ALLOCENTRIC VS. EGOCENTRIC NEGLECT IN STROKE PATIENTS: THE IMPACT ON FUNCTIONAL OUTCOMES.

by

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Allocentric vs. Egocentric Neglect in Stroke Patients: The Impact on Functional Outcomes

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Abstract

Objective: Few studies have investigated the assessment, frequency, and functional impact of egocentric and allocentric neglect among stroke patients. This study aimed to determine a) whether allocentric and egocentric neglect could be dissociated among a sample of stroke patients using eye-tracking technology, b) the frequencies of each neglect subtype and c) the nature of the relationship between neglect subtype and functional outcome.

Method: Sixteen acute stroke patients were administered comprehensive neuropsychological (NP) assessment batteries, a pencil-and-paper Apples Test, and an eye-tracking measure of neglect subtype. Descriptive analyses were conducted on Apples Test and eye-tracking scores to determine their sensitivities in detecting neglect subtype. Hierarchical regression was used to determine predictive utility of the eye-tracking measure above that of both NP test performance and Apples Test neglect scores. ANOVA was used to investigate the relationships between neglect subtype and functional outcome.

Results: The eye-tracking measure was more sensitive in identifying neglect subtype in patients than the traditional pen and paper Apples Test. Classification of neglect subtype based on eye-tracking performance was a significant predictor of functional outcome beyond that accounted for by both NP test performance and traditional Apples Test neglect classification. Patients with no neglect symptoms had superior functional outcomes compared to patients with either or both types of neglect. Patients with both types of neglect had significantly poorer functional outcomes than those with either subtype, or no neglect. Functional outcomes of patients with either allocentric or egocentric neglect did not differ significantly from each other.

Conclusion: Neglect subtype classification contributes independently to the prediction of functional status above and beyond that of neuropsychological test performance, and is a better predictor of function than traditional measures of allocentric and egocentric neglect. The significant relationship between neglect subtype and functional outcome highlights the importance of sensitive assessment and identification of neglect subtype amongst stroke patients to better predict prognosis and inform improved rehabilitative treatment planning.
Preface

The following research was reviewed by the University of British Columbia – Okanagan’s Behavioural Research and Ethics Board, certification number H15-01357. This ethics application was harmonized and approved by Kelowna General Hospital. The following research was conceptualized, designed, and carried out by Jennifer Upshaw, as was all data collection and analyses.
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I would also like to thank the staff of the Department of Psychology at Kelowna General Hospital and the members of the PLAN Lab at UBCO for their important contributions to this research project. Your support, guidance, advice, and smiles have made this process both possible and enjoyable.

Finally, I would like to thank my husband Dave, my parents Janet and Andy, and my sister Emily for inspiring me, sticking by my side through all the ups and downs, and understanding the sacrifices necessary to following my dreams. Whether it was something as simple as preparing me a meal when I didn’t have the time, or as significant as giving me the strength to push onwards when I wanted to give up, I appreciate all that they have done, more than they could possibly know.
Dedication

For mom, who shows me on a daily basis that women can be bosses in science, in the kitchen, and in the hearts of their families, all at the same time.
Chapter 1: Introduction

Hemispatial neglect is defined as a failure to report, respond, or orient to stimuli on the contralesional side of space in patients who have suffered damage to the brain. (Heilman & Valenstein, 1979). In other words, neglect causes an individual to behave as if the side of space opposite to their brain lesion is nonexistent. Neglect is most commonly associated with damage to the right hemisphere of the brain, occurring particularly frequently amongst patients who have suffered a stroke (Vallar & Perani, 1986). In behavioral manifestations, individuals with these right-sided stroke lesions may frequently collide with objects or structures such as doorframes on the left side of space, may only shave or apply makeup to the left side of their face, and may fail to acknowledge people or objects in the left visual field. Importantly, up to 85% of these patients demonstrate some degree of anosognosia, or unawareness of their deficits (Pedersen et al., 1996). Despite being a common and debilitating syndrome, affecting up to two-thirds of right-hemisphere stroke patients overall (Parton et al., 2004), neglect is a relatively poorly understood phenomenon. This may be due, in part, to the fact that neglect represents a complex syndrome with different patients showing varied combinations and levels of impairment. While researchers generally agree that neglect is a heterogeneous disorder, the different categories that may comprise the syndrome remain somewhat controversial. Some researchers propose a distinction between intentional neglect or directional hypokinesia (impaired movements toward the contralesional side), and attentional neglect or visuospatial inattention (impaired spatial attention toward the contralesional side of space) (Heilman et al., 1985; Na et al., 1998). Other authors have distinguished between near versus far neglect (Aimola et al., 2012; Bjoertomt et al., 2002), and personal versus extrapersonal neglect (Committieri et al., 2007). Still others have identified dissociations between perceptual neglect (neglect that is present for a particular sensory
stimulus) and representational neglect (neglect without external sensory input, such as in mental representations or memories) (Ortigue et al., 2001). Finally, there exists a growing body of literature to support the distinction between viewer-centered or egocentric neglect, and stimulus-centered or allocentric neglect (Bickerton et al., 2011; Marsh et al., 2008, Ota et al., 2001). Given this diversity, it is not surprising that simply defining the neglect population has been a significant obstacle to research on this topic.

1.1 Allocentric and Egocentric Neglect

Perhaps the most challenging aspect of the categorization of different neglect subtypes is distinguishing between allocentric and egocentric neglect, as the two subtypes are neither readily observable through everyday patient behavior, nor vastly different in their presentation. The two subtypes do, however, have distinct and meaningful impacts on a patient’s perceptual world. Egocentric neglect concerns a failure to perceive stimuli located on the contralesional side of space relative to the individual’s body midline (Chechlacz et al., 2010). By contrast, allocentric neglect refers to deficits in the perception of the contralesional side of individual objects, such as different items in a complex scene or individual words, regardless of their orientation or position relative to the body (Medina et al., 2009; Chechlacz et al., 2010). In a combined presentation, a patient might show simultaneous egocentric and allocentric deficits, evidenced by a failure to perceive both stimuli on the contralesional side of space, as well as the contralesional side of individual objects.

Though widely recognized, the relation between these two forms of neglect has been a topic of debate. A number of researchers have argued that allocentric neglect is merely a special form of egocentric neglect in which the patient’s attentional window has been limited to an individual stimulus (Driver & Pouget, 2000). Others propose that these presentations may not be
distinct at all, or that either pattern of neglect can appear in patients, depending on the instructions, situations, strategies, or requirements of the task designed to measure the type of neglect (Driver & Pouget, 2000; Mozer, 2002; Baylis et al., 2004; Karnath et al., 2011, Yue et al., 2012). Indeed, a recent study of right-hemisphere stroke patients conducted by Rorden et al. (2012) has suggested that allocentric deficits can only be observed in combination with an existing egocentric neglect. These authors also found a large corresponding overlap between the anatomical brain regions associated with egocentric and allocentric neglect.

In stark contrast to these findings are a number of studies that strongly support the dissociation between allocentric and egocentric neglect among stroke patients. One frequently utilized test for distinguishing between egocentric and allocentric neglect presentations is the Gap Detection task developed by Ota et al. (2001). In this task, patients are required to discriminate between complete shapes (e.g., circles), and shapes with a gap on either the left or right side. The patient must circle all complete shapes, and draw lines through all incomplete shapes. Ota et al. (2001) tested two right hemisphere stroke patients using this paradigm, and found that each exhibited very different patterns of performance on the task. One individual missed all stimuli on the contralesional side of space relative to the body, consistently attending to objects on the right half of the page while failing to attend to stimuli on the left side of the page. The other patient attended to all stimuli across the entire page, but incorrectly marked most of the circles with a gap on the left as being intact circles. These two distinct patterns of performance appear to provide compelling evidence for a strong behavioral dissociation, however the very small sample size (n=2) does raise concerns that these findings may not be generalizable to the overall neglect population.
Additional, and perhaps more robust, evidence for a dissociation between egocentric and allocentric neglect can be found in research by Hillis et al. (2005). These researchers assessed fifty right hemisphere stroke patients using a number of neglect measures, including line bisection, scene copying, sentence reading, and cancellation tasks. They found that eleven of these individuals exhibited exclusively egocentric neglect, four patients exhibited exclusively allocentric neglect, and only one exhibited both allocentric and egocentric neglect simultaneously. Marsh and Hillis (2008) also investigated stroke patients to attempt to distinguish between egocentric and allocentric patterns of deficit. They utilized both a standard and modified version of the test put forward by Ota et al. (2001), in which both visual and tactile modalities could be assessed. Nineteen of the stroke patients in this sample showed visual modality-specific neglect. Fifteen of these patients presented with pure egocentric neglect, two patients presented with pure allocentric neglect, and only two patients met criteria for both allocentric and egocentric neglect. The researchers concluded that egocentric and allocentric neglect should be considered distinct, dissociable syndromes that likely reflect damage to different brain areas. They also concluded that selective egocentric or allocentric neglect can occur in either the visual or tactile modality.

Bickerton et al. (2011) reported on twenty-five patients with either left or right hemisphere damage using the “Apples Test”. This test is similar to the task put forward by Ota et al. (2001), requiring patients to differentiate between whole apples, and apples with a gap on either the left or right side. Using this paradigm, it was found that five patients exhibited purely egocentric deficits, two patients exhibited purely allocentric deficits, and five patients presented with both neglect subtypes in combination. It was concluded in this study that reliable distinction
between egocentric and allocentric neglect can be accomplished with the use of sufficiently sensitive measures, such as the Apples Test.

Medina et al. (2009) investigated nearly two hundred right hemisphere stroke patients in the acute phase, using lexical and visuomotor tasks, as well as brain imaging techniques to distinguish between neglect subtypes. They observed clear-cut distinctions between neglect presentations among their patients, with thirty-two patients showing ‘pure’ egocentric neglect, thirteen patients showing ‘pure’ allocentric neglect, and twelve patients showing combined allocentric and egocentric deficits. These researchers also found that portions of the dorsal stream of visual processing (including the right supramarginal gyrus) were more involved in egocentric spatial encoding, whereas parts of the ventral stream (including the posterior inferior temporal gyrus) were more involved in allocentric encoding.

Verdon et al. (2010) investigated eighty right-hemisphere stroke patients using an extensive neuropsychological test battery to assess different manifestations of neglect, as well as statistical voxel-based lesion-symptom mapping to identify the neural correlates of distinct neglect profiles. These researchers found that allocentric-type errors in both gap detection and reading tasks were correlated with each other, and that this link was also correlated with injury to posterior temporal regions. Furthermore, Chechlacz et al. (2010) reported that egocentric deficits were correlated with damage to perisylvian regions while allocentric deficits were associated with posterior temporo-parietal junction injury in forty-one individuals from the same database as Bickerton et al. (2011). Similarly, in an examination of twenty-five stroke patients, Khurshid and colleagues (2011) reported that dorsal frontal-parietal reperfusion predicted earlier amelioration of egocentric neglect impairments, while more ventral posterior-temporal reperfusion was associated with recovery from allocentric neglect. Taken together, it becomes
evident that a significant number of studies support the dissociation between egocentric and allocentric neglect, and appear to suggest that distinct anatomical brain regions are differentially associated with each of these two neglect subtypes.

