# Measuring mild visual neglect: Do complex visual tests activate rightward attentional bias?

**Denise Taylor**
Senior Lecturer in Neurological Physiotherapy
Physical Rehabilitation Research Institute
School of Physiotherapy
Auckland University of Technology

**ABSTRACT**

Conventional clinical tests, such as the star cancellation test, may be valid and reliable to use with participants who have moderate to severe neglect but they may not be appropriate for participants with mild neglect. This pilot study was designed to assess if participants with a history of neglect, but no obvious signs on conventional clinical testing, show a rightward attentional bias during reaction time tests involving a complex visual field. Two participants completed a series of computer based tests. Simple (SRT) and complex (CRT) reaction time tests were used. The position of the stimulus target in the computerised tests did not appear to be related to response in the SRT (Participant A, $p>0.01$: Participant B, $p>0.01$). In the CRT the position of the stimulus target was related to the response, with a greater proportion of stimulus targets being missed on the side contralateral to the lesion (Participant A, $p<0.01$: Participant B, $p<0.01$). The results supported the premise that participants with mild neglect may show rightward attentional bias in complex visual tasks but not in simple tasks. Tests such as these may prove useful in detecting and measuring mild visual neglect. **Denise Taylor (2003). Measuring mild visual neglect: Do complex visual tests activate rightward attentional bias? New Zealand Journal of Physiotherapy 31(2): 67-72.**

**Keywords: Mild visual neglect; measurement; timed tasks; attentional bias**

## INTRODUCTION

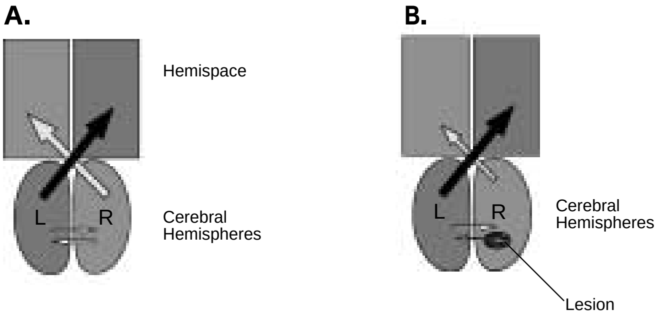
Visual neglect is an extraordinary clinical phenomenon whereby patients appear to be unable to respond to objects and people located on the side contralateral to a cerebral lesion (Halligan, & Marshall, 1993). It is one of the many manifestations that can occur in people following cerebrovascular accident (CVA), traumatic brain injury (TBI) and less commonly, with brain tumours. The incidence of visual neglect has been reported to be as high as 82% in right hemispheric stroke patients when assessed in the acute stage (Stone, Halligan & Greenwood, 1993.). Although visual neglect may be associated with damage to both the left and right hemispheres of the brain, it occurs more frequently and with greater severity following damage to the right hemisphere (Denes, Semanza, Stoppa, & Lis, 1982; Hier, Mondlock, & Caplan,1983; Vallar, & Perani, 1986; Vallar, 1993; Taylor, Ashburn, & Ward, 1994). The presence of visual neglect negatively affects a person's functional recovery from stroke (Kinsella & Ford, 1980; Denes, Semanza, Stoppa, & Lis, 1982; Kinsella & Ford, 1985; Taylor, Ashburn, & Ward, 1994; Jehkonen, Ahonen, Dastidar, et al, 2000) and adequate visual perceptual ability is reported to be fundamentally important for high level tasks such as driving a car (Falkmer, Vogel & Gregersen, 2001).

Definitions of neglect, such as that by Halligan and Marshall (1993) tend to suggest that all stimuli on the side contralateral to the brain lesion are ignored. This is not generally the case, it may be more realistic to imagine the visual field as a gradient, with stimuli on the extreme contralateral side having a higher probability of being ignored and stimuli closer to the midline having a lower probability of being ignored. In a person with severe visual neglect the unattended area may be large but in a person with mild visual neglect this area may be relatively small, or only be obvious under certain circumstances.

