshima and co-workers [32]. Therefore one block or more left on the board counted as directional hypokinesia.

PN – Controls performed symmetrically and made no errors, as found by Zocolotti and Judica [49]. Thus a score of 1 or more indicated personal neglect.

6.2. Performance of the patient group

Of the 107 patients tested, 65 (60.8%) scored at or above cut-off on all tests and were defined as 'non-neglecters'. Forty-two (39.2%) scored below the cut-off score in at least one of the tests and were defined as 'neglecters'. Table 1 presents the descriptive statistics for age, time post-stroke, gender distribution, and side of lesion for both groups.

There were no significant differences between the neglect group and the non-neglect group in age ($t = -0.07$, $p = 0.946$), gender distribution ($\chi 2 = 0.163$, $p = 0.69$) and days post-stroke ($t = 0.365$, $p = 0.72$). There was a significant relationship between side of brain damage and presence of neglect ($\chi 2 = 13.12, p < 0.001$), with a much higher proportion of neglecters having RBD than LBD (Table 1).

Table 2 provides the tests failed by each of the 42 patients scoring below cut-off on any one test, in descending order. Only one patient scored below cut-off on all seven tests in the battery, four (9.5%) failed six tests, three (7.1%) failed five tests, four (9.5%) failed four tests, eight (19%) failed three tests, twelve (28.6%) failed two tests, and ten (23.8%) failed just one test. There was no relationship between age and number of tests failed ($r = -0.02$), or between number of days post-stroke and number of tests failed ($r = 0.04$).

Star Cancellation Test – 29 of the 42 neglecters (69%) scored below cut-off with a mean score of 30.7 (sd 15.4, range 4–50). Calculation of the Laterality Index showed that 20 of 29 had left sided neglect (all with RBD), 4 had right sided neglect (all with LBD), and 5 were non-lateralised (three with RBD and two with LBD).

Line Bisection – 29 of the 42 neglecters (69%) scored below cut-off. Of these, 26 had RBD and made rightward errors ($\overline{x}$ 2.25 cm, sd 1.24, range 1.08–6 cm), and three had LBD and made leftward errors ($\overline{x}$ -1.26 cm).

Baking Tray Task – 21 subjects (50%) had abnormal scores. Eighteen of the 21 had RBD and displayed left omissions ranging from 5L : 11R to 0L : 16R. Three of the 21 had LBD and displayed right omissions ranging from 11L : 5R to 16L : 0R. Two of the 21 subjects had abnormal scores solely with this test; one had RBD (score 5L : 11R) and one had LBD (score 11L : 5R).

Draw a Clock – 19 subjects (16 RBD, 3 LBD) or 45% scored below cut-off (modal score of 2). No subject failed to complete the whole circle of the clock-face; only numbers were omitted or transposed.

Copy a Daisy – 11 subjects (26%) had abnormal scores (10 RBD, 1 LBD) with a modal score of 1.

Exploratory Motor task – only four subjects (9.5%) omitted blocks (between 2 and 8 remained on the neglected half of the board) during motor exploration whilst blindfolded, indicating directional hypokinesia. All four had RBD and additionally demonstrated visuospatial neglect; two also had personal neglect.

Personal Neglect – Seven subjects (16.7%) showed some degree of PN, scoring between 1 and 9. All 7 had RBD, and all showed neglect in at least two other tests.

The SCT and LB tests showed some double dissociation, with 18 of the 42 neglecters scoring below cut-off on both tests (mean star score 27, mean bisection error

Table 2
Distribution of tests in the battery in which patients scored below cut-off (neglecters)

Subject number ($N = 42$)	Age (yrs)	Side of brain lesion	SCT	LB	Copy a Daisy	Draw a Clock	BTT	EM	PN
7	66	R	*	*	*	*	*	*	*
2	77	R	*	*	*	*	*		*
8	77	R	*	*		*	*	*	*
11	78	R	*	*	*	*	*		*
27	72	R	*	*	*	*	*		*
12	70	R	*	*	*		*	*	
29	85	R	*	*	*	*	*		
32	68	R	*	*	*		*	*	
16	87	L	*		*	*	*		
21	73	R	*	*		*	*		
25	83	R	*		*	*	*		
36	64	R	*	*	*				*
1	82	R	*	*		*			
9	70	R	*	*		*			
10	73	R	*	*			*		
15	77	R	*	*			*		
17	73	R		*			*		*
40	69	R	*		*		*		
41	77	R	*	*			*		
24	76	R	*	*		*			
4	84	L	*				*		
5	69	L	*			*			
6	79	R		*		*			
13	84	R		*		*			
14	78	L		*		*			
18	81	L	*	*					
22	82	R		*			*		
23	75	R	*	*					
28	87	R	*			*			
34	67	R		*		*			
37	68	R	*				*		
42	70	L		*		*			
3	67	R	*						
19	74	L					*		
20	73	R		*					
26	69	L	*						
30	76	R		*					
31	84	R	*						
33	72	R		*					
35	74	L	*						
38	67	R					*		
39	76	R		*					