1.2 Assessment of Allocentric and Egocentric Neglect

Much of the discrepancy between the results of studies conducted in this area may be due to the use of varying, and possibly insensitive, methods of measuring allocentric and egocentric neglect (Rorden et al., 2012). Most neuropsychological and functional assessments of neglect tend to focus heavily on egocentric deficits. As such, allocentric neglect may be under-represented and require specific and specialized assessment tools in order to be detectable amongst patients. Line bisection tasks are a commonly utilized mode of assessment for neglect, as well as target cancellation, visual search, and figure copying tasks (Ting et al., 2011). When patients with neglect due to right hemisphere damage are asked to bisect a horizontal line, their responses are generally located far to right of center. Such a deviation from the midpoint of the lines can reflect neglect either in relation to the left half of the body (i.e., egocentric neglect), or the left half of each individual line (i.e., allocentric neglect; Chatterjee, 1994). Therefore, such line bisection tasks in isolation may not be capable of effectively distinguishing between egocentric and allocentric neglect (Rorden, Berger, & Karnath, 2006). When combined, however, with other available tests of neglect, such as visual search or cancellation tasks, impairments observed in line bisection may help distinguish between these two types of neglect. For example, Golay et al. (2008) proposed that a patient can be said to have allocentric neglect if line bisection deficits are observed in concert with relatively unimpaired cancellation performance, and that a patient can be said to have egocentric neglect if impairment in target cancellation is shown with relatively normal line bisection performance. While this multi-test
method may indeed increase sensitivity, it does have a number of limitations. First, the use of multiple tests on each individual patient can be time-consuming and laborious for both participants and researchers seeking a brief, yet comprehensive, screening of neglect. Second, different tasks may target or emphasize different processing strategies amongst patients, potentially producing artificial, test-specific results rather than true differences among patients. To avoid these issues, other researchers have recommended more novel and specialized tests such as the Gap Detection task (Ota et al., 2001) and the Apples Test (Bickerton et al., 2011) to validly measure both egocentric and allocentric neglect using a single assessment tool. Compared to frequently used visual search tasks, such as the Bells test (Gauthier et al., 1989), which assesses lateralized asymmetry in the body-centered/egocentric reference frame only, figurative discrimination tasks like the Apples Test assess neglect in relation to the body as well as individual items (Bickerton et al., 2011). Another robust but uncommonly utilized method of measuring allocentric and egocentric neglect is through eye-tracking technology. Eye tracking systems provide a continuous measure of attention by sampling the velocity and direction of eye movements, fixation durations as well as total gaze duration. Although attention can be allocated to different spatial locations without making overt eye movements (i.e., Posner, 1980), this does not necessarily indicate that different independent processes are involved in the generation of eye movements and in the spatial allocation of attention. In classic experiments performed on normal populations, Crovitz and Davie (1962), Remington (1980), and Shepherd et al. (1986) elucidated a close relationship between eye movements and allocation of attention. In fact, these studies have provided support for an asymmetric relationship between these two phenomena; it is possible to shift attentional focus without making observable eye movements (i.e., covert attention), but it is not possible to
make an eye movement without shifting attention in the same direction (Shepherd et al., 1986). In other words, movement of the eyes typically necessitates a corresponding shift in the spatial orientation of attention. If neglect is considered to be a bias in attention toward the ipsilesional side of space or of individual objects, it follows that eye movements might be correspondingly affected (Marshall and Robertson, 2013). Indeed, a number of studies have suggested that eye movements among neglect patients are markedly different as compared to matched controls. In particular, it seems that when neglect patients’ eyes are free to scan and perform visual search tasks, there does not seem to be an invisible barrier at the midline of a stimulus beyond which their gaze will not stray (i.e., Marshall and Robertson, 2013; Ishii et al., 1992; Gainotti and Taicci, 1971). Rather, it can be inferred that the probability of prolonged fixation upon the contralesional side decreases as distance from the midline increases. While typical pencil-and-paper measures of neglect can only detect behavioral outcomes, these findings highlight the importance of including assessments of the unique attentional patterns underlying neglect in order to gain a more comprehensive understanding of the disorder. Furthermore, eye-tracking measures provide the unique ability to distinguish between early automatic stages of attention versus later, more controlled attention mechanisms. Specifically, first fixation duration, which is defined as the length of time the eyes fixate on the target the first time they land on it, is taken to reflect initial attentional processes that are largely outside of overt cognitive control mechanisms. Conversely, dwell time, which is the sum of all fixations and refixations on the target, reflects later more controlled stages of attention (Rayner, 1998; Libben & Titone, 2009). To date, there has been a paucity of research investigating the time-course of attention deficits in hemispatial neglect.
While it seems intuitive that eye-tracking technology might be useful in distinguishing between allocentric and egocentric neglect in a reliable way, very few studies have attempted to use this methodology for such a purpose. However, in one study by Karnath et al. (2011), simple drawings of houses were presented at five different egocentric positions in the horizontal plane and patients’ eye and head movements were recorded as they explored the images. These researchers found that patients exhibited both egocentric and allocentric patterns of visual attention. Interestingly, neglect of the houses’ left side was strong at contralesional egocentric positions, but improved as their location shifted to a more ipsilesional location. In other words, they found that allocentric neglect can vary based on egocentric position. Despite this observed relation between allocentric and egocentric neglect, the authors concluded that their results did not argue against the possibility that stroke patients with neglect may exhibit neglect relative to only one frame of reference at a time. In addition, they acknowledged the inherent limitations of their study, citing a small sample size of only three participants as a primary issue. Finally, the researchers suggest that future investigations are necessary to understand the pattern of eye and head positions that patients with neglect demonstrate when performing cancellation-type tasks, such as the Gap Detection task created by Ota and colleagues (2001). The relative paucity of research assessing allocentric and egocentric neglect using eye-tracking equipment appears to be due to the fact that such multi-method neglect research is generally viewed as both expensive and arduous. It is clear, however, that this important technology has the potential to further general understanding of neglect subtypes, as well as improve their measurement.

1.3 Neglect Subtypes and Functional Outcome

Given that neglect is a common and debilitating condition that is frequently associated with anosognosia, it is not surprising that the presence of a neglect syndrome is considered a
poor prognostic indicator for functional recovery following a stroke. The time course of spontaneous neurological recovery of neglect tends to follow a natural logistic curve up to approximately 12 weeks post-stroke, after which neglect symptoms become stable and chronic (Nijboer et al., 2013). Importantly, only 43% of neglect patients experience such spontaneous improvement in the acute phase, and only 9% recover from symptoms completely (Farne et al., 2004). Individuals with chronic neglect have poorer functional outcomes than stroke patients without neglect (Buxbaum et al., 2004; Cherney et al., 2001), and neglect has been specifically associated with longer lengths of hospital stay (Jehkonen et al., 2006), less likelihood of being discharged home (Wee & Hopman, 2008), increased risk for falls and injuries (Czernuszenko et al., 2006), poor return to independent living (Luate, 2006), and poor overall self care (Nijboer et al., 2013).

While it is generally accepted that neglect, as a whole, can have severe consequences for patients’ functional recovery, it is unclear whether the neglect subtypes might differentially impact patient outcomes. In a meta-analysis conducted by Jehkonen and colleagues (2006), it was found that the majority of the literature addressed neglect as a whole, without specifying its subtypes to any degree. The authors identified only four studies that categorized neglect into subtypes, but none of these specified the possible impact of subtype on functional outcome. Furthermore, these authors noted that most assessments of functional outcome used in the existing literature consisted of mainly motoric aspects of functioning, and largely ignored the equally important facets of social, cognitive, emotional, and quality of life outcomes.

One exception to the lack of differentiation between neglect subtypes as they pertain to functional outcomes is the study by Bickerton et al. (2011). Here it was observed that individuals with allocentric neglect tended to be more impaired in everyday activities (as measured by the
Barthel questionnaire, Mahoney & Barthel, 1965), compared to those with pure egocentric neglect. In addition, patients with both types of neglect tended to have worse functional outcomes than patients with only egocentric or allocentric neglect in isolation. Finally, it was found that the presence of both egocentric and allocentric neglect simultaneously was associated with a greater likelihood of depressive symptoms. These preliminary results highlight the importance of distinguishing between allocentric and egocentric neglect among stroke patients in order to facilitate understanding of their relative influences on patient recovery outcomes, as well as enhance care quality and effective rehabilitative treatment planning for stroke patients.

1.4 Hypotheses

Given the contradictory nature of neglect subtype research, the measurement issues surrounding these constructs, and the lack of investigation of the relative impacts of allocentric and egocentric neglect on functional outcomes, it is evident that further study in this area is warranted. The goals of this research project were fourfold: First, we aimed to determine whether allocentric and egocentric neglect presentations could be accurately and sensitively dissociated among a sample of stroke patients using figurative discrimination tasks in conjunction with eye-tracking technology. Second, we sought to determine the relative frequencies of pure allocentric neglect, pure egocentric neglect, and combined allocentric and egocentric neglect presentations among stroke patients experiencing hemispatial neglect. Third, we sought to investigate the specific attentional patterns of neglect as they pertain to both the location and duration of patients’ eye movements. Finally, we aimed to illuminate the nature of the potential relationship between these neglect subtypes and patient prognosis, in terms of functional outcomes. Our specific hypotheses are were as follows:
1. We hypothesized that we would find a distinct dissociation between patients in the sample who demonstrated allocentric neglect, egocentric neglect, or both types of neglect simultaneously, and that the eye-tracking measure would be more sensitive in detecting these subtypes than other tests of neglect.

2. In concordance with recent studies, we hypothesized that pure egocentric neglect would appear more frequently in the sample than pure allocentric neglect (Bickerton et al., 2011; Khurshid et al., 2012).

3. We hypothesized that the specific patterns of attention evidenced on the eye-tracking measure would differ between patients based on their neglect subtype classification. Specifically, we expected to find no difference between global spatial allocation of attention for individuals with no neglect or allocentric neglect, and a bias against the left side of space in egocentric neglect and combined egocentric and allocentric neglect. We hypothesized that these attentional patterns would hold true for dwell time, but not initial fixations, indicating preserved initial and automatic processing with impaired sustained attention in this disorder.

4. Finally, based on Bickerton et al. (2011), we hypothesized that those suffering from egocentric neglect would have better functional outcomes than those with either allocentric neglect or both neglect subtypes.
Chapter 2: Methodology

2.1 Participants

Sixteen participants (8 male and 8 female) were recruited from the Rehabilitation Center at Kelowna General Hospital. Patients were referred for neuropsychological assessment as part of the rehabilitation process following recovery from an ischemic or hemorrhagic stroke. Inclusion criteria included a diagnosis of recent stroke resulting in hospitalization, probable neglect based on lesion location and observed patient behavior, absence of prior psychiatric history, ability to provide consent and understand/follow direction, and patient age between 17 and 90 years. Invitation to participate in the study was provided at the start of the neuropsychological assessment. Patients were told that participation was voluntary with no compensation provided, and testing involved completing various cognitive tasks, as well as a functional assessment interview. Participants were informed that cognitive testing was part of routine clinical care, but had been augmented for study purposes; further, information obtained from the functional assessment interview and from eye-tracking assessment would be used solely for study purposes and would not affect the course of their treatment or discharge from hospital. Information on gender, age, ethnicity, level of education, marital status, and living arrangements was collected from all patients. In addition, information regarding date of stroke, lesion location, and the nature of the lesion were gathered from electronic patient charts available through Meditech, the hospital’s electronic patient database. Participant characteristics, are presented in Table 1. Overall, our sample was well-educated ($M = 13$ years, $SD = 2.8$), almost exclusively right-handed (N=15, 94%), comprised mainly of senior citizens ($M = 61$ years, $SD = 18.1$), and balanced in terms of gender distribution (males = 50%, females = 50%).
Table 1
*Demographic and Stroke Information (N=16)*

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Mean (SD)</th>
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<tr>
<td>Age at stroke</td>
<td>61 (18.1)</td>
</tr>
<tr>
<td>Education</td>
<td>13 (2.8)</td>
</tr>
<tr>
<td>Gender, N (%)</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>8 (50%)</td>
</tr>
<tr>
<td>Female</td>
<td>8 (50%)</td>
</tr>
<tr>
<td>Handedness, N (%)</td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td>15 (94%)</td>
</tr>
<tr>
<td>Left</td>
<td>1 (6%)</td>
</tr>
<tr>
<td>Time from stroke to testing (days)</td>
<td>43 (35)</td>
</tr>
<tr>
<td>Type of Stroke, N (%)</td>
<td></td>
</tr>
<tr>
<td>Ischemic</td>
<td>11 (68%)</td>
</tr>
<tr>
<td>Hemorrhagic</td>
<td>4 (25%)</td>
</tr>
<tr>
<td>Unknown</td>
<td>1 (6%)</td>
</tr>
<tr>
<td>m-OCSP Classification, N (%)</td>
<td></td>
</tr>
<tr>
<td>Anterior</td>
<td>9 (56%)</td>
</tr>
<tr>
<td>Posterior</td>
<td>3 (19%)</td>
</tr>
<tr>
<td>Lacunar</td>
<td>3 (19%)</td>
</tr>
<tr>
<td>Unknown</td>
<td>1 (6%)</td>
</tr>
</tbody>
</table>

Note: m-OCSP Classification = modified - Oxfordshire Community Stroke Project Classification.

