Development of the Halifax Visual Scanning Test: A New Measure of Visual-Spatial Neglect for Personal, Peripersonal, and Extrapersonal Space

Christiane E. Whitehouse,[1] Janet Green,[1] Sarah M. Giles,[2] Rosanna Rahman,[3] Jamesie Coolican,[4] AND Gail A. Eskes[1,5]

[1]Department of Psychology and Neuroscience, Dalhousie University, Nova Scotia
[2]Department of Family Medicine, University of Ottawa, Ottawa, Canada
[3]Capital and Coast District Health Board, Wellington Regional Hospital, New Zealand
[4]IWK Health Centre, Nova Scotia
[5]Department of Psychiatry, Dalhousie University, Nova Scotia

Objectives: Visual-spatial neglect is a common attentional disorder after right-hemisphere stroke and is associated with poor rehabilitation outcomes. The presence of neglect symptoms has been reported to vary across personal, peripersonal, and extrapersonal space. Currently, no measure is available to assess neglect severity equally across these spatial regions and may be missing subsets of symptoms or patients with neglect entirely. We sought to provide initial construct validity for a novel assessment tool that measures neglect symptoms equally for these spatial regions: the Halifax Visual Scanning Test (HVST). **Methods:** In Study I, the HVST was compared to conventional measures of neglect and functional outcome scores (wheelchair navigation) in 15 stroke inpatients and 14 healthy controls. In Study II, 19 additional controls were combined with the control data from Study I to establish cutoffs for impairment. Patterns of neglect in the stroke group were examined. **Results:** In Study I, performance on all HVST subtests were correlated with the majority of conventional subtests and wheelchair navigation outcomes. In Study II, neglect-related deficits in visual scanning showed dissociations across spatial regions. Four inpatients exhibited symptoms of neglect on the HVST that were not detected on conventional measures, one of which showed symptoms in personal and extrapersonal space exclusively. **Conclusions:** The HVST appears a useful measure of neglect symptoms in different spatial regions that may not be detected with conventional measures and that correlates with functional wheelchair performance. Preliminary control data are presented and further research to add to this normative database appears warranted. (*JINS*, 2019, *25*, 490–500)

Keywords: Perceptual disorders, Hemispatial neglect, Attention, Stroke rehabilitation, Assessment, Patient outcomes

INTRODUCTION

Visual-spatial neglect (neglect) is a disabling neurological condition most commonly due to right brain damage, such as a stroke. Neglect is characterized by a failure to orient toward or respond to stimuli on the individual's contralesional side of space, not due to a primary sensory or motor deficit (Heilman, Watson, & Valenstein 1993). This attentional disorder is common particularly in stroke patients with damage to a variety of areas in fronto-parietal networks in the right-hemisphere (Bartolomeo, Thiebaut De Schotten, & Chica, 2012). The incidence of neglect can be as high as 82–85% during the acute phase and 69% in the early rehabilitation phase (Azouvi et al., 2002; Cherney, Halper, Kwasnica,

Harvey, & Zhang, 2001; Stone, Halligan, Marshall, & Greenwood, 1998). Neglect is associated with poor rehabilitation outcomes including slower recovery, increased length of stay at rehabilitation facilities, and decreased independence in activities of daily living (Cherney et al., 2001; Gillen, Tennen, & McKee, 2005; Katz, Hartman-Maeir, Ring, & Soroker, 1999). Thus, assessment of neglect and its impact on everyday function is of clinical importance for the development of effective rehabilitation strategies and improving the health outcomes of stroke patients.

Many theoretical interpretations of neglect suggest a deficit in spatial attentional factors mediated by a wide-spread neuroanatomical network (Corbetta & Shulman, 2011; Danckert & Ferber, 2006; Driver & Mattingley, 1998; Halligan & Marshall, 1994; Làdavas, Carletti, & Gori, 1994; Posner, Walker, Friedrich, & Rafal, 1984; Rafal, 1994; Vallar, 1998). Spatial representation is not unitary, however, and the

presence or severity of deficits seen in neglect patients can vary depending on a variety of factors (Bowen, McKenna, & Tallis, 1999) with neglect subtypes reported depending on spatial region of testing (Buxbaum et al., 2004; Committeri et al., 2006).

For example, Bisiach, Perani, Vallar, and Berti (1986) reported a double dissociation between personal and reaching space, in which some patients exclusively demonstrated symptoms of neglect in personal space, while others only demonstrated symptoms in reaching space. In some patients, symptoms occurred in both spaces. This double dissociation has been replicated in subsequent studies (Beschin & Robertson, 1997; Marangolo, Piccardi, & Rinaldi, 2003; Ortigue, Megevand, Perren, Landis, & Blanke, 2006).

Others have sought to further divide space beyond the body into reaching distance (also called peripersonal space) and beyond reaching distance (also called extrapersonal space). Studies have noted double dissociations between neglect symptoms in these regions (Aimola, Schindler, Simone, & Venneri, 2012; Butler, Eskes, & Vandorpe, 2004; Pitzalis, Di Russo, Spinelli, & Zoccolotti, 2001). In these studies, a variety of methods were used to assess neglect in peripersonal space: Verbally identifying visual targets (Butler et al., 2004), completing paper-and-pencil tasks (Aimola et al., 2012), and indicating the center of lines using a laser pointer (Pitzalis et al., 2001). Neglect in extrapersonal space was assessed using the same peripersonal tasks adapted to extrapersonal space, either using a laser pointer or verbal naming to respond.

Although symptoms of neglect have been shown to vary across spatial regions, few clinical assessment tools examine neglect outside of peripersonal space. Stand-alone tasks administered in personal space have been developed to assess personal neglect (also referred to as "body representational neglect" by some authors), such as the Fluff Test (Cocchini, Beschin, & Jehkonen, 2001), the Vest Test (Glocker, Bittl, & Kerkhoff, 2006), and the Comb and Razor Test (Beschin & Robertson, 1997). All tasks require patients to interact with stimuli in personal space and show good reliability. However, these measures still attend to only one spatial region.

Batteries of tasks have been created to examine the occurrence of neglect symptoms in different spatial regions, although it is difficult to compare between tasks that are not equated for difficulty or test requirements. For example, to assess the occurrence of various neglect subtypes, Buxbaum and colleagues (2004) administered subtests of the Behavioral Inattention Test (BIT; paper-and-pencil tasks completed in peripersonal space) and a modification of the Fluff Test. These tasks differed not only in their number of target stimuli but also in the nature of their stimuli, and even in the method by which the task was completed (written *vs.* motor response). Thus, performance differences observed between tasks could be attributed to factors other than neglect, such as task difficulty or a specific motor deficit.

