Top Lang Disorders
Vol. 42, No. 3, pp. 212–235

A Scoping Review of the Relationship Between Nonlinguistic Cognitive Factors and Aphasia Treatment Response

Victoria A. Diedrichs, Courtney C. Jewell, and Stacy M. Harnish

Purpose: The purpose of this article was to explore the extent to which nonlinguistic cognitive factors demonstrate a relationship with aphasia treatment outcomes. To that end, we conducted a scoping review to broadly characterize the state of the literature related to this topic. **Methods:** Reporting guidelines from the PRISMA extension for scoping reviews were used to conduct our study, which queried two common databases used in the health science literature, PubMed and Web of Science. Search terms and eligibility criteria are provided. Results are organized by the four nonlinguistic domains of cognition explored across the included studies (i.e., attention, memory, executive functioning, and visuospatial skills). **Results:** Of 949 unique articles identified from our database searches, 17 articles with 18 distinct studies were included in the final scoping review. Notably, most studies included in the scoping review targeted impairment-based aphasia treatments. Most studies also examined multiple domains of nonlinguistic cognition. A relationship between cognition and poststroke aphasia therapy outcomes was identified in nine of 15 studies addressing executive functioning, four of nine studies examining memory, four of eight studies examining visuospatial skills, and two of five studies exploring attention. **Discussion:** The results among included studies were mixed, with few discernible patterns within each of the four cognitive domains, though it appears that the influence of nonlinguistic cognition may depend on the timing (i.e., immediate vs. delayed post-treatment) and type (i.e., trained vs. untrained, generalized) of aphasia therapy outcomes. Future study designs should address maintenance, by including outcome measures at follow-up, and generalization, by including measures of performance on either untrained stimuli or trained stimuli in untrained contexts. Future work should also strive for larger sample sizes, perhaps through collaborations, or prioritize replicability to produce more reliable conclusions. **Key words:** *aphasia*, *attention*, *cognition*, *executive function*, *memory*, *rehabilitation*, *treatment*, *visuospatial*

Author Affiliation: *Department of Speech and Hearing Science, The Ohio State University, Columbus.*

We would like to thank Amanda Rinehart, the Life Sciences Librarian at The Ohio State University, for her assistance in developing the search strategy for our scoping review.

The authors on this review article were supported by the National Institute on Deafness and Other Communication Disorders of the National Institutes of Health under award number R01DC017711 awarded to S.M.H. Additionally, the first author was supported, in part, by the National Center for Advancing Translational Sciences of the National Institutes of Health under Grant Number TL1TR002735. 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 have no other competing interests.

Supplemental digital content is available for this article. Direct URL citations appear in the printed text and are provided in the HTML and PDF versions of this article on the journal's Web site (www.topicsinlanguagedisorders.com).

Author disclosures can be found at http://links.lww.com/TLD/A91.

Corresponding Author: *Stacy M. Harnish, Department of Speech and Hearing Science, The Ohio State University, 1070 Carmack Rd, 110 Pressey Hall, Columbus, OH 43210 (harnish.18@osu.edu).*

DOI: 10.1097/TLD.0000000000000290

IN GENERAL, stroke rehabilitation fields tend to recognize the importance of identifying patient-specific factors that may account for variability in recovery of lost function with or without treatment. Investigating these patient-specific factors that predict outcomes is especially promising, as rehabilitation fields move toward more personalized medicine. In terms of clinical aphasia rehabilitation, the historical pendulum swings between valuing very personalized treatment approaches that mix and match therapeutic tasks according to the needs of the patient and prioritizing "canned" therapies with perhaps a stronger evidence base. The merit of therapies that have very prescribed targets and ingredients (Van Stan et al., 2019) is clear if the empirical evidence shows that the therapy works for the target demographic. However, factors other than language skills, such as nonlinguistic cognitive abilities, may be overlooked when defining the target demographic for a particular therapy, as they have often been overlooked in the aphasia population more generally (El Hachioui et al., 2014). The unintended effect is that efficacy studies may group persons with strong and weak nonlinguistic cognitive abilities together in the same treatment, thus washing out differential treatment effects as a function of cognition. Moreover, studies for treatment of poststroke aphasia often exclude comorbidities, including nonlinguistic cognitive deficits; however, these cognitive abilities or deficits may impact response to therapy. Not only does this obscure the person-specific factors that might be key in predicting treatment response, but it limits the specificity with which the field can identify appropriate treatments for any given individual; that is, identifying *for whom* particular treatments may be most beneficial, instead of simply asking whether a treatment works. With better understanding of how cognitive factors may relate to therapy gains, the field will move toward gaining a clearer perspective on how to tailor collections of treatment ingredients for a given patient profile, as opposed to the use of one-size-fits-all treatments. Arguably, this evolution of the field of clinical aphasiology is inevitable. We have developed efficacious therapies, but we still leave some people behind as "nonresponders."

In addition to the clinical significance of investigating nonlinguistic cognitive factors and response to aphasia treatments, there may be theoretical significance in psycholinguistic and neurocognitive models that aim to parse steps in complex cognitive and linguistic tasks, as well as determine how brain networks are organized to complete these tasks. Just as lesion studies have been useful in identifying brain–behavior relationships, studies exploring the relationship between nonlinguistic cognition and language in individuals with aphasia have the potential to inform our understanding of cognitive–linguistic processing. For example, specific nonlinguistic cognitive factors (e.g., nonverbal working memory) that are predictive of response to language therapy may provide support for the evolution of working memory theories to focus more on central processing of verbal and nonverbal information via central executive mechanisms (Cowan, 1988) as opposed to separate verbal and nonverbal mechanisms (Baddeley & Hitch, 1974).

The presence of nonlinguistic cognitive deficits in the domains of executive function, memory, and attention has also been well established as potentially co-occurring symptoms of aphasia (De Renzi & Nichelli, 1975; Purdy, 2002; Robin & Rizzo, 1989; Villard & Kiran, 2017). Executive functions, such as initiation, planning, self-monitoring, and cognitive flexibility, have been reported as impaired in persons with aphasia (Murray, 2017). Additional studies have further reported that executive control is independent of an individual's language disorder, leading to conclusions that executive functioning itself may lead to varied treatment outcomes (Brownsett et al., 2014; Simic et al., 2020).

Likewise, memory impairments have been routinely assessed in individuals with aphasia, with the most common domains of memory examined being short-term memory (STM) and working memory (WM; Potagas et al., 2011). A common method to examine nonlinguistic memory in individuals with aphasia is through spatial span assessments, such as the Corsi Block-Tapping Task (also known as Corsi block span; Kessels et al., 2000). De Renzi and Nichelli (1975) administered the Corsi Block-Tapping Task to 70 individuals with left hemisphere brain damage. Results indicated that participants with a diagnosis of aphasia performed worse at the spatial memory task in comparison to participants without aphasia. More recently, Potagas et al. (2011) reported low performance in the Corsi Block-Tapping Task in persons with aphasia, indicating impairments in both nonlinguistic STM and WM.

Regarding attention, previous research has documented that individuals with aphasia may have concomitant deficits in the areas of orienting to tasks and sustaining attention (Murray, 1999). Further studies have reported deficits in controlled, automatic, divided, and allocated attention (Erickson et al., 1996; Hunting-Pompon et al., 2011; Peach et al., 1993). Of note, although visuospatial abilities may be examined less frequently in individuals with aphasia, they can play a role in a variety of other nonlinguistic cognitive skills, such as executive functioning and memory. For example, design fluency, as utilized by Murray (2012), is an executive function task that incorporates visuospatial functioning. Further, the Corsi Block-Tapping Task and spatial span are also thought to assess visuospatial learning while assessing memory (Potagas et al., 2011). Taken together, the nonlinguistic cognitive deficits reported among individuals with aphasia may have a substantial impact on treatment adherence, response, and overall outcomes, warranting further investigation.

The purpose of this article is to explore the extent to which nonlinguistic cognitive factors demonstrate a relationship with aphasia treatment outcomes. To that end, we conducted a scoping review to broadly characterize the state of the literature related to this topic. Although the topic is relatively niche, our goal is that more treatment studies will take nonlinguistic cognitive factors into account in the future to better understand their impact on language outcomes for individuals with aphasia. To organize our scoping review, we have employed four nonverbal cognitive domains outlined by Helm-Estabrooks (2002) that are all recruited during the process of aphasia rehabilitation: attention, executive functions, memory, and visuospatial skills. We specifically chose the framework used by Helm-Estabrooks (2002) due to its basis in the aphasia treatment literature as well as its simplicity and broad applicability to studies exploring the impact of nonlinguistic cognition on linguistic outcomes for individuals with aphasia. Functionally, these four domains are not necessarily mutually exclusive, potentially interacting to varying degrees. Many daily tasks, as well as assessments of cognition, engage multiple domains simultaneously. However, given the different ways that specific cognitive abilities may impact response to aphasia therapy, it is useful to employ these four domains as a framework for exploring the potential differences in their impact. (See Figure 1 for a nonexhaustive list of functions encompassed by each of the four nonlinguistic cognitive domains, some of which appear in multiple domains.)