2.2 Measures

2.21 Assessment of Hemispatial Neglect

*Stroke Classification.* The *Oxford Community Stroke Project (OCSP).* The OCSP classification system was initially developed to assist diagnoses of stroke, and has previously been used when neuroimaging technology was unavailable to clinicians. Classification is based on the initial physical and cognitive presentation of the patient, and vasculature of the brain. Patients with a Total Anterior Circulation Infarct (TACI) would present with a combination of higher cerebral dysfunction (e.g., dysphasia, dyscalculia, visuospatial disorder), homonymous field defect, and ipsilateral motor and/or sensory deficit of at least two areas of the face, arm, and leg. Patients with a Partial Anterior Circulation Infarct (PACI) would present with two of the three components (e.g., motor/sensory deficit in one limb) of the TACI. Patients with a Lacunar
Circulation Infarct (LACI) would present with pure motor, sensory, sensory-motor, or hemiparetic stroke. Patients with a Posterior Circulation Infarct (POCI) would present with bilateral motor and/or sensory deficit. Findings from research conducted by Bamford et al (1991) suggest that these four subtypes have distinct features and varying degrees of outcome. Specifically, a stroke classified as TACI has the poorest prognosis of functional outcome and highest mortality rate. The PACI stroke is highly linked to recurring strokes and compounding neurological sequelae. The LACI is likely to be classified as "mild" and shows a better prognosis for treatment. The POCI has a high mortality rate early in the stroke occurrence, likely due to the proximity of vital brainstem structures, and a high risk of recurring strokes. This classification system has been used extensively in stroke studies examining functional, emotional, and cognitive outcomes (Asgadi, Jeerakathil, Hameed, et al., 2011; Subramanian, Silva, Silver, et al., 2009; Barker-Collo, Starkey, Lawes, et al., 2012; Al-Buhairi, Phillips, Llewellyn, et al., 1998; Patel, Coshall, Rudd, et al., 2002; Oztop, Ayas, Ustaomer, Cosar, & Yemisci, 2013; Langhorne, Bernhardt, & Kwakkel, 2011).

*The Apples Test.* The Apples Test (Bickerton et al., 2011) is an assessment of neglect that is sensitive to both allocentric and egocentric response styles (Appendix A). The Apples Test consists of 150 apple shapes on a single page. Two thirds of the apples are distractor items (half with an opening on the left side and half with an opening on the right side), and the remaining apples are targets (full apples). The apples are scattered across the page such that, when divided into 10 equal sections, each type of apple appears exactly five times per section. This task requires participants to cross out all complete apples while ignoring all incomplete apples. Asymmetry scores based on suggested accuracy cutoffs are calculated to determine each patient’s level of allocentric and/or egocentric neglect. Egocentric asymmetry scores are
calculated by subtracting the number of whole apples correctly selected in the four rightmost sections from the number of whole apples correctly selected in the four leftmost sections. Similarly, allocentric asymmetry scores are calculated by subtracting the number of false positives (apples with a left-sided gap incorrectly marked) in the four rightmost sections from the number of false positives in the four leftmost sections. Overall accuracy score of less than 42 (of 50 fully-outlined apples) indicate an overall impaired performance. Positive values of asymmetry scores indicate spatial neglect of the left egocentric and/or allocentric space. An egocentric asymmetry score greater than 2 indicates left egocentric neglect; an allocentric asymmetry score greater than 1 indicates left allocentric neglect. Test-retest reliability for the Apples Test is high, with concordance rates of 88% on a classification of patients having (or not having) egocentric neglect and a concordance rate of 94% on classifying patients as having (or not having) allocentric neglect. In order to allow for measurement of patients’ eye and head movements during completion of the Apples Test, we modified the traditional paper-and-pencil Apples Test to be displayed on a computer screen (Appendix B). The Apples Test paradigm was displayed on a 12 x 8 inch computer monitor and participants marked responses via mouse click.

Eye-Tracking. The RED-m remote eye tracker is an ultra-light, fully portable eye-tracking device produced and distributed by SensoMotoric Instruments (SMI). The SMI RED-m eye tracker relies on non-invasive, video-based eye tracking that does not involve a head mounted device. The system incorporates head movement compensation, utilizing a large working area with high quality gaze and pupil data to ensure accurate and reliable results. A sampling rate of 60Hz was used in the current study. Defined interest areas were calibrated to surround each distinct shape in the Apples Test. In addition, areas of interest were calibrated to separate the stimulus page into four horizontal sections: a far left section, a middle-left section, a
middle-right section, and a far right section. Eye-tracking measures of interest included total Dwell Time (i.e., the sum of durations from all saccades and fixations on a given side of an apple or side of the page) and First Fixation Duration (i.e., the duration of the first fixation on a given side of an apple or side of a page, regardless of whether it is the only fixation or the first of multiple fixations) (Rayner, 1998). The Dwell Time measure of eye movement was used as it represents the total length of time a participant spends gazing at a particular area of interest. Given that the attentional biases underlying hemispatial neglect appear to be related to fixation duration rather than relative location of stimuli (Gainotti and Taicci, 1971), the Dwell Time measure is one of the most appropriate for investigating the patterns of sustained attention present in a sample of patients with this syndrome. As a means of assessing early attention, we included the First Fixation Duration measure, which is considered to be largely automatic and independent of mechanisms of cognitive control (Rayner, 1998).

2.2.2 Neuropsychological Assessment

Test selection for the neuropsychological battery was based on the standardized stroke and MCI neuropsychological test protocol proposed by the NINDS-CSN (Hachinski, et al., 2006). Memory, language, visuospatial-constructional skills, and executive function were assessed using the following measures:

Rey-Osterrieth Complex Figure Test. The Rey-O Complex Figure Test (RCFT; Osterrieth, 1944) assesses visuospatial recall, visuospatial recognition, response bias, processing speed, and visuospatial constructional ability. This test requires the individual to first copy the stimulus figure onto 8 1/2" x 11" paper. The stimulus figure is removed and the participant is asked to draw the figure from memory after 3- and 30-minute delays. The time, in seconds, it takes to complete the copy is recorded. The accuracy and placement of the 18 specific elements
that make up the figure are scored. The test-retest reliability of the RCFT ranges from .76 to .89, and inter-rater reliability ranges from .93 to .99 (Lezak, Howieson, Loring, Hannay, Fischer, 2004). Administration time is approximately 45-minutes, and is appropriate for individuals 6 - 89 years of age.

**Color Trails Test.** The Color Trails Test (CTT; Maj, D’Elia, Satz, Janssen, Zaudig, Uchiyama, Starace, Galderisi, & Chervinsky, 1993) assesses sustained attention, sequencing, and other executive functions. Additionally, it reduces language requirements and cultural bias. This test requires participants to quickly connect a sequence of numbered, colored (alternating pink and yellow) circles from 1 to 25. In the first trial, a participant uses a pencil to connect the circles, without the use of colors, from 1 to 25 as quickly as possible. The second trial is similar to the first, but the participant must alternate the color of the circle with each subsequent number. The examiner uses a stopwatch to record completion time, in seconds, on each trial. Other indicators of brain dysfunction are also examined such as prompting, near-misses, color sequence errors, and number sequences errors. Clinical studies suggest a severe slowing in parts 1 and 2 for participants with traumatic brain injury (Straus, Sherman, & Spreen, 2006). Test-retest reliability is reported to be .64 for part 1 and .79 for part 2. The test manual contains age and education corrected normative data for interpretation between groups. Administration time is approximately 3 -8 minutes. The CTT is appropriate for adults 18 - 89 years of age.

**The Consonant Trigrams Test.** Also known as the Brown-Peterson technique (CCC; Brown, 1958, as cited in Melton, 1963) is an assessment tool for short-term memory, divided attention, and information processing speed. The task starts with the examiner reading aloud three consonants, and the participant is required to remember the consonants for 0, 3, 9, and 18-second intervals. During intervals of 3, 9, and 18-seconds, a number is given after the three
consonants and the participant is asked to count backwards by 3’s from the specified number. At the end of the interval the examiner knocks on the table, and asks the participant to recall the three letters that were presented. Intervals are timed after the last consonant is spoken. Participants are not allowed to recall out loud the consonants while counting backwards. Participant responses are recorded by the examiner. Scoring is based on correct recall of the consonants, and the maximum score achievable is 60. Psychometric properties reported in the literature are limited to the Turkish translation of CCC; however, 3-, 9-, and 18-second delay intervals have shown an internal consistency of .85 (Mitrushina, 2005).

_The Wechsler Adult Intelligence Scale - Fourth Edition (WAIS-IV) Block Design._ The Block Design subtest assesses visuospatial and motor skills (Maccow, 2008). It is a core subtest of the Perceptual Reasoning Scale in the Wechsler Adult Intelligence Scale - Fourth Edition (WAIS-IV). The participant is required to create patterns as quickly as possible and within a time limit, as presented in the stimulus booklet, using various numbers of blocks consisting of all white sides, all red sides, and red and white sides. The presented picture in the sample trial and trials 1-4 are accompanied by a model, whereas trials 5-14 consist of only the picture in the stimulus booklet. The time it takes to complete each trial is recorded, and used for scoring (0-2 on trials 1-4, 0 - 4 on trials 5-8, and 0 or 4-7 on trials 9-14). A discontinue criterion is applied if the participant scores two consecutive scores of 0. The test can be scored with or without a time bonus. The raw scores range from 0 - 66 (48 without time bonus), and are converted to a standardized score from 1-20. Normative data for standardizing scores are corrected for age. The Block Design is appropriate for participants 16 - 90 years of age.

_The Wechsler Adult Intelligence Scale - Fourth Edition (WAIS-IV) Coding._ The Coding subtest measures processing speed, short-term visual memory, psychomotor speed, visual
perception and scanning ability, visual-motor coordination, attention, and concentration (Maccow, 2008). Coding is a subtest to the Information Processing Scale. The participant copies symbols that are paired with numbers in a specified time limit. A standard score is calculated from the raw score of the number of symbols correctly written and subtracting the number of symbols incorrectly written or skipped. This subtest has been shown to predict functional outcome in a stroke population (Wagle, 2011).

*Wisconsin Card Sorting Test.* The Wisconsin Card Sorting Test (WCST; Grant & Berg, 1948, as cited in Nagahama, et al., 1996) measures executive function; strategic planning, organized searching, utilizing environmental feedback to shift cognitive sets, goal-directing behavior, and modulating impulsive behavior (Heaton et al, 1981, 1993, as cited in Strauss, 2006). Raw scores may be transformed to standardized scores, percentiles, and t-scores. This test is appropriate for individuals 7 - 89 years of age. Administration time is approximately 20-30 minutes.

*The California Verbal Learning Test-Second Edition.* The California Verbal Learning Test-Second Edition (CVLT-II; Delis, Kramer, Kaplan, & Ober, 2000) is a measure of verbal learning and memory. The CVLT-II comprises two 16-word lists—List A, which is read five times and List B, which is read only once and serves as an interference task. Examinees’ memory of List A is tested both immediately and following a delay through free recall, cued recall, and recognition tasks. Immediate memory testing of List A occurs after each of the 5 consecutive list presentations, while delayed memory testing occurs once following a short delay in which List B is presented, and then again after a 20-minute delay. Responses to the CVLT-II exhibit adequate validity and reliability for clinical samples (Chronbach’s α = .80) (Delis et al., 2000; Hubley, 2004). The variable of primary interest for the purposes of this study was the *Long Delay Free*
Recall score, which provides a global measure of verbal memory (Delis et al., 2000). In comparison to other facets of the CVLT, this measure’s retest reliability is one of the most stable ($r = .88$) (Delis et al., 2000).

**Controlled Oral Word Association Test.** The Controlled Oral Word Association Test (COWAT) is a measure of verbal fluency, and specifically phonemic fluency, that requires participants to spontaneously generate words belonging to the same category (i.e., animals) or beginning with the same designated letter. The COWAT is particularly sensitive to damage associated with the left frontal region (Spreen & Benton, 1977). Age, education, sex, ethnicity, reading level, and verbal IQ (WAIS) have moderating effects on scores (Strauss et al. 2006). Tombaugh et al. (1999; as cited in Strauss et al. 2006) found internal reliability between the F, A, and S categories to be high ($r = .83$). In addition, test-retest reliability was also high shown to be high at two-week and five year intervals ($r > .70$). The FAS test has been utilized in clinical studies of aphasia (Spreen & Benton, 1977), head injury (Levin & Kraus, 1994), dementia (Henry & Crawford, 2004c), and mood and thought disorders (Henry & Crawford, 2005a). Demographically corrected normative data (i.e., sex, age, and education) is available. The FAS is appropriate for ages 7 to 95.