The brain codes visual information with reference to spatial frames. These spatial frames can be described as personal, peripersonal and extrapersonal (Robertson & Halligan, 1999). Personal space relates to one's own body, peripersonal space relates to space within arm's reach, and extrapersonal space is space beyond arm's reach. Patients with right hemispheric brain lesions can demonstrate neglect in any, or all, of these spatial frames of reference (Bartolomeo, 2002; Halligan & Marshall, 1991).

Visual extinction is a phenomenon associated with visual neglect, in which patients fail to respond to one of two stimuli when the stimuli are presented simultaneously. When the stimuli are presented independently of each other they are detected (Vallar, 1998). In functional daily tasks multiple visual stimuli are simultaneously presented and mechanisms are required to selectively direct attention to relevant stimuli (Bartolomeo & Chokron, 2002). One model that has been used to explain visual neglect is the orientational bias model (Kinsbourne. 1993). In this model each hemisphere of the brain directs attention toward contralateral hemispace by inhibiting the other hemisphere; however the left hemisphere is considered to have a stronger orienting tendency than the right. Therefore following right hemisphere lesions the left hemisphere is disinhibited and this leads to a rightward attentional bias and gives rise to left visual neglect (see Figure 1). This model suggests that patients with neglect do not simply ignore objects in left hemispace but that they are drawn to objects in the right hemispace (Bartolomeo & Chokron, 2002). Marshall and Halligan (1989) suggested the term 'right attentional capture' rather than 'left neglect' might better describe a patient's performance on cancellation tasks.

**Figure 1. The orientational bias model of visual neglect.**




A. Illustrates the model in a neurologically intact individual.
B. Illustrates the model in a person with visual neglect
Each hemisphere attends to the contralateral space. The diagonal arrows represent the attentional bias (the larger the arrow the greater the bias). The horizontal arrows represent the amount of inhibitory influence from the cortex.

Anatomical studies of people with visual neglect following right hemisphere damage suggest that spatial representation and awareness are complex processes with many areas of the brain involved (Halligan, Fink, Marshall, & Vallar, 2003). A variety of cortical and subcortical lesions are associated with neglect phenomena including: the inferior-posterior parietal regions, the posterior and medial portions of the thalamus and the premotor cortex (Cappa, Guariglia, & Messa, 1991; Vallar & Perani 1986; Watson & Heilman 1979). Experiments using transcranial magnetic stimulation (TMS) in neurologically unimpaired volunteers support the view that the right posterior parietal cortex is the main area connected with signs of neglect (Fierro, Brighina, et al 2000).

A variety of different clinical tests have been developed over the years to assess visual neglect. Many of these are pen and paper based tests; a sheet of paper is placed in front of the patient and they are required to perform such tasks as bisecting lines, crossing out target stimuli or copying figures (Albert, 1973; Diller & Weinberg, 1977; Oxbury, Campbell & Oxbury, 1974). These tests have been shown to be reliable and valid in people with moderate to severe neglect. The Behavioural Inattention Test (BIT) developed by Wilson, Cockburn and Halligan (1987) is a battery of tests, which was designed to measure visual neglect. There are two sections in the BIT, one includes conventional tests, such as letter and star cancellation tests, line bisection tests and copying tests, the other section includes behavioural tests such as coin sorting, dialling a number on a telephone, and reading aloud. In the conventional sub-tests on the BIT scores at or below 129 suggest the presence of visual neglect and in the behavioural sub-tests scores at or below 67 suggest the presence of visual neglect. By including the behavioural section of tests the BIT aims to give useful information about the impact visual neglect has on the day to day functioning of patients. The BIT has good inter-rater ($r = 0.99$; $p<0.001$) and test-retest ($r = 0.99$; $p<0.001$) reliability (Halligan, Cockburn & Wilson, 1991). A recent reliability study by Hannaford, Gower, Potter, Guest and Fairhurst (2003) reports high inter-rater reliability for the total BIT score (ICC = 0.994). However they identified that on the copying tasks inter-rater reliability was lower than for the total BIT score (ICC = 0.586 for the isosceles triangle copying task) and that this increased scoring variability was greatest for the stroke participants who had mild impairments.

