ASHA American Speech-Language-Hearing Association

JSLHR

Research Article

# Identifying Spatial Neglect in Chronic Right Hemisphere Stroke Survivors Using the RHDBank Outcomes

**Jamila Minga,[a] Timothy Rich,[b] Olga Boukrina,[b] Peii Chen,[b] and Kimberly Hreha[c]**

[a] Department of Head and Neck Surgery & Communication Sciences and Department of Neurology, Duke University, Durham, NC [b] Center for Stroke Rehabilitation Research, Kessler Foundation, West Orange, NJ [c] Occupational Therapy Doctorate Division, Department of Orthopaedic Surgery, Duke University, Durham, NC

ARTICLE INFO

Article History:
Received May 3, 2023
Revision received August 23, 2023
Accepted October 19, 2023

Editor-in-Chief: Julie A. Washington
Editor: Sarah Elizabeth Wallace

https://doi.org/10.1044/2023_JSLHR-23-00285

ABSTRACT

**Purpose:** The chronicity of spatial neglect (SN) and the utility of existing diagnostic measures used by speech-language pathologists remain poorly understood. In this retrospective study, we examined how the RHDBank test battery informs the identification of SN after right hemisphere brain damage (RHD) during the chronic phase of recovery.
**Method:** Data from 29 right hemisphere stroke survivors were extracted from the RHDBank, including SN tests, for which we performed laterality index scoring: a 51-item demographic survey, the Apples Test, the Indented Paragraph Test, and the clock drawing task from the Cognitive Linguistic Quick Test (CLQT). Two groups (SN+ and SN–) were identified using the Apples Test. A hierarchical cluster analysis explored CLQT performance clusters in association with SN, and group comparisons of demographic variables and test scores were conducted.
**Results:** Ten patients were identified as having SN+ (34%) using the Apples Test. The Indented Paragraph Test and the CLQT's clock drawing test identified only two of the 20 stroke survivors with SN+. Cluster analyses showed that domain and task scores on the CLQT carried information to classify participants into SN+ and SN– in concordance with performance on the Apples Test. Participants in the SN+ cluster had moderately impaired attention and executive function skills and mildly impaired visuospatial skills.
**Conclusions:** The Apples Test differentiated SN in a group of chronic right hemisphere stroke survivors. Using multiple measures from the CLQT seemed to capture a greater range of problems than clock drawing and paragraph reading tests alone. Therefore, the RHDBank test battery as a whole—and in part the CLQT, Apples Test, and Indented Paragraph Test—can detect certain subtypes of SN in the chronic deficit profile after RHD and is a starting point for diagnostic integration by speech-language pathologists.

Stroke incidence in the United States is approximately 795,000 annually (Tsao et al., 2023). With the decrease in stroke mortality due to recent advances in acute management and care, there is an increase in the cost related to rehabilitation care and postacute management. The fiscal burden of stroke-related disability in the United States is nearly $34 billion annually (Benjamin et al., 2019; Go et al., 2014). Stroke-related disability and its severity often depend on the extent and location of brain damage, with the severity of residual deficits impacting daily function. While unilateral stroke can affect either hemisphere, right hemisphere brain damage (RHD) is slightly less frequent (46%; Hedna et al., 2013) and often less detected (Portegies et al., 2015). RHD can result in a host of impairments including compromised executive function; memory; attention; spatial skills; and language-

Correspondence to Jamila Minga: jamila.minga@duke.edu. ***Disclosure:*** *Jamila Minga codeveloped the RHDBank and the RHDBank protocol and is the sole contributor to the Minga RHDBank corpus. All other authors have declared that no competing financial or nonfinancial interests existed at the time of publication.*

related functions, such as the interpretation of nonliteral language, question asking, and the appropriate use of language for the context of the communication (Champagne-Lavau & Joanette, 2009; Ferretti & McCallion, 2019; Minga, Fromm, et al., 2022; Nys et al., 2007).

## Spatial Neglect and RHD

Spatial neglect (SN)[1] deficits occur in 20%–80% of stroke survivors with RHD, and the varied prevalence estimations are related to assessment methods and the time point during recovery, when an assessment occurs (Esposito et al., 2021). Some patients experience SN acutely, which may resolve within hours or days poststroke (Karnath et al., 2011; Ringman et al., 2004). However, in up to 40% of patients with RHD, SN symptoms persist months or years after stroke, causing long-term barriers to functional independence (Esposito et al., 2021; Karnath et al., 2011; Nijboer et al., 2013).

While visual symptoms of SN are most observable and thus extensively investigated, it is the combination of visual and other perceptual modalities (auditory, tactile, proprioceptive) that supports the ability to receive and process spatial information. Together, impairments across modalities can impact a wide range of cognitive–communicative (e.g., discourse-related tasks, reading, mental imagery, spatial memory retrieval) and motor functions (e.g., planning, initiation, and completion; Buxbaum et al., 2004; Coslett et al., 1990; Gainotti, 2010; Heilman, 1979; Heilman et al., 2000; Hillis et al., 2005; Minga, Fromm, et al., 2022; Nijboer et al., 2014; Rode et al., 2017; Ronchi et al., 2016; Salvato et al., 2014). SN after RHD typically results in the left side of space being neglected. The space can be on the body (personal), within arm's reach (peripersonal), or surrounding the person (extrapersonal). The side of space can be classified based on the frame of reference: either egocentric SN, which is failed or incomplete processing of stimuli located on the contralesional side of space in reference to the person's trunk, or allocentric SN, which is characterized by the inability to process the left side of an individual object or group of objects, regardless of its location in egocentric space (Chen & Toglia, 2022; Medina et al., 2009). The multimodal symptomology of SN is functionally impactful and predictive of poor rehabilitation outcomes and suboptimal stroke recovery (Chen et al., 2015; Katz et al., 1999; Lee et al., 2009; Paolucci et al., 2001; Ten Brink et al., 2017; Yoshida et al., 2022). Reduced awareness of SN symptomology, particularly in the chronic phase of recovery, may lead to missed opportunities to treat patients for their specific needs.

Speech-language pathologists (SLPs) are well suited to contribute to SN care by influencing the therapeutic focus in the chronic phase of recovery. There are an extensive number of standardized SN screening and assessment tools (Checketts et al., 2020; Williams et al., 2021). Observation or informal assessment, however, is a common practice among SLPs, with 66% indicating insufficient access to materials for diagnosing deficits associated with RHD and SN assessment occurring during acute care for all survey respondents (Ramsey & Blake, 2020). There is heterogeneity in the deficit profile after RHD, with many survivors functioning at reduced capacity throughout the chronic phase of recovery. Through a secondary analysis of the Minga corpus collected in the RHDBank, we retrospectively examined SN in a group of right hemisphere stroke survivors in the chronic phase of recovery to gain greater understanding of the utility of the test battery for the identification of SN.

## The RHDBank and SN Measures

The RHDBank (https://rhd.talkbank.org; Minga et al., 2021) is an internationally shared multimedia database developed for the study of communication using discourse while assessing underlying cognitive processes. It consists of the RHDBank protocol and the RHDBank test battery. The RHDBank protocol elicits various types of discourse including free speech, conversation, picture description, procedural discourse, storytelling, and question asking. The RHDBank test battery includes a comprehensive demographic survey of 51 items (e.g., sex, race, age, education, handedness, employment, and therapeutic history wherein survivors describe their therapy focus/tasks) and measures of discourse participation. The battery includes the Cognitive Linguistic Quick Test (CLQT; Helm-Estabrooks, 2001), which assesses five domains: attention, memory, executive functioning, spatial skills, and language. Given the high prevalence of SN post right hemisphere stroke, the RHDBank test battery also includes SN measures that primarily assess peripersonal space, which is within reaching distance. The Indented Paragraph Test (Caplan, 1987) captures neglect dyslexia, that is, reading difficulties due to SN (Boukrina et al., 2020; Galletta et al., 2014; Vallar et al., 2010). The Apples Test (Bickerton et al., 2011) detects both egocentric and allocentric SN.