SCT = Star Cancellation Test; LB = Line Bisection Test; BTT = Baking Tray Task; EM = Exploratory Motor Task; PN = Personal Neglect Test.

2.73 cm). Nine (5 RBD, 4 LBD) had abnormal star scores ($\overline{x}$ 35, sd 13.8, range 16–48) but normal LB, while eleven (9 RBD, 2 LBD) had abnormal LB ($\overline{x}$ 1.27 cm, sd 0.12, range 1.09–1.42 cm) but normal SCT. Two were unable to complete LB and two had normal scores on both.

Relative sensitivity for the four different neglect tests in the visuo-spatial dimension is given in Table 3. To estimate relative sensitivity, detection performance on each test was compared with that on the other three tests, using the formula:

$$\text{sensitivity} = \text{true positives}/(\text{true positives} + \text{false negatives})$$

As there exists no criterion measure for neglect, 'true positives' were taken as the number of patients who scored below the cut-off on at least one of the four tests for visuo-spatial neglect; 'false negatives' were taken as the number of patients scoring at or above cut-off on the test in question.

The correlation matrix between age and the tests for neglect is presented in Table 4. There was no significant

Table 3
Relative test sensitivity for visuo-spatial neglect

Test	Relative sensitivity
Star Cancellation	76.4%
Line Bisection	76.4%
Baking Tray Task	66.7%
Copy a Daisy	57.5%

relationship between age and test performance. All the tests of visuo-spatial neglect were significantly inter-correlated, except for clock drawing, and daisy copying which only correlated significantly with the BTT ratio. Tests for EM and PN were not included in this analysis due to small numbers identified with these modalities of neglect.

7. Discussion

7.1. Rate of occurrence of hemineglect

Findings of neglect occurrence are comparable with previous studies [1,22,44,48]. Although subjects with LBD were included in this study, a number (30% of the total sample) were still not testable, largely due to aphasia. LBD patients remain under-represented [26]. Overall rate of neglect occurrence in this study was 39.2%, with 79% having right-sided brain damage. This finding compares with the 37.5% found using the BIT [48], on a smaller sample of 80 patients, average age 56 years, with acute stroke. Stone and colleagues [44] found a much higher occurrence of visual neglect (82% in RBD and 49% in LBD) in a sample of 171 acute stroke patients of mean age 72.4 years, using a modified BIT. This higher figure may be due to the sample being tested at only 2–3 days post-stroke. Mild neglect in some may have resolved spontaneously had they been tested at a later time post-stroke. In the present study, the mean time of testing was 22 days post-stroke. However, no relationship was found between number of days post-stroke and number of tests failed. A much lower figure (23%) was reported by Pedersen et al. [38] in a large sample of 602 acute stroke patients. However, they only used a circle cancellation task to assess visuo-spatial neglect, and required the patient to "reach out for the upper limb" on the affected side, in order to identify personal neglect. A larger battery, including more sensitive tests, may have found a higher number of subjects showing neglect.

7.2. Neglect is not a unitary phenomenon

While all of the four tests for visuo-spatial neglect assess the ability to direct attention to contralesional hemispace, each task has slightly different demands. For example, star cancellation uses visual search, line bisection requires a judgement about relative length, copying employs graphic skills and the BTT involves spatial judgements. Thus, although these tests are used to identify visual neglect, they may each be assessing different aspects of the neglect syndrome, which may also partly explain the double dissociations found. Visuo-spatial neglect was found to be the most common manifestation of the syndrome, and only a small number of patients demonstrated either directional hypokinesia or personal neglect. The significant correlations between tests of visuo-spatial neglect indicate that they are measuring at least some aspects of a common construct; however, dissociations demonstrated by these same tests show that visuo-spatial neglect is not a unitary phenomenon.