METHODS

The present study used reporting guidelines from the PRISMA extension for scoping reviews (PRISMA-ScR; Tricco et al., 2018) as well as recommendations from Arksey and O'Malley (2005). A librarian at the authors' institution was consulted to assist in developing the search strategy. PubMed and Web of Science databases were searched for research articles addressing the influence of nonlinguistic cognitive skills on language outcomes following aphasia therapy. Our systematic search strategy was carried out in December

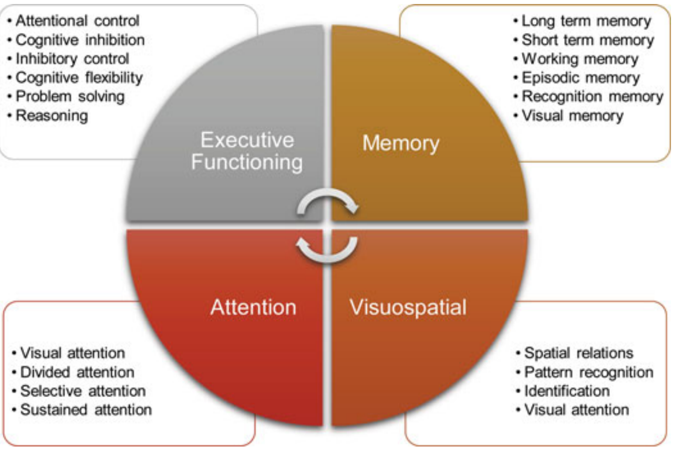

Figure 1. Nonlinguistic cognitive domains. *Note.* This graphic depicting the four nonlinguistic cognitive domains described by Helm-Estabrooks (2002) demonstrates the interaction between and frequent overlap among cognitive skills. This figure is available in color online (www.topicsinlanguagedisorders.com).

2021 by the first and second authors. Search terms for PubMed and Web of Science are shown in Table 1.

Studies were included in the scoping review if they met the following criteria, established a priori: (1) a sample of participants with poststroke aphasia was included, (2) participants received a language treatment for aphasia, (3) participants were assessed in the language domain treated pre- and post-treatment, (4) participants' nonlinguistic cognitive skills (e.g., attention, executive functioning, memory, and visuospatial skills) were assessed, (5) an analysis of the relationship between nonlinguistic cognitive factors and treatment outcome(s) was included, (6) the article was written in English (due to the feasibility constraints related to time and translation costs to include articles written in other languages), and (7) the article was

Table 1. Search strategy for PubMed and Web of Science databases

Database	Terms	Refined by
PubMed	(aphasia) AND (stroke) AND (therapy OR treatment) AND ((cogniti*) OR (attention*) OR (executive function*) OR (memory) OR (visual spatial OR visuospatial))	Year: 1991–2021 Language: English
Web of Science	(aphasia) AND (stroke) AND (therapy OR treatment) AND ((cogniti*) OR (attention*) OR (executive function*) OR (memory) OR (visual spatial OR visuospatial)) NOT (pediatric OR child* OR dementia OR (primary progressive))	Year: 1991–2021 Language: English Document type: article, review article, and clinical trial

Note. The Web of Science search included additional search terms and categories to refine the search due to a much larger number of results than the PubMed search.

published in a peer-reviewed journal in or after 1991. This year was chosen to narrow our search and emphasize the most recent scientific findings.

Studies were excluded if they met any of the following criteria: (1) results for participants with poststroke aphasia could not be differentiated from results for participants with other etiologies (e.g., primary progressive aphasia and traumatic brain injury), if included, and (2) the article was a review, comment, or book chapter that did not present new data (although these were used to identify additional studies that may not have been included in our search results).

Search results from the research databases were exported to Mendeley and duplicates were removed. Titles and abstracts were first screened by the first and second authors for inclusion and exclusion criteria. Approximately 20% (n = 190) of abstracts were assessed for reliability between the two authors screening. Agreement between the two authors was 91.5%. The full text of articles with titles and abstracts that met inclusion and did not meet exclusion criteria were further reviewed by all three authors (n = 135). Prior to full-text reviews, full agreement on a single training article across the three authors was set as criterion. Therefore, the three authors trained by independently reviewing a single article and meeting to discuss decisions regarding eligibility. There was 100% agreement between the three authors on the training article and additional factors influencing eligibility were discussed (i.e., factors that did not appear in the training article but may appear in other articles to be reviewed). After final inclusion and exclusion decisions were made on the full-text articles reviewed, the following details from the included studies were aggregated in a spreadsheet: (1) author names, (2) year of publication, (3) title, (4) time post-stroke of the participant sample (i.e., acute, subacute, or chronic), (5) aphasia type of the participant sample (e.g., fluent and nonfluent), (6) age of the participant sample, (7) language assessments utilized, (8) nonlinguistic cognitive assessments utilized, (9) language therapy utilized, (10) primary findings, and (11) notable limitations. The first two authors verified these details and they are further expanded upon in the Results section.

Our results begin with details about the included studies, their participants, and the assessments and treatments used. Then, the results of the individual studies included in our review are discussed, primarily organized by cognitive domain. Within each domain, studies that specifically compared therapeutic outcomes immediately post-treatment with outcomes at a later follow-up are mentioned. Generalization to untrained targets or contexts is also discussed within each domain.

RESULTS

A total of 949 unique articles were identified from the search results across both databases (excluding duplicates). After screening and review processes, 11 of these articles were determined to meet inclusion criteria without meeting any exclusionary criteria. Six additional articles identified through other means (e.g., references from primary research articles or reviews) were also found to meet inclusion and exclusion criteria. In sum, a total of 17 articles were included in the present scoping review. A flowchart depicting the article selection process is shown in the PRISMA diagram (Figure 2). Notably, one article (Gilmore et al., 2019) included two separate studies; therefore, a total of 18 individual studies were included in the present scoping review. Publication years for the included articles ranged from 1994 to 2021. Eight studies were conducted in the United States (two of which were from the same article: Gilmore et al., 2019), whereas three were conducted in the United Kingdom, two were conducted in Australia, and one each was conducted in Austria, Germany, Poland, the Netherlands, and Canada.

Participants

In the 18 studies, 390 participants with aphasia resulting from cerebrovascular accident (CVA) participated in a variety of

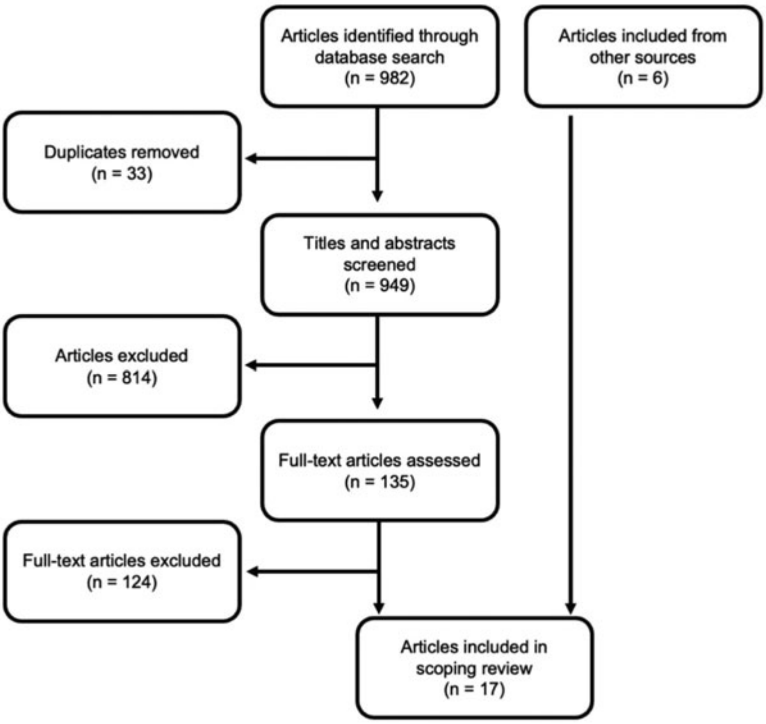

Figure 2. PRISMA diagram.

language therapies and nonlinguistic cognitive assessments. Given that Gilmore et al. (2019) utilized a subset of 27 participants from their first study for their second study and Lambon Ralph et al. (2010) included 10 participants from a study already part of this review (Fillingham et al., 2006) in their analyses, there were a total of 353 unique participants. Individual studies included from one to 67 participants with an estimated age range of 18–87 years, based on studies that reported participant age ranges. The majority of participants were right-handed, though not all studies reported handedness. Female participants were underrepresented in the included studies, overall (37% of participants), given the roughly equivalent incidence of aphasia in males and females (Hier et al., 1994). Aphasia type and severity, as well as time post-onset, varied across participants and were reported differently across studies. Some studies reported the number of fluent and nonfluent participants, whereas some reported the number with more specific types of aphasia (e.g., Broca's and Wernicke's). Other studies did not report the types of aphasia represented in their sample at all. Based on studies that reported the range of time post-onset, the participants included in the present scoping review were examined between approximately 2 months and 25 years post-CVA. None of the studies included in the present review examined individuals in the acute stage of aphasia (1–7 days post-stroke; Bernhardt et al., 2017). All studies included participants in the subacute (7 days to 6 months post-stroke) or chronic stage (6 months or more post-stroke; Bernhardt et al., 2017). Participant demographics across all included studies are summarized in Supplemental Digital Content Table 2 (available at: http://links.lww.com/TLD/A89), organized alphabetically by the first author's last name.

Nonlinguistic cognitive assessments and language therapy

Many different nonlinguistic cognitive assessments were used in the included studies, but all relate to the four domains outlined by Helm-Estabrooks (2002): executive functioning, attention, memory, and visuospatial functioning, so were classified accordingly (Table 2). The executive functioning domain yielded the greatest number of different assessments with 20 unique tests. Next, the memory domain included 10 distinct assessments. The visuospatial and attention domains were represented by the fewest assessments, with visuospatial functioning measured by five assessments and attention assessed by two. Most of the assessments (75%) were only utilized in one study apiece, demonstrating considerable variability among the cognitive assessments utilized to investigate similar research questions. Assessments that occurred most frequently were the Rey Complex Figure Test (RCFT; Meyers & Meyers, 1995; $n = 5$; 27.7%), the Cognitive Linguistic Quick Test (CLQT; Helm-Estabrooks, 2001; $n = 4$; 22.2%), Raven's Progressive Matrices (RPM; Raven et al., 1978; $n = 3$; 16.6%), Corsi block span (Kessels et al., 2000; $n = 3$; 16.6%), and the Wisconsin Card Sorting Test (WCST; Grant & Berg, 1993; $n = 3$; 16.6%).