## Spatial Processing and Discourse

Knowledge of the interplay between cognition and communication, and more specifically, discourse production,

[1]We use "spatial neglect" as an umbrella term to refer to deficits commonly termed as "unilateral spatial neglect," "hemi-neglect," "visuospatial neglect," "inattention," or simply "neglect in the RHD literature. "

after RHD is growing. Discourse necessitates the integration and interpretation of multimodal information including that taken from visual modalities (Peach & Hanna, 2021; Sherratt & Bryan, 2012). After a right hemisphere stroke, nonlinguistic cognitive disorders such as SN co-occur, modulate, and can even influence discourse (Cherney et al., 2001; Minga et al., 2021; Tompkins et al., 2013). That is, when deficits in attention and processing of information occur in the left side of space (extrapersonal and peripersonal) or an object, the ability to identify, consider, and integrate spatial information pertinent to organizing and planning discourse may be limited. This is particularly so when considering that many adults with RHD experience apragmatism (Minga, Sheppard, et al., 2022), a communication disorder characterized by challenges interpreting and producing language (both verbal and nonverbal) to communicate in a way that is contextually appropriate (Minga, Sheppard, et al., 2022; Myers, 2001). The following scenario demonstrates how SN may contribute to an apragmatic episode: Two people are in a room. Person 1 (with SN post RHD) and Person 2 are facing each other and discussing a plan to celebrate for Person 3, who enters the room via a door on the left side of Person 1 (extrapersonal space). Using their right hand (left side for Person 1 in peripersonal space), Person 2 points toward Person 3 entering the room. The presence and absence of Person 3 and recognition of the gesture in the neglected space are just two of the pragmatic nuances that can dictate whether or not details about the celebration are shared openly, whether a prompt for a future discussion is needed, and whether there is a need to change the topic of discussion. However, Person 1 continues discussing the celebration plan as if Person 3 did not enter the room, and Person 2 did not gesture.

Modulations of discourse production and reduction of meaningful, appropriate content when SN is present have been documented (Cherney et al., 1997), but there has been no recent inquiry. In the example provided, Person 1's contribution to the communication was inappropriate for the context. Visual information about the communication partners (i.e., presence of Person 3 and gesturing of Person 2) can impact the communication exchange. Moreover, as with many discourse tasks, the inability to perceive and integrate information from pictures or written stimuli can further affect the quality of discourse. Thus, SN can have a real impact on apragmatism. Enhancing knowledge concerning SN can contribute to understanding the overall chronic deficit profile after a right hemisphere stroke.

### Present Study

The present study used the RHDBank database to answer the following questions. Do components of the RHDBank protocol aid in the identification of SN in chronic survivors? Is the cognitive performance of right hemisphere stroke survivors on the RHDBank test battery associated with the presence of SN? This retrospective analysis aims to provide insight about the SN knowledge to be gained when using the RHDBank test battery for chronic right hemisphere stroke survivors and offers suggestions to SLPs who provide care to individuals with RHD.

## Method

### Participants

Data from 30 adults who were at least 6 months post a single right hemisphere stroke (as evidenced by radiology report) with complete data transcripts were extracted from the Minga corpus of the RHDBank[2] (https://rhd.talkbank.org; Minga et al., 2021). Specifically, data of corpus members with a completed transcript were extracted from the Minga corpus demographic spreadsheet using the RHDBank webpage by the first author (J.M.). Each individual also met the following inclusion criteria: English spoken as the primary language; no history of alcohol, drug abuse, or learning disability; and right-handed with functional hearing and vision, by self-report with an accessible Apples Test response form. Participant characteristics are reported in Table 1. Institutional review boards at Duke University School of Medicine and North Carolina Central University approved this study.

### Procedure

The RHDBank test battery was administered to each participant in a campus clinic or in their home (in person or via a videoconferencing platform). Test administration was completed by a graduate speech-language pathology student or a certified SLP. Three assessments from the battery were examined in this study: the Apples Test (Bickerton et al., 2011), the CLQT (Helm-Estabrooks, 2001), and the Indented Paragraph Test (Caplan, 1987). The Apples Test was used to determine within-group differences in the presence of SN. Scoring was completed at the time of data collection, and the three measures used here were rescored to examine SN-related biases specifically.

### Measures

The Apples Test simultaneously evaluates egocentric and allocentric symptoms of SN. Participants are instructed to place a mark on targets (whole apples) and

[2]We use participant numbers as identifiers, but the corpus name plus number are identifiers in the RHDBank.

**Table 1.** Demographics of participants with and without spatial neglect as identified by the Apples Test.

| Variable | RHD with spatial neglect (SN+; *N* = 10) | RHD without spatial neglect (SN−; *N* = 19) | Test statistic, *p* |
|---|---|---|---|
| Age, *M* (*SD*, range) | 55.4 (8.6, 39.4–65.3) | 52.6 (13.2, 25.2–78.7) | $U = 69.5, p = .25$ |
| Sex (female), *n* (%) | 4 (40) | 15 (78.9) | $\chi^2 = 4.4, p = .04$ |
| Race | | | $\chi^2 = 0.01, p = .93$ |
| White, *n* (%) | 7 (70) | 13 (68.4) | |
| Black, *n* (%) | 3 ( 27.2) | 6 (31.5) | |
| Education (years), *n* (%) | | | $\chi^2 = 2.41, p = .49$ |
| 11–13 | 1 (10) | 2 (10.5) | |
| 14–16 | 7 (70) | 8 (42.1) | |
| 17–19 | 1 (10) | 6 (31.5) | |
| Over 20 | 1 (10) | 3 (15.7) | |
| Employment status (retired), *n* (%) | 9 (90) | 15 (78.9) | $\chi^2 = 0.56, p = .45$ |
| Vision correction (wears glasses), *n* (%) | 9 (90) | 3 (15.7) | $\chi^2 = 14.87, p < .001$ |
| Apraxia of speech, *n* (%) | 1 (10) | 1 (5) | $\chi^2 = 0.23, p = .63$ |
| Dysarthric, *n* (%) | 2 (20) | 2 (10.5) | $\chi^2 = 0.49, p = .48$ |
| RHD duration (years), *M* (*SD*, range) | 10.1 (11.4, 0.7–38.1) | 5.5 (5.8, 0.2–25.2) | $U = 69.5, p = .25$ |
| Lesion etiology (ischemic), *n* (%) | 6 (60) | 10 (52.3) | $\chi^2 = 0.14, p = .70$ |
| Number of participants who reported having therapeutic intervention with SLP who focused on SN, *n* (%) | 0 (0) | 3 (15.7) | |

*Note.* See Table 2 for details of therapeutic focus as per survivors at the time of data collection. RHD = right hemisphere brain damage; SN = spatial neglect; SLP = speech-language pathologist.

not on distractors (apples with a gap on the right or left side) within 5 min. There are 150 stimuli scattered across a letter-size paper, including 50 targets, 50 distractors with a left-sided gap, and 50 distractors with a right-sided gap. For the current study, a determination of SN+ and SN− was made using the Apples Test asymmetry scores, the difference in the number of complete apples and incomplete apples (either left or right gap) identified on the right side of the page and those on the left side of the page. Following Bickerton et al.'s (2011) criteria, SN was deemed present in patients with asymmetry scores ≥ 3 (both egocentric and allocentric) on the Apples Test.

The CLQT assesses function across five domains: attention, memory, executive functioning, spatial skills, and language. We particularly focused on the design generation task and the clock drawing task from the CLQT to identify symptoms of SN in this cohort. Participants' performance on the symbol cancellation task was at ceiling (all but one participant received the maximum score) and therefore was not isolated. In the clock drawing task, participants are presented with an open circle and are instructed to draw the numbers 1–12, an hour hand, and a minute hand in the correct spatial positions to form an analog clock face. For the design generation task, participants were asked to produce drawings using four lines to connect four dots on a page in landscape orientation without repeating a drawing modeled by the examiner. Visual inspection of the designs and traditional task scores were considered in the analysis.

The Indented Paragraph Test consists of a 30-line passage with right-justified (i.e., "align right") text printed on a letter-size paper in a 12-point font. Each line is indented between zero and 25 spaces from the left margin (Towle & Lincoln, 1991). Participants are instructed to read the text aloud.

## Laterality Indices Scoring Procedure

All three measures were rescored using the laterality index (LI) method (Halligan et al., 1991) for the purpose of comparing spatial biases in performance across tests. The LI is calculated as the number of left-sided correct responses divided by the number of left- and right-sided correct responses. The normal range is between 0.48 and 0.52. Scores < 0.48 indicate left-sided SN, and scores > 0.52 indicate right-sided SN.

For the Apples Test LI, targets were grouped into five regions on a landscape-oriented page for scoring (see Figure 2 in Chen et al., 2017)—two regions on either side of the page and one region in the center. The number of targets correctly marked on the left side of the page was divided by the number of targets correctly marked on the left and right sides of the page. The central targets were excluded from the LI scoring procedure.