7.3. Differential test performance

The double dissociations found for the SCT, LB and the BTT are consistent with previous research, as these results show not only differential performance in a battery of tests [30,39], but also dissociations between test performance in the same modality (visuo-spatial neglect in reaching space). Halligan and Marshall [19], who were the first to report double dissociation in SCT and LB, argued that such fractionation challenges the validity of the concept of 'visuo-spatial neglect'. Indeed, 4 of the 9 subjects in the present study, who had normal LB but abnormal star scores, had star ratios indicating severe lateralising neglect. On the other hand, the remaining 5 subjects with normal LB scored between 45 and 48 on the SCT, and none of the 11 patients with only abnormal LB deviated more than 1.4 cm away from true midline. Thus an alternative explanation may be that subjects with either LB or SCT errors only, may have had less severe neglect than those subjects with errors in both tests.

On the other hand, subjects may have been using different strategies for each test. Binder et al. [5] considered that cancellation involved motor exploration, whereas bisection involved a perceptual judgement to compare the relative lengths of each half of the line. In contrast, Harvey and Milner [24] posited that reduced motor exploration explained some cases of abnormal line bisection. Only four subjects in the present

Table 4
Spearman's correlation between age and five of the seven tests used

	Age	SCT score	Star ratio	Daisy copying	Clock drawing	Line bisection	BTT ratio
Age	–						
SCT score	−0.06	–	–	–	–	–	–
Star ratio	0.09	0.85*	–	–	–	–	–
Daisy copying	0.19	0.62*	0.59*	–	–	–	–
Clock drawing	−0.19	0.14	0.16	0.15	–	–	–
Line bisection	0.09	−0.61*	−0.61*	−0.38	−0.14	–	–
BTT ratio	−0.05	0.75*	0.79*	0.59*	0.15	−0.66*	–

*$p < 0.001$, one-tailed test; SCT = Star Cancellation Test; BTT = Baking Tray Task.

study showed reduced motor exploration in contralesional hemispace during the EM task, which may have contributed to their abnormal scores on other tests requiring such a motor response. Koyama et al. [31] suggested that bisection in more severe cases might be due to failure to estimate true line length, because the subject's gaze is attracted to the ipsilesional end of the line. Less severe cases may perceive the whole line length but fail to compare right and left halves accurately. Contrary to findings of Marsh and Kersel [33], lateralisation of neglect, demonstrated by the star ratio, was found in the majority of cases. This suggests that the Star Ratio can provide the clinician with a useful measure of the lateralised extent and severity of omissions in contralesional space.

7.4. *Relative test sensitivity for visuo-spatial neglect and clinical usefulness of the test battery*

The SCT and the LB tests were found to be relatively the most sensitive in identifying visuo-spatial neglect, with an equal sensitivity of 76.4%. This is comparable to previous findings for SCT and LB [1,22], although SCT relative sensitivity was lower than the 100% found by Friedman [16]. However, due to the reported dissociations in test performance, and because a criterion test for neglect does not exist, it is not possible to absolutely identify the 'true positive' and 'false negative' test results that are required for correct statistical calculation of test sensitivity. Thus, the notion of 'sensitivity' for tests of neglect may be artificial [1]. Using a cut-off score of 44, as recommended by Friedman [16], would have further reduced sensitivity for the SCT. Results from the control subjects in this study did not indicate the need to lower the 51 cut-off score proposed by Wilson et al. [48], supported by the fact that no relationship was shown here between age and test performance. Independence of test performance and age has been found by others [22,39]. Due to dissociations found in this study, we recommend inclusion of the SCT and LB tests in any neglect battery. This combination would increase the likelihood of identifying visuo-spatial neglect.