Some assessments were difficult to classify, particularly those that targeted more than one domain. For example, RPM was frequently classified as an assessment of executive functioning across studies, but Seniów et al. (2009) reported RPM as an assessment of executive functioning as well as visuospatial skills. Additionally, the RCFT assesses recall memory through a visuospatial paradigm. For the purposes of the present scoping review, we chose to classify each assessment within only one of the four cognitive domains (e.g., RPM in executive functioning), while attempting to maintain consistency with the original intention of the authors utilizing these assessments in their research (Table 3, see complete Table 3 as Supplemental Digital Content Table 4, available at: http://links.lww.com/TLD/A90) to the extent possible. We expand on important caveats to this classification in the discussion. Of note, organization of cognitive assessments in their respective domains is consistent with the classification scheme of Fonseca et al. (2017)[1].

Many different language therapies were utilized in the included studies as well. Most of the studies we found that investigated the role of nonlinguistic cognition on aphasia therapy outcomes were impairment-based. Of these, most included studies treated naming, but used different approaches (e.g., intensive therapy, cueing hierarchies, and errorless learning). Some treatments were less structured and used an individualized format, including a variety of language targets catered to each participant's unique needs (e.g., semantic, phonological, or syntactical approaches to treat reading, writing, naming, or comprehension). It is beyond the scope of the present review to formally evaluate the differences between such therapeutic approaches; however, see Table 3 (complete Table 3 as Supplemental Digital Content Table 4 is available at: http://links.lww.com/TLD/A90) for a full list of the language treatments utilized across all included studies.

The relationship between nonlinguistic cognitive abilities and language therapy outcomes

The 18 studies included in the present scoping review addressed a variety of nonlinguistic cognitive skills encompassed by the four domains outlined by Helm-Estabrooks

[1]Many, although not all of the assessments are classified according to neuropsychological standards. For the purposes of this review, we chose to favor the classification of the included articles' original authors' when there was disagreement with neuropsychological standards. See the text by Lezak, et al. (2004) for neuropsychological classification.

Table 2. Nonlinguistic cognitive assessments

Cognitive Domain	Tests and Tasks	*n*[a]
Executive functioning	Association learning[b]	1
	Card sorting[b]	1
	Cognitive Linguistic Quick Test[c]	4
	Delis–Kaplan Executive Function Test	1
	Design fluency[b]	1
	Doors visual recognition	1
	Flanker[d]	1
	Geometric inclusion	1
	Go no-go[d]	1
	Nonverbal cognitive control triad[e]	1
	Plus minus 1 and 2[d]	1
	Raven's Colored Progressive Matrices	1
	Raven's Progressive Matrices	3
	Recent negatives[d]	1
	Spatial stroop[d]	1
	Stop-Signal Task[f]	1
	Trail Making[d]	1
	Western Aphasia Battery Block design	1
	Weigel Sorting Test	1
	Wisconsin Card Sorting Test	3
Memory	One-back	1
	Camden Memory Test	2
	Concurrent spatial span[b]	1
	Corsi block span (forward and backward)	3
	Face recognition[b]	1
	Picture recognition[b]	1
	Repeatable Battery for the Assessment of Neuropsychological Status—Recall	1
	Rey Complex Figure Test—Recall	5
	Rivermead Behavioral Memory Test	1
Visuospatial skills	Brief-Visuospatial Memory Test—Revised	1
	Benton Visual Retention Test—Multiple Choice Administration	1
	Geometric matching	1
	Rey Complex Figure Test—Copy	4
	Repeatable Battery for the Assessment of Neuropsychological status—Copy	1
Attention	Test of Everyday Attention	2
	Trail Making Test	2

[a]Number of papers utilizing test/task.
[b]Nonstandardized tasks that were independently developed by Goldenberg et al. (1994).
[c]The following subtests were used as part of the CLQT: Design Generation, Design Memory, Mazes, Symbol Cancellation, and Symbol Trails.
[d]Nonstandardized tasks that were independently developed by Simic et al. (2020).
[e]Task used by Sandberg et al. (2021).
[f]Task used by Votruba et al. (2013).

Table 3. Preview—methods and results of included articles

Study	Treatment Target	Intervention	Language Assessments	Baseline Cognitive Assessments	Relationships Between Cognitive Assessments and Language Outcomes (Yes/No)	Relationships Between Cognitive Assessments and Language Outcomes: Statistics and Results
Dignam et al. (2017)	Naming	Aphasia language impairment and functioning therapy; intensive vs. distributed condition Schedule: 48 hr of treatment within 2 weeks	CAT	BVMT-R (VS)		
				Delayed score	Yes	Post: $r = -.406^*$ FU: $r = .438^*$
				Learning score	Yes	Post: $r = -.410^*$ FU: $r = .396^*$
				Total score	Yes	Post: $r = -.425^*$
				D-KEFS (EF)		
				Trails (CF)	Yes	Post: $r = -.421^*$
				Sorting (total; PS)	Yes	Post: $r = -.403^*$ FU: $r = -.409^*$
				Sorting (description; PS)	Yes	Post: $r = -.652^{**}$ FU: $r = .507^{**}$ Gen post: $r = .424^*$; FU: $r = .445^*$
				TEA		
				Elevator counting (SusA)	No	—
				Elevator distract (SelA)	No	—

Note. See the online supplement for all included studies. Complete Table 3 as Supplemental Digital Content Table 4 is available at: http://links.lww.com/TLD/A89. BVMT-R = Brief Visuospatial Memory Test—Revised; CAT = Comprehensive Aphasia Test; CF = cognitive flexibility; D-KEFS = Delis–Kaplan Executive Function System Test; EF = executive functioning; FU = follow-up; Gen = generalization; PS = problem solving; SelA = selective attention; SusA = sustained attention; TEA = Test of Everyday Attention; VS = visuospatial.

$^*p < .05$.

$^{**}p < .01$.

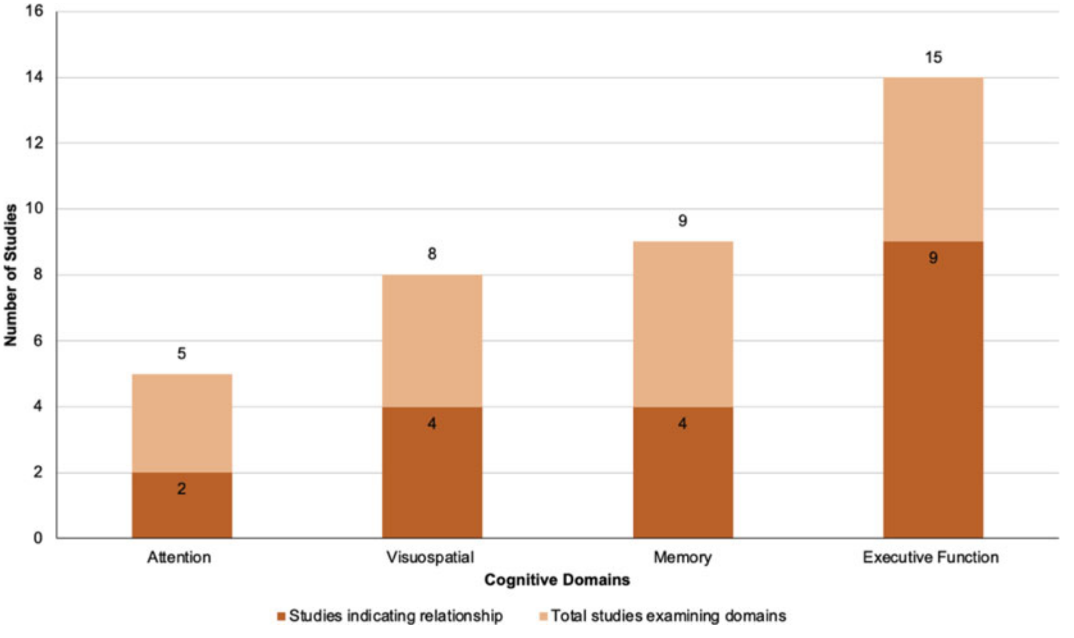

Figure 3. Number of studies examining each cognitive domain with outcomes. *Note.* The chart is not weighted for the number of participants or significance of findings. See Table 2 for a comprehensive list of the cognitive assessments classified within the four domains. This figure is available in color online (www.topicsinlanguagedisorders.com).

(2002; Figures 1 and 3). Executive functioning was the domain most frequently investigated (15 of 18 studies, 83% of total) and also the domain with the greatest number of studies demonstrating a relationship with language therapy outcomes (nine of 15 studies, 60%). Fewer studies examined memory (nine of 18 studies, 50% of total) and visuospatial functioning (eight of 18 studies, 44% of total). Four memory studies (of nine, 44%) and four visuospatial functioning studies (of eight, 50%) found a relationship with aphasia therapy response. Attention was the domain least explored (five of 18 studies, 28% of total) and least likely to be reported as having a relationship to outcomes after language therapy (two of five studies, 40%). The overall findings within each domain will be discussed in turn, organized by the following categories of outcomes: immediate post-treatment, delayed follow-up, and stimulus generalization to either untreated targets (e.g., untrained pictures) or a new modality (e.g., naming to definition after being trained to name pictures). Results within each outcome category are roughly grouped by type of assessment.

Executive functioning

Immediate post-treatment

Fillingham et al. (2006) found that the number of categories completed on the WCST positively correlated with immediate effects of a combination of errorless and errorful naming treatment. This finding was subjectively supported by Conroy and Scowcroft (2012), who compared percentile rankings of WCST scores (number of categories) and therapy outcomes 1-week post-treatment (their first posttreatment assessment). However, Conroy and Scowcroft (2012) did not formally analyze this relationship in their small sample and reported no relationship between therapy outcomes and the number of trials to the first complete category on the WCST. Moreover, Lambon Ralph et al. (2010) found no significant correlation between WCST performance and outcomes of a picture-naming therapy at posttreatment. The study by Lambon Ralph et al. (2010) included more participants (33 total) than the other two studies (Conroy & Scowcroft, 2012; Fillingham et al., 2006) and aligned with findings from Goldenberg et al. (1994) that reported performance on a card-sorting task assessing cognitive flexibility did not correlate with immediate outcomes from an intensive aphasia therapy (or with measures of spontaneous recovery). The team led by van de Sandt-Koenderman et al. (2007) reported comparable results in their 30-participant study, with no significant correlation between the Weigl Sorting Test (WST; Weigl, 1927), a measure similar to the WCST, and their participants' effective use of an augmentative and alternative communication aid immediately following treatment.