Through a comprehensive literature review, Menon and Korner-Bitensky (2004) identified 62 assessment tools used to examine symptoms of neglect. Of these, they identified only one that measured symptoms across all three spatial regions: the Catherine Bergego Scale (CBS). In the initial validation study of the CBS (Azouvi, 1996) and subsequent study of its psychometric properties (Azouvi et al., 2003), the CBS was compared to conventional neuropsychological assessment tasks and showed increased specificity for identifying symptoms of neglect. The CBS requires approximately 20–40 min to administer and involves direct observation of a patient post-stroke as they complete 10 daily living activities. Although the Kessler Foundation Research Centre has developed a standardized protocol (Chen, Hreha, Fortis, Goedert, & Barrett, 2012), it is difficult to specifically define neglect subtypes in these spatial regions, given the global functional demands of the test.

Since Menon and Korner-Bitensky's (2004) comprehensive review other functional assessment tools have been identified and developed, such as the Árnadóttir OT-ADL Neurobehavioral Evaluation (Gardarsdóttir & Kaplan, 2002) and the Activities of Daily Living battery (Eschenbeck et al., 2010). Although Eschenbeck and colleagues (2010) discussed the need to assess neglect symptoms in different spatial regions, neither of the above-mentioned measures allow the assessor to compare performance on tasks standardized and matched across these regions. The Sunnybrook Neglect Assessment Procedure (Leibovitch, Vasquez, Ebert, Beresford, & Black, 2012) has also been developed as a bedside battery to meet the need for early assessment of neglect, yet measures neglect in peripersonal space exclusively. Similarly, stand-alone tasks exist to assess extrapersonal neglect only (e.g., The Dublin Extrapersonal Neglect Assessment; Cunningham, O'Rourke, Finlay, & Gallagher, 2017).

Given the behavioral evidence supporting a dissociation of neglect symptoms experienced in different spatial regions and the lack of current standardized clinical measures to assess neglect severity specifically across these regions, we have developed a novel measure to assess symptoms of neglect matched by stimuli and task difficulty across personal, peripersonal, and extrapersonal space: the Halifax Visual Scanning Test (HVST). The goal of the current studies was to provide initial construct validity for this assessment measure by examining performance on the HVST in a sample of stroke patients in comparison to conventional and functional outcomes. In addition, these studies sought to accumulate healthy adult normative data to create a basis for evaluating stroke-related impairment.

STUDY I: COMPARISONS OF THE HVST TO CONVENTIONAL TASKS AND WHEELCHAIR NAVIGATION

Navigating while walking or using a wheelchair is often impaired in individuals with neglect (Turton et al., 2009) and collisions while walking or using a wheelchair were found to be one of the most sensitive functional outcomes during the CBS validation (Azouvi, 1996). The purpose of Study I was

to assess the construct validity of the HVST by comparing this novel assessment tool to a conventional measure for neglect (the BIT) and a functional task (wheelchair navigation) in both stroke patients and healthy adult controls.

Method

Participants

A convenience sample of 15 right-hemisphere stroke inpatients from a tertiary-care rehabilitation unit were recruited for the study (stroke group). Ten were later classified as having left neglect (67%), and five were classified as not exhibiting symptoms of neglect (see Results). The occurrence of neglect in this sample was consistent with other prevalence estimates of neglect in an early rehabilitation setting (69%; Cherney et al., 2001). Sixteen adults living independently in the community were also recruited for the study (control group).

Participants were required to have normal or corrected-to-normal visual acuity and normal reading ability. Participants were excluded if they had a neurological or extrapyramidal motor system disorders (except for stroke in the stroke group), peripheral motor impairment that would interfere with wheelchair performance (except for contralesional hemiparesis in the stroke group), or severe arthritis.

Data from two controls were eliminated from analyses. The first was eliminated due to the presence of bilateral upper limb weakness (grip strength, L:R = 5.5:6.5 lb; average L:R grip strength in the control group = 29.6:32.9 lb) that could potentially interfere with wheelchair mobility. The second control was eliminated because their performance on the measure of overall intellectual functioning was more than two standard deviations below the range of the group (Wechsler Abbreviated Scale of Intelligence

[WASI]; see Measures). This left 14 individuals remaining in the control group. See Table 1 for detailed participant information.

Measures

Halifax Visual Scanning Test (HVST).

The HVST was developed to characterize subtypes of neglect by measuring participant's visual scanning in three spatial regions. Subtests were created with a focus on matching the stimuli across these regions. Stimuli consisted of words with four or more letters, one to three syllables, and a word frequency of more than 25 appearances per million (Thorndike & Lorge, 1972). Each list included 12 natural object nouns, 12 man-made object nouns, and 12 non-words. The three lists were equated as closely as possible for word frequency and the number of syllables per word. These words were printed among distracter symbols (stars) and were presented at three different distances matched for visual angle: personal space (on a shirt worn by the participant in a seated position; Shirt subtest), peripersonal space (on a sheet of paper on a table placed 62.5 cm directly in front of the participant; Table subtest), and extrapersonal space (on a board mounted on a wall 250 cm away from the participant; Wall subtest). Words were roughly organized in four columns centered on the participant's midline, with each column containing three natural object nouns, three man-made object nouns, three non-words, and eight stars. No words were repeated across the three spatial regions. Images of the HVST subtests are depicted in Figure 1.

Participants were instructed to "look all over the [shirt, table, or wall] and read aloud as many real words as you can find" in a 2-min time limit. Thus, they were asked to visually scan each region of space (personal, peripersonal, or

Table 1. Study I: Participant demographic and baseline testing information

	Stroke group N = 15	Healthy control group N = 14	Group comparisons
Gender	Male: n = 12 (80.0%)	Male: n = 8 (57.1%)	X^2 (1, N = 29) = 1.77, p = .18
Dominant hand	Right: n = 13 (86.7%)	Right: n = 13 (92.9%)	X^2 (1, N = 29) = .30, p = .58
Years of education	10.9 (4.1)[a]	13.0 (3.8)	U = 64.0, p = .12
Age (years)	63.2 (13.4)	67.8 (6.5)	U = 94.5, p = .65
Days post-stroke	56.3 (26.6)	N/A	N/A
Judgement of Line Orientation[b]	15.2 (7.8)	26.1 (4.0)	U = 18.5, p < .001*
Digit Span Forward[b]	5.7 (1.4)	6.7 (1.1)	U = 61.5, p = .05
Digit Span Backwards[b]	3.3 (1.0)	4.8 (1.6)	U = 46.5, p = .008*
WASI Vocabulary[c]	43.1 (12.8)	48.3 (9.1)	U = 76.0, p = .20
WASI Matrix Reasoning[c]	35.3 (12.0)	59.7 (6.9)	U = 14.0, p < .001*
Grip Strength (Right)[b]	28.4 (9.8)	32.7 (12.6)	U = 85.0, p = .38
Grip Strength (Left)[b]	4.5 (8.7)	29.6 (13.1)	U = 12.0, p < .001*