The LI for the CLQT clock drawing task was calculated by first determining the correct spatial placement of numbers 1–5 on the right and numbers 7–11 on the left

(Halligan et al., 1991). Five points were possible on each side of the clock face. Then, the number of left-sided points was divided by the number of left- and right-sided points. The placement of numbers 12 and 6 was excluded from the LI scoring procedure because they exist at the horizontal midline of the clock face. See Figure 1 for an example of the scoring.

To determine if there were differences in reading accuracy within egocentric and allocentric frames of reference, we calculated two different LIs for the Indented Paragraph Test: egocentric page-centered LIs, relative to the midpoint of the page, and allocentric line-centered LIs, relative to the midpoint of the lines. To calculate page-centered LIs, for each line, the distance in millimeters was measured between the leftmost accurately read word and the right edge of the page. Next, each of these distances was divided by the total width of the page from the left edge to the right edge to determine the proportion of each line read accurately relative to the width of the page. Finally, the mean proportion of accurately read text was divided by 2 to determine the LI for each participant.

To calculate line-centered LIs, using the midpoint of each line as a frame of reference, words accurately read on the left side of the line were divided by words read on both sides of the line. Line-by-line LIs and mean LIs for both page- and line-centered indices were calculated.

### *Data Analysis*

We examined the presence of SN (SN+) among participants with RHD using components of the RHDBank test battery and compared their demographics and performance patterns with the remainder of the cohort without SN (SN–).

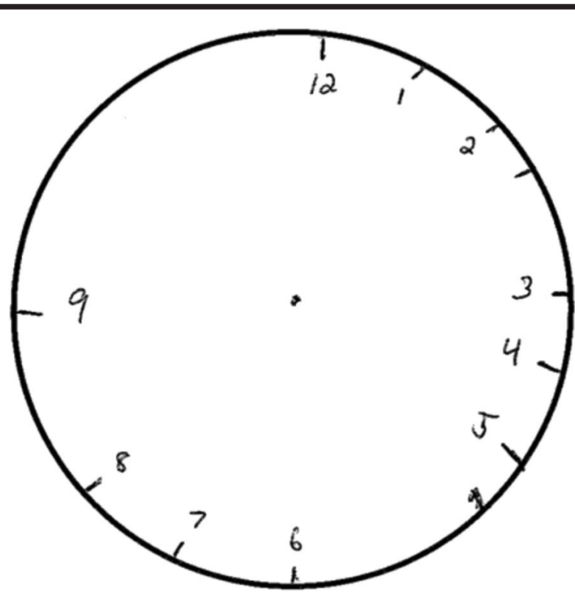


**Figure 1.** The laterality index of this clock drawing. The laterality index of this clock drawing was 3(left-sided)/8(right-sided) = 0.375.

Participants were grouped with SN (SN+) or without SN (SN–) based on the Apples Test results. A Mann–Whitney $U$ test (due to non-Gaussian distributions) or a chi-square test was used as appropriate to determine whether there were differences (α level set at .05) in demographic data between the SN+ and SN– groups.

To determine if, collectively, measures on the CLQT capture information associated with SN, we performed an exploratory hierarchical clustering analysis (Murtagh, 1985) using Euclidean distance and the Ward clustering method (Murtagh & Legendre, 2011) available as part of the HCLUST package in RStudio (R Version 4.2.2). The clustering analysis builds a hierarchy of clusters by continually merging data subgroups. The groupings are visualized in a treelike dendrogram, allowing for a detailed understanding of the nested clustering structure within the data. This technique can help identify meaningful taxonomies or structures in data sets. The cut level can be selected at different points in the dendrogram to examine cluster characteristics. We computed clusters based on CLQT domain scores, clock drawing LIs, design generation scores, and Indented Paragraph Test LIs to determine if these scores can inform SN screening. To this end, we compared our clustering solution (at $k = 2$) with SN classification based on the Apples Test performance.

## Results

### *Participant Demographics, SN Incidence, and Treatment History*

One participant was excluded after scoring positively for both left and right SN, resulting in a total study sample of 29 adults. Twenty-six percent of the sample ($n = 8$) identified as Black, and 63% ($n = 19$) identified as female. A total of 10 RHD participants were included in the SN+ group and 19 in the SN− group. Table 1 displays characteristics of the two groups. No statistical differences were found in age, race, education, employment status, presence of dysarthria and apraxia, and RHD duration. The SN+ group was more likely to have corrected vision. Most participants were educated beyond high school. The SN+ group reported that no treatment specifically focused on SN was provided by the SLP, whereas three members of the SN– group report having treatment.

Table 2 outlines the timing and types of skilled speech-language therapeutic history, by participant report.

**Table 2.** Time and type of skilled speech-language therapeutic history by participant report.

| Without spatial neglect (Cluster 2) | | | With spatial neglect (Cluster 1) | | |
|---|---|---|---|---|---|
| **Participant ID** | **Tx focus areas** | **Time of tx** | **Participant ID** | **Tx focus areas** | **Time of tx** |
| 02 | Left neglect, problem solving | A | 05 | Organization | AC |
| 08 | Language, organization, left neglect, shock therapy, memory | AC | 06 | Evaluation only | n/a |
| 14 | Swallowing, attention | AC | 18 | Speech | AC |
| 15 | Speech volume, music, organization, short-term memory | AC | 23 | Swallowing | A |
| 16 | Focus, math, reasoning | AC | 24 | Memory, activities of daily living | A |
| 21 | Memory, cognitive | AC | 25 | Executive function | AC |
| 22 | Word-finding, sentences, maps | A | 42 | Functional tasks, math skills, speech production | AC |
| 26 | Slurred speech, dysphagia | A | 72 | Organization, problem-solving activities, vision | |
| 27 | Articulation, voice | AC | 77 | U | AC |
| 28 | U | U | 79 | U | AC |
| 31 | Evaluation only | A | | | |
| 37 | Executive functions, organization, working memory, goal setting, ordering tasks | AC | | | |
| 40 | Swallowing, memory, concentration, verbal expression | AC | | | |
| 45 | Pronunciation, memory, organization, reading & recall | A | | | |
| 56 | Reading, writing, memory | A | | | |
| 58 | Executive function, recall | A | | | |
| 67 | Executive function, math, left-sided awareness, reading, relay information | AC | | | |
| 69 | Muscle rehabilitation | A | | | |
| 70 | Read stories | C | | | |
| 78 | Academic work, monotone voice, /s/ | C | | | |

*Note.* ID = identifier; tx = treatment; A = acute; AC = acute and chronic; n/a = not applicable; U = unknown; C = chronic as per the RHDBank codebook.

Cognitive-focused therapy (e.g., attention organization, memory) occurred for 4/10 of SN+ participants and 12/19 SN− participants ($\chi^2$ = 1.42, *p* = .23, ns [nonsignificance]). A total of 8/10 in the SN+ group and 9/19 in the SN− group received therapy in both the acute and chronic phases of recovery ($\chi^2$ = 2.88, *p* = .09, ns), while four participants, regardless of SN status, had therapy only in the chronic phase of recovery.

## Types of SN

The frequency of left-sided versus right-sided SN by egocentric or allocentric frame of reference was determinable using the RHDBank test protocol. Eight participants (27%) produced only egocentric errors; four participants (14%) produced only allocentric errors. Two participants (7%) produced both egocentric and allocentric errors. Contralesional (left-sided) errors were more common than ipsilesional (right-sided) errors (34% vs. 7%, respectively).

Table 3 displays the LIs for the Indented Paragraph Test and CLQT clock drawing scores of the 10 participants who were identified as SN+ using the Apples Test. All participants in this subset showed signs of SN on the Apples Test, either egocentric or allocentric, as noted by the bold scores in these two columns. Six participants showed signs of SN based on the Apples Test LIs. Participant 72 was the only person to have both a page-centered and a line-centered SN; Participant 77 shows a CLQT rating indicative of SN. Figure 2 demonstrates an example of SN performance by Participants 72 and 77 on the Apples Test, CLQT clock drawing, and design generation.