**2.2.3 Functional Outcome Assessment**

*Mayo-Portland Adaptability Inventory-4.* The Mayo-Portland Adaptability Inventory-4 (Malec, 2008) consists of four indices: **ability, adjustment, participation,** and **pre-existing and associated conditions** (Appendix C). The inventory can be completed by professional staff (single or team consensus), people with acquired brain injury (ABI), or a significant other. Each of these methods has its own normative data set to convert raw scores to standardized $T$-scores. For accurate assessment, a manual is available that outlines specific criteria for scoring each item.
that is based on an ordinal scale from 0 (None) to 4 (Severe problems; interferes with activities more than 75% of the time). An example of an item from this inventory is, “Impaired self-awareness: Lack of recognition of personal limitations and disabilities and how they interfere with everyday activities and work or school”. The MPAI-4 is typically used for clinical evaluation during inpatient, outpatient, and community settings, and for developing appropriate rehabilitation programs tailored to patient needs. The literature suggests the MPAI-4 demonstrates good test-retest reliability, with coefficients ranging from .72 in early patient recovery to .93 in later follow-up recovery (Oddson, Rumney, Johnson, & Stonell, 2006). Malec et al. (2012) conducted single parameter (Rasch) item-response analyses on the MPAI-4, and found the construct validity and internal consistency to be very good in a stroke population.

2.3 Procedure

Data were collected at Kelowna General Hospital over a 6-month period (December 2015 to May 2016). The study was approved by the University of British Columbia Okanagan and Interior Health Harmonized Research Ethics Board. Neglect test scores, interview information on perceived current level of function, demographic information, and stroke location based on radiology reports and therapists' progress reports (i.e., occupational, physical, and/or speech-language) were collated for analyses.

Neuropsychological evaluation, including cognitive testing, lasted approximately four hours. Testing was conducted over two sessions to avoid test fatigue, but was completed within a two-week time frame to reduce the impact of rehabilitation and natural recovery from stroke on test performance. Neuropsychological test scores were standardized based on age-, sex- and education-corrected normative data from the manual for each test or published normative data (see Table 2 for normative data source of each test). If a participant was unable to complete a
particular test due to impairment, such as going over the allotted time on the Color Trails Test or being unable to recall drawing the Rey-O Complex Figure Design, they were delegated the lowest score based on normative data (i.e., T-score of 10 or 4SD below the mean), a standard clinical practice and method of maintaining sample size in clinical research (Nys et al., 2005). This process also preserves the variable performance of the sample, and avoids selection bias and inflating average performance scores on testing. In the current sample, this method was employed for a total of two participants, each with two neuropsychological tests requiring score substitution. The neuropsychological test battery is summarized in Table 2. Minor test substitutions were made from the NINDS-CSN protocol to provide more robust and current measures of cognition: the proposed Wechsler Adult Intelligence Scale - III (WAIS-III) subtests were updated to the current WAIS-IV subtests, and the Wisconsin Card Sort Test (WCST) and Consonant Trigrams (CCC) tests were added to provide more robust measures of cognition, and allocated as measures of executive function as per the tests' authors (for review see Strauss, Sherman, & Spreen, 2006).
Table 2

Neuropsychological Domains, Corresponding Tests, and Standardization Sources

<table>
<thead>
<tr>
<th>Neuropsychological Domain</th>
<th>Test Name</th>
<th>Abbreviation</th>
<th>Scores Used</th>
<th>Standardization Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Memory</td>
<td>Rey-Osterrith Complex Figure Test</td>
<td>ROCTF</td>
<td>30' Delay</td>
<td>ROCFT Scoring Manual</td>
</tr>
<tr>
<td>Language</td>
<td>Controlled Oral Word Association Test (FAS)</td>
<td>COWAT</td>
<td>Total Words</td>
<td>COWAT (Tombaugh, Kozak, &amp; Reese, 1996)</td>
</tr>
<tr>
<td></td>
<td>Brown-Peterson Task/Consonant Trigrams</td>
<td>CCC</td>
<td>Total</td>
<td>(Boone et al., 1990)</td>
</tr>
<tr>
<td></td>
<td>Wisconsin Card Sort Test</td>
<td>WCST</td>
<td>Perseverative Errors No. of Categories</td>
<td>WCST Scoring Manual</td>
</tr>
<tr>
<td></td>
<td>Colour Trails Test</td>
<td>CT2</td>
<td>Colour Trails 2</td>
<td>CT 1 &amp; 2 Manual</td>
</tr>
</tbody>
</table>

Evaluation of neglect, including both eye-tracking and pencil-and-paper measures, lasted approximately thirty minutes. Testing was conducted in a quiet room with a single examiner present to provide task instructions, calibrate eye-tracking equipment, and facilitate computer-based task presentation. In order to improve measurement accuracy of the eye-tracker, a modified computerized version of the Apples Test was created. The total number of apple shapes was reduced from 150 to 90 to ensure that each shape occupied at least the recommended
minimum pixel-based size for accurate eye movement detection. Original ratios of whole, left-gap, and right-gap apples were retained. Each participant completed paper-and-pencil versions of the original Apples Test and the modified Apples Test without eye-tracking, as well as the modified computerized Apples Test with eye-tracking. The order of administration of each version of the Apples Test was counterbalanced between participants. Each computerized Apples Test trial began with the mouse cursor placed at the center of the screen to avoid artificially influencing participants’ initial gaze patterns.

Evaluation of patients’ functional outcomes via the MPAI-4 was conducted in a separate thirty to sixty minute session either immediately following or immediately preceding neglect testing. Interviews were conducted by trained examiners who were blind to patients’ scores on tests of neglect. MPAI-4 scores were based on a semi-structured interview with the participant, and review of therapists’ progress notes contained within patient charts. To avoid over- or under-inflating scores, only progress notes up to two weeks of the start date of neglect testing were reviewed for scoring. Reviewing notes much earlier or later from the time of neglect evaluation may provide inaccurate comparisons of functional outcome and neglect subtype. During the interview, it was emphasized that scores on the MPAI-4 were strictly for study purposes and did not influence decisions made by the patient's clinical care team.

Stroke and demographic information were obtained via the Meditech electronic patient chart system. Stroke information was obtained from radiology reports by radiologists blind to the study, and categorized via the OCSP classification system and left-right hemisphere location. To allow for sufficient power in analyses, a modified OCSP (m-OCSP) classification was used here; TACI and PACI strokes were collapsed into "anterior stroke". This approach has been used by other researchers to classify and compare anterior and posterior strokes (Tao, Liu, Fisher, et al.,
The category of “posterior stroke” was retained for analyses. We also chose to retain lacunar strokes as they have been shown to display distinct deficits and outcomes compared to the other stroke location subtypes (De Jong, Kessels, Lodder, 2002; Asdaghi, Jeerakathil, Hameed, et al., 2011; Hachinski et al., 2006; Ng et al., 2007). Lacunar strokes are caused mainly by occlusion of small perforating arteries and are relatively more difficult to detect with neuroimaging techniques (e.g., CT scan), despite presentation of physical and/or cognitive impairments (Bamford et al., 1991; Edwards, Jacova, Sepehry, 2013). Demographic data included age, sex, education, and number of days since stroke onset/admittance to hospital.
Chapter 3: Statistical Analyses

SPSS statistical software, version 20.0 was used for all analyses, and all \( p \)-values reflect two-tailed tests with \( p \)-values less than .05 considered statistically significant. Dependent variables included functional outcome for analyses designed to assess patient outcomes, and Dwell Time and First Fixation Duration for analyses of patient attentional patterns. Independent variables included demographic variables (i.e., age, gender, education, etc.), stroke lesion-related variables (i.e., stroke type and location), cognitive variables (i.e., neuropsychological test performance), and neglect subtype (i.e., egocentric, allocentric, both or no neglect).

All assessments were administered and scored based on standardized procedures set out by the author/publisher. Standardized scored from the MPAI-4 and cognitive assessments were entered as continuous variables. Stroke location, sex, and neglect classification (none, egocentric, allocentric, or both) were entered as categorical variables.

3.1 Preliminary Data Analyses

To maximize use of data, cases that had data points missing on variables of interest were deleted pair-wise for correlational and regression analyses. Descriptive statistics for each variable (e.g., means, standard deviations, minimum and maximum values, skewness, and kurtosis) were calculated and examined. Data were screened for univariate outliers and data points that were beyond 3 times the interquartile range for a given variable were considered extreme values. Variables of interest were assessed for normality both by examining normal q-q plots for the presence of reasonably straight diagonal lines and by examining skewness and kurtosis values.

Data was also examined for multivariate outliers by determining whether Mahalanobis Distances (\( D^2 \)) exceeded a critical chi square value that is dependent on the sample size and the
number of predictors used in the regression equations (Tabachnick & Fidell, 2007). In addition, cases that may have exhibited influence on regression coefficients were assessed by examining both global and specific measures of influence (i.e., Cook’s $D_i$ and DFBETAIj respectively; Cook’s $D_i$ values >1 and DFBETAIj values >1 were considered influential). Multicollinearity for variables considered for the regression analysis was examined by inspecting variables with correlations exceeding $r = .70$ and variance inflation factor (VIFj) values greater than 10.

Bivariate scatterplots of potential predictors against the dependent variable were plotted and assessed for linear relationships. To test the assumptions of Multiple Linear Regression, q-q plots and residual plots were examined. Specifically, scatterplots of standardized residuals plotted against the standardized predicted values were examined for cloud-like shape and a mean close to 0 for fulfilling the assumptions of: 1) linearity; 2) homogeneity of variance; and 3) independence of observations. The assumption of normality of errors was examined by plotting and inspecting normal q-q plots for approximately straight lines. The assumption of homogeneity of variance was further assessed through Levene’s test.

### 3.2 Descriptive Analyses

Means, standard deviations, skew, and kurtosis for Apples Tests, MPAI-4, and cognitive variables are presented in Table 3. While a number of variables appeared to demonstrate skewness in violation of a normal distribution, none of these values met cutoffs for significant skew (i.e., skew levels that were outside the range of $\pm 2X SE$ skewness) given the small sample size. Square root and log transformations applied to variables did not result in improvements in normality. As such, all analyses were conducted with untransformed variables.
3.3 Test Equivalency and Variable Reduction

*Equivalency of Paper-and-Pencil Apples Test Versions.* In order to test for measure equivalency, a paired-samples t-test was conducted to compare egocentric and allocentric asymmetry scores for both the original and short-form paper-and-pencil Apples Tests. For egocentric asymmetry scores, there was not a significant difference between scores on the original version (M=4.00, SD=5.94) and the short-form (M=3.40, SD=4.19) of the Apples Test; $t(14)=0.899$, $p = 0.384$. Similarly, for allocentric asymmetry scores, there was not a significant difference between scores on the original version (M=3.73, SD=4.82) and the short-form (M=2.47, SD=3.83) of the Apples Test; $t(14)=1.73$, $p = 0.106$. As the two measures were
demonstrated to be statistically equivalent, all subsequent analyses used neglect scores derived from the short-form version of the Apples Test.

**Equivalency of Paper-and-Pencil vs. Computerized Apples Tests.** In order to test for measure equivalency between the short-form paper-and-pencil Apples Test and the short-form computerized Apples Test, another paired-samples t-test was conducted. For egocentric asymmetry scores, there was not a significant difference between scores on the short-form paper-and-pencil Apples Test (M=3.40, SD=4.19) and scores on the computerized Apples Test (M=3.31, SD=4.23); t(15)= -.222, p = 0.827. For allocentric asymmetry scores, there was not a significant difference between scores on the short-form paper-and-pencil Apples Test (M=3.73, SD=4.82) and scores on the computerized Apples Test (M=3.41, SD=4.22); t(15)= -.892, p = 0.342. Similarly, no significant difference was found between total number of targets crossed out on the paper-and-pencil (M= 21.63, SD=1.98) and computerized version (M=22.69, SD=1.88) of the Apples Tests; t(15)= -.194, p = 0.849.

**Apples Test Neglect Scores.** As raw page- and item-based asymmetry scores do not allow for meaningful comparison between Apples Test scores and Eye-tracking measures, Apples Test scores were transformed to categorize each participant as having one of the following; Egocentric neglect, allocentric neglect, both, or none. This categorical variable was computed based on asymmetry cut-off values described by the author/publisher of the measure. Positive values of asymmetry scores indicated spatial neglect of the left egocentric and/or allocentric space. Participants with egocentric asymmetry scores greater than 2 were classified as having left egocentric neglect; Participants with allocentric asymmetry scores greater than 1 were classified as having left allocentric neglect; Participants with both ego- and allocentric asymmetry scores beyond their respective cut-off values were classified as having both types of neglect;
Participants with neither asymmetry score beyond these cut-off values were classified as having no neglect.