Clinical assessments of neglect, whether pen and paper based or more functionally based, may not be sensitive enough to detect neglect phenomenon in all patients; for example those with mild visual neglect may learn to compensate by voluntarily directing their attention towards the contralateral side (Mattingley, Bradshaw, Bradshaw, & Nettleton, 1994). However, whilst this strategy might be successful in simpler tasks, or in tasks where there is no requirement to respond quickly to a signal they may not be appropriate in complex tasks such as driving, where time dependent responses are important. Functioning in daily life requires people to operate within a complex visual environment and the ability to deal with this is a crucial safety issue particularly in activities such as driving. It seems prudent to develop tests that predict whether or not a person will be able to return to safe driving following a cerebral insult (Falkmer, Vogel & Gregersen, 2001). Safe driving is largely dependent on the ability to integrate and respond to complex visuoperceptual information (Simms, 1985) and requires fast and controlled responses when something unexpected occurs in the traffic (Michon, 1979). A high level central executive function is needed to direct and control attention during complex tasks such as driving (Lundquist & Rönnberg, 2001). Patients who are able to compensate for mild visual neglect in conventional pen and paper tests may fail to do so with an increasingly complex visual stimulus that challenge the attentional mechanisms (Friedrich, & Margolin, 1993) and produce a rightward attentional bias.

One way to increase the sensitivity of tests of visual neglect is to increase the visual complexity of the stimulus material and to provide a time constraint in which the person has to respond. Participants with mild visual neglect may respond to stimuli in both sides of space but may show a bias in processing that will result in more rapid responses to stimuli in some locations than others (Friedrich, & Margolin, 1993; Ladavas, 1987). Responses to stimuli in the right visual field may be faster than responses to stimuli in the left visual field (Friedrich, & Margolin, 1993). Reid and Jutai (1995) described the development of a computerised test of visual perception in which a target stimulus has to be identified among four other stimuli. Each stimulus could be located in one of five positions in a row on the computer screen. There were increasing levels of complexity of the stimulus with complex stimuli having a greater number of attributes; for example a simple stimulus would be a two lined cross whereby a complex stimulus would consist of multiple lines in different orientations. The time taken to respond to the target stimuli could be recorded. Reid and Jutai discuss the testing of reliability of the instrument in children, yet do not present any data in their report nor do they relate the utility of the test in identifying difficulties in driving performance.

The relationship between standard clinical tests of visual neglect and reaction time tests has not been thoroughly explored, but there is some evidence to suggest that reaction time tests may be sensitive in detecting visual neglect. Posner, Walker, Freidrich, and Rafal (1984) selected participants with parietal lobe injury; all of these participants showed some left-right asymmetry when performing reaction time tests, yet only five participants had clinically recorded visual neglect. None of the control participants demonstrated this asymmetry. Similarly, in Friedrich and Margolin's (1993) single case study the participant showed no signs of neglect when measured using clinical tests, but on a cued target detection task the participant consistently showed evidence of a left-right asymmetry in reaction time with a longer time to respond to targets on the left. When there are visual stimuli to the left and right of a fixation point or when there is a limited time to respond to the signal patients tended to show a rightward attentional bias.