## Hierarchical Cluster Analysis

The multivariate data, including CLQT domain scores, clock drawing LIs, design generation scores, and Indented Paragraph Test LIs, were scaled and centered. Figure 3 shows the results of the exploratory hierarchical

**Table 3.** Individual scores and laterality indices (LIs) from RHDBank survivors with left-sided spatial neglect (SN).

| | Egocentric | | | | Allocentric | |
|---|---|---|---|---|---|---|
| Participant number | Apples Test score | Apples Test LI | Indented Paragraph Test page-centered LI | CLQT–clock drawing LI | Apples Test score | Indented Paragraph Test line-centered LI |
| 5 | 1 | .49 | 0.50 | 0.50 | **5** | 0.50 |
| 6 | **–4** | .55 | 0.50 | 0.50 | 0 | 0.50 |
| 18 | **5** | **.43** | 0.50 | 0.50 | 0 | 0.50 |
| 23 | **4** | **.44** | 0.50 | 0.50 | **13** | 0.50 |
| 24 | **4** | **.44** | 0.50 | 0.50 | 0 | 0.50 |
| 25 | –1 | .51 | 0.50 | 0.50 | **3** | 0.49 |
| 42 | **3** | **.46** | 0.50 | 0.50 | 0 | 0.50 |
| 72 | **15** | **.11** | **0.47** | 0.50 | **21** | **0.45** |
| 77 | **10** | **.33** | 0.49 | **0.38** | 0 | 0.48 |
| 79 | –3 | .54 | 0.50 | 0.50 | 0 | 0.50 |

*Note.* Patient study number is as identified by the same number used in the RHDBank database. Readers may access full transcripts and test scores at rhd.talkbank.org; (–) means the errors occurred on the right side indicating right-sided spatial neglect; (+) number means that the errors occurred on the left side. The scores that are bolded for the LIs were, if lower than 0.48, indicative of left-sided SN. For traditional rating of the Apples Test, a left-sided SN is indicated by a score ≥ 3, with lower numbers indicating less errors, and a right-sided SN is indicated by a score ≥ –3. CLQT = Cognitive Linguistic Quick Test.

**Figure 2.** Case examples of two participants with spatial neglect. The Apples Test for Participant 72 was administered upside down and is represented this way here and scored oriented as such.

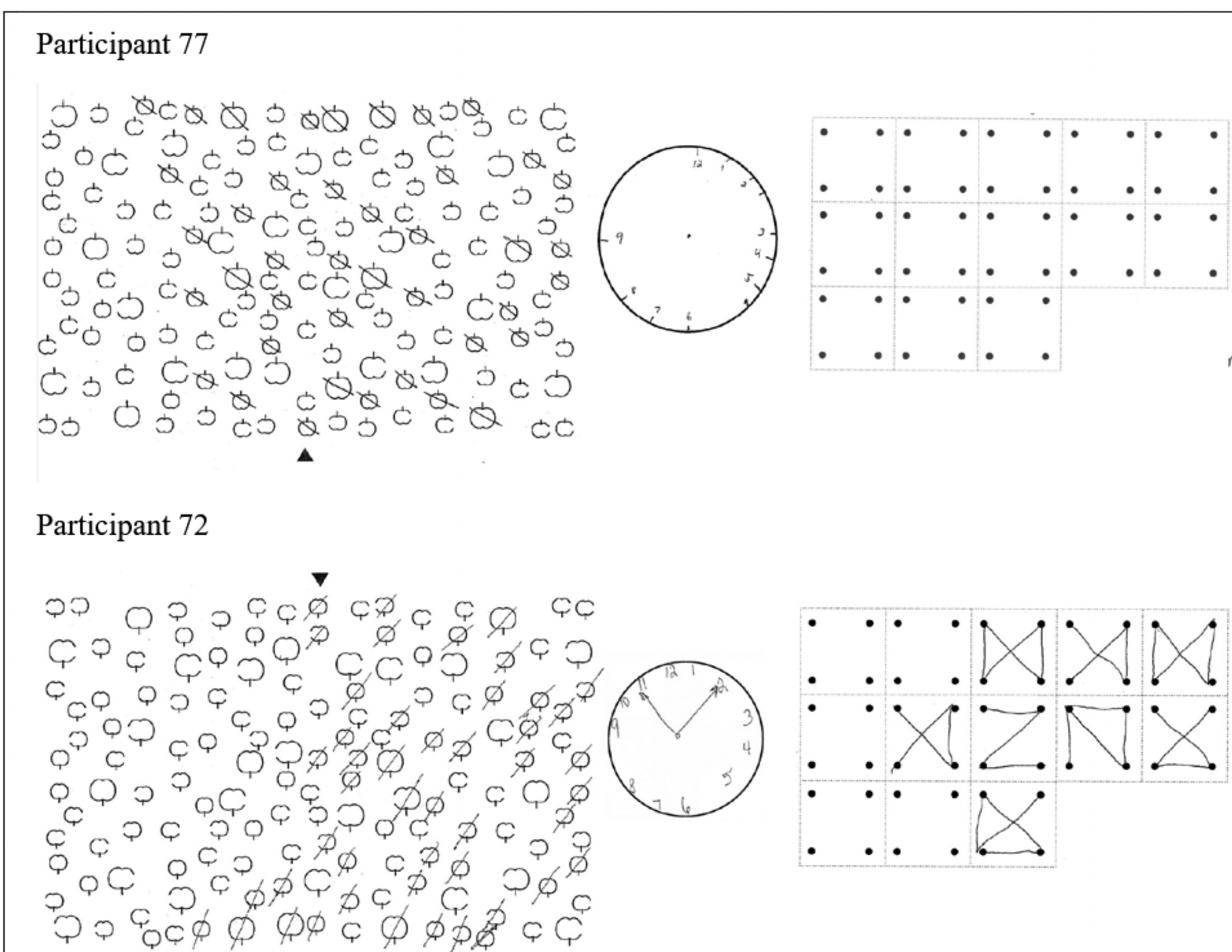
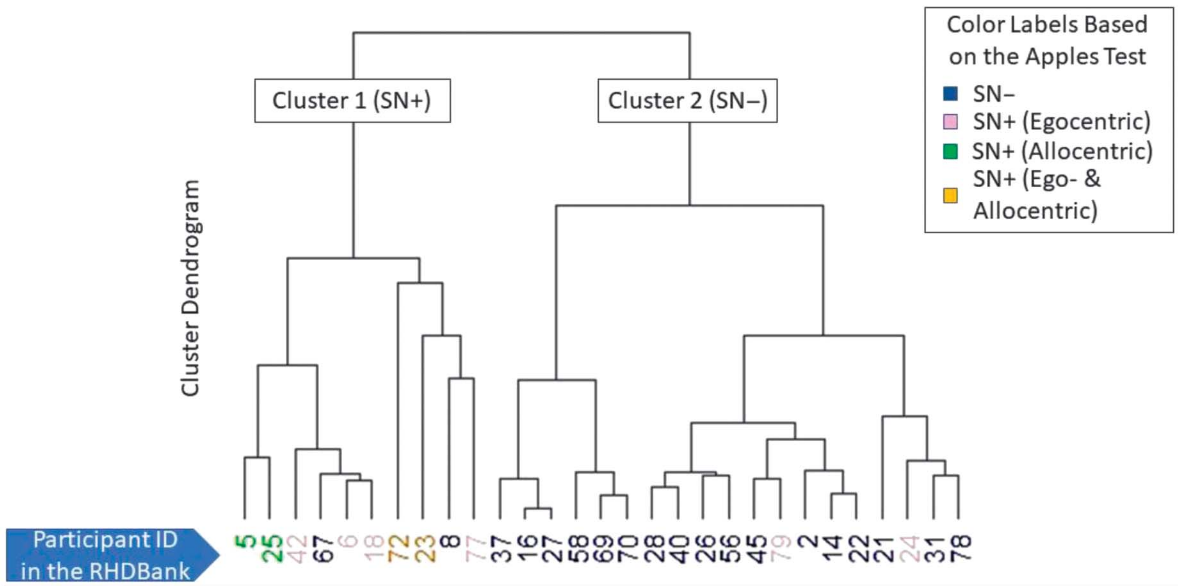


**Figure 3.** Hierarchical clustering of CLQT domain scores, design generation, clock laterality indices, and Indented Paragraph Reading Test metrics for all stroke participants. Full score range inclusive of each severity rating provided for CLQT domains. Adding design generation in addition to domain scores and laterality indices significantly improved the ability of the cluster solution to separate participants into those with and without SN. CLQT = Cognitive Linguistic Quick Test; SN = spatial neglect.




| Cluster | CLQT – Domain Scores | | | | | Design Generation | Group Average Laterality Indices (LI) | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Attention (0–215) | Memory (0–185) | Executive Function (0–40) | Language (0–37) | Visuospatial (0–105) | | Clock Drawing | Reading, Page | Reading, Line | Reading, *N* Words Omitted |
| Cluster 1 (Neglect) | 138.90 | 169.90 | 18.50 | 31.80 | 66.40 | 4.00 | 0.48 | 0.49 | 0.50 | 4.60 |
| Cluster 2 (Non-neglect) | 192.95 | 162.00 | 28.95 | 31.32 | 89.37 | 6.68 | 0.50 | 0.50 | 0.50 | 0.89 |

cluster analysis. Our clustering solution suggests that performance on the CLQT and the Indented Paragraph Reading Test identifies two main clusters: a cluster made up of mainly SN+ participants (Cluster 1) and a cluster made up of mainly SN– participants (Cluster 2), with cluster labels independently verified using the Apples Test (not used in the clustering analysis). Within Cluster 1, there is some organization by SN reference frames, with three smaller subclusters: allocentric neglect subcluster, egocentric neglect subcluster, and mixed subcluster (subcluster labels are based on the Apples Test performance). Overall, most individuals with SN fell within Cluster 1. There were two outliers with egocentric neglect within Cluster 2 (SN–), Participants 24 and 79, and two participants without neglect within Cluster 1 (SN+), Participants 08 and 67. Whereas Cluster 2 (SN–) demonstrated skills for ratings within functional limits for all cognitive domains, participants falling within Cluster 1 (SN+) had memory within functional limits but scored as moderately impaired in domains of attention (impairment score range: 50–124) and executive function (16–19) and mildly impaired for visuospatial skills (52–81) for 18–69 years of age. Design generation was low for both groups, with a maximum rating of 13. Participants with SN omitted more words during reading of the indented paragraph.