**Eye-tracking Neglect Scores.** A Repeated Measures ANOVA with the factors of Page (left side of page, right side of page) and Apple (left side of apple, right side of apple) was conducted for each participant’s raw Dwell Time data. These data were chosen over First Fixation Duration data as the Dwell Time measure represents the total length of time a participant spends gazing at a particular area of interest, rendering it a more comprehensive measure of a patient’s global performance during the entire stimulus presentation. A significant main effect for Page served as indication of the presence of egocentric neglect (i.e., the time spent on the right side of the page was significantly different than the time spent on the left side of the page). Similarly, a significant main effect for Apple indicated the presence of allocentric neglect (i.e., the time spent on the right side of the apple was significantly different than the time spent on the left side of the apple). If there was a significant main effect for both factors, the presence of both forms of neglect simultaneously was indicated.

**Neuropsychological Variables.** As detailing specific level of functioning on each neuropsychological measure or domain was not the purpose of this study, scores on the 8 cognitive variables of interest (i.e., ROCFT, CVLT-II, WAIS-IV Block Design, CCC, WAIS-IV Coding, CT2, WCST, and COWAT) were used to compute a single independent variable for traditional cognitive functioning. This method allows data from multiple and distinct variables to be summarized in a meaningful way to improve reliability and assist in the interpretation of analyses by reducing the number of independent variables. Raw scores were converted into t-scores and were averaged across all measures for each participant to create a composite for cognitive functioning. This cognitive composite was used in subsequent analyses.
3.4 Regression Analysis

To determine whether patients’ eye-tracking performance had significant predictive value on the dependent variable, over and above that of Apples Test performance, hierarchical multiple linear regression (MLR) was used. Prior to conducting regression analysis, intercorrelations among independent variables (demographics, cognitive, and stroke-related) and functional outcome (MPAI-4 total score) were assessed through Pearson and point biserial correlations. In the interest of preserving power, we chose to include only those variables that demonstrated significant correlations at the a priori criterion of $p < .01$ with MPAI-4 score in our regression model. Only the cognitive composite score was significantly associated at the a priori criterion of $p < .01$ and was therefore included in the regression analysis. Variables that were not significantly predictive of functional outcome when included in the full regression model were removed from the final, simple regression model. In order to allow for use of the 4-level categorical variable of neglect score (i.e., egocentric, allocentric, both, none) in regression analysis, the neglect variables for both the Apples Test and the eye-tracking measure were dummy coded to create a number of separate dichotomous variables appropriate for use in, and interpretation of, the regression model.

To assess the predictive value of eye-tracking performance beyond both cognitive variables and the paper-and-pencil Apples Test, we entered the cognitive composite variable in Step 1, the Apples Test neglect scores in Step 2, and the Eye-tracking neglect scores in Step 3. We examined standardized regression coefficients ($\beta$) for main predictors to identify the directionality and the strength of the relationship with functional outcome. We also examined the change in $R^2$ ($\Delta R^2$) between steps and corresponding $F$ tests to determine the predictive utility of
variables beyond those in the previous steps. Finally, estimates of effect size for the MLR model were obtained using $R^2$ values by calculating $f^2$ as outlined by Cohen (1992).

3.5 Analysis of Variance

To determine the relative influence of each neglect subtype on patients’ functional outcomes, a one-way Analysis of Variance (ANOVA) was conducted using MPAI-4 scores as the dependent variable, and eye-tracking neglect classification (i.e., egocentric, allocentric, both, none) as the independent variable. Tukey post-hoc tests were examined to determine the nature of observed relationships between groups.

In order to investigate the specific attentional patterns of the sample, Repeated Measures ANOVA was used. The factor of page area (i.e., far left page, middle-left page, middle right page, and far right page) served as the within-subjects variable, while patients’ eye-tracking neglect classification (i.e., egocentric, allocentric, both, none) served as the between-subjects factor. Two separate ANOVAs were conducted using Dwell Time and First Fixation Duration data to contrast early vs. late attention processes. To avoid potential wash-out effects of comparing Dwell Time and First Fixation Duration data between individuals with left and right patterns of neglect, individuals with right neglect (n=1) were removed for this analysis. Fischer’s Least Significant Difference (LSD) and Bonferroni post-hoc tests, as well as individually conducted t-tests were examined to determine the nature of observed relationships between groups.
Chapter 4: Results

4.1 Performance on Apples Test and Eye-tracking

Information on neglect subtypes amongst the sample and comparisons between classifications based on the pencil-and-paper Apples Test, the computerized Apples Test, and Eye-tracking measure are presented in Tables 4 and 5. Based on the pencil-and-paper Apples Test, 1 patient (6% of sample) displayed pure egocentric neglect, 1 patient (6% of sample) displayed pure allocentric neglect, 5 patients (31% of sample) displayed combined egocentric and allocentric neglect, and 9 patients (56% of sample) displayed no neglect. Based on Eye-tracking, 2 patients (12.5% of sample) displayed pure egocentric neglect, 5 patients (31% of sample) displayed pure allocentric neglect, 5 patients (31% of sample) displayed combined egocentric and allocentric neglect, and 4 patients (25% of sample) displayed no neglect. Neglect subtype classification based on scores obtained on the pencil-and-paper Apples Test, and the computerized Apples Test was highly consistent, with only 1 patient obtaining a different neglect classification for each measure.
Table 4
Classification based on Apples Test and Eye-Tracking Measures of Neglect

<table>
<thead>
<tr>
<th>Subject</th>
<th>Neglect Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Computerized Apples Test</td>
</tr>
<tr>
<td>1</td>
<td>None</td>
</tr>
<tr>
<td>2</td>
<td>None</td>
</tr>
<tr>
<td>3</td>
<td>Egocentric</td>
</tr>
<tr>
<td>4</td>
<td>Both</td>
</tr>
<tr>
<td>5</td>
<td>Both</td>
</tr>
<tr>
<td>6</td>
<td>None</td>
</tr>
<tr>
<td>7</td>
<td>Allocentric</td>
</tr>
<tr>
<td>8</td>
<td>Both</td>
</tr>
<tr>
<td>9</td>
<td>Both</td>
</tr>
<tr>
<td>10</td>
<td>None</td>
</tr>
<tr>
<td>11</td>
<td>None</td>
</tr>
<tr>
<td>12</td>
<td>Allocentric</td>
</tr>
<tr>
<td>13</td>
<td>None</td>
</tr>
<tr>
<td>14</td>
<td>None</td>
</tr>
<tr>
<td>15</td>
<td>Both</td>
</tr>
<tr>
<td>16</td>
<td>None</td>
</tr>
</tbody>
</table>

Note. Grey box denotes differences in scores differ between versions of Apples Test or between Apples Test and Eye-tracking.

Table 5
Neglect Subtype Information

<table>
<thead>
<tr>
<th>Measure</th>
<th>Neglect Subtype</th>
<th>N (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apples Test</td>
<td>Egocentric</td>
<td>1 (6%)</td>
</tr>
<tr>
<td></td>
<td>Allocentric</td>
<td>1 (6%)</td>
</tr>
<tr>
<td></td>
<td>Both</td>
<td>5 (31%)</td>
</tr>
<tr>
<td></td>
<td>None</td>
<td>9 (56%)</td>
</tr>
<tr>
<td>Eye-Tracking</td>
<td>Egocentric</td>
<td>2 (13%)</td>
</tr>
<tr>
<td></td>
<td>Allocentric</td>
<td>5 (31%)</td>
</tr>
<tr>
<td></td>
<td>Both</td>
<td>5 (31%)</td>
</tr>
<tr>
<td></td>
<td>None</td>
<td>4 (25%)</td>
</tr>
</tbody>
</table>

4.2 Correlational Analyses

Pearson product moment correlations between variables relevant for regression analyses, which included demographics (age, gender, years of education), stroke variables (time from stroke to testing, stroke type, m-OCSP classification), cognitive variables (cognitive composite
score), Apples Test neglect scores, Eye-tracking neglect scores, and MPAI-4 total score, are presented in Table 6. Only cognitive composite, Apples Test neglect, Eye-tracking neglect, and MPAI-4 scores were significantly associated at the a priori criterion of \( p < .01 \) and were therefore retained for the regression analysis.

### Table 6. Intercorrelations among Variables for Regression Analysis

<table>
<thead>
<tr>
<th>Variable</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Age</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>2. Gender</td>
<td>.03</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>3. Education</td>
<td>-.05</td>
<td>-.58*</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>4. Stroke Time</td>
<td>.56*</td>
<td>-.28</td>
<td>-.18</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>5. m-OCSP</td>
<td>.33</td>
<td>.03</td>
<td>.04</td>
<td>-.11</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>6. Stroke Type</td>
<td>-.38</td>
<td>.26</td>
<td>.12</td>
<td>-.43</td>
<td>.49</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>7. Cognitive Composite</td>
<td>.47</td>
<td>.09</td>
<td>.01</td>
<td>-.06</td>
<td>.89**</td>
<td>.61</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>8. Apples Test Neglect</td>
<td>-.10</td>
<td>-.18</td>
<td>.21</td>
<td>-.10</td>
<td>-.29</td>
<td>-.42</td>
<td>-.72*</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>9. Eye-tracking Neglect</td>
<td>-.03</td>
<td>-.38</td>
<td>.25</td>
<td>.05</td>
<td>.00</td>
<td>-.21</td>
<td>-.42</td>
<td>.82**</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>10. MPAI-4</td>
<td>-.30</td>
<td>-.09</td>
<td>.21</td>
<td>-.13</td>
<td>-.25</td>
<td>-.17</td>
<td>-.76**</td>
<td>.78**</td>
<td>.83**</td>
<td>--</td>
</tr>
</tbody>
</table>

Note: *\( p < .05 \), **\( p < .01 \). Education (years); Stroke Time = time from stroke to testing (days); m-OCSP Classification = modified - Oxfordshire Community Stroke Project Classification (i.e., anterior, posterior, lacunar); Stroke Type (i.e., ischemic vs. hemorrhagic); Apples Test Neglect (i.e., egocentric, allocentric, both, none); Eye-tracking Neglect (i.e., egocentric, allocentric, both, none); MPAI-4 = Mayo-Portland Adaptability Inventory – 4 Total Score.

### 4.3 Regression Analysis

Evaluation of bivariate scatterplots of predictor variables to be entered into the regression model (cognitive composite, Apples Test neglect, and Eye-tracking neglect scores) against the MPAI-4 measure suggested sufficiently linear relationships. In addition, examination of q-q plots and plots of standardized residuals indicated that the assumptions necessary for an interpretable regression analysis were met. Examination of Mahalanobis Distances indicated no multivariate outliers, and Variance Inflation Factors indicated no multicollinearity among variables. Evaluation of measures of influence revealed no influential cases. Levene’s test for homogeneity of variance was non-significant.
4.4 Research Question: Does Eye-tracking performance account for a significant proportion of variance in functional outcome beyond the effect of cognitive factors and Apples Test performance?

Results from the regression analysis are presented in Table 7. Analysis revealed that at Step 1, cognitive functioning contributed significantly to the regression model \((F(1, 14) = 8.276, p < .05)\), such that poorer performance on cognitive testing predicted worse functional outcomes overall. The cognitive composite variable accounted for 37.2\% of the variation in functional outcome \((R^2 = .372)\). Introducing the Apples Test variable explained an additional 21.2\% of variation in functional outcome, however Apples Test performance did not significantly add to the prediction of functional outcome \((\Delta R^2 = .212; F(3,11) = 1.872, ns)\). Adding the Eye-tracking variable to the regression model in Step 3 explained an additional 25\% of the variation in functional outcome and this change in \(R^2\) was significant \((\Delta R^2 = .252; F(3,8) = 4.099, p < .05)\). Together the three independent variables accounted for 91.4\% of the variance in function \((R^2 = .914; F(3,8) = 5.826, p < .05)\).

Table 7.