For this study two computer based tests were developed by the author. The purpose was to develop a test that had characteristics likely to result in a rightward attentional bias in participants who had a history of visual neglect but no longer demonstrated signs of neglect according to pen-and-paper tests. These characteristics were a limited time in which to respond to a target signal and visual stimuli in one or both visual fields. A simple reaction time test (SRT) required the participant to see and respond to a signal within a defined period of time. A simple decision process had to be undertaken: 'was that a signal, yes or no'. The complex reaction time test (CRT) required a higher-level decision process to be initiated; the participant had to choose between the various signals and decide if one matched the target criteria. In the CRT the task was to detect the stimuli and then to make a decision about whether the signal was a target stimulus or a distractor stimulus. Similarly to the SRT the response time on the CRT was limited.

The two computer based tests developed for this project did not strictly measure 'reaction time' but rather they imposed a time limit during which the participant could respond. A response time of 800 milliseconds and 1300 milliseconds were chosen for the SRT and CRT tests respectively because five participants between the ages of 24 and 52 years with no neurological or visual difficulties were able to score between 90 and 100% on repeated trials of the test using these time periods (unpublished data). The selected reaction times for this pilot were similar to those reported by Laeng, Brennen and Espeseth (2002) in a group of control subjects performing reaction time tasks in simple and complex situations.

It was hypothesised that participants with a history of visual neglect, who no longer demonstrated signs of neglect according to the Behavioural Inattention Test, would fail to respond to target signals presented in the left visual field when the visual scene was complex and there was a limited time in which to respond to the target signal. This pilot study was designed to determine if participants who had a history of neglect but no longer recorded any signs of visual neglect as measured on the Behavioural Inattention Test showed a rightward attentional bias when performing reaction time tasks within simple and complex visual environments.

## METHOD

### Participants

Two potential participants who had been referred in the previous month for a driving assessment following a cerebral lesion and who had previously shown signs of visual neglect as recorded in their medical notes (lasting more than 3 months) were approached by the head of the Disabled Driving Assessment Centre and given information pertaining to the pilot study. The potential participants telephoned the researcher if they wished to participate in the pilot study. Exclusion criteria included more than one stroke, cerebellar or brainstem stroke, other serious medical condition, and visual impairment not correctable by glasses. Both potential participants were eligible for entry and agreed to take part in the pilot study. SDRHA Ethical Committee approval was given for the study and both participants gave informed written consent. The research took place in the vision research laboratory, Loughborough University, UK.

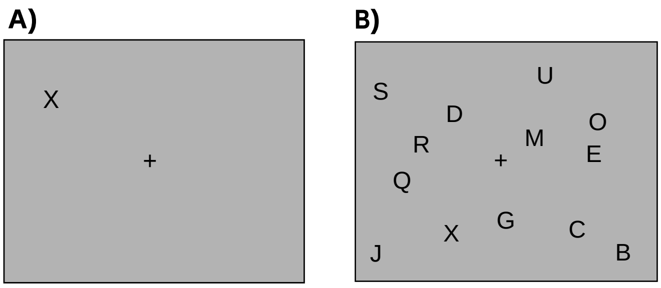
### Procedure

The participants were screened by the researcher using the Behavioural Inattention Test (BIT) and had to score above the cut-off points described in the BIT before they could participate in the pilot study.

Two computer based tests were used, a visually simple test (SRT) and a visually complex test (CRT). During both tests the participant was seated and looked at a computer screen that had a central fixation point, but was otherwise blank. In the SRT the participants were instructed to look at the central fixation point and to respond if they saw the letter 'X' appearing anywhere on the screen by pressing a key on the keyboard (see Figure 2). The target signal ('X') would appear in a random position on the screen and remain visible for 800ms. If the participant responded within 800ms the computer registered the target as a hit. If the target was not responded to in the time allowed the target was registered as a miss.

In the CRT test 12 distractor signals appeared in addition to the target signal. The time allowance was increased to 1300ms. The target signal was the letter 'X' and the distractor signals were made up of other letters of the alphabet, excluding angular letters such as 'K'. This was done to minimise confusion with the letterform. The target signal ('X') appeared in a random position on the screen. During each test signals appeared 30 times but the appearance of the target signal was randomised, so it did not occur on each individual trial. In the CRT the participants were instructed to look at the central fixation point and to respond if they saw the letter 'X' appearing anywhere on the screen by pressing a key on the keyboard; they were informed that there would be other signals appearing on the screen and that the target signal might not appear on every trial (see Figure 2).