We also considered the concordance between the Apples Test and the clustering solution using multivariate data from the CLQT and the Indented Paragraph Reading Test. The result is shown in Table 4 in the form of a confusion matrix. Specifically, the table considers participants classified as SN+ and SN– according to the Apples

**Table 4.** Confusion matrix comparing the results of the cluster analysis and spatial neglect status based on the Apples Test.

| **Spatial neglect status** | **CLQT and indented paragraph cluster classification ($k$ = 2)** | | |
|---|---|---|---|
| **Apples Test** | **Spatial neglect present** | **Spatial neglect absent** | **Total** |
| Spatial neglect present | 8 | 2 | 10 |
| Spatial neglect absent | 2 | 17 | 19 |
| Total | 10 | 19 | 29 |

*Note.* CLQT = Cognitive Linguistic Quick Test.

Test, against those classified as SN+ and SN– according to the cluster solution (with $k = 2$ clusters). This concordance is shown along the table diagonal, whereas the misclassifications are shown off diagonal. These results suggest that including the Apples Test should yield the best SN detection rate, while the multivariate CLQT and Indented Paragraph Reading Test data can identify SN with a sensitivity of 80% (8/10) and a specificity of 89% (17/19).

## Discussion

Although SN is commonly experienced after a right hemisphere stroke, it is less commonly assessed, reported, and treated than many other conditions in neurorehabilitation (Fink, 2005; Vitti et al., 2022). In this study, we explored the feasibility of using the RHDBank test battery to identify SN in chronic right hemisphere stroke survivors. SN was identified in 34% of the sample using the Apples Test, which is commensurate with previous studies (Esposito et al., 2021; Hillis et al., 2005). We also found that very few participants in this study reported receiving speech therapy that they thought focused on improving SN. It is recognized that patient reports provide one part of the rehabilitative story; therefore, our patient-centered clinical approach supports the acknowledgment of the reported views with caution. Nevertheless, SN deficits may not be well identified by SLPs during the early phases of recovery, consistent with research suggesting that SN is underdiagnosed (Chen et al., 2013; Edwards et al., 2006). Underdiagnosis may have contributed to participants not being treated or perhaps indicates that SN treatment may not have been prioritized over other cognitive deficit domains after right hemisphere stroke. There is a need to modify SLPs' approach to and understanding of SN in the chronic phase of recovery.

Treatment of an impairment is predicated on its identification. SN is often underdiagnosed after stroke (Azouvi et al., 2002; Chen et al., 2013; Esposito et al., 2021; Lindell et al., 2007; Pitteri et al., 2018). As such, the use of multiple tests of SN is recommended for greater diagnostic sensitivity (Azouvi et al., 2002; Esposito et al., 2021). It is particularly important that SLPs have diagnostic guidance when providing care to individuals with RHD. While CLQT and reading tasks are often administered by SLPs, the Apples Test alone in the present analysis showed within-group diagnostic differentiation. Given the heterogeneity of the RHD population, this is a clinically significant finding. The exploratory cluster analysis suggests that, collectively, components of the RHDBank test battery—CLQT, Apples Test, and Indented Paragraph Test—are important assessments to implement in a clinical setting as detection of SN should be included in the chronic deficit profile after a right hemisphere stroke.

The present findings show that participants with SN had ratings of either moderately or mildly severe impairments in cognitive domains of attention, executive function, and visuospatial skills. Such findings may serve as a clinical indicator to SLPs to perform additional diagnostic assessments for SN to meet the rehabilitative needs of disabling impairments. There is little research on the impact of deficits such as SN on discourse in the chronic phase of recovery. SLPs, however, can more comprehensively and routinely administer SN assessments alongside other cognitive and communication assessments.

### Clinical Implications

The chronic deficit profile after a right hemisphere stroke is an emerging aspect of the literature. Three participants reported having skilled speech-language therapy focused on improving SN. These participants were not identified as having SN now in the chronic phase of recovery, suggesting treatment success. SLPs can aid in increasing the relative identification and treatment of SN. We provide options for diagnostic considerations using the RHDBank test battery, a resource that is increasingly being used for clinical and research purposes and demonstrates that the Apples Test is particularly helpful with differentiating within-group SN diagnostically, especially given that SLPs tend to select assessment tools that are available and easy to administer in a relatively short period of time (Ramsey & Blake, 2020). Moreover, diagnostic Cluster 1 of the domain scores from the CLQT can serve as a clinical signal to SLPs to further assess for SN when there are lateralized spatial errors. Use of the Apples Test test will aid in further delineating a comprehensive SN profile. In addition, interprofessional collaboration with practitioners such as occupational therapists may be beneficial and important to ensure comprehensive care for people with SN. This may already be occurring in some rehabilitation settings where therapists frequently work side by side in the same space, but interprofessional collaboration can be strengthened (Chen et al., 2021). Finally, efforts should be made to use the same vocabulary when discussing SN to facilitate cohesive interdisciplinary care (Chen et al., 2021). The lack of specificity in the use of terminology (e.g., visual neglect, unilateral spatial attention) has been shown to result in miscommunication and can be a barrier to how individuals are assessed for SN and ultimately treated because of the confusion it creates (Chen et al., 2021). As evidenced by this sample, SN does not always resolve spontaneously. SN deficits were not targeted for participants in this study, as per patient report, suggesting a lack of either detection or prioritization of SN within their rehabilitative course. With total stroke medical costs expected to increase exponentially (Ovibagele et al., 2013), focused and targeted detection and treatment of SN deficits can improve the fiscal burden and optimize clinical outcomes after RHD.

There are multiple treatment options for SN that can be easily adopted by SLPs. For example, one report provided a summary of 22 treatments that can be incorporated clinically (Chen et al., 2018), and many of these treatments are also recommended by the American Heart Association, the American Stroke Association, and Canadian Stroke Best Practices for adults with SN poststroke (Teasell et al., 2020; Winstein et al., 2016). A popular treatment is visual scanning training, which was developed using reading materials (Weinberg et al., 1977). It guides patients with left-sided SN to find an "anchor" (i.e., a salient visual cue) placed near the left edge of the workspace (e.g., the beginning of a sentence or paragraph, for reading). Gradual guidance and visual scanning training techniques are outlined to progress to limited use of an anchor (Weinberg et al., 1977) with successful implementation and efficacy by many clinicians in their practice (Chen et al., 2018; Liu et al., 2018). Complementary therapeutic approaches, such as the spatial exploration strategy training (Toglia & Chen, 2022), provide a multicontext treatment approach, with added feedback to implement guided training in reading or nonreading tasks. This highly personalized approach to improving SN enhances the patient's ability to self-recognize and manage symptoms across different tasks and task variations (Toglia & Foster, 2021).

With the screening tools in the RHDBank, SLPs are encouraged to integrate evidence-based strategies into therapy activities when working with clients whose reading and communication abilities are affected by SN. This area of research is equally underexplored. It will be important to assess SN as a concomitant and interrelated deficit of the RHD deficit profile. In the meantime, this article affords clinicians with information pertinent to deficits in the chronic phase of recovery after RHD stroke.