Note. *Indicates a statistically significant difference (two-tailed) at α = 0.01
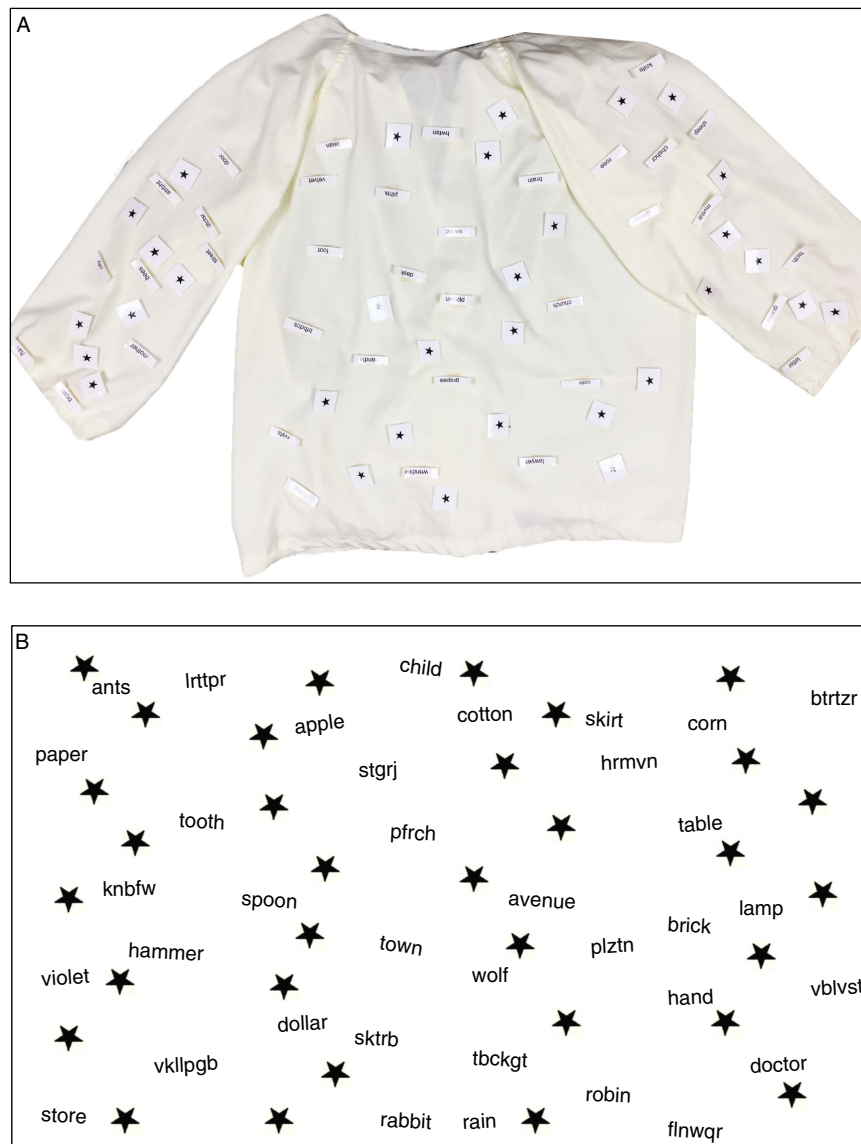[a]Mean (SD).
[b]Raw score.
[c]Percentile.

Fig. 1. A: Shirt worn by participants to measure Personal neglect. B: Image used for producing the Table and Wall subtests. Stimuli in each spatial region were matched in word frequency, length, and frequency of word type. To receive materials to use the HVST, please contact the corresponding author.

extrapersonal) to find and read the words. The total score was the number of words read aloud by the participant (maximum = 24 words in each space). HVST administration requires approximately 10 min.

Behavioral Inattention Test (BIT)

The BIT is a battery of six paper-and-pencil tasks used to assess attention post-stroke (Wilson, Cockburn, & Halligan, 1987). The BIT is a recommended and commonly used tool for the assessment of neglect symptoms due to its established cutoff values for impairment and its comprehensive assessment of neglect in peripersonal space (Halligan, Cockburn, & Wilson, 1991; Intercollegiate Stroke Working Party, 2012; Salter et al., 2013).

The three visual scanning subtests of the BIT were used for comparison: Star Cancellation, Letter Cancellation, and Line Crossing. These subtests involve crossing out stars or letters among distractors, or crossing out lines that are randomly oriented across a piece of paper. Scores for each task are the total number of target items successfully crossed out.

Baseline neuropsychological screening

Additional baseline neuropsychological tests were administered and scored according to standardized instructions to screen for dementia and to characterize the neuropsychological profile of the stroke group in relation to the control group. The test battery included: (1) a measure of overall intellectual functioning - the WASI (Wechsler, 1999), (2) measures of attention and working memory - Digit Span Forwards and Backwards (Wechsler, 1987), (3) a measure of visual-spatial ability - Judgment of Line Orientation (Benton, Hamsher, Varney, & Spreen 1983), and (4) Grip strength.
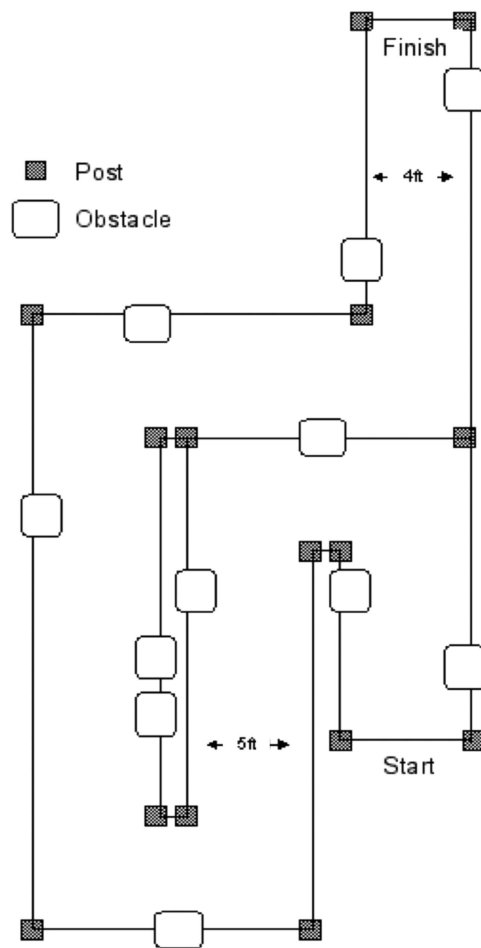
Figure 2. Illustration of the wheelchair obstacle course.