Despite the lack of significant findings by Lambon Ralph et al. (2010) mentioned earlier, the authors did find that a cognitive factor identified in a principal components analysis that included WCST scores positively correlated with therapy outcomes at posttreatment. Additionally, the Delis–Kaplan Executive Function System (D-KEFS; Delis et al., 2001) Trails (i.e., switching and cognitive flexibility) and Sorting (i.e., concept formation and problem-solving) tasks both showed a strong positive correlation with posttreatment outcomes following naming therapy in a study with a sample size of 32 (Dignam et al., 2017), similar to the number reported in Lambon Ralph et al. (2010).

Rose et al. (2013) found that Raven's Colored Progressive Matrices (RCPM) did not significantly correlate with combined effect sizes for multimodal and constraint-induced aphasia therapies. Similarly, Seniów et al. (2009) did not find a significant impact of RPM scores on naming, comprehension, or repetition immediately following an individualized language therapy protocol. Of note, the study by Rose et al. (2013) only included 11 participants and may have been underpowered to detect a positive relationship, but Seniów et al. (2009) had a larger sample consisting of 47 participants.

Goldenberg et al. (1994) found no significant correlations between an association learning task of inhibition and outcomes immediately following spontaneous recovery or an intensive language therapy but may have been underpowered to do so given their sample of 18 participants. Simic et al. (2020) also found that measures of executive functioning assessing inhibition, as well as shifting and WM updating, did not significantly correlate with outcomes at initial posttreatment testing, though may have been similarly underpowered with a sample size of 10. However, Votruba et al. (2013) reported that a measure of inhibition (Stop Signal Task), among other nonlinguistic cognitive tasks, did not significantly correlate with posttreatment language therapy outcomes in a much larger study of 50 participants, perhaps substantiating the findings of the smaller studies.

Nicholas et al. (2011) found that subtests of the CLQT (i.e., Design Generation, Design Memory, Mazes, Symbol Cancellation, and Symbol Trails) significantly correlated with posttreatment outcomes from a therapy utilizing an augmentative and alternative communication assistive device. In a larger study, Gilmore et al. (2019) found similar results. First, in Study 1, the same group of CLQT subtests were identified as a component predictive of posttreatment response in a principal components analysis and significantly contributed to explaining variance in treatment response in a backward elimination regression. Performance on these same CLQT subtests also interacted with treatment type, demonstrating a greater influence on outcomes from naming treatment than on outcomes from sentence comprehension treatment. When further analyzed in a subset of participants from the naming treatment group in Study 2, nonverbal subtests of the CLQT were split into separate components, revealing that subtests specifically addressing executive functioning significantly predicted treatment response post-therapy. Unlike Nicholas et al. (2011) and Gilmore et al. (2019), Goldenberg et al.

(1994) found that their design fluency task, similar to the CLQT's Design Generation, did not significantly correlate with treatment outcomes immediately following an intensive language therapy (or with measures of spontaneous recovery). Although this evidence may call into question the impact of the CLQT Design Generation subtest, it is worth reiterating that with a sample size of 18, Goldenberg et al. (1994) may have been underpowered to identify a positive relationship.

Delayed follow-up

The posttreatment effects of most studies presented earlier aligned with their maintenance effects (if maintenance was assessed). For example, Fillingham et al. (2006) found that the number of categories completed on the WCST positively correlated with follow-up effects of a combination of errorless and errorful naming treatment, whereas Lambon Ralph et al. (2010) found no significant correlation between WCST performance and outcomes of a picture-naming therapy at follow-up. However, the cognitive factor identified by Lambon Ralph et al. (2010) in a principal components analysis that included WCST scores positively correlated with therapy outcomes at follow-up as well. Conroy and Scowcroft (2012) also reported subjective maintenance outcomes similar to posttreatment: outcomes at an 8-week follow-up (their second posttreatment assessment) roughly aligned with the percentile rankings of WCST scores (number of categories, but not trials to first correct category).

Consistent with their posttreatment outcomes, Goldenberg et al. (1994) found no significant correlations between nonlinguistic cognitive tasks (including the card-sorting, inhibition, and design fluency tasks) and total outcomes, which was calculated as a difference score on standardized language testing at study onset and at an 8-week posttherapy follow-up. Likewise, the findings of Gilmore et al. (2019) echoed their immediate posttreatment effects: in Study 2, the nonverbal subtests of the CLQT specifically addressing executive functioning significantly predicted treatment response at follow-up.

Two studies reported follow-up outcomes that differed from initial posttreatment outcomes. In the study by Dignam et al. (2017), only the D-KEFS Sorting task (not Trails) demonstrated similar positive correlations with treatment outcomes at follow-up. Additionally, despite finding no significant correlations with immediate posttherapy outcomes, Simic et al. (2020) found that measures of executive functioning assessing inhibition, as well as shifting and WM updating, correlated with treatment outcomes at 4- and 8 weeks post-treatment, indicating a potential role of inhibition in longer-term maintenance. An executive functioning composite score (combining inhibition, shifting, and WM updating) was most predictive of their follow-up treatment outcomes overall.

Generalization

Of the 15 studies investigating executive functioning, five addressed generalization. Notably, the primary outcome measure (performance on five real-life functional communication activities) used by Nicholas et al. (2011) inherently targeted generalization to new conditions. The authors found that subtests of the CLQT significantly correlated with posttreatment outcomes on the five functional communication activities while using an assistive communication device, after participants were trained to use the device in different, structured therapy tasks. In another study, one measure (D-KEFS Sorting description score) showed a positive relationship with stimulus generalization to phonologically related items (Dignam et al., 2017). Simic et al. (2020) similarly reported that shifting ability (not other executive control skills) predicted generalization to untreated targets at posttreatment only (not at follow-up). The remaining two studies did not statistically analyze the relationship between executive functioning and treatment outcomes, but subjectively report their findings. Kendall et al. (2014) anecdotally reported that their participant with the greatest stimulus generalization across semantic categories also demonstrated the highest score on RPM. Similarly, Sandberg et al. (2021) describe a case study revealing an imbalance in inhibitory control, which the authors hypothesize may have impacted their participant's ability to generalize treatment outcomes to his untreated language.

Summary

According to the studies included in the present review, especially larger studies by Lambon Ralph et al. (2010) and van de Sandt-Koenderman et al. (2007), performance on card-sorting tasks assessing abstract thinking and cognitive shifting, like the WCST, appears to have little bearing on initial or follow-up response to language treatment (generalization was not explored in relation to the WCST). However, Dignam et al. (2017) found that a similar task, the D-KEFS Sorting subtest was positively related to immediate, delayed, and generalization outcomes for their word-retrieval-based treatment and Simic et al. (2020) identified a significant role of shifting on generalization to untreated items. Therefore, more work is needed to address this discrepancy.

Other executive functioning skills, such as reasoning (e.g., RPM) and inhibition (e.g., Stop Signal Task), similarly lacked a significant relationship with treatment outcomes in most studies included in this review. That said, the studies employing RPM or RCPM (Rose et al., 2013; Seniów et al., 2009) lacked a clear analysis of effects on treatment maintenance and one (Simic et al., 2020) of the two studies examining the relationship between inhibition and maintenance reported a positive result. Therefore, future studies should continue to investigate the potential impact of reasoning and inhibition on delayed follow-up assessment, as well as further explore evidence of their impact on generalization (Kendall et al., 2014; Sandberg et al., 2021).

Subtests of the CLQT demonstrated a relatively consistent relationship with language therapy response at posttreatment, though these assessments were only explored in two studies (Gilmore et al., 2019; Nicholas et al., 2011). Only one of the two studies examined and found a significant impact of CLQT performance on treatment response at follow-up (Gilmore et al., 2019) and one involved generalization in posttreatment findings (Nicholas et al., 2011). As a result, future work including the CLQT should further examine treatment outcomes at all levels.

Memory

Immediate posttreatment

Harnish and Lundine (2015) found that the forward Corsi block span, commonly recognized as an STM task, did not significantly predict effect size following a naming treatment, but that the backward Corsi block span, recognized as a WM task, had a large, positive correlation with and significantly predicted treatment effect size. Goldenberg et al. (1994) did not include the backward Corsi block span, but similarly reported that neither the forward Corsi block span nor the Concurrent spatial span significantly correlated with treatment outcomes following an intensive language therapy or with measures of spontaneous recovery. However, Harnish et al. (2018) in a later study found no significant correlation between the backward Corsi block span or the one-back (another measure of WM) and posttreatment outcomes. Importantly, the nonsignificant results of both Goldenberg et al. (1994) and Harnish et al. (2018) may have been due to a lack of power in their small sample sizes (18 and seven participants, respectively).

Studies examining picture recognition from the Camden Memory Test (CMT; Conroy & Scowcroft, 2012), Rivermead Behavioral Memory Test (van de Sandt-Koenderman et al., 2007), and other sources (Goldenberg et al., 1994) found no significant pattern or correlation with outcomes of various language therapies. Goldenberg et al. (1994) also examined face recognition and again found no correlation with their treatment outcomes or with measures of spontaneous recovery.

Although Conroy and Scowcroft (2012) and Goldenberg et al. (1994) may have been underpowered (with four and 18 participants, respectively), van de Sandt-Koenderman et al. (2007) had a much larger 30-participant sample in their study. However, Fillingham et al. (2006) did report a positive correlation between the topographical recognition memory subtest of the CMT and immediate effects of a combined errorless and errorful treatment approach.

