Stroke

FOCUSED UPDATES

How Much Attention Do We Pay to Attention Deficits in Poststroke Aphasia?

Maria Varkanitsa, PhD; Erin Godecke, PhD; Swathi Kiran, PhD

ABSTRACT: Although language deficits are the primary area of weakness, people with poststroke aphasia often experience challenges with nonlinguistic cognitive skills, including attention processing. The purpose of this review is to synthesize the evidence for the relationship between attention deficits and language deficits in people with poststroke aphasia. Three different types of studies are reviewed: (1) studies exploring whether people with poststroke aphasia exhibit concomitant attention and language deficits, (2) studies explicitly exploring the relationship between attention and language deficits in people with poststroke aphasia, and (3) either language or attention (or both) treatment studies exploring whether treatment gains in one domain generalize to the other. In the last section, we briefly review research evidence for the neural basis of the attention-language relationship in aphasia.

GRAPHIC ABSTRACT: A graphic abstract is available for this article.

Key Words: aphasia ■ attention ■ language ■ review ■ stroke

Aphasia is described as the loss or impairment of language functions caused by brain damage. Although linguistic deficits remain the primary area of weakness, growing evidence suggests that many people with poststroke aphasia (PWA) also experience challenges with global, underlying cognitive abilities, including attention,[1] memory,[2] executive function,[3] and learning.[4] The degree of interdependence between language and other cognitive deficits in aphasia, beyond its theoretical interest, also has important clinical implications regarding the prognosis of aphasia, the planning of language rehabilitation and the autonomy and quality of life of PWA. However, this topic remains an important open question. This review aims to evaluate the frequency and the profile of attention deficits in PWA and link these deficits to treatment outcomes as well as their neural correlates. The reason we focus on attention is that, among the abovementioned cognitive processes, attention is the most fundamental, being essential for the successful execution of a variety of other more complex operations. As such, attention impairment can compromise patients' participation in rehabilitation as well as the benefit of treatment. References for this review were identified by searches of Google Scholar and PubMed, and references from relevant articles. The search terms "aphasia" and "attention" combined with the operator "AND" were used. There were no time restrictions, however only studies published in English were reviewed. The final reference list was generated based on relevance to the topics covered in this review. Specifically, studies should have explored at least one of the following topics: (1) attention deficits in PWA, (2) the relationship between attention and language deficits in PWA, (3) the role of baseline attention deficits in language treatment outcomes, and (4) the effects of attention treatment on language recovery and vice versa. Based on these criteria, we identified 29 studies; 28 studies were identified during the initial search and 1 study was published while the article was under revision. One study was eliminated, because the analyses performed included principal component factors that included measures of other cognitive domains as well, resulting in 28 studies in total.

See related articles, p 5, p 10, p 20, p 30, p 44

Correspondence to: Maria Varkanitsa, PhD, Aphasia Research Laboratory, Boston University, 635 Commonwealth Ave, Room 326, Boston, MA 02215. Email mvarkan@bu.edu

For Sources of Funding and Disclosures, see page 65.

Stroke is available at www.ahajournals.org/journal/str

Attention is a complex, multidimensional construct. There exist many different models of attention in healthy individuals from various theoretical,[5,6] neuroanatomical,[7] and clinical[8] perspectives. A common feature of these models is the existence of multiple types or levels of attention, depending on task demands. For the purposes of this review, we will primarily refer to the types of attention presented in Sohlberg and Mateer's clinical neuropsychological model.[8] According to this model, the first and simplest type of attention is focused attention (ie, the ability to respond discretely to specific stimuli), followed by the more complex sustained attention or vigilance (ie, the ability to maintain attention or respond consistently over a period of time). Next is selective attention (ie, the ability to attend to relevant stimuli and disregard or suppress irrelevant competing stimuli) followed by alternating attention (ie, the ability to shift attention between tasks or features), and finally, the most complex type, divided attention (ie, the ability to simultaneously respond to multiple attentional demands).

The existence of different types of attention is highly relevant to understanding attention in the context of aphasia. Depending on the task and the situation, both assessment and treatment require most, or all the types of attention. For instance, maintaining focus throughout an assessment or treatment session likely places demands on sustained attention, whereas selective attention may be required in cases of busy therapy settings with numerous sources of visual and auditory distractions.[9] A recurrent debate is whether language deficits in PWA are simply a consequence of attention deficits or if these 2 may be disentangled. Hula and McNeil[10] proposed that language deficits in PWA are caused by damage to the attentional processes that support language processing rather than damage to linguistic knowledge itself. Villard and Kiran[9] suggested a weaker relationship between attention deficits and language deficits; they agree that various levels of attention provide support for language processing tasks, however, being independent components of cognition, both attention and language may be selectively affected by brain damage.