<table>
<thead>
<tr>
<th>Variables entered</th>
<th>Step 1</th>
<th>Step 2</th>
<th>Step 3</th>
<th>(F)</th>
<th>(\Delta F)</th>
<th>(R^2)</th>
<th>(\Delta R^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cognitive Composite</td>
<td>-.610**</td>
<td>-.421</td>
<td>-.323</td>
<td>8.276*</td>
<td>8.276*</td>
<td>.372</td>
<td>.372</td>
</tr>
<tr>
<td>Apples Test</td>
<td>.391</td>
<td>.140</td>
<td>3.859*</td>
<td>1.872</td>
<td>.584</td>
<td>.212</td>
<td></td>
</tr>
<tr>
<td>Eye-tracking</td>
<td>-.486*</td>
<td>.5826*</td>
<td>4.099*</td>
<td>.836</td>
<td>.252</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total (R^2)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.836</td>
<td></td>
</tr>
</tbody>
</table>

Note: *\(p<.05\), **\(p<.01\).
4.5 Research Question: Do Neglect Subtypes Differentially Impact Functional Outcome?

Results from the one-way ANOVA are presented in Tables 8 and 9. This analysis revealed a statistically significant difference between neglect subtype groups \( F(3,11) = 24.148, p < .001 \). A Tukey post-hoc test revealed that the MPAI-4 scores for patients without neglect \( (M = 42.3, SD = 2.63) \) were significantly better than those of the pure Egocentric neglect patients \( (M = 49.0, SD = 2.83, p < .05) \), the pure Allocentric neglect patients \( (M = 51.75, SD = 3.40, p < .01) \), and the patients with combined Egocentric and Allocentric neglect \( (M = 56.2, SD = .88, p < .001) \). In addition, patients with combined Egocentric and Allocentric neglect showed significantly worse functional outcome scores than both the pure Egocentric \( (p < .05) \) and pure Allocentric \( (p < .05) \) patients. There were no statistically significant differences between the pure Egocentric and pure Allocentric patients \( (p = .842) \).

Table 8. 
*Results of One-Way ANOVA*

<table>
<thead>
<tr>
<th></th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>( F )</th>
<th>( \eta^2 )</th>
<th>( p )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>436.633</td>
<td>3</td>
<td>145.544</td>
<td>24.148</td>
<td>0.86</td>
<td>.000</td>
</tr>
<tr>
<td>Within Groups</td>
<td>66.300</td>
<td>11</td>
<td>6.027</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>502.933</td>
<td>14</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: One-way ANOVA performed with dependent variable = Mayo-Portland Adaptability Inventory – 4 Total Score; independent variable = Eye-tracking neglect classification (i.e., none, egocentric, allocentric, both)

Table 9. 
*Results of One-Way ANOVA Post-Hoc Tests*

<table>
<thead>
<tr>
<th>Neglect Classification</th>
<th>MPAI-4 Total M</th>
<th>SD</th>
<th>Tukey HSD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. None</td>
<td>42.25</td>
<td>2.63</td>
<td>1 &lt; 2, 3, 4</td>
</tr>
<tr>
<td>2. Egocentric</td>
<td>49.00</td>
<td>2.83</td>
<td>1 &lt; 2 &lt; 4</td>
</tr>
<tr>
<td>3. Allocentric</td>
<td>51.75</td>
<td>3.40</td>
<td>1 &lt; 3 &lt; 4</td>
</tr>
<tr>
<td>4. Both</td>
<td>56.20</td>
<td>.837</td>
<td>1 &lt; 2/3 &lt; 4</td>
</tr>
</tbody>
</table>
4.6 Research Question: What are the Specific Patterns of Attention for each Neglect Subtype?

Results from the repeated-measures ANOVAs are presented in Table 10. The analysis for Dwell Time data revealed a significant main effect of page section ($F(3,10) = 5.25, p < .05$). A significant interaction between page section and neglect subtype was also present ($F(9,24) = 22.517, p < .05$). Results of follow-up testing via paired-samples t-tests are presented in Table 11 and Figure 1. For patients with no neglect, Egocentric neglect, or Allocentric neglect no significant differences in Dwell Time were observed between any two sections of the page. For patients with simultaneous Egocentric and Allocentric neglect, patients spent significantly less time on the far left of the page ($M = 10.72, SD = 13.81$) than the far right of the page ($M = 53.79, SD = 29.33, t(4) = -4.39, p < .05$), and significantly less time on the middle-left of the page ($M = 21.56, SD = 26.61$) than the middle-right ($M = 43.06, SD = 41.92, t(4) = -2.77, p = .05$) and far right of the page ($M = 53.79, SD = 29.33, t(4) = -3.29, p < .05$).

The repeated measures-ANOVA analysis for First Fixation Duration revealed no significant main effect for page section ($F(3, 10) = 3.974, ns$), and no significant interaction between page section and neglect subtype ($F(3, 10) = 1.129, ns$).

<table>
<thead>
<tr>
<th>Data Analyzed</th>
<th>Effect</th>
<th>F</th>
<th>df</th>
<th>Error df</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dwell Time</td>
<td>Page Section</td>
<td>5.250</td>
<td>3.00</td>
<td>10.00</td>
<td>.020</td>
</tr>
<tr>
<td></td>
<td>Page Section * Neglect Subtype</td>
<td>2.517</td>
<td>9.00</td>
<td>24.48</td>
<td>.034</td>
</tr>
<tr>
<td>First Fixation Duration</td>
<td>Page Section</td>
<td>1.974</td>
<td>3.00</td>
<td>10.00</td>
<td>.209</td>
</tr>
<tr>
<td></td>
<td>Page Section * Neglect Subtype</td>
<td>1.129</td>
<td>9.00</td>
<td>24.48</td>
<td>.369</td>
</tr>
</tbody>
</table>
Table 11
Means and standard error of Dwell Time (milliseconds) by page section and neglect classification

<table>
<thead>
<tr>
<th>Eyetracking Neglect Score</th>
<th>Page Section</th>
<th>Mean (ms)</th>
<th>Far Left</th>
<th>Mid Left</th>
<th>Mid Right</th>
<th>Far Right</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>Far Left</td>
<td>23851</td>
<td>n/a</td>
<td>34</td>
<td>274</td>
<td>408</td>
</tr>
<tr>
<td></td>
<td>Mid Left</td>
<td>23885</td>
<td>-</td>
<td>n/a</td>
<td>308</td>
<td>374</td>
</tr>
<tr>
<td></td>
<td>Mid Right</td>
<td>23577</td>
<td>-</td>
<td>-</td>
<td>n/a</td>
<td>682</td>
</tr>
<tr>
<td></td>
<td>Far Right</td>
<td>24259</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>n/a</td>
</tr>
<tr>
<td>Egocentric</td>
<td>Far Left</td>
<td>21886</td>
<td>n/a</td>
<td>8462</td>
<td>8635</td>
<td>8434</td>
</tr>
<tr>
<td></td>
<td>Mid Left</td>
<td>30348</td>
<td>-</td>
<td>n/a</td>
<td>-173</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>Mid Right</td>
<td>30521</td>
<td>-</td>
<td>-</td>
<td>n/a</td>
<td>201</td>
</tr>
<tr>
<td></td>
<td>Far Right</td>
<td>30320</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>n/a</td>
</tr>
<tr>
<td>Allocentric</td>
<td>Far Left</td>
<td>36776</td>
<td>n/a</td>
<td>3227</td>
<td>2295</td>
<td>1691</td>
</tr>
<tr>
<td></td>
<td>Mid Left</td>
<td>40003</td>
<td>-</td>
<td>n/a</td>
<td>932</td>
<td>1536</td>
</tr>
<tr>
<td></td>
<td>Mid Right</td>
<td>39071</td>
<td>-</td>
<td>-</td>
<td>n/a</td>
<td>604</td>
</tr>
<tr>
<td></td>
<td>Far Right</td>
<td>38467</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>n/a</td>
</tr>
<tr>
<td>Both</td>
<td>Far Left</td>
<td>10720</td>
<td>n/a</td>
<td>10838</td>
<td>32338*</td>
<td>43073*</td>
</tr>
<tr>
<td></td>
<td>Mid Left</td>
<td>21558</td>
<td>-</td>
<td>n/a</td>
<td>21500*</td>
<td>32235*</td>
</tr>
<tr>
<td></td>
<td>Mid Right</td>
<td>43058</td>
<td>-</td>
<td>-</td>
<td>n/a</td>
<td>10735</td>
</tr>
<tr>
<td></td>
<td>Far Right</td>
<td>53793</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>n/a</td>
</tr>
</tbody>
</table>

Note: * = difference significant at the $p < .05$ level. Difference Value = absolute value of difference (subtraction) between page sections

Figure 1
Graphical representation of means for Dwell Time (ms) data by neglect subtype
Chapter 5: Discussion

The overarching aim of the proposed study was to assess neglect subtypes among stroke patients using novel eye-tracking technology, and to determine the relationship between these subtypes and patient prognosis in terms of functional outcomes. Specifically, we sought to determine whether eye-tracking measures could be used to enhance the detection of neglect symptoms and subtypes, and add predictive value to patient functioning beyond that of a pen-and-paper measure. The modified computerized version of the Apples Test used in this study closely aligned with the original Apples Test, a measure designed by Bickerton et al. (2011) to enable detection of egocentric or allocentric neglect among stroke patients. In comparing patients’ performance on the paper-and-pencil version of the Apples Test and their corresponding eye movements while completing the measure, we were able to demonstrate that the eye-tracking measure of neglect may be more sensitive in detecting neglect symptoms than the Apples Test. We further determined that neglect subtype classification based on eye-tracking performance was more predictive of patients’ functional outcomes than subtype classification based on the Apples Test. Finally, we demonstrated that while there was no observed difference between the functional outcomes of patients with egocentric vs. allocentric neglect, those with no neglect had better outcomes than those with either or both neglect subtypes. In addition, those patients who exhibited both subtypes of neglect had significantly worse functional outcomes than those with egocentric, allocentric, or no neglect symptoms. The specific hypotheses set for this study are discussed in sequence below.
5.1 **Hypothesis #1: Eye-tracking Allows for Differentiation Between Neglect Subtypes, and has Enhanced Sensitivity over Traditional Measures of Neglect Subtype.**

While a number of researchers have argued that allocentric and egocentric neglect do not represent distinct and separable conditions (Driver & Pouget, 2000; Mozer, 2002; Baylis et al., 2004; Karnath et al., 2011, Yue et al., 2012, Rorden et al. 2012), we hypothesized that we would find a distinct dissociation between patients in the sample who demonstrated allocentric neglect, egocentric neglect, or both types of neglect simultaneously using both the Apples Test and a novel eye-tracking measure. Results indicated that both measures of neglect successfully identified patients as having no neglect, pure egocentric neglect, pure allocentric neglect, or both neglect subtypes. Agreement between the two measures was high for those identified as having neglect by the Apples Test. However, the eye-tracking measure appeared to be more sensitive in detecting neglect among patients whose performance on the pencil-and-paper Apples Test was normal. Specifically, the Apples Test identified neglect in 44% of the sample while the eye-tracking measure identified neglect in 75% of the sample. Interpretation of these results may be aided by considering existing research on neglect and corresponding eye movements. Gainotti and Taicci (1971) proposed that, while patients with neglect may be able to shift eye movements toward the neglected side of space, the probability of prolonged fixation upon the contralesional side decreased as distance from the midline increased. The eye-tracking measure used in our study provided a continuous measure of time spent fixating on either a side of the page or side of an individual apple. As such, it follows that the eye-tracking measure may be more sensitive in detecting the subtle attentional biases inherent in neglect than the Apples Test, which simply reflects performance in a dichotomous (correct/incorrect) manner. In addition to the enhanced
sensitivity of the eye-tracker based on the data output available, it is possible that the nature of the computerized activity itself may have improved the measure’s sensitivity.

While patients were permitted to move their head and body position during the eye-tracking task, the computerized display offered a more controlled stimulus presentation than the pencil-and-paper Apples Test. During eye-tracking, patients tended to remain at a greater and more consistent distance from the stimulus page. In addition, they did not have the benefit of using their own hand and pencil as a cue to continue scanning the adjacent stimulus page. Indeed, research indicates that neglect biases may be momentarily ameliorated by providing cues (such as pointing or other directional hand movements) to attend to the neglected side of space (e.g., Harvey et al., 1995; Mennemeier et al., 1997; McCourt et al., 2005). If the enhanced sensitivity of the eye-tracking task in the present study could be solely attributed to patients’ head and body position, we might expect to also see behavioral differences between the standard pencil-and-paper Apples Test and the computerized Apples Test. As the scores on these two measures were statistically equivalent, however, we consider it unlikely that sensitivity in the eye-tracking task was meaningfully enhanced by the nature of participant positioning.