**Figure 2.**




A) Test condition for the Simple Reaction Time (SRT) task
B) Test condition for the Complex Reaction Time (CRT) task

### Data Analysis

Chi-square tests for independence were used to ascertain whether any differences in the proportion of hits to misses across the left, middle and right areas of the screen were statistically significant. Yates' correction was used when the expected numbers in the cells were below 5. The alpha level was set at 0.01.

## RESULTS

### Participants

Participant A was a 58 year old man who had a right CVA 29 months prior to the study. He had limited movement in his left arm and leg but was walking independently indoors and for short distances outdoors. He had no language or visual field deficits. There was a history of severe visual neglect recorded in his medical notes that was ongoing for more than three months. The Star Cancellation Test had been used to measure the ongoing presence of neglect. Participant B was a 54 year old woman who had a right subdural haematoma 22 months prior to the study. She had good movement left arm and leg and she could perform most ADL activities bilaterally. She had no language or visual field deficits but had a history of visual neglect recorded in her medical notes for longer than three months following the haematoma as measured by the Star Cancellation Test. Both participants were right handed.

### Behavioural Inattention Test

On the initial assessment participant A scored below the cut-off point of both the conventional and behavioural sub-tests of the BIT indicating that there were still some difficulties with visual neglect. Participant A was re-tested three months later and scored above the cut-off points and was then included in the study. Participant B scored above the cut-off points on the first assessment and was entered into the study (see Table 1).

### Simple Reaction Time test

The first 15 trials in the SRT test were used as a familiarisation phase and results from these trials were not included in the analysis; all other trials were included in the data analysis. Sixty two targets were presented in the trials and for the purposes of analysis the screen was divided into three columns, left, middle and right. The x-y co-ordinates of the target signal were recorded on the computer. Using these co-ordinates it was determined which column the target had appeared in. A target was counted as a 'hit' if it was responded to within the time limit, otherwise it was counted as a 'miss'.

### Participant A

As Table 2 indicates, there were no statistically significant differences in the proportion of hits and misses according to their position, left, middle or right, on the screen (Chi-square = 3.9, df = 2, p = 0.14) for participant A.

### Participant B

As with participant A there were no statistically significant differences in the proportion of hits and misses according to their position on the screen (Chi-square = 5.9, df = 2, p = 0.05) for participant B (see Table 3).

### Complex Reaction Time test

For the CRT test 150-270 trials were completed, the first 30 were used to familiarise the participant with the test procedure and was not included in the analysis; all other trials were included in the data analysis.

**Table 1. Scores on the Conventional and Behavioural sub-sections of the BIT**

| | Score: Test 1 | | Score: Test 2 | |
|---|---|---|---|---|
| | Conventional max score = 146 | Behavioural max score = 81 | Conventional max score = 146 | Behavioural max score = 81 |
| Participant A | 125 | 67 | 140* | 81* |
| Participant B | 144* | 81* | | |

* Score above the cut-off point (>129 on conventional sub-tests; >67 on the behavioural sub-tests)

**Table 2. Participant A: Scores on the SRT.**

| | Left column | Middle column | Right column | Total |
|---|---|---|---|---|
| Hits | 9 | 13 | 12 | 34 |
| Misses | 14 | 6 | 8 | 28 |
| Total | 23 | 19 | 20 | 62 |

### Participant A

Participant A completed 120 trials that were used in the analysis; in these trials the target signal appeared 56 times. Of the 56 target signals presented within the trials, there were 19 target signals in the left column, 17 in the middle column and 20 in the right column. The proportion of hits to misses was significantly different in the three columns (Chi-square = 10.5, df = 2, p = 0.005). The differences lay between the left and the middle column (Yates' Chi-square = 7.3, df = 1, p = 0.002) and the left and the right columns (Yates' Chi-square = 7.3, df = 1, p = 0.007) but not between the middle and right columns (Yates' Chi-square = 0.07, df = 1, p = 0.79) (see Table 4).