Goldenberg et al. (1994) found that the mean of the Immediate and Delayed Recall subtests of the RCFT was the only measure in their battery to positively correlate with response to intensive language therapy, suggesting a unique role in treatment response due to the absence of a correlation with spontaneous recovery. Lambon Ralph et al. (2010) found that the Delayed, but not Immediate, Recall subtest of the RCFT significantly predicted response to treatment outcomes at posttreatment. However, other studies have not replicated these findings. Subjectively, Conroy and Scowcroft (2012) found no similarities between their participants' performance on the Immediate and Delayed RCFT Recall tasks and their therapy outcomes. Similarly, Rose et al. (2013) did not identify significant correlations between RCFT Delayed Recall and response to multimodal and constraint-induced aphasia therapy in a study with 11 participants. Likewise, in a study with the same number of participants, Fillingham et al. (2006) found that baseline performance on Immediate and Delayed Recall subtests of the RCFT did not correlate with overall immediate therapy outcomes. Moreover, Votruba et al. (2013) report no significant correlation between a similar task, the Repeatable Battery for the Assessment of Neuropsychological Status Figure Recall subtest, and therapy outcomes in a large sample of 50 participants. Of note, the Figure Copy subtest of the RCFT as well as additional measures of visual memory has been discussed in the section on visuospatial skills.

Delayed follow-up

Of the nine studies examining memory, four explored maintenance effects. Two of the studied exploring memory and maintenance effects reported similar findings at posttreatment and follow-up. First, in the study by Conroy and Scowcroft (2012), patterns of follow-up treatment outcomes aligned with posttreatment, meaning they did not reflect participant scores on the CMT picture recognition or RCFT Recall subtests. Likewise, Lambon Ralph et al., (2010) again found that the Delayed, but not Immediate, Recall subtest of the RCFT significantly predicted response to treatment outcomes at follow-up.

Although some follow-up results from Fillingham et al. (2006) were consistent with their posttreatment findings (a positive correlation with the topographical recognition memory subtest of the CMT; no correlation with performance on the Immediate or Delayed Recall subtests of the RCFT), they did find one difference. The Immediate and Delayed Recall subtests of the RCFT correlated with the difference between outcomes on errorless and errorful therapy approaches at follow-up. The authors suggest this finding highlights that better visual recall was linked with a greater long-term response to errorful therapy. Therefore, it is possible that the role of visual memory in treatment outcomes may differ based on the specific therapeutic approach (i.e., errorful vs. errorless).

Finally, Goldenberg et al. (1994) reported that none of their memory assessments (Corsi block span, concurrent spatial span, picture recognition, face recognition, and RCFT recall) significantly correlated with total outcomes, which was calculated as a difference score on standardized language testing at study onset and at an 8-week posttherapy follow-up. This contradicted their positive posttreatment correlation with the Recall subtests of the RCFT but was consistent with the posttreatment findings related to their other memory assessments.

Generalization

One of the nine studies examining memory analyzed generalization. Although Harnish et al. (2018) found no significant correlation between the backward Corsi block span or the one-back and post-treatment outcomes, they did identify significant correlations with generalization to untreated conditions (i.e., naming to definition for items trained via picture naming) for both tasks.

Summary

Measures of WM (e.g., Corsi block span) revealed little relation to posttreatment or follow-up language therapy outcomes. However, it is important to keep in mind that these studies may have been underpowered to detect a relationship between WM tasks and treatment outcomes (Goldenberg et al., 1994; Harnish & Lundine, 2015; Harnish et al., 2018). Additionally, the findings of Harnish et al. (2018) suggest WM may play a role in generalization to untreated contexts (e.g., definition naming vs. picture naming).

Based on the articles included in the present review, recognition memory appears to play a minimal role in treatment response. Although some studies may have lacked power to identify a relationship between recognition memory and language therapy outcomes, the study by van de Sandt-Koenderman et al. (2007) included 30 participants and found no significance of picture recognition performance. However, the group led by Fillingham et al. (2006) did find a positive correlation between the topographical recognition memory subtest of the CMT and both immediate and follow-up effects of a combined errorless and errorful treatment approach.

Finally, the studies included in our review that utilized the figure recall subtests of the RCFT reveal complex and inconsistent results. Lambon Ralph et al. (2010) showed that the Delayed, but not Immediate Recall subtest of the RCFT significantly predicted response to treatment outcomes at posttreatment and follow-up. Goldenberg et al. (1994) found that the mean of the Immediate and Delayed Recall RCFT subtests positively correlated with posttreatment, but not follow-up outcomes of an intensive language therapy. However, other studies, including the large analysis ($n = 50$) by Votruba et al. (2013), report no significant correlation between visual recall and therapy outcomes. Perhaps future studies can explain the differences in these results by further exploring the relationship between visual recall and different types of aphasia treatment with comprehensive outcome measures (i.e., acquisition, maintenance, and generalization).

Attention

Immediate posttreatment

Two studies employed the Trail Making Test (TMT), versions A and B, which are widely accepted measures of sustained and divided attention, respectively (Reed & Reed, 1997). Votruba et al. (2013) reported no significant correlations between the TMT-A/B and immediate therapy outcomes. When controlling for the effect of their standard verbal treatment, Kroenke et al. (2013) also failed to detect a significant correlation between TMT-A/B and the immediate effect of their gesture treatment. Furthermore, neither TMT version increased the amount of explained variance in their stepwise multiple regression analysis.

Three studies in our review (Dignam et al., 2017; Fillingham et al., 2006; Lambon Ralph et al., 2010) made use of two subtests from the Test of Everyday Attention (TEA), the Elevator Counting task, a measure of sustained attention, and the Elevator Counting with Distraction task, a measure of selective attention (Robertson et al., 1996). Dignam et al. (2017) found no correlation between either task and language therapy outcomes immediately post-treatment. Fillingham et al. (2006) similarly did not identify a significant correlation between either TEA subtest and their overall immediate treatment effects. Contrary to these results, Lambon Ralph et al. (2010) found that while the sustained attention task did not significantly predict treatment outcomes in their sample, the selective attention task, Elevator Counting with Distraction, did predict treatment response immediately post-treatment. Although Fillingham et al. (2006) may have been underpowered to identify such a relationship, the studies by Dignam et al. (2017) and Lambon Ralph et al. (2010) had similar, larger sample sizes of 32 and 33 participants, respectively.

Delayed follow-up

Three of the five studies exploring attention examined follow-up effects. The two studies that did not assess therapy outcomes beyond immediate posttreatment effects were those that utilized the TMT (Kroenke et al., 2013; Votruba et al., 2013). Dignam et al. (2017) found no correlation between either subtest of the TEA and language therapy outcomes at a 1-month delayed follow-up, comparable to their posttreatment findings. The immediate posttreatment results of Lambon Ralph et al. (2010) were also consistent with their 5-week delayed follow-up, where they again saw that the selective attention task (Elevator Counting with Distraction), but not the sustained attention task, predicted treatment response. Although Fillingham et al. (2006) did not identify a significant correlation between either TEA subtests and their follow-up treatment effects (at a delay of 5 weeks post-treatment on average), they did find that the task with distraction significantly correlated with the difference between outcomes on errorless and errorful therapy approaches at follow-up. This is comparable to their findings related to the RCFT recall subtest in the Memory subsection earlier.

Generalization

Only one of the five studies to examine attention assessed generalization of treatment gains to untreated items or conditions. Dignam et al. (2017) did not find a significant correlation between either measure of attention and stimulus generalization to untreated items for their participants.

Summary

Few studies included in the scoping review examined attention (five out of 18). Neither version A or B of the TMT demonstrated a relationship with immediate treatment effects in either study utilizing this assessment (Kroenke et al., 2013; Votruba et al., 2013); however, the relationship between TMT performance and maintenance was not explored. None of the three studies employing the TEA (Dignam et al., 2017; Fillingham et al., 2006; Lambon Ralph et al., 2010) found a significant relationship between the sustained attention subtest and immediate treatment effects, but Lambon Ralph et al. (2010) found that the selective attention task predicted treatment response. The authors found that the selective attention task also predicted treatment response at a delayed follow-up. Although Dignam et al. (2017) did not report significant results at follow-up, Fillingham et al. (2006) found a correlation between the selective attention subtest and the difference between their participants' performance on errorless and errorful therapies (i.e., better selective attention was related to better errorful outcomes). In light of the differences in results between the studies examining the impact of the TEA on therapy outcomes at a delayed follow-up, it remains unclear whether selective attention may play a greater role than sustained attention in response to aphasia treatments, especially those requiring more effort (i.e., errorful treatments). There is no evidence among the articles included in this scoping review that measures of attention relate to generalization of language therapy gains (Dignam et al., 2017), though it is difficult to draw conclusions due to the lack of studies that explored this relationship.

Visuospatial skills

Immediate posttreatment

Most studies utilizing the RCFT Figure Copy task found no pattern or correlation with immediate outcomes of various language therapies (Conroy & Scowcroft, 2012; Fillingham et al., 2006; Goldenberg et al., 1994; Votruba et al., 2013). Notably, the study by Votruba et al. (2013) may have been the only one sufficiently powered to detect significant findings (n = 50). However, one study (Lambon Ralph et al., 2010) did identify the RCFT Figure Copy subtest as a significant predictor of response to intervention at posttreatment.

Despite the lack of a clear impact of visuospatial copying skills on aphasia therapy response, two additional tasks may reveal a greater role of visual memory. Dignam et al. (2017) found that both immediate visuospatial learning and delayed recall of geometric figures on the Brief Visuospatial Memory Test—Revised (BVMT-R), as well as the total score of both tasks, had positive correlations with initial language therapy outcomes. Similarly, the team led by Seniów et al. (2009) found that the number of errors on the Benton Visual Retention Test—Multiple Choice Administration (BVRT-MCA) significantly correlated with maximum possible improvement percentages in naming and comprehension, though not repetition, immediately following individualized language therapy. Moreover, Gilmore et al. (2019) identified a visual STM component of their cognitive assessment battery in a principal components analysis and scores on this cluster of assessments significantly predicted response to therapy at posttreatment in a subset of participants from their naming therapy group.