### *Limitations and Future Directions*

Although the rate of SN detected in this sample was similar to what has been previously reported, this was a retrospective analysis of data collected using a test battery primarily developed for the study of discourse production after RHD. Therefore, it is possible that SN was present yet undetected in this cohort. The sample is small, and therefore, the results should be cautiously interpreted. Nevertheless, the study findings advance the growing literature concerning the clinical profile of patients with RHD and the relative representation of chronic SN. Future studies should seek to understand the various ways that SN can be manifested and the relationship between areas of damage and other deficits. For example, future studies may explore the specific ways that SN, particularly in the chronic phase of recovery, influences discourse. Our understanding of the chronic deficit profile hinges on teasing apart the behaviors associated with SN and perhaps its varying components.

## Conclusions

In this study, we found evidence of SN in chronic right hemisphere stroke survivors through a secondary analysis of data collected for the RHDBank database. It was determined that 34% of the group had SN based on the CLQT, Apples Test, and Indented Paragraph Test. More research is needed to clarify the co-occurrence of SN and other cognitive and communication deficits common to RHD (Blake et al., 2002; Ferré et al., 2012; Minga, Sheppard, et al., 2022). The prevalence and functional challenges posed by SN should heighten clinical recognition and focused rehabilitation efforts. Assessment and treatment of SN is within the scope of practice for SLPs. Therefore, we encourage SLPs to incorporate, at a minimum, the Apples Test into their clinical practice while evaluating spatially lateralized performance on the CLQT.

## Data Availability Statement

RHDBank data are available as part of the TalkBank system. Interested people may contact Dr. Brian MacWhinney (macw@cmu.edu) with your academic affiliation, postal address, and e-mail address and a description of your plans for the data. The specific raw data used in this article are available on request.

## Acknowledgments

This work was supported in part by National Institute on Deafness and Other Communication Disorders Grants 3R01-DC008524-11S1, L60DC019755, and 1K23DC020236-01A1; the Office of Research on Women's Health through the Building Interdisciplinary Research Careers in Women's Health program under Grant K12-HD043446-16; and the National Institute on Minority Health and Health Disparities through the Research Centers in Minority Institutions program under Grant 5U54MD012392-03 (awarded to Jamila Minga). The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health. The authors would like to thank the participants of the RHDBank for donating their time and data to right hemisphere stroke research advances. A special note of gratitude to the North Carolina Central University graduate students, Marcia Rodriguez, La'Toria Jallah, Brian MacWhinney, Davida Fromm, and Carnegie Mellon University staff for their dedication to enhancing the RHDBank.

## References


**Azouvi, P., Samuel, C., Louis-Dreyfus, A., Bernati, T., Bartolomeo, P., Beis, J.-M., Chokron, S., Leclercq, M., Marchal, F., Martin, Y., De Montety, G., Olivier, S., Perennou, D., Pradat-Diehl, P., Prairial, C., Rode, G., Sieroff, E., Wiart, L., & Rousseaux, M.** (2002). Sensitivity of clinical and behavioural tests of spatial neglect after right hemisphere stroke. *Journal of Neurology, Neurosurgery & Psychiatry, 73*(2), 160–166. https://doi.org/10.1136/jnnp.73.2.160

**Benjamin, E. J., Muntner, P., Alonso, A., Bittencourt, M. S., Callaway, C. W., Carson, A. P., Chamberlain, A. M., Chang, A. R., Cheng, S., Das, S. R., Delling, F. N., Djousse, L., Elkind, M. S. V., Ferguson, J. F., Fornage, M., Jordan, L. C., Khan, S. S., Kissela, B. M., Knutson, K. L., . . . American Heart Association Council on Epidemiology and Prevention Statistics Committee and Stroke Statistics Subcommittee.** (2019). Heart disease and stroke statistics—2019 update: A report from the American Heart Association. *Circulation, 139*(10), e56–e528. https://doi.org/10.1161/CIR.0000000000000659

**Bickerton, W. L., Samson, D., Williamson, J., & Humphreys, G. W.** (2011). Separating forms of neglect using the Apples Test: Validation and functional prediction in chronic and acute stroke. *Neuropsychology, 25*(5), 567–580. https://doi.org/10.1037/a0023501

**Blake, M. L., Duffy, J. R., Myers, P. S., & Tompkins, C. A.** (2002). Prevalence and patterns of right hemisphere cognitive/communicative deficits: Retrospective data from an inpatient rehabilitation unit. *Aphasiology, 16*(4–6), 537–547. https://doi.org/10.1080/02687030244000194

**Boukrina, O., Chen, P., Budinoska, T., & Barrett, A. M.** (2020). Exploratory examination of lexical and neuroanatomic correlates of neglect dyslexia. *Neuropsychology, 34*(4), 404–419. https://doi.org/10.1037/neu0000619

**Buxbaum, L. J., Ferraro, M. K., Veramonti, T., Farne, A., Whyte, J., Ladavas, E., Frassinetti, F., & Coslett, H. B.** (2004). Hemispatial neglect: Subtypes, neuroanatomy, and disability. *Neurology, 62*(5), 749–756. https://doi.org/10.1212/01.WNL.0000113730.73031.F4

**Caplan, B.** (1987). Assessment of unilateral neglect: A new reading test. *Journal of Clinical and Experimental Neuropsychology, 9*(4), 359–364. https://doi.org/10.1080/01688638708405056

**Champagne-Lavau, M., & Joanette, Y.** (2009). Pragmatics, theory of mind and executive functions after a right-hemisphere lesion: Different patterns of deficits. *Journal of Neurolinguistics, 22*(5), 413–426. https://doi.org/10.1016/j.jneuroling.2009.02.002

**Checketts, M., Mancuso, M., Fordell, H., Chen, P., Hreha, K., Eskes, G. A., Vuilleumier, P., Vail, A., & Bowen, A.** (2020). Current clinical practice in the screening and diagnosis of spatial neglect post-stroke: Findings from a multidisciplinary international survey. *Neuropsychological Rehabilitation, 31*(9), 1495–1526. https://doi.org/10.1080/09602011.2020.1782946

**Chen, P., Caulfield, M. D., Hartman, A. J., O'Rourke, J., & Toglia, J.** (2017). Assessing viewer-centered and stimulus-centered spatial bias: The 3s spreadsheet test version 1. *Applied Neuropsychology: Adult, 24*(6), 532–539. https://doi.org/10.1080/23279095.2016.1220382

**Chen, P., Hreha, K., Kong, Y., & Barrett, A. M.** (2015). Impact of spatial neglect on stroke rehabilitation: Evidence from the setting of an inpatient rehabilitation facility. *Archives of Physical Medicine and Rehabilitation, 96*(8), 1458–1466. https://doi.org/10.1016/j.apmr.2015.03.019

**Chen, P., McKenna, C., Kutlik, A. M., & Frisina, P. G.** (2013). Interdisciplinary communication in inpatient rehabilitation facility: Evidence of under-documentation of spatial neglect after stroke. *Disability and Rehabilitation, 35*(12), 1033–1038. https://doi.org/10.3109/09638288.2012.717585

**Chen, P., Pitteri, M., Gillen, G., & Ayyala, H.** (2018). Ask the experts how to treat individuals with spatial neglect: A survey study. *Disability and Rehabilitation, 40*(22), 2677–2691. https://doi.org/10.1080/09638288.2017.1347720

**Chen, P., & Toglia, J.** (2022). The 3s spreadsheet test version 2 for assessing egocentric viewer-centered and allocentric stimulus-centered spatial neglect. *Applied Neuropsychology: Adult, 29*(6), 1369–1379. https://doi.org/10.1080/23279095.2021.1878462

**Chen, P., Zanca, J., Esposito, E., & Barrett, A. M.** (2021). Barriers and facilitators to rehabilitation care of individuals with spatial neglect: A qualitative study of professional views. *Archives of Rehabilitation Research and Clinical Translation, 3*(2). https://doi.org/10.1016/j.arrct.2021.100122

**Cherney, L. R., Drimmer, D. P., & Halper, A. S.** (1997). Informational content and unilateral neglect: A longitudinal investigation of five subjects with right hemisphere damage. *Aphasiology, 11*(4/5), 351–363. https://doi.org/10.1080/02687039708248476

**Cherney, L. R., Halper, A. S., Kwasnica, C. M., Harvey, R. L., & Zhang, M.** (2001). Recovery of functional status after right hemisphere stroke: Relationship with unilateral neglect. *Archives of Physical Medicine and Rehabilitation, 82*(3), 322–328. https://doi.org/10.1053/apmr.2001.21511

**Coslett, H. B., Bowers, D., Fitzpatrick, E., Haws, B., & Heilman, K. M.** (1990). Directional hypokinesia and hemispatial inattention in neglect. *Brain, 113*(2), 475–486. https://doi.org/10.1093/brain/113.2.475