In light of the finding of enhanced sensitivity of neglect detection in the eye-tracking measure, it is important to discuss the possibility of over-diagnosis of neglect using this diagnostic tool. It is possible that the eye-tracking task increased the rate of “false positives,” providing an indication of neglect when the disorder was not in fact present. It is a limitation of the current study that no age-matched control group was assessed using the eye-tracking task. However, results indicating that the eye-tracking task possesses predictive superiority in terms of functional outcomes over-and-above that of the Apples Test are encouraging. The relatively stronger functional predictive power of the eye-tracking task suggests that this measure is indeed
detecting real and meaningful differences among participants. Furthermore, there is no widely accepted “gold standard” measure for allocentric and egocentric neglect to further compare eye-tracking measures against. In light of this, we can conclude that at the very least, eye-tracking tasks show promise in enhancing detection of neglect subtypes, and have the potential to be clinically useful diagnostic tools.

In sum, current findings suggest that the subtypes of egocentric and allocentric neglect can be dissociated among the larger population of neglect patients using sufficiently sensitive measures such as the Apples Test and eye-tracking technology. Furthermore, results indicate that eye-tracking may provide enhanced sensitivity in identifying neglect subtypes due to the ability of the system to detect more subtle attentional biases, and the controlled nature of the task.

5.2 Hypothesis #2: Pure Egocentric Neglect Will Appear More Frequently than Pure Allocentric Neglect.

The results of the current study stand in contrast with hypotheses and previous research suggesting that pure egocentric neglect is more common among patients than pure allocentric neglect (Bickerton et al., 2011; Khurshid et al., 2012). Based on eye-tracking neglect subtype classification, 31% of our sample (n=5) presented with pure allocentric neglect, while only 12.5% of the sample (n=2) presented with pure egocentric neglect. Interestingly, a relatively large proportion of the sample (31%, n=5) presented with combined ego- and allocentric neglect. While a small sample size may have resulted in an artificially unequal distribution of neglect subtypes, the frequencies at which egocentric, allocentric, and combined neglect were observed among the sample warrant further consideration. Recent studies (Chechlacz et al., 2010; Medina et al., 2009; Verdon et al., 2009) have examined the underlying neural correlates of egocentric and allocentric neglect, and most tend to agree that the two forms of neglect are linked to lesions
in different brain regions. Specifically, these studies indicate that anterior parietotemporal damage typically results in egocentric neglect while posterior parietooccipital damage is linked to allocentric neglect. Chechlacz et al. (2010) also found that patients with both forms of neglect typically evidenced damage to another distinct site; the right temporoparietal junction. The results of the current study did not show significant correlations between location of stroke lesion and neglect subtype, but it is possible that the m-OCSP rating system used to categorize stroke location may have been too rudimentary to observe significant effects. As such, further investigation into the links between lesion location and resulting neglect subtype is warranted.

In addition to these within-hemisphere differences, recent research indicates that between hemisphere differences may exist in terms of the neglect subtypes they result in. Though left hemisphere strokes less commonly result in a right-sided neglect, it has been observed that allocentric neglect may occur more frequently than egocentric neglect in this population (Khurshid et al., 2012; Kelinman et al., 2007). A possible explanation for this hemisphere-based pattern reversal lies in theory regarding hemispheric specialization. Specifically, it has been postulated that the right hemisphere is dominant for global processing, while the left hemisphere is dominant for more localized processing (Roberson, Lamb & Knight, 1988). In the interest of preserving power and retaining as large a sample size as possible, the current study collapsed across both right and left hemispatial neglect in favour of a general categorization of neglect subtype. As such, neglect subtype frequency among our sample may be broadly applicable to the larger stroke population, but less so for left- or right-hemispatial neglect groups specifically.

Another possible explanation for the increased identification of allocentric neglect amongst our sample may lie in differences between the relative likelihoods of detecting allocentric neglect between traditional paper-and-pencil measures and eye-tracking measures. It
is possible that sensitive eye-tracking technology affords a greater probability of allocentric neglect detection than behavioral data alone. Indeed, while behavior-based neglect performance was equivalent between the pencil-and-paper Apples Test and the computerized Apples Test, performance based on eye-tracking data was significantly more likely to lead to a categorization of allocentric neglect as compared to both Apples Test measures. This finding brings into question the true prevalence of each neglect subtype, as crude behavioral measures of neglect may provide somewhat biased estimates of the distribution amongst samples. Evidently, further investigation into the relative population frequencies of each neglect subtype is warranted.

5.3 Hypothesis #3: Spatial Allocation of Attention will Differ Based on Neglect Subtype.

Hemispatial neglect can be conceptualized as a bias in attention against the contralesional side of space. As such, researchers have suggested that that eye movements might follow a similarly biased pattern (Marshall and Robertson, 2013), with eye movements of neglect patients being markedly different from those of normal controls. Expanding on previous research (see Gainotti and Taicci, 1971), we hypothesized that these differences would manifest in terms of Dwell Time (a measure of duration of prolonged fixation), but not in terms of First Fixation Duration (a measure of the duration of the first fixation on a stimulus item). In other words, we hypothesized that patients with neglect would initially scan and fixate on stimulus items across the page in a similar manner to those without neglect, but that the neglect patients would have a lower probability of prolonged fixation on the neglected side of space. Given the presentations of the two neglect subtypes investigated, we hypothesized that this pattern would only be present for those with egocentric neglect or a combined egocentric and allocentric neglect presentation. Results of the current study supported these hypotheses to a degree.
Significant interactions between page area (i.e., far left, middle left, middle right, far right) and neglect subtype were observed for the Dwell Time data, but not for the First Fixation Duration Data. This finding indicates that patients with neglect are in fact scanning and fixating on stimuli across both the left and right sides of sensory space, but that they are less able to sustain attention on the left side. When investigating these effects as they pertain to neglect subtypes, small sample size and correspondingly low statistical power did not enable us to find significant results for comparisons among the pure egocentric group, however the general trends observed in these data are worth discussing. For participants with no neglect or allocentric neglect, sustained attention across the entirety of sensory space was relatively equal. In comparison, for patients with egocentric neglect, probability of prolonged fixation across the page decreased from right to left. This pattern was also observed in patients with combined egocentric and allocentric neglect, and results for this group were significant.

These patterns of spatial allocation of attention may be indicative of preserved initial/automatic processing in concert with impaired sustained attention in patients with an egocentric component to their neglect symptomology. Investigation into this pattern of attention in neglect by Vuilleumier and Landis (1998) may provide support for these findings. These researchers reported on three neglect patients who were unable to detect the left inducers of Kanizsa illusory figures (an optical illusion that evokes the perception of an edge) in a same/different judgment task, but nonetheless showed implicit perception of the figures in a midpoint judgment. These researchers concluded that there may be a sparing of preattentive, early visual processing in hemispatial neglect. Further investigation into the specific patterns of spatial allocation of attentional resources amongst neglect patients is vital to understanding the disorder and improving rehabilitative treatment strategies.
Hypothesis #4: Neglect Subtype Will Differentially Impact Functional Outcome.

Previous studies have shown that the presence of neglect is related to poor functional outcomes in patients (Buxbaum et al., 2004; Cherney et al., 2001). The results of the current study align with this approach. The presence of either type of neglect was associated with impaired performance on a range of cognitive tasks as well as overall functional impairment as measured by the MPAI-4. To our knowledge, this is the only study to assess the specific contributions of each neglect subtype to functional outcome using both a comprehensive measure of global functioning and controlling for cognitive performance. We hypothesized that those with egocentric neglect would have better functional outcomes as measured by the MPAI-4 than those with either allocentric or both neglect subtypes. Furthermore, we hypothesized that those with both neglect subtypes would have poorer functional outcomes than those with either egocentric or allocentric neglect (Bickerton et al., 2011). Results of the current study indicate that patients with no neglect were the least functionally impaired. Patients with either egocentric or allocentric neglect, while not significantly different from each other, demonstrated significantly poorer functional outcomes than those without neglect. Finally, those with both ego- and allocentric neglect evidenced the poorest functional outcomes of the four groups. These results again fit with the idea that patients showing both egocentric and allocentric neglect actually have a distinct problem related to distinct neuroanatomical substrates (i.e., the right temporoparietal junction), as compared to patients who present with “pure” forms of each subtype of neglect (Chechlacz et al., 2010).

While the results of the current study did not show different functional outcomes between patients with either egocentric or allocentric neglect, the small number of egocentric neglect patients included in the sample (n=2) may have reduced the probability of seeing significant
differences between these two groups. Though not statistically significant, the overall trend in the data was one of slightly more impaired functioning for allocentric neglect patients as compared to those with egocentric neglect. With more equal distribution of neglect subtypes, greater numbers of participants, and a corresponding increase in power, it is possible that a statistically significant different between these two groups might emerge. Taken together, these findings provide rationale for screening for neglect in order to better predict functional outcomes in patients, and specifically, the importance of including a measure that is sensitive to both allocentric and egocentric neglect simultaneously.

5.5 Limitations

This study presents with some limitations that may affect the generalization of results to other acute stroke inpatients experiencing neglect. First, participants were excluded if they presented with profound cognitive deficits that prevented consent to participate in the study or follow direction for testing purposes. Further, given the location of data collection, results of the current study may only generalize to patients referred to rehabilitation, and not to those who would not meet criteria for acute rehabilitation while in hospital. Second, the sample used here is not a "pure neglect" sample; participants likely presented with various pre-morbid medical, psychiatric, and neurological histories that were not controlled for in analyses. This makes it difficult to differentiate the functional outcome effects of neglect from the effects of other co-morbid conditions; however, it is arguable that filtering such co-morbid conditions could detrimentally limit generalization of findings, as most patients presenting with stroke suffer from co-morbidities. Third, the comprehensive nature of the neuropsychological battery used, as well as the costly eye-tracking equipment used for testing may not be entirely feasible in other locations which require more rapid or cost-effective assessments. Fourth, the relatively small
sample size may have had detrimental impacts on statistical power and the ability to detect true and meaningful differences between groups in the sample. Finally, it is most ideal for patients’ scores on the MPAI-4 to be determined by multiple professional raters; unfortunately this was not feasible in the current study. Where possible, scores were determined by a single reviewer during interviews with each patient. When patients were not available for interview, MPAI-4 scores were assigned based on thorough review of medical files and previous interviews with patients to gather as much information as possible. While necessary given the setting in which the study was conducted, these inconsistencies may have influenced scores on the MPAI-4.
Chapter 6: Conclusion

The current study supports the use of eye-tracking in conjunction with comprehensive neuropsychological testing in determining functional outcomes for patients with hemispatial neglect. Eye-tracking provides a highly sensitive measure of neglect subtype, and subtype classification based on this measure (i.e., egocentric, allocentric, both, none) accounts for a significant amount of variation in patients’ functional outcomes above and beyond that accounted for by traditional paper-and-pencil measures of neglect. The present study highlights the importance of the identification of neglect subtypes as risk factors for poorer functional outcomes amongst stroke patients, and specifically, the need to measure and distinguish between allocentric and egocentric neglect in the primary care of these individuals. In this preliminary study, the observed variability between patients’ functional outcomes based on their neglect subtype classification may start to raise questions about the development of distinct treatment strategies based on neglect subtype presentation. Further investigation of the assessment, frequency, and functional outcome implications of the subtypes of neglect is a vital step towards improving our understanding of this prevalent and debilitating condition, and may have the potential to inform improved rehabilitative treatment planning for patients.
References


http://doi.org/10.1016/j.bandc.2006.10.005


movements during reading. *Journal of Experimental Psychology: Learning, Memory, and
Cognition, 35*(2), 381.

comparing psychometrics in cerebrovascular accident to traumatic brain injury. *Archives
of Physical Medicine and Rehabilitation, 93*(12), 2271–5.
doi:10.1016/j.apmr.2012.06.013

visuospatial and tactile neglect in acute stroke. *Cortex, 44*(9), 1215-1220.

studies*. Psychology Press.

asymmetric line geometry share a common attentional origin in the modulation of

Medina, J., Kannan, V., Pawlak, M. A., Kleinman, J. T., Newhart, M., Davis, C., ... & Hillis, A.
E. (2009). Neural substrates of visuospatial processing in distinct reference frames:
evidence from unilateral spatial neglect. *Journal of Cognitive Neuroscience, 21*(11),
2073-2084.