**Table 3. Participant B: Scores on the SRT**

| | | | | |
|---|---|---|---|---|
| Hits | 11 | 15 | 20 | 46 |
| Misses | 8 | 6 | 2 | 16 |
| Total | 19 | 21 | 22 | 62 |

### Participant B

The CRT test was repeated nine times. The first run through the test was used to familiarise the participant with the test procedure and was not included in the analysis. Participant B completed 240 trials that were used in the analysis; in these trials the target signal appeared on 100 occasions. Of the 100 target signals presented, there were 37 target signals in the left column, 25 in the middle column and 38 in the right column. The proportion of hits and misses were significantly different in the three columns (Chi-square = 14.6, df = 2, p = 0.0007). The differences lay between the left and the middle column (Yates' Chi-square = 9.9, df = 1, p = 0.002) and the left and the right columns (Chi-square = 13.6, df = 1, p = 0.0002) but not between the middle and right columns (Chi-square = 0.005, df = 1, p = 0.94) (see Table 5).

Participant A made three errors of commission, pressing the key when a target was not presented, on the CRT and Participant B made one. This suggests that the participants were not just pressing the keyboard at random.

**Table 4. Participant A: Scores on the CRT.**

| | Left column | Middle column | Right column | Total |
|---|---|---|---|---|
| Hits | 0 | 7 | 8 | 15 |
| Misses | 19 | 10 | 12 | 41 |
| Total | 19 | 17 | 20 | 56 |

## DISCUSSION

Both participants in this study had a history of visual neglect but at the time of testing they scored above the cut-off point on the Behavioural Inattention Test. On the basis of the results of the tests completed in the BIT neither participant would have been described as having visual neglect. During the SRT test there were no differences in the proportion of hit to missed targets across the three columns. It appeared that on this test the position of the target stimulus was independent of whether the participant responded to it within the allocated time period. Even with a restricted time in which to respond, if there were no other visual distractions the participants identified and responded to the signal and did not show signs of rightward attentional bias. This test, therefore supported the results from the clinical tests in indicating that the participant did not have visual neglect. However, during the complex reaction time test both participants tended to miss a significantly greater proportion of targets when they appeared in the left third of the screen. In this test it appeared that the position of the target signal was related to whether or not the participant responded to it within the allocated time period. The participants, when there was a target stimulus in the left column and there were distractor signals present in the right visual field, frequently failed to detect the target in the left visual field and demonstrated signs of rightward attentional bias. In agreement with Freidrich and Margolin (1993) it appeared that increasing the task difficulty by adding to the complexity of the visual field prevented the participants from compensating for mild visual neglect. In the SRT there were no stimuli competing for attention whereas in the CRT there were signals to the left and right of the screen. The presence of these competing stimuli may provoke the attentional mechanisms resulting in a rightward bias.

It may not be enough to use conventional pen and paper tests of visual neglect, particularly if one is concerned with being able to relate performance on such tests with performance on high level, visually complex tasks, such as driving a car. A larger study of people with a history of visual neglect that score within normal limits on clinical tests of visual neglect needs to be undertaken to support or refute the findings from this pilot study. The results from this pilot study suggest that new measures of visual neglect may need to be developed that are more sensitive at the top end and bear some relation to complex motor and cognitive tasks. However, there does need to be some indication of the relationships between reaction time tests and functional tasks before predictions can be made about the ability of patients to perform certain complex motor and cognitive tasks. A limit in using computer based tests may be related to the fact that targets are in peripersonal space, which is the same for the BIT, but in driving many of the critical actions occur in extrapersonal space. It is not known whether this

**Table 5. Participant B: Scores on the CRT.**

| | Left column | Middle column | Right column | Total |
|---|---|---|---|---|
| Hits | 1 | 9 | 14 | 24 |
| Misses | 36 | 16 | 24 | 76 |
| Total | 37 | 25 | 38 | 100 |

affects the utility of computer based tests of the nature developed for this study. Whilst there is little known about the relationship between the tests used in this study and functional tasks, they do appear to be more sensitive than conventional tests of visual neglect for people with mild neglect. In addition, they are simple and quick to administer and may be of use in a clinical situation.