Wheelchair obstacle course

The wheelchair obstacle course was based on a method described by Webster and colleagues (1989). Participants were asked to guide their wheelchair along a 61-m course twice, once in each direction. The course contained three right and three left turns. The boundaries were marked by rope, held by pylons at roughly eye level when sitting in a wheelchair (see Figure 2). Twelve common objects (e.g., chairs, garbage cans, caution pillars) served as obstacles placed equally frequently on either the right or left side of the course. The course was wide enough to allow space between an obstacle and the course boundary (81 cm—the width of a standard door frame). Participants were videotaped as they navigated through the course for the blind scoring of errors. Errors recorded included direct hits (contact of the frontal plane of the wheelchair with obstacles) and sideswipes (contact with the side plane of the chair), as previously defined by Webster and colleagues (1989).

Procedure

As the control participants were not familiar with navigating in a wheelchair and wheelchair expertise in the stroke group may not have been consistent, all participants completed a practice day in the wheelchair course. On this day, participants also completed the cognitive assessment measures. The three word-sets were counterbalanced among the three HVST subtests. Participants completed the wheelchair obstacle course again, within 1 week of their practice run. The experimenter recorded the number and location of collisions (i.e., direct hits and side swipes) that the participants made with their wheelchair. Participants in the stroke group completed the same obstacle course again before their inpatient discharge, approximately 30 days after their initial testing session (Time 2).

Our stroke participants had moderate to severe hemiparesis, and thus used only their unaffected side for wheelchair navigation. To equate method of navigation between groups, controls were only allowed to use their right arm and leg to complete the course and their left arm was braced as a reminder. Control participants were allowed to practice navigating turns using a slalom-like series of three pylons placed 1.5 m apart until they felt comfortable (10 min time limit), before completing their practice day on the wheelchair course.

Procedures were in accord with the ethical standards of the Capital Health District Health Authority Research Ethics Board. As multiple comparisons were used to examine the numerous variables of interest, a more conservative alpha of 0.01 was used to determine statistical significance when comparing groups.

Results

Participant demographics

The majority of participants in both groups were male and right-handed. In the stroke group, time since stroke ranged from one to four months. Comparisons between groups using either Mann-Whitney U or chi-square tests, as applicable, revealed that the control and stroke groups did not differ in age, education, frequency of right-handedness, or gender. The two groups did not differ in estimated premorbid IQ (WASI Vocabulary). The control group had significantly stronger grip strength on their left side, compared to the stroke group. There was no difference between groups on their right side (see Table 1).

Visual scanning tasks

The BIT Line Crossing, Letter, and Star Cancellation subtests were used for comparison with the three HVST subtests. The BIT cancellation tasks are visual scanning tasks completed in peripersonal space exclusively. Performance on all visual scanning tasks was compared between groups using two-tailed Mann-Whitney U tests, given the non-normal distribution (see Table 2). Although the control group had higher raw scores on all visual scanning tasks compared to the stroke group, performance on the BIT Line Crossing subtest did not significantly differ between stroke patients and controls.

Table 2. Performance on HVST subtests and BIT cancellation subtests in Study I

		Stroke group N = 15	Healthy control group N = 14	Group comparisons	Effect size (r)
HVST	Shirt subtest	14.9 (4.9; 6–21)[a]	22.4 (2.3; 16–24)	U = 9.5, p < .001*	−.78
	Table subtest	18.9 (5.3; 7–24)	23.2 (.9; 22–24)	U = 46.0, p = .008*	−.49
	Wall subtest	19.4 (5.8; 7–24)	23.8 (.4; 23–24)	U = 37.0, p = .001*	−.60
BIT	Star Cancellation	45.1 (13.0; 9–54)	53.7 (.6; 52–54)	U = 28.5, p < .001*	−.66
	Letter Cancellation	34.1 (7.6; 10–40)	38.8 (1.6; 36–40)	U = 42.0, p = .005*	−.52
	Line Crossing	32.9 (7.9; 13–36)	35.9 (.5; 34–36)	U = 84.5, p = .17	−.25

Note. *Indicates a statistically significant group difference (two-tailed) at $\alpha = 0.01$, Mann-Whitney U test.
[a]Mean correct (*SD*; range of scores). Maximum possible scores: HVST subtests = 24, BIT Star Cancellation = 54, BIT Letter Cancellation = 40, BIT Line Crossing = 36.

Non-parametric Spearman's correlations were calculated between each of the HVST subtests and the three cancellation subtests of the BIT. Most HVST subtests correlated significantly with each of the three BIT cancellation subtests (*r*'s ranged from 0.38 to 0.74). However, the HVST Wall subtest was not correlated with the BIT Letter Cancellation (*r* = 0.33; see Table 3).

As the stimuli for the HVST are organized in four columns, additional analyses were completed comparing the location of HVST errors (rightmost, middle-right, middle-left, and leftmost columns), within the different spatial regions (Shirt, Table, Wall subtests), between control and stroke group participants. A 4 (Column) × 3 (Spatial Region) × 2 (Group) repeated-measures analysis of variance was run. There was a significant main effect of Column, however, this was qualified by a significant Column by Group interaction [$F(2.21, 59.65) = 7.49$, $p = .001$; effect size $(\eta p^2) = 0.22$]. For the control group, participant's scores remained consistent across columns (from left to right: *M* = 5.57, 5.74, 5.90, 5.93). For the stroke group, however, participant's scores increased as they moved from left to right (*M* = 3.29, 4.56, 4.80, 5.09), consistent with symptoms of neglect.

Wheelchair navigation performance

Direct hits and sideswipes were scored by blinded observers uninformed about group membership. Overall, the stroke group made significantly more errors compared to the control group for both direct hits (effect size *r* = −0.67) and sideswipes (effect size *r* = −0.54; see Table 4). Although the

Table 3. Correlations between the HVST subtests and the three BIT cancellation subtests for all participants (*N* = 29) in Study I

	HVST		
BIT	Shirt subtest	Table subtest	Wall subtest
Star Cancellation	.74**	.54**	.61**
Letter Cancellation	.67**	.41*	.33
Line Crossing	.41*	.38*	.42*

*Significant spearman correlation (two-tailed) at $\alpha = .05$.
**Significant spearman correlation (two-tailed) at $\alpha = .01$.

stroke group did decrease in their number of total direct hits and total sideswipes between the two time-points (pre- and post-rehabilitation), this difference was not significant [direct hits: paired $t(11) = 0.83$; $p = 0.42$; side swipes: paired $t(11) = 1.35$; $p = .20$].