Relative sensitivity of the BTT (66.7%) was less than either SCT or LB. Further, it added virtually no additional predictive value based on results in Table 2. This is in contrast to the findings of Tham and Tegner [47]. They used a smaller sample of stroke patients ($n = 19$) with neglect, and found sensitivity of 100%, also double dissociation from cancellation, line bisection, drawing and copying tasks in seven subjects. The BTT did show double dissociation in two subjects, and so it may be a useful addition to a test battery, being a more functionally based task, and simple to administer and interpret. However, some patients found the idea of such a large 'baking tray' unrealistic (even though it was smaller than the original proposed), and some had difficulty with the idea of what they had to do following instruction, particularly male subjects (who may have had less experience of 'baking'). A less 'gender specific' test, using materials used in 'real life' may need to be developed (e.g. planting large seeds in a seed tray). The BTT correlated with data from the SCT and LB, contrary to the findings of Tham and Tegner [47]. Similar strength of relationships between tests of visuo-spatial neglect was also found by Halligan and co-workers [22]. These significant relationships imply a common underlying construct, which may be the early orientation of attention towards ipsilesional space demonstrated in neglect patients [17].

Daisy copying showed low relative sensitivity (57.5%), possibly due to use of an expanded scoring scale, which only counted lateralised omissions as abnormal. For the original daisy copying test in the

BIT [48], scoring is based on 'major omissions' and does not specify where omissions might occur. Because of the possibility of subjectivity in scoring, the low sensitivity found in this study, and more demanding graphic skills than the Star Cancellation or Line Bisection Tests, daisy copying is not recommended as a test to identify visuo-spatial neglect.

Clock drawing was found to have questionable validity in the assessment of representational neglect. Consistent with previous findings [27,30], it's use as a screening measure is not indicated from these results. Reasons include subjectivity in scoring, and questionable validity in that the task may also reflect cognitive impairment [15], constructional apraxia, or impaired planning ability [30]. Despite previous reports of poor sensitivity [22], clock drawing was included in this battery, as it is commonly used to assess neglect [2]. Interestingly, Halligan and Marshall [20] pointed out one feature "that has rarely been mentioned" which is that the circumference of the clock-face is "not usually affected". They suggest this may be because part of a circle would be unlikely to be imagined in this context. This feature was confirmed by the present study, where all subjects completed the entire circle of the clock-face. Di Pellegrino [11] disputes the idea that abnormal clock drawing demonstrates a representational deficit, and suggests that it represents a deficit in ability to disengage attention from numbers commenced on the right side of the clock-face. Because tests of representational neglect appear to relate closely to behavioural observation of neglect in everyday activities [30], these authors suggest that a clinically valid test for representational neglect is needed. Grossi and co-workers [18] have described a test based on imagining times on a clock-face, however, the test has not been validated and may not be suitable for elderly patients.

The EM task was a potentially useful and simple test to distinguish directional hypokinesia and required no complex equipment. The identification of only four subjects (9.5%) with this neglect modality suggests that it is either not common or that the test is insufficiently sensitive. The larger board used in the present study might have been expected to improve sensitivity, as the subject had to reach further across into contralesional hemispace. Maeshima et al. [32] found 14 out of their sample of 20 (70%) had an exploratory-motor problem, none in isolation from visuo-spatial neglect. However, most of these 14 had cerebro-vascular damage involving the frontal lobes, considered to be related to motor aspects of neglect [5].

Presence of PN (around 17%) is comparable with the 20% found in some studies [29,39], but much lower than the 59% found in others [4]. Sensitivity of the original test [49] may be improved if the method used by Beschin and Robertson [4] is employed; this involves counting how many movements are made on each side of the face, over a period of 30 seconds, for each task used. This would also give more objective scoring.

8. Conclusions

Hemineglect is not a single entity and requires a range of tests to be used to maximise the possibility of identifying neglect disorders and to distinguish selective impairments. Use of a combination of the SCT and LB test would increase the possibility of identifying visuo-spatial neglect. Modifications of the BTT (such as the suggested 'seed-planting' task) may make it more relevant to 'real life' activity and improve it's face validity. Sensitivity in assessment of personal neglect may be increased by use of comparative timing on left and right sides for each activity used. Additionally, these tests are straightforward and quick to use and easy to interpret, do not require complex equipment, and would be suitable for use by therapists in the clinical situation. The reduced battery (all tests used in this study minus the clock-drawing and daisy copying tests) would take around only ten minutes to complete, a useful feature for patients who are likely to tire easily. However, further evaluation is required to assess the validity and sensitivity of the EM task for directional hypokinesia. Clock drawing is not recommended for the assessment of representational neglect, and daisy copying is insufficiently sensitive as a test for visuo-spatial neglect. Validated and clinically practical tests for representational neglect, true motor neglect and neglect in far space need to be developed.

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