As attention is a multifaceted process, the assessment of attention requires the use of specific neuropsychological tests. The studies reviewed here utilized various standardized, normed assessments that evaluate different aspects of attentional skills. These tests can be categorized into 5 distinct paradigms, namely cross-out or symbol search, (cued) flanker, co/no-go, and tone discrimination tasks. A few studies used more complex paradigms, using 2 tasks simultaneously (ie, dual tasks). A short description of the paradigms is provided in Table 1.

The rest of the article is organized as follows. The first section includes studies whose focus is to determine whether PWA also suffer from domain-general attention deficits using nonlinguistic tasks, as well as studies that directly compare the performance of PWA on linguistic versus nonlinguistic attention tasks. Next, studies investigating the relationship between attention deficits and language deficits in PWA using correlation and regression analyses are reviewed. The next section includes studies examine (1) the role of attention deficits in language treatment outcomes and (2) the effects of attention treatment on language recovery and vice versa. The final section reviews neuroimaging studies that provide evidence for the neural basis of the attention-language relationship. In the conclusions section, an updated version of Villard and Kiran's[9] schema of attention and language in aphasia is presented.

Attention Deficits in Aphasia

Our review revealed 9 studies whose aim was to explore attention deficits in PWA, without linking those deficits to language impairments (Table 2). Five out of these studies investigated attention deficits using nonverbal attention tasks, whereas 3 studies investigated attention deficits using both linguistic and nonlinguistic stimuli.

LaCroix and colleagues[11] used a cued flanker task (ie, a central imperative stimulus is flanked by distractors that can indicate the same or opposite response to the imperative stimulus) to assess the 3 subsets of selective attention according to Posner and Petersen's model,[23] namely alerting attention (ie, the ability to

Table 1. Types of Tests Used for the Evaluation of Attention Abilities in Patients With Aphasia

Paradigm	Short description
Cross-out/symbol search task	Participants cross-out specific figures within similar figures
(Cued) flanker task	Participants make directional responses to certain targets flanked by non-target stimuli which correspond either to the same directional response as the target (congruent flankers), to the opposite response (incongruent flankers), or to neither (neutral flankers)
Go/no-go task	Participants respond by pressing a button when they see a "go" signal, and not respond when they see the "no-go" signal
Cueing task	Participants decide whether a target symbol is present or not. In some trials, a cue correctly/incorrectly indicates the location of the target (valid/invalid cue trials)
Tone discrimination task	Participants manipulate a continuous stream of sounds in different ways (eg, decide whether or not a tone stimulus is high or low, distinguish a complex harmonic sound from pure tone sounds, etc)
Dual-task	Participants perform 2 tasks simultaneously (eg, tone discrimination while sorting cards)

Table 2. Studies Investigating Attention Deficits in PWA

Study	Participants	Attention assessment	Relevant findings
Studies using nonverbal stimuli			
LaCroix et al[11]	Chronic PWA (n=22) Controls (n=20)	ANT[12]	Impaired performance on at least one attention task/condition
Robin and Rizzo[13]	Chronic PWA (n=4) Stroke survivors w/out aphasia (n=4) Controls (n=30)	Orienting Tasks	Impaired performance on at least one attention task/condition
Hunting-Pompon et al[14]	Chronic PWA (n=14) Controls (n=9)	COVAT[15] COVAT+Read	Impaired performance on at least one attention task/condition
Erickson et al[16]	Chronic PWA (n=10) Controls (n=10)	Tone discrimination task combined with the Wisconsin Card Sorting Task[17]	Impaired performance on at least one attention task/condition
Spaccavento et al[18]	Acute and chronic PWA (n=77) Acute and chronic stroke survivors w/out aphasia (n=127) Controls (n=42)	TAP[19]	Impaired performance on at least one attention task/condition
Studies using both linguistic and nonlinguistic stimuli			
Laures et al[20]	Chronic PWA (n=10) Controls (n=10)	Tone discrimination task	Impaired performance on at least one attention task/condition regardless of the nature of the stimuli
Murray et al[21]	Chronic PWA (n=16) Controls (n=8)	Tone discrimination task	Worse performance when the secondary task includes linguistic stimuli
Hula et al[22]	Chronic PWA (n=15) Controls (n=20)	Tone discrimination task	Worse performance when the secondary task includes linguistic stimuli

ANT indicates attention network test; COVAT, covert orienting of visuospatial attention test; PWA, patients with aphasia ; and TAP, test of attentional performance.