To examine the association of our novel visual scanning measures with a functional measure of performance, Spearman's correlations were calculated between the HVST and performance on the wheelchair course at Time 1 for all participants (see Table 5). Significant correlations were found between wheelchair direct hits and all HVST subtests (Shirt *r* = −0.67; $p \leq .01$; Table *r* = −0.39; $p \leq .05$; Wall *r* = −0.55; $p \leq .01$). Wheelchair side swipes correlated significantly with the Shirt (*r* = −0.54; $p \leq .01$) and Table (*r* = −0.59; $p \leq .01$) subtests, but not the Wall subtest (*r* = −0.26).

STUDY II: DEVELOPING A HVST NORMATIVE DATABASE

Results from Study I suggested that the HVST may be an informative measure for assessing the functional prognosis of neglect rehabilitation in addition to currently used assessment measures for neglect. As such, further development of the HVST was deemed appropriate. The purpose of Study II was to collect further normative data on the HVST in healthy adults to establish cutoffs for impairment that could be then applied to stroke patients. An additional cancellation subtest (i.e., Figure Cancellation) commonly used to detect neglect in stroke patients was also administered for further comparison with the HVST.

Method

Participants

Healthy adults were recruited from the community using online advertisements as well as through a volunteer contact list. Participants did not receive compensation for participating in the study. Participants were required to: (1) be 45 + years of age, (2) have self-reported normal or corrected-to-normal vision, and (3) be able to read English (from self-report). Participants were excluded if their self-reported health history

Table 4. Wheelchair obstacle course performance

Wheelchair course performance	Stroke group N = 15		Healthy control group N = 14	Group comparisons Stroke group vs. healthy control group	Effect size (r)
	Time 1	Time 2			
Direct-hits	2.87 (4.17)[a]	2.17 (2.76)	.00 (.00)	U = 35.0, p < .001*	−.67
Side-swipes	5.27 (3.51)	3.50 (3.37)	1.78 (1.31)	U = 39.0, p = .004*	−.54

[a]Mean (SD).
*Indicates a statistically significant different (two-tailed) at α = 0.01.

indicated that they had: (1) experienced a stroke, (2) received a diagnosis of dementia or another neurological disorder/disease, or (3) if they received a score of 23 or lower on the Montreal Cognitive Assessment (MoCA). An exclusion cutoff score of 23 or lower was used given its increased specificity for correctly identifying older adults without mild cognitive impairment (Luis, Keegan, & Mullan, 2009).

Although 27 participants were originally recruited, eight were removed from the study based on the following criteria: improper procedures ($n = 5$), not meeting the minimum required score on the MoCA for inclusion ($n = 2$), and poor vision ($n = 1$). The study concluded with 19 participants in total.

Measures

Figure Cancellation subtest (Sunnybrook Neglect Assessment Procedure; SNAP).

The Figure Cancellation test from the SNAP was included for further comparison of the HVST with another standard visual scanning measure. The SNAP is a short assessment battery designed to be administered to patients at their bedside (Leibovitch et al., 2012). The Figure Cancellation subtest requires participants to cross out 60 designated targets among distractor symbols.

Montreal Cognitive Assessment (MoCA).

The MoCA (www.mocatest.org) is a validated short screening tool used to detect MCI (Luis et al., 2009; Nasreddine et al., 2005; Smith, Gildeh, & Holmes, 2007). The measure totals to 30 points and examines seven cognitive domains:

Table 5. Correlations between the HVST and wheelchair course performance for all participants in Study I

Wheelchair course performance (Time 1)	HVST subtests		
	Shirt	Table	Wall
Direct hits	−.67**	−.39*	−.55**
Side swipes	−.54**	−.59**	−.26

*Significant spearman correlation (two-tailed) at α = .05.
**Significant spearman correlation (two-tailed) at α = .01.

visual-spatial/executive abilities, naming, attention, language, abstraction, delayed recall, and orientation.

Halifax Visual Scanning Task.

See Study I Materials for a full description of this task.

Procedure

Participants were invited for a one-time testing session at the Nova Scotia Rehabilitation and Arthritis Centre (Halifax, Nova Scotia). The session began with two screening measures that were later used to confirm eligibility for inclusion: a brief demographic and health history questionnaire, and the MoCA. Participants then completed two measures of visual scanning: The Figure Cancellation subtest of the SNAP and the HVST.

Procedures were in accord with the ethical standards of the Nova Scotia Health Authority Research Ethics Board. As multiple comparisons were used to examine the numerous variables of interest, a more conservative alpha of 0.01 was used to determine statistical significance.

Results

Participant demographics

The Study I control group and the Study II participants were combined to form a normative database for the HVST (see Table 6 for combined participant demographic information; see Table 7 for combined visual scanning task performance).

Neglect in Different Spatial Regions

Performance on the HVST was compared between the normative database and the stroke group from Study I using two-tailed Mann-Whitney U tests. Participants in the normative database had significantly higher performance scores on all HVST subtests compared to the stroke group (all $p < .001$).

The normative database was used to establish cutoff scores for impairment on the HVST. Given the skewed nature of the healthy adult performance on the HVST subtests (i.e., many healthy adults had perfect scores for each column), it was decided to use the lower range of scores to establish cutoffs for abnormal performance. An abnormal score thus was

Table 6. Healthy adult normative database demographic information

	Study I Control group ($N = 14$)	Study II Healthy adults ($N = 19$)	Study I + II Healthy adult normative database ($N = 33$)
Gender	Male: $n = 8$ (57.1%)	Male: $n = 5$ (26.3%)	Male: $n = 13$ (39.4%)
Dominant hand	Right: $n = 13$ (92.9%)	Right: $n = 17$ (89.5%)	Right: $n = 30$ (90.9%)
Years of education[a]	13.0 (3.8)	16.7 (2.0)	15.1 (3.4)
Age[a]	67.8 (6.5)	57.8 (9.2)	62.0 (9.5)

[a]Mean (*SD*).

defined as any score less than or equal to the lowest score obtained in the normative database.

Individual data from all participants in the stroke group of Study I were then examined for the presence of neglect in each spatial region using the newly established HVST cutoff criteria (shown in Table 8). Given these criteria, 14 of 15 individuals were classified as having neglect in at least one spatial region on the HVST. Of the 14 individuals with neglect symptoms, 5 showed symptoms of neglect in all spatial regions, 3 showed neglect in two spatial regions (peripersonal/extrapersonal space, $n = 2$; personal/extrapersonal space, $n = 1$), and 4 showed neglect in only one spatial region (personal space, $n = 1$; peripersonal space, $n = 3$).