Contributions of the left and right cerebral hemispheres to line bisection.


Mozer, M. C. (2002). Frames of reference in unilateral neglect and visual perception: a
computational perspective. *Psychological Review, 109*(1), 156.


Appendices

Appendix A: The Apples Test
Appendix B: The Apples Test Short-Form
Appendix C: Mayo-Portland Adaptability Inventory – Fourth Edition

Mayo-Portland Adaptability Inventory-4

Muriel D. Lezak, PhD, ABPP & James F. Malec, PhD, ABPP

Name: ___________________________  Clinic #: ___________________________  Date: ___________________________

Person reporting (circle one): Single Professional  Professional Consensus  Person with brain injury  Significant other: _________

Below each item, circle the number that best describes the level at which the person being evaluated experiences problems. Mark the greatest level of problem that is appropriate. Problems that interfere rarely with daily or valued activities, that is, less than 5% of the time, should be considered not to interfere. Write comments about specific items at the end of the rating scale.

**For Items 1-20, please use the rating scale below.**

<table>
<thead>
<tr>
<th>Rating</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>None</td>
</tr>
<tr>
<td>1</td>
<td>Mild problem but does not interfere with activities; may use assistive device or medication</td>
</tr>
<tr>
<td>2</td>
<td>Mild problem, interferes with activities 5-24% of the time</td>
</tr>
<tr>
<td>3</td>
<td>Moderate problem, interferes with activities 25-75% of the time</td>
</tr>
<tr>
<td>4</td>
<td>Severe problem, interferes with activities more than 75% of the time</td>
</tr>
</tbody>
</table>

**Part A: Abilities**

1. Mobility: Problems walking or moving, balance problems that interfere with moving about
   - 0 |
   - 1 |
   - 2 |
   - 3 |
   - 4 |

2. Use of hands: Impaired strength or coordination in one or both hands
   - 0 |
   - 1 |
   - 2 |
   - 3 |
   - 4 |

3. Vision: Problems seeing, double vision; eye, brain, or nerve injuries that interfere with seeing
   - 0 |
   - 1 |
   - 2 |
   - 3 |
   - 4 |

4. Audition: Problems hearing; ringing in the ears
   - 0 |
   - 1 |
   - 2 |
   - 3 |
   - 4 |

5. Dizziness: Feeling unsteady, dizzy, light-headed
   - 0 |
   - 1 |
   - 2 |
   - 3 |
   - 4 |

6. Motor speech: Abnormal slowness or rate of speech; stuttering
   - 0 |
   - 1 |
   - 2 |
   - 3 |
   - 4 |

7A. Verbal communication: Problems expressing or understanding language
   - 0 |
   - 1 |
   - 2 |
   - 3 |
   - 4 |

7B. Nonverbal communication: Restricted or unusual gestures or facial expressions; talking too much or not enough; missing nonverbal cues from others
   - 0 |
   - 1 |
   - 2 |
   - 3 |
   - 4 |

8. Attention/Concentration: Problems ignoring distractions, shifting attention, keeping more than one thing in mind at a time
   - 0 |
   - 1 |
   - 2 |
   - 3 |
   - 4 |

9. Memory: Problems learning and recalling new information
   - 0 |
   - 1 |
   - 2 |
   - 3 |
   - 4 |

10. Fund of Information: Problems remembering information learned in school or on the job; difficulty remembering information about self and family from years ago
    - 0 |
    - 1 |
    - 2 |
    - 3 |
    - 4 |

11. Novel problem-solving: Problems thinking up solutions or picking the best solution to new problems
    - 0 |
    - 1 |
    - 2 |
    - 3 |
    - 4 |

12. Visual-spatial abilities: Problems drawing, assembling things, route-finding, being visually aware on both the left and right sides
    - 0 |
    - 1 |
    - 2 |
    - 3 |
    - 4 |

**Part B: Adjustment**

13. Anxiety: Tense, nervous, fearful, phobias, nightmares, flashbacks of stressful events
    - 0 |
    - 1 |
    - 2 |
    - 3 |
    - 4 |

14. Depression: Sad, blue, hopeless, poor appetite, poor sleep, worry, self-criticism
    - 0 |
    - 1 |
    - 2 |
    - 3 |
    - 4 |

15. Irritability, anger, aggression: Verbal or physical expressions of anger
    - 0 |
    - 1 |
    - 2 |
    - 3 |
    - 4 |

16. Pain and headache: Verbal and nonverbal expressions of pain; activities limited by pain
    - 0 |
    - 1 |
    - 2 |
    - 3 |
    - 4 |

17. Fatigue: Feeling tired; lack of energy, tiring easily
    - 0 |
    - 1 |
    - 2 |
    - 3 |
    - 4 |

18. Sensitivity to mild symptoms: Focusing on thinking, physical or emotional problems attributed to brain injury; rate only how concern or worry about these symptoms affects current functioning over and above the effects of the symptoms themselves
    - 0 |
    - 1 |
    - 2 |
    - 3 |
    - 4 |

19. Inappropriate social interaction: Acting childish, silly, rude, behavior not fitting for time and place
    - 0 |
    - 1 |
    - 2 |
    - 3 |
    - 4 |

20. Impaired self-awareness: Lack of recognition of personal limitations and disabilities and how they interfere with everyday activities and work or school
    - 0 |
    - 1 |
    - 2 |
    - 3 |
    - 4 |

Use scale at the bottom of the page to rate item #21

21. Family/significant relationships: Interactions with close others, describe stress within the family or those closest to the person with brain injury; “family functioning” means cooperating to accomplish those tasks that need to be done to keep the household running
    - 0 |
    - 1 |
    - 2 |
    - 3 |
    - 4 |

Use scale at the bottom of the page to rate item #21

0 Normal stress within family or other close network of relationships
    | 1 | Mild stress that does not interfere with family functioning
    | 2 | Mild stress that interferes with family functioning 5-24% of the time
    | 3 | Moderate stress that interferes with family functioning 25-75% of the time
    | 4 | Severe stress that interferes with family functioning more than 75% of the time
### Part C. Participation

#### 22. Initiation: Problems getting started on activities without prompting

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>None</td>
</tr>
<tr>
<td>1</td>
<td>Mild problem but does not interfere with activities; may use assistive device or medication</td>
</tr>
<tr>
<td>2</td>
<td>Mild problem; interferes with activities 5-24% of the time</td>
</tr>
<tr>
<td>3</td>
<td>Moderate problem; interferes with activities 25-75% of the time</td>
</tr>
<tr>
<td>4</td>
<td>Severe problem; interferes with activities more than 75% of the time</td>
</tr>
</tbody>
</table>

#### 23. Social contact with friends, work associates, and other people who are not family, significant others, or professionals

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Normal involvement with others</td>
</tr>
<tr>
<td>1</td>
<td>Mild difficulty in social situations but maintains normal involvement with others</td>
</tr>
<tr>
<td>2</td>
<td>Mildly limited involvement with others (75-95% of normal interaction for age)</td>
</tr>
<tr>
<td>3</td>
<td>Moderately limited involvement with others (25-74% of normal interaction for age)</td>
</tr>
<tr>
<td>4</td>
<td>No or rare involvement with others (less than 25% of normal interaction for age)</td>
</tr>
</tbody>
</table>

#### 24. Leisure and recreational activities

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Normal participation in leisure activities for age</td>
</tr>
<tr>
<td>1</td>
<td>Mild difficulty in these activities but maintains normal participation</td>
</tr>
<tr>
<td>2</td>
<td>Mildly limited participation (75-95% of normal participation for age)</td>
</tr>
<tr>
<td>3</td>
<td>Moderately limited participation (25-74% of normal participation for age)</td>
</tr>
<tr>
<td>4</td>
<td>No or rare participation (less than 25% of normal participation for age)</td>
</tr>
</tbody>
</table>

#### 25. Self-care: Eating, dressing, bathing, hygiene

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Independent completion of self-care activities</td>
</tr>
<tr>
<td>1</td>
<td>Independent completion of self-care activities, occasional omissions or mildly slowed; may assistive device or require occasional prompting</td>
</tr>
<tr>
<td>2</td>
<td>Requires a little assistance or supervision from others (5-24% of the time)</td>
</tr>
<tr>
<td>3</td>
<td>Requires moderate assistance or supervision from others (25-75% of the time)</td>
</tr>
<tr>
<td>4</td>
<td>Requires extensive assistance or supervision from others (more than 75% of the time)</td>
</tr>
</tbody>
</table>

#### 26. Residence: Responsibilities of independent living and homemaking (such as, meal preparation, home repairs and maintenance, personal health maintenance beyond basic hygiene including medication management) but not including managing money (see #29)

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Independent; living without supervision or concern from others</td>
</tr>
<tr>
<td>1</td>
<td>Living without supervision but others have concerns about safety or managing responsibilities</td>
</tr>
<tr>
<td>2</td>
<td>Requires a little assistance or supervision from others (5-24% of the time)</td>
</tr>
<tr>
<td>3</td>
<td>Requires moderate assistance or supervision from others (25-75% of the time)</td>
</tr>
<tr>
<td>4</td>
<td>Requires extensive assistance or supervision from others (more than 75% of the time)</td>
</tr>
</tbody>
</table>

#### 27. Transportation

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Independent in all modes of transportation including independent ability to operate a personal motor vehicle</td>
</tr>
<tr>
<td>1</td>
<td>Independent in all modes of transportation, but others have concerns about safety</td>
</tr>
<tr>
<td>2</td>
<td>Requires a little assistance or supervision from others (5-24% of the time); cannot drive</td>
</tr>
<tr>
<td>3</td>
<td>Requires moderate assistance or supervision from others (25-75% of the time); cannot drive</td>
</tr>
<tr>
<td>4</td>
<td>Requires extensive assistance or supervision from others (more than 75% of the time); cannot drive</td>
</tr>
</tbody>
</table>

#### 28A. *Paid Employment:* Rate either item 28A or 28B to reflect the primary desired social role. Do not rate both. Rate 28A if the primary social role is paid employment. If another social role is primary, rate only 28B. For both 28A and 28B, “support” means special help from another person with responsibilities (such as, a job coach or shadow, tutor, helper) or reduced responsibilities. Modifications to the physical environment that facilitate employment are not considered as support.

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Full-time (more than 30 hrs/wk) without support</td>
</tr>
<tr>
<td>1</td>
<td>Part-time (3 to 30 hrs/wk) without support</td>
</tr>
<tr>
<td>2</td>
<td>Full-time or part-time with support</td>
</tr>
<tr>
<td>3</td>
<td>Sheltered work</td>
</tr>
<tr>
<td>4</td>
<td>Unemployed; employed less than 3 hours per week</td>
</tr>
</tbody>
</table>

#### 28B. *Other employment:* Involved in constructive, role-appropriate activity other than paid employment.

Check only one to indicate primary desired social role: Childrearing/care-giving Homemaker, no childrearing or care-giving Student Volunteer Retired (Check retired only if over age 60; if unemployed, retired as disabled and under age 60, indicate “Unemployed” for item 28A).

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Full-time (more than 30 hrs/wk) without support; full-time course load for students</td>
</tr>
<tr>
<td>1</td>
<td>Part-time (3 to 30 hrs/wk) without support</td>
</tr>
<tr>
<td>2</td>
<td>Full-time or part-time with support</td>
</tr>
<tr>
<td>3</td>
<td>Activities in a supervised environment other than a sheltered workshop</td>
</tr>
<tr>
<td>4</td>
<td>Inactive; involved in role-appropriate activities less than 3 hours per week</td>
</tr>
</tbody>
</table>

#### 29. Managing money and finances: Shopping, keeping a check book or other bank account, managing personal income and investments; if independent with small purchases but not able to manage larger personal finances or investments, rate 3 or 4.

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Independent, manages small purchases and personal finances without supervision or concern from others</td>
</tr>
<tr>
<td>1</td>
<td>Manages money independently but others have concerns about larger financial decisions</td>
</tr>
<tr>
<td>2</td>
<td>Requires a little help or supervision (5-24% of the time) with large finances; independent with small purchases</td>
</tr>
<tr>
<td>3</td>
<td>Requires moderate help or supervision (25-75% of the time) with large finances; some help with small purchases</td>
</tr>
<tr>
<td>4</td>
<td>Requires extensive help or supervision (more than 75% of the time) with large finances; frequent help with small purchases</td>
</tr>
</tbody>
</table>