**Edwards, D. F., Hahn, M. G., Baum, C. M., Perlmutter, M. S., Sheedy, C., & Dromerick, A. W.** (2006). Screening patients with stroke for rehabilitation needs: Validation of the post-stroke rehabilitation guidelines. *Neurorehabilitation and Neural Repair, 20*(1), 42–48. https://doi.org/10.1177/1545968305283038

**Esposito, E., Shekhtman, G., & Chen, P.** (2021). Prevalence of spatial neglect post-stroke: A systematic review. *Annals of Physical and Rehabilitation Medicine, 64*(5), Article 101459. https://doi.org/10.1016/j.rehab.2020.10.010

**Ferretti, L. A., & McCallion, P.** (2019). Translating the chronic disease self-management program for community-dwelling adults with developmental disabilities. *Journal of Aging and Health, 31*(Suppl. 10), 22S–38S. https://doi.org/10.1177/0898264318822363

**Ferré, P., Fonseca, R. P., Ska, B., & Joanette, Y.** (2012). Communicative clusters after a right-hemisphere stroke: Are there universal clinical profiles? *Folia Phoniatrica et Logopaedica, 64*(4), 199–207. https://doi.org/10.1159/000340017

**Fink, J. N.** (2005). Underdiagnosis of right-brain stroke. *The Lancet, 366*(9483), 349–351. https://doi.org/10.1016/S0140-6736(05)67004-3

**Gainotti, G.** (2010). The role of automatic orienting of attention towards ipsilesional stimuli in non-visual (tactile and auditory) neglect: A critical review. *Cortex, 46*(2), 150–160. https://doi.org/10.1016/j.cortex.2009.04.006

**Galletta, E. E., Campanelli, L., Maul, K. K., & Barrett, A. M.** (2014). Assessment of neglect dyslexia with functional reading materials. *Topics in Stroke Rehabilitation, 21*(1), 75–86. https://doi.org/10.1310/tsr2101-75

**Go, A. S., Mozaffarian, D., Roger, V. L., Benjamin, E. J., Berry, J. D., Blaha, M. J., Dai, S., Ford, E. S., Fox, C. S., Franco, S., Fullerton, H. J., Gillespie, C., Hailpern, S. M., Heit, J. A., Howard, V. J., Huffman, M. D., Judd, S. E., Kissela, B. M.,**

**Kittner, S. J., . . . American Heart Association Statistics Committee and Stroke Statistics Subcommittee.** (2014). Executive summary: Heart disease and stroke statistics—2014 update: A report from the American Heart Association. *Circulation, 129*(3), 399–410. https://doi.org/10.1161/01.cir.0000442015.53336.12

**Halligan, P., Robertson, I., Pizzamiglio, L., Homberg, V., Weber, E., & Bergego, C.** (1991). The laterality of visual neglect after right hemisphere damage. *Neuropsychological Rehabilitation, 1*(4), 281–301. https://doi.org/10.1080/09602019108402259

**Hedna, V. S., Bodhit, A. N., Ansari, S., Falchook, A. D., Stead, L., Heilman, K. M., & Waters, M. F.** (2013). Hemispheric differences in ischemic stroke: Is left-hemisphere stroke more common? *Journal of Clinical Neurology, 9*(2), 97–102. https://doi.org/10.3988/jcn.2013.9.2.97

**Heilman, K. M.** (1979). Neglect and related disorders. In I. H. Robertson & J. C. Marshall (Eds.), *Clinical neuropsychology* (pp. 268–307). Oxford University Press.

**Heilman, K. M., Valenstein, E., & Watson, R. T.** (2000). Neglect and related disorders. *Seminars in Neurology, 20*(04), 463–470. https://doi.org/10.1055/s-2000-13179

**Helm-Estabrooks, N.** (2001). *Cognitive Linguistic Quick Test: CLQT*. Psychological Corporation.

**Hillis, A., Newhart, M., Heidler, J., Marsh, E. B., Barker, P., & Degaonkar, M.** (2005). The neglected role of the right hemisphere in spatial representation of words for reading. *Aphasiology, 19*(3–5), 225–238. https://doi.org/10.1080/02687030444000705

**Karnath, H.-O., Rennig, J., Johannsen, L., & Rorden, C.** (2011). The anatomy underlying acute versus chronic spatial neglect: A longitudinal study. *Journal of Neurology, 134*(Pt. 3), 903–912. https://doi.org/10.1093/brain/awq355

**Katz, N., Hartman-Maeir, A., Ring, H., & Soroker, N.** (1999). Functional disability and rehabilitation outcome in right hemisphere damaged patients with and without unilateral spatial neglect. *Archives of Physical Medicine and Rehabilitation, 80*(4), 379–384. https://doi.org/10.1016/S0003-9993(99)90273-3

**Lee, B. H., Suh, M. K., Kim, E.-J., Seo, S. W., Choi, K. M., Kim, G.-M., Chung, C.-S., Heilman, K. M., & Na, D. L.** (2009). Neglect dyslexia: Frequency, association with other hemispatial neglects, and lesion localization. *Neuropsychologia, 47*(3), 704–710. https://doi.org/10.1016/j.neuropsychologia.2008.11.027

**Lindell, A. B., Jalas, M. J., Tenovuo, O., Brunila, T., Voeten, M. J. M., & Hämäläinen, H.** (2007). Clinical assessment of hemispatial neglect: Evaluation of different measures and dimensions. *The Clinical Neuropsychologist, 21*(3), 479–497. https://doi.org/10.1080/13854040600630061

**Liu, K. P., Hanly, J., Fahey, P., Fong, S. S., & Bye, R.** (2018). A systematic review and meta-analysis of rehabilitative interventions for unilateral spatial neglect and hemianopia poststroke from 2006 through 2016. *Archives of Physical Medicine and Rehabilitation, 100*(5), 956–979. https://doi.org/10.1016/j.apmr.2018.05.037

**Medina, J., Kannan, V., Pawlak, M., Kleinman, J., Newhart, J., Davis, C., Heidler-Gary, J., Herskovits, E., & Hillis, A.** (2009). Neural substrates of visuospatial processing in distinct reference frames: Evidence from unilateral spatial neglect. *Journal of Cognitive Neuroscience, 21*(11), 2073–2084. https://doi.org/10.1162/jocn.2008.21160

**Minga, J., Fromm, D., Jacks, A., Stockbridge, M. D., Nelthropp, J., & MacWhinney, B.** (2022). The effects of right hemisphere brain damage on question-asking in conversation. *Journal of Speech, Language, and Hearing Research, 65*(2), 727–737. https://doi.org/10.1044/2021_JSLHR-21-00309

**Minga, J., Johnson, M., Blake, M. L., Fromm, D., & MacWhinney, B.** (2021). Making sense of right hemisphere discourse using RHDBank. *Topics in Language Disorders, 41*(1), 99–122. https://doi.org/10.1097/tld.0000000000000244

**Minga, J., Sheppard, S. M., Johnson, M., Hewetson, R., Cornwell, P., & Blake, M. L.** (2022). Apragmatism: The renewal of a label for communication disorders associated with right hemisphere brain damage. *International Journal of Language & Communication Disorders, 58*(2), 651–666. https://doi.org/10.1111/1460-6984.12807

**Murtagh, F.** (1985). *Multidimensional clustering algorithms*. Physica-Verlag.

**Murtagh, F., & Legendre, P.** (2011). Ward's hierarchical clustering method: Clustering criterion and agglomerative algorithm. *Journal of Classification*, *31*(3), 274–295. https://doi.org/10.48550/arXiv.1111.6285

**Myers, P. S.** (2001). Toward a definition of RHD syndrome. *Aphasiology, 15*(10–11), 913–918. https://doi.org/10.1080/02687040143000285

**Nijboer, T., van de Port, I., Schepers, V., Post, M., & Visser-Meily, A.** (2013). Predicting functional outcome after stroke: The influence of neglect on basic activities in daily living. *Frontiers in Human Neuroscience, 7,* Article 182. https://doi.org/10.3389/fnhum.2013.00182

**Nijboer, T. C. W., Ten Brink, A. F., van der Stoep, N., & Visser-Meily, J. M. A.** (2014). Neglecting posture: Differences in balance impairments between peripersonal and extrapersonal neglect. *NeuroReport, 25*(17), 1381–1385. https://doi.org/10.1097/WNR.0000000000000277

**Nys, G. M. S., van Zandvoort, M. J. E., de Kort, P. L. M., Jansen, B. P. W., de Haan, E. H. F., & Kappelle, L. J.** (2007). Cognitive disorders in acute stroke: Prevalence and clinical determinants. *Cerebrovascular Diseases, 23*(5–6), 408–416. https://doi.org/10.1159/000101464