Individual data from all participants in the stroke group were also examined using the established cutoff criteria for the BIT (shown in Table 8). Neglect was defined as having a score at or below the cutoff for impairment (Wilson et al., 1987) on one or more of the three cancellation subtests. Ten participants in the stroke group met these criteria for exhibiting symptoms of neglect.

When comparing the BIT Line Crossing, Letter, and Star Cancellation subtests to performance on the HVST, four participants exhibited symptoms of neglect on the HVST subtests that were not identified by the BIT tasks (see Table 8).

GENERAL DISCUSSION

The purpose of the current studies was to evaluate a new measure, the Halifax Visual Scanning Test, intended to quantify neglect subtypes in three spatial regions: personal, peripersonal, and extrapersonal space. All three HVST subtests were found to correlate with both traditional visual scanning tests administered (medium to strong relationships; Cohen, 1992), with one exception. The association among tests of neglect has been shown to be variable, either due to the attentional variability inherent in neglect symptoms or to the possibility that different tests are measuring different aspects of neglect.

For example, previous validation work on the CBS similarly compared performance on their functional assessment for neglect in different spatial regions to the BIT (Luukkainen-Markkula, Tarkka, Pitkänen, Sivenius, & Hämäläinen, 2011). Luukkainen-Markkula and colleagues (2011) found only 5 of the 10 CBS tasks to correlate with at least 1 of the BIT tasks, despite both the BIT and CBS being established measures for neglect assessment. Variability in performance on neglect measures was also reported by Azouvi and colleagues (2002), who administered seven paper-and-pencil assessment tasks for neglect and the CBS to a large sample of stroke patients ($n = 206$). Stroke patient's performance varied on both the paper-and-pencil tasks and behavioral measures of the CBS, meeting criteria for neglect on some subtests and not others.

Our findings demonstrate that the HVST similarly captures both unique and overlapping symptoms when compared to other standard measures. While a strong relationship was observed between some subtests of the HSVT and BIT, HVST subtests that were less related to these conventional tasks may be identifying additional aspects of neglect not captured by the BIT.

Table 7. Comparison of healthy adult normative database participants on visual scanning tasks

		Study I Control group ($N = 14$)	Study II Healthy adults ($N = 19$)	Study I + II Healthy adult normative database ($N = 33$)
HVST	Shirt subtest	22.4 (2.2; 16–24)	21.3 (2.8; 14–24)	21.8 (2.6; 14–24)
	Table subtest	23.2 (.9; 22–24)	23.8 (.5; 22–24)	23.5 (.8; 22–24)
	Wall subtest	23.8 (.4; 23–24)	23.7 (.7; 22–24)	23.7 (.6; 22–24)
Conventional visual scanning tasks[a]	% Correct	99.5 (1.1; 96.3–100.0)	99.3 (2.3; 90.0–100.0)	99.4 (1.9; 90.0–100.0)

Note. Mean (*SD*; range of scores).
[a]Study I participants, BIT Star Cancellation; Study II participants, SNAP Figure Cancellation.

Table 8. HVST and BIT performance for each stroke group participant

Age/Gender	HVST Shirt (≤14)	HVST Table (≤22)	HVST Wall (≤22)	BIT Line (≤34)	BIT Letter (≤32)	BIT Star (≤51)	BIT total score
71/F*	7	7	11	13	10	9	34
79/M	6	10	7	14	39	22	86
75/M*	8	12	12	35	29	38	105
54/M*	13	20	12	36	37	47	127
46/M*	20	19	23	36	40	43	130
55/F	13	19	22	36	32	51	131
52/M	15	17	24	36	32	50	133
72/F	14	24	24	36	29	52	133
77/M*	17	22	23	35	37	48	133
56/M	16	20	24	36	36	54	139
59/M	14	24	21	36	38	52	140
59/M	20	24	22	36	39	50	140
79/M	19	20	21	36	39	53	141
37/M	20	22	21	36	37	54	143
77/M	21	24	24	36	38	54	144

Note. Participants are organized in ascending order according to BIT total score. Cutoff scores for impairment are indicated in parentheses. Shaded-cells indicate subtests in which the participant was classified as exhibiting neglect. See text for definition of impairment. Age is reported in years. * Indicates participant had a visual field deficit.
F = female, M = male.

When examining performance on the wheelchair obstacle course, all three HVST subtests were associated with wheelchair navigation outcomes. Webster and colleagues (1989), who sought to better understand the impact of neglect on wheelchair navigation, recruited both stroke patients who demonstrated symptoms of neglect on two standard paper-and-pencil tests and stroke patients who did not demonstrate neglect. When participants then completed a wheelchair task, the two groups did not differ in their number of sideswipe wheelchair collisions on the left errors consistent with the more general effects of right-hemisphere stroke). Observations such as these suggest that conventional paper-and-pencil tasks may fail to capture the functional subtleties of neglect, demonstrating the importance of developing new measures that are associated with functional outcomes.

In comparison to three conventional scanning measures, the three subtests of the HVST identified more stroke patients as exhibiting symptoms of neglect (14 patients vs. 10). Three of these patients had abnormal performance on the HVST peripersonal task that was not seen in the BIT subtests, also completed in peripersonal space. This difference could be due to the difference in task demands. The HVST draws more heavily on working memory due to the use of oral report. Thus, participants are required to remember which words they have already identified and read aloud, in order to know which words are remaining to be read. In contrast, participants cross out the target items on the BIT, and, therefore, do not have to keep track of which target items they have already identified. Spatial working memory deficits have been cited as a key element in neglect (Danckert & Ferber, 2006); thus, the oral report methods of the HVST may make it more sensitive to neglect symptoms.

One other patient exhibited neglect symptoms exclusively in personal and extrapersonal space on the HVST, while performing in the normal range on the peripersonal tasks of both the BIT and HVST. These results are consistent with previous studies that have identified double-dissociations between symptoms of neglect in peripersonal and personal space (Beschin & Robertson, 1997; Bisiach, Perani, Vallar, & Berti, 1986), as well as peripersonal and extrapersonal space (Aimola et al., 2012; Butler et al., 2004; Pitzalis et al., 2001). Given that the HVST equates for task requirement and difficulty across spatial regions, the dissociations identified in the current study can be more confidently attributed to differences in visual scanning abilities in different spatial regions compared to previous research. The current data contribute to the literature highlighting the variability in symptom expression among those experiencing neglect. They further support the need for assessment measures to quantify neglect symptoms using multiple tests, including those targeting different spatial regions. Importantly, commonly used measures for assessing neglect may be missing symptoms that are expressed outside of peripersonal space, which would have negative implications with regards to rehabilitation planning for those individuals.