## ACKNOWLEGEMENTS

Thanks go to Adrian Bailey of the Department of Human Sciences, Loughborough University, UK, for writing the computer programmes.

This work was undertaken whilst the author was a lecturer at Loughborough University, U.K.

## References

Albert, M.L., (1973). A simple test of visual neglect, Neurology, 23: 658-664.

Bartolomeo, P. (2002). The relationship between visual perception and visual mental imagery: a reappraisal of the neuropsychological evidence. Cortex. 38: 357-378.

Bartolomeo, P., & Chokron, S., (2002). Orienting of attention in left unilateral neglect. Neuroscience and Biobehavioral Reviews. 26: 217-234.

Cappa, F., Guariglia, C., Messa, C., Pizzamiglio, L., & Zoccolotto, P.L., (1991). CT-Scan correlates of chronic unilateral neglect. Neuropsycholgy, 5. 195-204.

Denes, G., Semanza, C., Stoppa, E., & Lis, A., (1982), Unilateral spatial neglect and recovery from hemiplegia, Brain, 105: 543-552.

Diller, L., & Weinberger, J., (1977). Hemiattention and rehabilitation: evolution of a rational remediation program. Advances in Neurology, 18: 63-82.

Falkmer, T., Vogel, K., & Gregersen, N.P., (2001). The test of visual perceptual skills (non-motor) upper level is not a valid predictor for the outcome of driver education. Scandinavian Journal of Occupational Therapy. 8: 72-78.

Fierro, B., F. Brighina, et al. (2000). "Contralateral neglect induced by right posterior parietal rTMS in healthy subjects. Neuroreport **11**(7): 1519-21.

Friedrich, F.J., Margolin, D.I., (1993). Response time measures of hemi-inattention: A longitudinal case report. Neuropsychiatry, Neuropsychology and Behavioural Neurology. 6: 54-59.

Halligan, P.W., Cockburn, J., & Wilson, B.A., (1991). The behavioural assessment of visual neglect. Neuropsychological Rehabilitation. 1: 5-32.

Halligan, P.W., Fink, G.R., Marshall, J.C., & Vallar, G., (2003). Spatial cognition: evidence from visual neglect. Trends in Cognitive Sciences. 7: 125-133.

Halligan, P.W., & Marshall, J.C., (1991). Left neglect for near but not far space in man. Nature. 350: 498-500.

Halligan, P.W., & Marshall, J.C., (1993). The history and clinical presentation of neglect. In; Robertson, I.H., Marshall, J.C. (Eds). Unilateral neglect; clinical and experimental studies, Lawrence Erlbaum Associates, Hove, UK.

Hannaford, S., Gower, G., Potter, J.M., Guest, R.M., & Fairhurst, M.C. (2003). Assessing visual inattention: study of inter-rater reliability. British Journal of Therapy and Rehabilitation. 10: 72-75.

Hier, D.B., Mondlock, B.A., Caplan, M.D.,(1983). Behavioural abnormalities after right hemisphere stroke, Neurology, 33: 337-345.

Jehkonen, M., Ahonen, J.P., Dastidar, P., Koivisto, A.M., Laippala, P., Vilkki, J., & Molnar, G., (2000). Visual neglect as a predictor of functional outcome one year after stroke. Acta Neurologica Scandanavica. 101: 195-201.