Delayed follow-up

Six of the eight studies investigating visuospatial skills assessed follow-up. Similar to the immediate posttreatment outcomes earlier, Lambon Ralph et al. (2010) were again the only group to identify the RCFT Figure Copy subtest as a significant predictor of response to intervention at follow-up. Other studies that included follow-up testing did not report positive findings (Conroy & Scowcroft, 2012; Fillingham et al., 2006; Goldenberg et al., 1994). Consistent with posttreatment findings, Dignam et al. (2017) found that both immediate visuospatial learning and delayed recall of geometric figures on the BVMT-R had positive correlations with follow-up language therapy outcomes, but contrary to posttreatment findings, the total score of both tasks did not. Finally, scores on the visual STM assessments identified by Gilmore et al. (2019) significantly predicted response to therapy at follow-up, as with posttreatment, in their naming therapy subset group.

Generalization

The only study to explore generalization within the visuospatial domain was the study by Dignam et al. (2017). The authors found that both immediate visuospatial learning and delayed recall of geometric figures on the BVMT-R, but not the total score on both tasks, had positive correlations with performance on untreated items at follow-up, but not posttreatment.

Summary

The relatively pure visuospatial skills employed during the RCFT Figure Copy subtest, with little influence from other cognitive domains, did not appear to relate to outcomes of language therapy for people recovering from aphasia in our review (except for in Lambon Ralph et al., 2010). The relationship between performance on the RCFT Figure Copy subtest and generalization was not explored in any of the included articles. However, studies that used tasks of visual memory demonstrated more promising results. The BVMT-R (Dignam et al., 2017), BVRT-MCA (Seniów et al., 2009), and a visual STM subsection of a cognitive assessment battery (Gilmore et al., 2019) all demonstrated significant positive relationships with language therapy outcomes at posttreatment. Two of these studies examined maintenance and revealed additional significant results (Dignam et al., 2017; Gilmore et al., 2019), but only one explored and identified a significant relationship with generalization (Dignam et al., 2017). Together, these findings suggest a perhaps more meaningful role of visual memory in aphasia treatment response than the results of studies discussed earlier, in the memory domain section. However, the precise contribution of visual memory to aphasia therapy response warrants further investigation.

DISCUSSION

The purpose of this scoping review was to explore the extent to which nonlinguistic cognitive factors demonstrate a relationship with aphasia treatment outcomes. When examining studies conducted between 1991 and 2021, we found a relatively small number that investigated the impact of nonlinguistic cognitive factors on response to poststroke aphasia treatment. Among these, the nonlinguistic cognitive assessments employed differed greatly, contributing to the challenge of comparing and summarizing their results. The variability among cognitive assessments may impede investigators' ability to replicate findings, despite similar research questions. For example, we encountered three different card sorting tasks all used to evaluate executive functioning: the WCST (Grant & Berg, 1993), the WST (Weigl, 1927), and a proprietary card sorting task (Goldenberg et al., 1994). Adding to that, studies employing other assessments targeting similar executive functioning constructs, such as the D-KEFS (Delis et al., 2001), further complicate comparisons. Other sources of study variability, such as the number of participants, individual participant characteristics, type and duration of treatment, and statistical analyses, exacerbated the challenge of synthesizing results.

Despite the difficulties of comparing studies with diverse methodologies, the present scoping review provides an important perspective on the current state of the literature investigating the extent to which nonlinguistic cognition influences aphasia treatment outcomes. The overall findings in the executive function domain were mixed. The studies in our review did not provide conclusive evidence for an effect of cognitive flexibility, shifting, and problem-solving, determined by assessments such as the WCST and D-KEFS, on response to poststroke language therapy. However, their involvement cannot be ruled out. Based on the results of Goldenberg et al. (1994), Simic et al. (2020), and Votruba et al. (2013), inhibition may be a better predictor of long-term (e.g., maintenance) than immediate treatment response and may play a role in generalization (Sandberg et al., 2021). Despite difficulty parsing the specific constructs at play in studies employing the CLQT, due to the assessment's breadth and overlap with other cognitive domains, a set of predominantly nonlinguistic CLQT subtests (i.e., design generation, mazes, symbol trails, symbol cancellation, and design memory), which only require verbal processing of instructions supported by clinician demonstration and practice items, shows preliminary evidence (Gilmore et al., 2019; Nicholas et al., 2011) of playing a role in poststroke aphasia therapy outcomes. This finding is encouraging for future work, and perhaps suggests that the impact of individual, narrow cognitive abilities (e.g., shifting) may be more difficult to detect than a broader, cooperative effect (e.g., overall executive function).

The results of studies addressing the memory domain were also mixed. Based on the results of Harnish et al. (2018), WM may be a better predictor of treatment generalization than of immediate or delayed outcomes on treated stimuli. Another interesting finding comes from Fillingham et al. (2006) whose results suggest that therapies requiring a greater amount of effort (i.e., errorful versus errorless) may be more strongly influenced by tasks such as visual memory. Although the constraint-induced naming therapy used by Rose et al. (2013) likely required greater effort than their multimodality treatment, the authors did not utilize a subtractive technique like Fillingham's group (2006) to analyze the difference in response to the two therapies. Rose's group (2013) instead saw no impact of delayed figure recall on a combined posttreatment effect size for both therapies.

Three studies in particular revealed interesting, though somewhat contradictory results pertaining to attention. Lambon Ralph et al. (2010) demonstrated an effect of selective attention (based on the Elevator

Counting with Distraction subtest of the TEA) on posttreatment and follow-up outcomes from their naming therapy. Although Fillingham et al. (2006) did not have the same results, they did find that the difference in response to their errorful and errorless therapies correlated with performance on the same selective attention task (similar to their findings for visual memory described earlier). However, the group led by Dignam et al. (2017) found no relationship between scores on the same selective attention task and posttreatment, follow-up, or generalization outcomes from their naming therapy.

Finally, visuospatial skills that minimize overlap with other cognitive domains, such as those involved in figure copying tasks, appear to bear little relation to aphasia therapy response. All but one study (Lambon Ralph et al., 2010) failed to detect a relationship between figure copying tasks and poststroke language therapy outcomes. On the other hand, a variety of tasks engaging visual memory did identify relationships with therapy outcomes at posttreatment (Dignam et al., 2017; Gilmore et al., 2019; Seniów et al., 2009) and follow-up (Dignam et al., 2017; Gilmore et al., 2019). These results could be due to the prominent role that visual memory may have played in picture-naming or engaging with other visual materials involved in the treatments used in these studies, as is common in many research and clinical settings.

Limitations

The present scoping review provides a thorough description of the current evidence regarding the impact of nonlinguistic cognition on language treatment outcomes, though several limitations exist. First, the scope of the present study was to focus on nonlinguistic cognition, excluding any cognitive assessments that involved linguistic capacities. Given the nature of aphasia, nonlinguistic stimuli are beneficial in circumventing the impaired language system to provide a clear measure of cognitive impairment. However, excluding verbal cognitive assessments, such as the digit span, prevented our examination of analyses utilizing such assessments, which may also offer insight as to predictors of treatment outcomes. Additionally, although nonlinguistic cognitive assessments utilize nonlinguistic stimuli, participants are still required to understand verbal instructions. Therefore, it is not possible to eliminate the involvement of language all together. As such, the nonlinguistic nature of the cognitive assessments discussed in this scoping review must be interpreted with caution.

Second, cognitive domains are interconnected and can be difficult to disentangle to analyze individually. Rather, although an assessment may aim to examine a certain domain (e.g., sustained attention), it is possible that the task also relies on another (e.g., STM). To simplify our overall interpretation of the results, we chose to categorize each assessment into only one of the four cognitive domains, with the understanding that this classification scheme came with limitations. To interpret results of the studies as accurately as possible, assessments were largely classified as they were described in the original studies unless there was disagreement between studies using the same assessment. In such cases, we aligned our classification with the most frequent domain reported to underlie the assessment among the included studies. For example, Seniów et al. (2009) classified RPM as a measure of executive functioning and visuospatial skills, whereas all other studies simply referred to RPM as an executive functioning task. Therefore, we followed the majority of studies using RPM and classified it within the executive functioning domain, despite the fact that visuospatial skills are clearly involved. Of note, RCFT was categorized into two domains, but this was because the subtests—copy, immediate recall, and delayed recall—were separated. Authors of the studies included in our scoping review unanimously described the copy subtest as examining visuospatial functioning and the recall subtests as examining memory. Because these subtests are inherently distinct and the authors were in agreement, they were categorized accordingly. The interconnectedness of cognitive domains and the limitations of our classification scheme should be taken into consideration when interpreting the results of our scoping review.

Third, there were methodological limitations to the present scoping review, as is typically the case with any systematized approach. For example, we chose to specifically explore the relationship between nonlinguistic cognition and response to treatments for aphasia targeting language. This precluded any analysis of other therapies that might target nonlinguistic modes of communication (e.g., gesture and drawing) or quality of life. As such, most studies included in the present scoping review took an impairment-based approach to aphasia treatment. However, response to other therapies (e.g., those addressing nonlinguistic modes of communication or quality of life) may also be influenced by nonlinguistic cognition and should therefore be explored in future work as well. Additionally, although the authors collaboratively developed the search strategy and eligibility criteria and used a reliability assessment at the screening phase to promote consistency, it is still possible that appropriate articles were missed during the database search, abstract screening, or full article review processes. Thus, our results may not reflect the full evidence base addressing the relationship between nonlinguistic cognitive skills and linguistic outcomes of aphasia treatment. Moreover, the articles included in our scoping review were not critically appraised for quality, as this is not a requirement of the PRISMA guidelines as it would be for a systematic review or meta-analysis. As a result, the quality of evidence included in our review may be a further limitation.