**Ovibagele, B., Goldstein, L., Higashida, R., Howard, V., Johnston, S. C., Khavjou, O. A., Lackland, D. T., Lichtman, J. H., Mohl, S., Sacco, R. L., Saver, J. L., & Trogdon, J. G.** (2013). Forecasting the future of stroke in the United States: A policy statement from the American Heart Association and American Stroke Association. *Stroke, 44*(8), 2361–2375. https://doi.org/10.1161/STR.0b013e31829734f2

**Paolucci, S., Antonucci, G., Grasso, M. G., & Pizzamiglio, L.** (2001). The role of unilateral spatial neglect in rehabilitation of right brain-damaged ischemic stroke patients: A matched comparison. *Archives of Physical Medicine and Rehabilitation, 82*(6), 743–749. https://doi.org/10.1053/apmr.2001.23191

**Peach, R. K., & Hanna, L. E.** (2021). Sentence-level processing predicts narrative coherence following traumatic brain injury: Evidence in support of a resource model of discourse processing. *Language, Cognition and Neuroscience, 36*(6), 694–710. https://doi.org/10.1080/23273798.2021.1894346

**Pitteri, M., Chen, P., Passarini, L., Albanese, S., Meneghello, F., & Barrett, A. M.** (2018). Conventional and functional assessment of spatial neglect: Clinical practice suggestions. *Neuropsychology, 32*(7), 835–842. https://doi.org/10.1037/neu0000469

**Portegies, M. L., Selwaness, M., Hofman, A., Koudstaal, P. J., Vernooij, M. W., & Ikram, M. A.** (2015). Left-sided strokes are more often recognized than right-sided strokes: The Rotterdam study. *Stroke, 46*(1), 252–254. https://doi.org/10.1161/STROKEAHA.114.007385

**Ramsey, A., & Blake, M. L.** (2020). Speech-language pathology practices for adults with right hemisphere stroke: What are we missing? *American Journal of Speech-Language Pathology, 29*(2), 741–759. https://doi.org/10.1044/2020_AJSLP-19-00082

**Ringman, J. M., Saver, J. L., Woolson, R. F., Clarke, W. R., & Adams, H. P.** (2004). Frequency, risk factors, anatomy, and course of unilateral neglect in an acute stroke cohort.

*Neurology, 63*(3), 468–474. https://doi.org/10.1212/01.WNL.0000133011.10689.CE
**Rode, G., Pagliari, C., Huchon, L., Rossetti, Y., & Pisella, L.** (2017). Semiology of neglect: An update. *Annals of Physical and Rehabilitation Medicine, 60*(3), 177–185. https://doi.org/10.1016/j.rehab.2016.03.003
**Ronchi, R., Algeri, L., Chiapella, L., Gallucci, M., Spada, M. S., & Vallar, G.** (2016). Left neglect dyslexia: Perseveration and reading error types. *Neuropsychologia, 89,* 453–464. https://doi.org/10.1016/j.neuropsychologia.2016.07.023
**Salvato, G., Sedda, A., & Bottini, G.** (2014). In search of the disappeared half of it: 35 years of studies on representational neglect. *Neuropsychology, 28*(5), 706–716. https://doi.org/10.1037/neu0000062
**Sherratt, S., & Bryan, K.** (2012). Discourse production after right brain damage: Gaining a comprehensive picture using a multi-level processing model. *Journal of Neurolinguistics, 25*(4), 213–239. https://doi.org/10.1016/j.jneuroling.2012.01.001
**Teasell, R., Salbach, N. M., Foley, N., Mountain, A., Cameron, J. I., de Jong, A., Acerra, N. E., Bastasi, D., Carter, S. L., Fung, J., Halabi, M.-L., Iruthayarajah, J., Harris, J., Kim, E., Noland, A., Pooyania, S., Rochette, A., Stack, B. D., Symcox, E., . . . Lindsay, M. P.** (2020). Canadian Stroke Best Practice Recommendations: Rehabilitation, recovery, and community participation following stroke. Part one: Rehabilitation and recovery following stroke; 6th edition update 2019. *International Journal of Stroke, 15*(7), 763–788. https://doi.org/10.1177/1747493019897843
**Ten Brink, A. F., Verwer, J. H., Biesbroek, J. M., Visser-Meily, J. M. A., & Nijboer, T. C. W.** (2017). Differences between left- and right-sided neglect revisited: A large cohort study across multiple domains. *Journal of Clinical and Experimental Neuropsychology, 39*(7), 707–723. https://doi.org/10.1080/13803395.2016.1262333
**Toglia, J., & Chen, P.** (2022). Spatial exploration strategy training for spatial neglect: A pilot study. *Neuropsychological Rehabilitation, 32*(5), 792–813. https://doi.org/10.1080/09602011.2020.1790394
**Toglia, J., & Foster, E.** (2021). *The multicontext approach to cognitive rehabilitation: A metacognitive strategy intervention.* Gatekeeper Press. https://multicontext.net/mc-book/paperback/paperback
**Tompkins, C. A., Klepousniotou, E., & Scott, A. G.** (2013). Nature and assessment of right hemisphere disorders. In I. Papathanasiou, P. Coppens, & C. Potagas (Eds.), *Aphasia and related neurogenic communication disorders* (pp. 297–332). Jones and Bartlett.
**Towle, D., & Lincoln, N. B.** (1991). Use of the indented paragraph test with right hemisphere-damaged stroke patients. *British Journal of Clinical Psychology, 30*(1), 37–45. https://doi.org/10.1111/j.2044-8260.1991.tb00918.x
**Tsao, C. W., Aday, A. W., Almarzooq, Z. I., Anderson, C. A. M., Arora, P., Avery, C. L., Baker-Smith, C. M., Beaton, A. Z., Boehme, A. K., Buxton, A. E., Commodore-Mensah, Y., Elkind, M. S. V., Evenson, K. R., Eze-Nliam, C., Fugar, S., Generoso, G., Heard, D. G., Hiremath, S., Ho, J. E., . . . American Heart Association Council on Epidemiology and Prevention Statistics Committee and Stroke Statistics Subcommittee.** (2023). Heart disease and stroke statistics—2023 update: A report from the American Heart Association. *Circulation, 147*(8), e93–e621. https://doi.org/10.1161/CIR.0000000000001123
**Vallar, G., Burani, C., & Arduino, L. S.** (2010). Neglect dyslexia: A review of the neuropsychological literature. *Experimental Brain Research, 206*(2), 219–235. https://doi.org/10.1007/s00221-010-2386-0
**Vitti, E., Kim, G., Stockbridge, M. D., Hillis, A. E., & Faria, A. V.** (2022). Left hemisphere bias of NIH Stroke Scale is most severe for middle cerebral artery strokes. *Frontiers in Neurology, 13,* Article 912782. https://doi.org/10.3389/fneur.2022.912782
**Weinberg, J., Diller, L., Gordon, W. A., Gerstman, L. J., Lieberman, A., Lakin, P., Hodges, G., & Ezrachi, O.** (1977). Visual scanning training effect on reading-related tasks in acquired right brain damage. *Archives of Physical Medicine and Rehabilitation, 58*(11), 479–486.
**Williams, L. J., Kernot, J., Hillier, S. L., & Loetscher, T.** (2021). Spatial neglect subtypes, definitions and assessment tools: A scoping review. *Frontiers in Neurology, 12,* Article 742365. https://doi.org/10.3389/fneur.2021.742365
**Winstein, C. J., Stein, J., Arena, R., Bates, B., Cherney, L. R., Cramer, S. C., Deruyter, F., Eng, J. J., Fisher, B., Harvey, R. L., Lang, C. E., MacKay-Lyons, M., Ottenbacher, K. J., Pugh, S., Reeves, M. J., Richards, L. G., Stiers, W., Zorowitz, R. D., the American Heart Association Stroke Council, . . . Council on Quality of Care and Outcomes Research.** (2016). Guidelines for adult stroke rehabilitation and recovery: A guideline for healthcare professionals from the American Heart Association/American Stroke Association. *Stroke, 47*(6), e98–e169. https://doi.org/10.1161/STR.0000000000000098
**Yoshida, T., Mizuno, K., Miyamoto, A., Kondo, K., & Liu, M.** (2022). Influence of right versus left unilateral spatial neglect on the functional recovery after rehabilitation in sub-acute stroke patients. *Neuropsychological Rehabilitation, 32*(5), 640–661. https://doi.org/10.1080/09602011.2020.1798255