Recovery post stroke is a highly dynamic process and the present analyses provide only a snapshot of stroke patients during their recovery. We, therefore, are unable to comment on the recovery course of neglect symptoms in different spatial regions. The value that this additional assessment information may provide with regard to outcomes requires further consideration. Performance on the HVST appears to correlate with some functional measures, but more research and psychometric testing is needed to understand the value of this assessment to rehabilitation planning.

While the HVST can measure neglect symptoms in different spatial regions, the contribution of other underlying influences to performance is unknown (e.g., directional akinesia *vs.* inattention, working memory deficits, allocentric neglect). Future studies could explore these mechanisms, as well as examine the underlying brain mechanisms of neglect subtypes through more detailed lesion localization. Although the HVST advances our ability to test for symptoms of neglect across spatial regions, the reading and working memory demands may prove a challenge for some patients and limit the application of this test. Further development using different stimuli and detection methods may improve the applicability of the HVST to all stroke patients.

As explained by Buxbaum and colleagues (2004), assessing for subtypes of neglect is the first step toward determining their effects on treatment outcomes. The HVST is easily administered in one session and performance is not affected by a motor deficit. These characteristics facilitate the integration of the HVST into clinical care and future research

examining treatments for neglect to characterize patients by subtypes of neglect (i.e., personal, peripersonal, and extra-personal neglect). This addition to treatment study outcomes may account for unique variability in treatment progress that is frequently observed in interventions for neglect post stroke.

Conclusions

The current analyses provide initial construct validity for a novel and sensitive assessment measure of subtypes of neglect in personal, peripersonal and extrapersonal space. These data further support the idea that symptoms of neglect can differ across these regions and demonstrate the need to assess neglect outside of peripersonal space. Although there is recognition that neglect symptoms can differ across spatial regions, standardized and validated measures are needed (Lindell et al., 2007). These analyses suggest that the HVST may fill this need. Proper assessment of neglect symptoms is necessary in planning rehabilitation strategies and identifying heterogeneity in individuals that may explain differences in treatment outcomes. Given the variation in neglect symptom expression, a multifactorial approach to neglect assessment for clinical and research purposes is needed (Azouvi et al., 2002). This novel measure shows potential to become an informative addition to the conventional assessment battery.

ACKNOWLEDGMENTS

REFERENCES

Aimola, L., Schindler, I., Simone, A. M., & Venneri, A. (2012). Near and far space neglect: Task sensitivity and anatomical substrates. *Neuropsychologia*, *50*(6), 1115–1123.

Azouvi, P. (1996). Functional consequences and awareness of unilateral neglect: Study of an evaluation scale. *Neuropsychological Rehabilitation*, *6*(2), 133–150.

Azouvi, P., Olivier, S., De Montety, G., Samuel, C., Louis-Dreyfus, A., & Tesio, L. (2003). Behavioral assessment of unilateral neglect: Study of the psychometric properties of the Catherine Bergego Scale. *Archives of Physical Medicine and Rehabilitation*, *84*(1), 51–57.

Azouvi, P., Samuel, C., Louis-Dreyfus, A., Bernati, T., Bartolomeo, P., Beis, J. M., . . . French Collaborative Study Group on Assessment of Unilateral Neglect (GEREN/GRECO). (2002). Sensitivity of clinical and behavioural tests of spatial neglect after right hemisphere stroke. *Journal of Neurology, Neurosurgery, and Psychiatry*, *73*(2), 160–166.

Bartolomeo, P., Thiebaut De Schotten, M., & Chica, A. B. (2012). Brain networks of visuospatial attention and their disruption in visual neglect. *Frontiers in Human Neuroscience*, *6*, 110.

Benton, A. L., Hamsher, K. D., Varney, N. R., & Spreen, O. (1983). *Contributions to neuropsychological assessment*. New York, NY: Oxford University Press.

Beschin, N., & Robertson, I. H. (1997). Personal versus extra-personal neglect: A group study of their dissociation using a reliable clinical test. *Cortex*, *33*(2), 379–384.

Bisiach, E., Perani, D., Vallar, G., & Berti, A. (1986). Unilateral neglect: Personal and extra-personal. *Neuropsychologia*, *24*(6), 759–767.

Bowen, A., McKenna, K., & Tallis, R. C. (1999). Reasons for variability in the reported rate of occurrence of unilateral spatial neglect after stroke. *Stroke*, *30*(6), 1196–1202.

Butler, B. C., Eskes, G. A., & Vandorpe, R. A. (2004). Gradients of detection in neglect: Comparison of peripersonal and extra-personal space. *Neuropsychologia*, *42*(3), 346–358.

Buxbaum, L., Ferraro, M., Veramonti, T., Farne, A., Whyte, J., Ladavas, E., . . . Coslett, H. (2004). Hemispatial neglect subtypes, neuroanatomy, and disability. *Neurology*, *62*(5), 749–756.

Chen, P., Hreha, K., Fortis, P., Goedert, K. M., & Barrett, A. M. (2012). Functional assessment of spatial neglect: A review of the Catherine Bergego Scale and an introduction of the Kessler Foundation Neglect Assessment Process. *Topics in Stroke Rehabilitation*, *19*(5), 423–435.

Cherney, L. R., Halper, A. S., Kwasnica, C. M., Harvey, R. L., & Zhang, M. (2001). Recovery of functional status after right hemisphere stroke: Relationship with unilateral neglect. *Archives of Physical Medicine and Rehabilitation*, *82*(3), 322–328.

Cocchini, G., Beschin, N., & Jehkonen, M. (2001). The Fluff Test: A simple task to assess body representation neglect. *Neuropsychological Rehabilitation*, *11*(1), 17–31.

Cohen, J. (1992). A power primer. *Psychological Bulletin*, *112*(1), 155.

Committeri, G., Pitzalis, S., Galati, G., Patria, F., Pelle, G., Sabatini, U., ... Pizzamiglio, L. (2006). Neural bases of personal and extrapersonal neglect in humans. *Brain*, *130*(2), 431–441.

Corbetta, M., & Shulman, G. L. (2011). Spatial neglect and attention networks. *Annual Review of Neuroscience*, *34*, 569–599.

Cunningham, L. J., O'Rourke, K., Finlay, C., & Gallagher, M. (2017). A preliminary investigation into the psychometric properties of the Dublin Extrapersonal Neglect Assessment (DENA): A novel screening tool for extrapersonal neglect. *Neuropsychological Rehabilitation*, *27*(3), 349–368.

Danckert, J., & Ferber, S. (2006). Revisiting unilateral neglect. *Neuropsychologia*, *44*(6), 987–1006.

Driver, J., & Mattingley, J. B. (1998). Parietal neglect and visual awareness. *Nature Neuroscience*, *1*(1), 17–22.