Finally, this review is limited by the available published evidence, which mainly consists of studies with relatively small sample sizes and heterogenous samples of individuals with aphasia. Although the initial database search elicited over 900 results, the majority were eliminated by our eligibility criteria in order to adequately compare and synthesize the results. Therefore, due to the variability in study samples as well as protocols, it is not yet appropriate to draw firm conclusions regarding the impact of nonlinguistic cognition on aphasia therapy outcomes; however, it is our hope that future research may benefit from the themes outlined in this review.

Future directions

The present scoping review presents the current state of evidence regarding nonlinguistic cognitive predictors of treatment outcomes and has identified important gaps in the literature that may be of value to examine. Here, we summarize those gaps and offer potential solutions (Figure 4). First, the classification scheme used in the present scoping review subjectively categorized each assessment into mutually exclusive domains, which limited our ability to examine the overlap of cognitive skills that contribute to each task. This is a result of the inherent challenge of investigating cognitive skills that are distinct, yet related, and often used in combination to accomplish functional activities. Therefore, future work should investigate the overlap of cognitive skills engaged in various behavioral tasks, perhaps with the aim of developing methodologies to parse the unique contributions of each skill on the task and on aphasia treatment response. Where appropriate, it may also be beneficial to quantify the combined effect and impact of such overlapping cognitive skills. Such methodologies may allow for greater consistency across researchers and improve the potential for replicating findings.

Additionally, future work should examine immediate (i.e., acquisition) versus delayed (i.e., acquisition and maintenance) effects of nonlinguistic cognitive deficits on treatment outcomes. Recall, Simic et al. (2020) identified statistically significant relationships between multiple nonlinguistic cognitive variables and treatment effects at 4 weeks and 8 weeks post-treatment, but none immediately following treatment. To determine whether nonlinguistic cognition plays a different role in acquisition versus maintenance, future work should include this consideration in

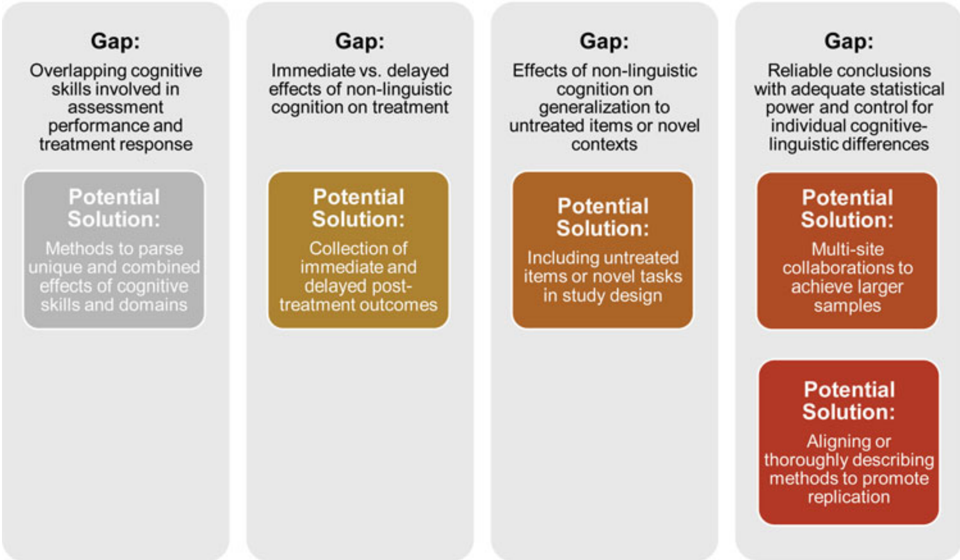

Figure 4. Gaps and recommendations for future study of nonlinguistic cognition in aphasia. This figure is available in color online (www.topicsinlanguagedisorders.com).

experimental design. Similarly, relatively few studies in this review (six out of 18) examined the relation between cognition and generalization to untreated stimuli or contexts. Of the studies that did, there were mixed results regarding the domains of cognition that may play a role in generalization. Three of five studies examining generalization in relation to executive functioning found a significant relationship (Dignam et al., 2017; Nicholas et al., 2011; Simic et al., 2020). The only study to explore the relationship between memory and generalization (Harnish et al., 2018) reported significant results and the same was true for visuospatial skills (Dignam et al., 2017). Meanwhile, no relationship was found between attention and generalization (Dignam et al., 2017). This direction of research is crucial given the importance of transferring learned therapy tasks to unlearned items and situations in everyday life.

Finally, with the given difficulty of recruiting individuals with aphasia and the time investment in conducting treatment studies, the samples tend to be small, but they also tend to be heterogenous. A potential solution is collaboration among researchers to align data collection procedures, which could allow for aggregating data to analyze larger samples with more statistical power or explore subsamples with more homogenous cognitive–linguistic characteristics. As has been suggested in the broader realms of stroke (Ali et al., 2013) and aphasia (Wallace et al., 2019) rehabilitation research, a core set of assessments could be agreed upon to achieve consistency across studies. Attention to descriptions of data collection procedures and methods would also promote the replicability of smaller studies, which could similarly lead to more reliable conclusions in the field.

CONCLUSIONS

The purpose of the present scoping review was to explore the extent to which nonlinguistic cognitive factors demonstrate a relationship with poststroke aphasia treatment outcomes. We identified a relatively small number of studies that examined this relationship, which were diverse in terms of their sample sizes, their participant characteristics, their treatment protocols, and the cognitive domain(s) studied. The results of the included studies do not offer conclusive evidence regarding the potential influence of nonlinguistic cognition on response to (primarily impairment-based) aphasia treatment; however, an emerging pattern is that nonlinguistic cognition may demonstrate a differential and perhaps greater impact on delayed treatment response as well as generalization when compared with immediate treatment response. Thus, future work should emphasize study designs that incorporate follow-up testing and measures of generalization, as well as either large enough sample sizes to achieve sufficient power or methods to promote replicability, with controls for participant heterogeneity.

REFERENCES

Ali, M., English, C., Bernhardt, J., Sunnerhagen, K. S., Brady, M., VISTA-Rehab Collaboration. (2013). More outcomes than trials: A call for consistent data collection across stroke rehabilitation trials. *International Journal of Stroke*, *8*(1), 18–24. https://doi.org/10.1111/j.1747-4949.2012.00973.x

Arksey, H., & O'Malley, L. (2005). Scoping studies: Towards a methodological framework. *International Journal of Social Research Methodology*, *8*(1), 19–32. https://doi.org/10.1080/1364557032000119616

Baddeley, A., & Hitch, G. (1974). Working memory. In G. Bower (Ed.), *Psychology of learning and motivation* (Vol. 8, pp. 47–90). Academic Press. https://doi.org/10.1016/S0079-7421(08)60452-1

Bernhardt, J., Hayward, K. S., Kwakkel, G., Ward, N. S., Wolf, S. L., Borschmann, K., Krakauer, J. W., Boyd, L. A., Carmichael, S. T., Corbett, D., & Cramer, S. C. (2017). Agreed definitions and a shared vision for new standards in stroke recovery research: The Stroke Recovery and Rehabilitation Roundtable taskforce. *International Journal of Stroke*, *12*(5), 444–450. https://doi.org/10.1177/1747493017711816

Brownsett, S. L., Warren, J. E., Geranmayeh, F., Woodhead, Z., Leech, R., & Wise, R. J. (2014). Cognitive control and its impact on recovery from aphasic stroke. *Brain*, *137*(Pt. 1), 242–254. https://doi.org/10.1093/brain/awt289

Conroy, P., & Scowcroft, J. (2012). Decreasing cues for a dynamic list of noun and verb naming targets: A case-series aphasia therapy study. *Neuropsychological Rehabilitation*, *22*(2), 295–318. https://doi.org/10.1080/09602011.2011.641434

Cowan, N. (1988). Evolving conceptions of memory storage, selective attention, and their mutual constraints within the human information-processing system. *Psychological Bulletin*, *104*(2), 163–191. https://doi.org/10.1037/0033-2909.104.2.163

De Renzi, E., & Nichelli, P. (1975). Verbal and non-verbal short-term memory impairment following hemispheric damage. *Cortex*, *11*(4), 341–354. https://doi.org/10.1016/S0010-9452(75)80026-8

Delis, D. C., Kaplan, E., & Kramer, J. H. (2001). *Delis-Kaplan Executive Function System (D-KEFS)*. Pearson.

Dignam, J., Copland, D., O'Brien, K., Burfein, P., Khan, A., & Rodriguez, A. D. (2017). Influence of cognitive ability on therapy outcomes for anomia in adults with chronic poststroke aphasia. *Journal of Speech, Language, and Hearing Research*, *60*(2), 406–421. https://doi.org/10.1044/2016_JSLHR-L-15-0384

El Hachioui, H., Visch-Brink, E. G., Lingsma, H. F., Van De Sandt-Koenderman, M. W. M. E., Dippel, D. W. J., Koudstaal, P. J., & Middelkoop, H. A. M. (2014). Nonlinguistic cognitive impairment in poststroke aphasia: A prospective study. *Neurorehabilitation and Neural Repair*, *28*(3), 273–281. https://doi.org/10.1177/1545968313508467

Erickson, R. J., Goldinger, S. D., & LaPointe, L. L. (1996). Auditory vigilance in aphasic individuals: Detecting nonlinguistic stimuli with full or divided attention. *Brain and Cognition*, *30*(2), 244–253. https://doi.org/10.1006/brcg.1996.0016

Fillingham, J., Sage, K., & Lambon Ralph, M. A. (2006). The treatment of anomia using errorless learning. *Neuropsychological Rehabilitation*, *16*(2), 129–154. https://doi.org/10.1080/09602010443000254

Fonseca, J., Ferreira, J. J., Pavão, I., & Martins, I. P. (2017). Cognitive performance in aphasia due to stroke: A systematic review. *International Journal on Disability and Human Development*, *16*(2), 127–139. https://doi.org/10.1515/ijdhd-2016-0011

Gilmore, N., Meier, E. L., Johnson, J. P., & Kiran, S. (2019). Nonlinguistic cognitive factors predict treatment-induced recovery in chronic poststroke aphasia. *Archives of Physical Medicine and Rehabilitation*, *100*(7), 1251–1258. https://doi.org/10.1016/j.apmr.2018.12.024

Goldenberg, G., Dettmers, H., Grothe, C., & Spatt, J. (1994). Influence of linguistic and nonlinguistic capacities on spontaneous-recovery of aphasia and on success of language therapy. *Aphasiology*, *8*(5), 443–456. https://doi.org/10.1080/02687039408248669

Grant, D. A., & Berg, E. A. (1993). *Wisconsin Card Sorting Test*. Psychological Assessment Resources, Inc.