Kinsbourne, M., (1993). Orientational bias model of unilateral neglect: evidence from attentional gradients within hemispace. In Robertson, I.H., & Marshall, J.C., (Ed's.) Unilateral neglect: clinical and experimental studies, Lawrence Erlbaum Associates, Hove, UK.

Kinsella, G., Ford, B., (1980). Acute recovery patterns in stroke patients, Med J Aust, 2: 663-666.

Kinsella, G., Ford, B., (1985). Hemi-inattention and the recovery patterns of stroke patients, Int Rehab Med, 7: 102-106.

Ladavas, E., (1987). Is hemispatial neglect produced by right parietal lobe damage associated with retinal or gravitational coordinates? Brain, 110: 167-180

Laeng, B., Brennen, T., & Espeseth, T. (2002). Fast responses to neglected targets in visual search reflect pre-attentive processes: an exploration of response times in visual neglect. Neuropsychologia. 40: 1622-1636.

Lundquist, A., & Rönnberg, J., (2001). Driving problems and adaptive driving behavior after brain injury: a qualitative assessment. Neuropsychological Rehabilitation, 11: 171-185.

Marshall, J.C., & Halligan, P.W., (1989), Does the midsagittal plane play any privileged role in left neglect. Cogn Neuropsychol. 6: 403-422.

Mattingley, J.B., Bradshaw, J.L., Bradshaw, J.A., & Nettleton, N.C., (1994). Residual rightward attentional bias after apparent recovery from right hemisphere damage: implications for a multicomponent model of neglect. Journal of Neurology, Neurosurgery and Psychiatry. 57: 597-604.

Michon, J.A., (1979). Dealing with danger. Summary report of a workshop in the Traffic Research Centre, State University, Groningen, Netherlands.

Oxbury, J., Campbell, D.C., & Oxbury, S., (1974). Unilateral spatial neglect and impairement of spatial analysis and visual perception. Brain, 97. 551-564.

Posner, M.I., Walker, J.A., Freidrich, F.J., & Rafal, R.D., (1984). Effects of parietal lobe injury on covert orienting of visual attention. Journal of Neurosci. 4:1863-1874.

Reid, D.T., & Jutai, J., (1995). Assessment of visual perception with neurological disorders: a computerised process approach. Canadian Journal of Rehabilitation. 9: 33-38.

Robertson & Halligan, (1999). Spatial neglect: A Clinical Handbook for Diagnosis and Treatment. Psychology Press. Hove, UK.

Simms, B. (1985). Perception and driving: the theory and practice. British Journal of Occupational Therapy. 48: 363-6.

Stone, S.P., Halligan, P.W., & Greenwood, R.J., (1993). The incidence of neglect phenomena and related disorders in patients with an acute right or left hemisphere stroke. Age Ageing. 22: 46-52.

Taylor, D., Ashburn, A., & Ward, C.D., (1994). Asymmetrical trunk posture, unilateral neglect and motor performance following stroke. Clinical Rehabilitation 8: 48-53.

Vallar, G., (1993). The anatomical basis of spatial hemineglect in humans. In Robertson, I.H., & Marshall, J.C., Unilateral neglect: clinical and experimental studies, Lawrence Erlbaum Associates, Hove, UK.

Vallar, G., (1998). Spatial hemineglect in humans. Trends Cogn Sci. 2: 287-297.

Vallar, G., & Perani, D., (1986). The anatomy of unilateral neglect after right hemisphere stroke lesions: A clinical / CT scan correlation study in man, Neuropsychologia, 24: 609-622.

Wilson, B., Cockburn, J., & Halligan, P.W., (1987). Behavioural Inattention Test, Thames Valley Test Company, Suffolk, UK.

## ADDRESS FOR CORRESPONDENCE

Denise Taylor, Senior Lecturer in Neurological Physiotherapy, School of Physiotherapy Auckland University of Technology, Auckland email: denise.taylor@aut.ac.nz