Eschenbeck, P., Vossel, S., Weiss, P. H., Saliger, J., Karbe, H., & Fink, G.R. (2010). Testing for neglect in right-hemispheric stroke patients using a new assessment battery based upon standardized activities of daily living (ADL). *Neuropsychologia*, *48*(12), 3488–3496.

Gardarsdóttir, S., & Kaplan, S. (2002). Validity of the Árnadóttir OT-ADL Neurobehavioral Evaluation (A-ONE): Performance in activities of daily living and neurobehavioral impairments of persons with left and right hemisphere damage. *American Journal of Occupational Therapy*, *56*(5), 499–508.

Gillen, R., Tennen, H., & McKee, T. (2005). Unilateral spatial neglect: Relation to rehabilitation outcomes in patients with right hemisphere stroke. *Archives of Physical Medicine and Rehabilitation*, *86*(4), 763–767.

Glocker, D., Bittl, P., & Kerkhoff, G. (2006). Construction and psychometric properties of a novel test for body representational

neglect (Vest Test). *Restorative Neurology and Neuroscience*, *24* (4-6), 303–317.

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

Halligan, P. W., & Marshall, J. C. (1994). Toward a principled explanation of unilateral neglect. *Cognitive Neuropsychology*, *11* (2), 167–206.

Heilman, K. M., Watson, R. T., & Valenstein, E. (1993). Neglect and related disorders. *Clinical Neuropsychology*, *3*, 279–336.

Intercollegiate Stroke Working Party. (2012). *National clinical guideline for stroke*. London: Royal College of Physicians.

Katz, N., Hartman-Maeir, A., Ring, H., & Soroker, N. (1999). Functional disability and rehabilitation outcome in right hemisphere damaged patients with and without unilateral spatial neglect. *Archives of Physical Medicine and Rehabilitation*, *80*(4), 379–384.

Leibovitch, F. S., Vasquez, B .P., Ebert, P. L., Beresford, K. L., & Black, S.E. (2012). A short bedside battery for visuoconstructive hemispatial neglect: Sunnybrook Neglect Assessment Procedure (SNAP). *Journal of Clinical and Experimental Neuropsychology*, *34*(4), 359–368.

Lindell, A. B., Jalas, M. J., Tenovuo, O., Brunila, T., Voeten, M. J., & Hämäläinen, H. (2007). Clinical assessment of hemispatial neglect: Evaluation of different measures and dimensions. *The Clinical Neuropsychologist*, *21*(3), 479–497.

Luis, C. A., Keegan, A. P., & Mullan, M. (2009). Cross validation of the Montreal Cognitive Assessment in community dwelling older adults residing in the Southeastern US. *International Journal of Geriatric Psychiatry*, *24*(2), 197–201.

Luukkainen-Markkula, R., Tarkka, I., Pitkänen, K., Sivenius, J., & Hämäläinen, H. (2011). Comparison of the Behavioural Inattention Test and the Catherine Bergego Scale in assessment of hemispatial neglect. *Neuropsychological Rehabilitation*, *21*(1), 103–116.

Làdavas, E., Carletti, M., & Gori, G. (1994). Automatic and voluntary orienting of attention in patients with visual neglect: Horizontal and vertical dimensions. *Neuropsychologia*, *32*(10), 1195–1208.

Marangolo, P., Piccardi, L., & Rinaldi, M. C. (2003). Dissociation between personal and extrapersonal neglect in a crossed aphasia study. *Neurocase*, *9*(5), 414–420.

Menon, A., & Korner-Bitensky, N. (2004). Evaluating unilateral spatial neglect post stroke: Working your way through the maze of assessment choices. *Topics in Stroke Rehabilitation*, *11*(3), 41–66.

Nasreddine, Z. S., Phillips, N. A., Bédirian, V., Charbonneau, S., Whitehead, V., Collin, I., . . . Chertkow, H. (2005). The Montreal Cognitive Assessment, MoCA: A brief screening tool for mild cognitive impairment. *Journal of the American Geriatrics Society*, *53*(4), 695–699.

Ortigue, S., Megevand, P., Perren, F., Landis, T., & Blanke, O. (2006). Double dissociation between representational personal and extrapersonal neglect. *Neurology*, *66*(9), 1414–1417.

Pitzalis, S., Di Russo, F., Spinelli, D., & Zoccolotti, P. (2001). Influence of the radial and vertical dimensions on lateral neglect. *Experimental Brain Research*, *136*(3), 281–294.

Posner, M. I., Walker, J. A., Friedrich, F. J., & Rafal, R. D. (1984). Effects of parietal injury on covert orienting of attention. *Journal of Neuroscience*, *4*(7), 1863–1874.

Rafal, R. D. (1994). Neglect. *Current Opinion in Neurobiology*, *4* (2), 231–236.

Salter, K., Campbell, N., Richardson, M., Mehta, S., Jutai, J., Zettler, L., . . . Teasell, R. (2013). Outcome measures in stroke rehabilitation. In. Evidence-Based Review of Stroke Rehabilitation (EBRSR). Retrieved from http://www.ebrsr.com/sites/default/files/Chapter%2020_Outcome%20Measures.pdf

Smith, T., Gildeh, N., & Holmes, C. (2007). The Montreal Cognitive Assessment: Validity and utility in a memory clinic setting. *The Canadian Journal of Psychiatry*, *52*(5), 329–332.

Stone, S. P., Halligan, P. W., Marshall, J. C., & Greenwood, R. J. (1998). Unilateral neglect A common but heterogeneous syndrome. *Neurology*, *50*(6), 1902–1905.

Thorndike, E. L., & Lorge, I. (1972). *The teacher's word book of 30,000 words*. New York: Teachers College Press.

Turton, A. J., Dewar, S. J., Lievesley, A., O'Leary, K., Gabb, J., & Gilchrist, I. D. (2009). Walking and wheelchair navigation in patients with left visual neglect. *Neuropsychological Rehabilitation*, *19*(2), 274–290.

Vallar, G. (1998). Spatial hemineglect in humans. *Trends in Cognitive Sciences*, *2*(3), 87–97.

Webster, J. S., Cottam, G., Gouvier, W. D., Blanton, P., Beissel, G., & Wofford, J. (1989). Wheelchair obstacle course performance in right cerebral vascular accident victims. *Journal of Clinical and Experimental Neuropsychology*, *11*(2), 295–310.

Wechsler, D. (1987). *Wechsler Memory Scale-Revised Manual* (150 pp.). New York, NY: Psychological Corporation.

Wechsler, D. (1999). *Wechsler Abbreviated Scale of Intelligence Manual* (226 pp.). San Antonio, TX: Harcourt Brace & Co.

Wilson, B.A., Cockburn, J., & Halligan, P. (1987). *Behavioural inattention test: Manual*. Suffolk, UK: Thames Valley Test Company.