Harnish, S. M., & Lundine, J. P. (2015). Nonverbal working memory as a predictor of anomia treatment success. *American Journal of Speech-Language Pathology*, *24*(4), S880–S894. https://doi.org/10.1044/2015_AJSLP-14-0153

Harnish, S. M., Schwen Blackett, D., Zezinka, A., Lundine, J. P., & Pan, X. (2018). Influence of working memory on stimulus generalization in anomia treatment: A pilot study. *Journal of Neurolinguistics*, *48*, 142–156. https://doi.org/10.1016/j.jneuroling.2018.02.003

Helm-Estabrooks, N. (2001). *Cognitive linguistic quick test: Examiner's manual*. Psychological Corp.

Helm-Estabrooks, N. (2002). Cognition and aphasia: A discussion and a study. *Journal of Communication Disorders*, *35*(2), 171–186. https://doi.org/10.1016/s0021-9924(02)00063-1

Hier, D. B., Yoon, W. B., Mohr, J. P., Price, T. R., & Wolf, P. A. (1994). Gender and aphasia in the stroke data bank. *Brain and Language*, *47*(1), 155–167. https://doi.org/10.1006/BRLN.1994.1046

Hunting-Pompon, R., Kendall, D., & Bacon Moore, A. (2011). Examining attention and cognitive processing in participants with self-reported mild anomia. *Aphasiology*, *25*(6–7), 800–812. https://doi.org/10.1080/02687038.2010.542562

Kendall, D., Raymer, A., Rose, M., Gilbert, J. E., & Rothi, L. J. G. (2014). Anomia treatment platform as behavioral engine for use in research on physiological adjuvants to neurorehabilitation. *Journal of Rehabilitation Research and Development*, *51*(3), 391–400. https://doi.org/10.1682/JRRD.2013.08.0172

Kessels, R. P. C., van Zandvoort, M. J. E., Postman, A., Kappelle, L. J., & de Hand, E. H. F. (2000). The Corsi Block-Tapping Task: Standardization and normative data. *Applied Neuropsychology*, *7*(4), 252–258. https://doi.org/10.1207/S15324826AN0704_8

Kroenke, K.-M., Kraft, I., Regenbrecht, F., & Obrig, H. (2013). Lexical learning in mild aphasia: Gesture benefit depends on patholinguistic Profile and lesion pattern. *Cortex*, *49*(10), 2637–2649. https://doi.org/10.1016/j.cortex.2013.07.012

Lambon Ralph, M. A., Snell, C., Fillingham, J. K., Conroy, P., & Sage, K. (2010). Predicting the outcome of anomia therapy for people with aphasia post CVA: Both language and cognitive status are key predictors. *Neuropsychological Rehabilitation*, *20*(2), 289–305. https://doi.org/10.1080/09602010903237875

Lezak, M. D., Howieson, D. B., Loring, D. W., Hannay, H. J., & Fischer, J. S. (2004). *Neuropsychological assessment* (4th ed.). Oxford University Press.

Meyers, J. E., & Meyers, K. R. (1995). *Rey complex figure test and recognition trial (RCFT)*. Psychological Assessment Resources.

Murray, L. L. (1999). Attention and aphasia: Theory, research and clinical implications. *Aphasiology*, *13*(2), 91–111. https://doi.org/10.1080/026870399402226

Murray, L. L. (2012). Attention and other cognitive deficits in aphasia: Presence and relation to language and communication measures. *American Journal of Speech-Language Pathology*, *21*(2), S51–S64. https://doi.org/10.1044/1058-0360(2012/11-0067)

Murray, L. L. (2017). Design fluency subsequent to onset of aphasia: A distinct pattern of executive function difficulties? *Aphasiology*, *31*(7), 793–818. https://doi.org/10.1080/02687038.2016.1261248

Nicholas, M., Sinotte, M. P., & Helm-Estabrooks, N. (2011). C-Speak aphasia alternative communication program for people with severe aphasia: Importance of executive functioning and semantic knowledge. *Neuropsychological Rehabilitation*, *21*(3), 322–366. https://doi.org/10.1080/09602011.2011.559051

Peach, R. K., Newhoff, M., & Rubin, S. S. (1993). Attention in aphasia as revealed by event-related potentials: A preliminary investigation. *Clinical Aphasiology*, *21*, 323–333.

Potagas, C., Kasselimis, D., & Evdokimidis, I. (2011). Short-term and working memory impairments in aphasia. *Neuropsychologia*, *49*(10), 2874–2878. https://doi.org/10.1016/j.neuropsychologia.2011.06.013

Purdy, M. (2002). Executive function ability in persons with aphasia. *Aphasiology*, *16*(4–6), 549–557. https://doi.org/10.1080/02687030244000176

Raven, J. C., Court, J. H., & Raven, J. E. (1978). *Manual for Raven's progressive matrices and vocabulary scales* (Rev. ed.). H. K. Lewis.

Reed, J. C., & Reed, H. B. C. (1997). *The Halstead—Reitan Neuropsychological Battery*. Springer. https://doi.org/10.1007/978-1-4757-9820-3_4

Robertson, I. H., Ward, T., Ridgeway, V., & Nimmo-Smith, I. (1996). The structure of normal human attention: The Test of Everyday Attention. *Journal of the International Neuropsychological Society*, *2*(6), 525–534. https://doi.org/10.1017/S1355617700001697

Robin, D. A., & Rizzo, M. (1989). The effect of focal cerebral lesions on intramodal and cross-modal orienting of attention. *Clinical Aphasiology*, *18*, 61–74.

Rose, M. L., Attard, M. C., Mok, Z., Lanyon, L. E., & Foster, A. M. (2013). Multi-modality aphasia therapy is as efficacious as a constraint-induced aphasia therapy for chronic aphasia: A phase 1 study. *Aphasiology*, *27*(8), 938–971. https://doi.org/10.1080/02687038.2013.810329

Sandberg, C. W., Zacharewicz, M., & Gray, T. (2021). Bilingual Abstract Semantic Associative Network Training (BAbSANT): A Polish-English case study. *Journal of Communication Disorders*, *93*, 106143. https://doi.org/10.1016/j.jcomdis.2021.106143

Seniów, J., Litwin, M., & Leśniak, M. (2009). The relationship between non-linguistic cognitive deficits and language recovery in patients with aphasia. *Journal of the Neurological Sciences*, *283*(1–2), 91–94. https://doi.org/10.1016/j.jns.2009.02.315

Simic, T., Bitan, T., Turner, G., Chambers, C., Goldberg, D., Leonard, C., & Rochon, E. (2020). The role of executive control in post-stroke aphasia treatment. *Neuropsychological Rehabilitation*, *30*(10), 1853–1892. https://doi.org/10.1080/09602011.2019.1611607

Tricco, A. C., Lillie, E., Zarin, W., O'Brien, K. K., Colquhoun, H., Levac, D., Moher, D., Peters, M. D. J., Horsley, T., Weeks, L., Hempel, S., Akl, E. A., Chang, C., McGowan, J., Stewart, L., Hartling, L., Aldcroft, A., Wilson, M. G., Garritty, C., … Straus, S. E. (2018). PRISMA extension for scoping reviews (PRISMA-ScR): Checklist and explanation. *Annals of Internal Medicine*, *169*(7), 467–473. https://doi.org/10.7326/M18-0850

van de Sandt-Koenderman, W. M. E., Wiegers, J., Wielaert, S. M., Duivenvoorden, H. J., & Ribbers, G. M. (2007). High-tech AAC and severe aphasia: Candidacy for TouchSpeak (TS). *Aphasiology*, *21*(5), 459–474. https://doi.org/10.1080/02687030601146023

Van Stan, J. H., Dijkers, M. P., Whyte, J., Hart, T., Turkstra, L. S., Zanca, J. M., & Chen, C. (2019). The rehabilitation treatment specification system: Implications for improvements in research design, reporting, replication, and synthesis. *Archives of Physical Medicine and Rehabilitation*, *100*(1), 146–155. https://doi.org/10.1016/j.apmr.2018.09.112

Villard, S., & Kiran, S. (2017). To what extent does attention underlie language in aphasia? *Aphasiology*, *31*(10), 1226–1245. https://doi.org/10.1080/02687038.2016.1242711

Votruba, K. L., Rapport, L. J., Whitman, R. D., Johnson, A., & Langenecker, S. (2013). Personality differences among patients with chronic aphasia predict improvement in speech-language therapy. *Topics in Stroke Rehabilitation*, *20*(5), 421–431. https://doi.org/10.1310/tsr2005-421

Wallace, S. J., Worrall, L., Rose, T., Le Dorze, G., Breitenstein, C., Hilari, K., Babbitt, E., Bose, A., Brady, M., Cherney, L. R., Copland, D., Cruice, M., Enderby, P., Hersh, D., Howe, T., Kelly, H., Kiran, S., Laska, A. C., Marshall, J., … Webster, J. (2019). A core outcome set for aphasia treatment research: The ROMA consensus statement. *International Journal of Stroke*, *14*(2), 180–185. https://doi.org/10.1177/1747493018806200

Weigl, E. (1927). Zur Psychologie sogenannter Abstraktionsprozesse. *Zeitschrift Fuer Psychologie*, *103*, 2–45.