achieve and maintain an alert state), orienting attention (ie, the ability to select specific information from a given stimulus), and executive control (ie, the ability to achieve a correct response when relevant stimulus information conflicts with irrelevant stimulus information). The results showed that overall stroke survivors were slower and less accurate than neurotypicals. Within-group analyses showed that stroke survivors exhibited the expected executive control effects (ie, slower responses for incongruent trials compared with congruent trials); however, their alerting and orienting attention abilities were disrupted (ie, no alerting effect was observed, and the orienting effect had the opposite direction, with better performance on double cue trials compared with center cue trials). Orienting attention was also assessed by Robin and Rizzo[13] and Hunting-Pompon and colleagues.[14] Using a cueing task (in which an arrow cue was presented prior to a stimulus on the left or the right), Robin and Rizzo[13] found that all stroke patients performed slower than neurotypicals, but only PWA failed to benefit from the cues. This suggested that attentional cueing may be disrupted in PWA. Hunting-Pompon et al[14] manipulated the timing of cue presentation to test automatic processing (cue presented 100 ms prior to the target) and controlled processing (cue presented 800 ms prior to the target). They found that PWA were slower than controls during the 100 ms interval, indicating impaired automatic processing. They also administered a more complex version of the task, in which participants were instructed to read aloud a word that appeared on the screen while continuing to complete the primary task again at 2 interstimulus intervals. PWA were slower than controls regardless of the interval, indicating deficits in both automatic and selective attention during the complex version of the task.

Erickson et al[16] examined auditory sustained and divided attention using a tone discrimination task combined with the Wisconsin Card Sorting Task[17]; participants listened to a series of nonlinguistic pure tones and had to identify a target complex harmonic (in the simple condition), while they were simultaneously sorting cards (in the complex condition). PWA performed like neurotypicals in the simple condition involving only the tones and harmonics, but they exhibited lower accuracy than neurotypicals during the more complex condition. These results suggest that sustained attention may be intact in PWA, especially when the task involves one set of stimuli, whereas divided attention required during more complex conditions involving additional sets of stimuli is impaired. Finally, Spaccavento et al[18] reported that PWA tended to be slower than patients without aphasia in a Go-No Go task measuring selective attention.

The studies reviewed above examined domain-general attention in aphasia using tasks with nonlinguistic stimuli. Although they differ in terms of the methods and metrics used to examine attention, it is notable that each of them found evidence of impaired performance in PWA relative to neurotypicals on at least 1 task condition. Therefore, the results collectively suggest that stroke survivors with aphasia suffer from a broad attention deficit that impacts different types of attention in both the auditory and visual modalities, although the stimuli have no language.

Apart from the studies using nonlinguistic stimuli to assess attention deficits in aphasia, our review revealed 3 studies that attempted to investigate attention deficits in aphasia as a function of the nature of the stimuli, that is they attempted to directly compare PWA's performance on linguistic versus nonlinguistic attention tasks. In Laures et al's[20] study, PWA performed a discrimination task with linguistic (ie, a target monosyllabic word, "myth," and 4 non-target monosyllabic phonetically dissimilar words such as "pad") and nonlinguistic (ie, a target harmonic signal and 4 non-target pure tones) stimuli. Overall, the results showed decreased sustained attention in PWA regardless of the nature of the stimuli. Interestingly, the next 2 studies reported that in dual-task paradigms, where attention demands are higher, linguistic and nonlinguistic stimuli affect performance differently. Specifically, Murray et al[21] reported comparable accuracy among PWA and neurotypicals during the isolation conditions (ie, participants completed each task without distraction); however, PWA responded less accurately and more slowly than neurotypicals during the focused and divided attention conditions (ie, the primary and secondary stimuli were presented simultaneously, but participants completed only the primary task). In addition, all participants showed greater disruption of their skills when the secondary task included linguistic compared with nonlinguistic stimuli. Similar results have also been reported by Hula et al[22] in a study that used a comparable paradigm. Taken together, these studies suggest that PWA have difficulties with dual-task paradigms and, therefore, impaired focused and divided attention. In addition, they showed that these difficulties become worse when language processing demands are added, as in the cases with a linguistic secondary task. This shows that a highly taxed attention system might have a negative impact on language processing in PWA, which in turn suggests that, to some extent, language deficits may be attributed to attention deficits in some PWA.[9] This topic is further discussed in the following section, where studies that explicitly investigate the relationship between attention and language deficits in aphasia are reviewed.

ON THE RELATIONSHIP BETWEEN ATTENTION AND LANGUAGE DEFICITS IN APHASIA

The fact that several studies report evidence of a concomitant attention deficit in PWA has led researchers to directly explore the relationship between attention and language deficits in this population. A strong association between attention severity and language severity would be consistent with the concept of language deficits driven primarily by attention deficits. Our review resulted in 14 studies that have investigated this topic using a variety of language and attention assessment batteries. Two studies were excluded because the analyses performed included either total scores or principal component factors that included measures of other cognitive domains as well, resulting in twelve studies (Table 3). Our review begins with studies investigating the relationship between attention severity and overall aphasia severity (eg, Western Aphasia Battery[24]–Aphasia Quotient; n=7 studies) and continues with studies that focus on specific levels or aspects of language processing (eg, single word naming, reading, connected speech production etc; n=5 studies).

Attention Deficits and Overall Aphasia Severity

The evidence regarding the association between performance on attention tasks and aphasia severity is mixed. Specifically, Murray et al[21] were among the first to search for such an association using the Western Aphasia Battery–Aphasia Quotient (WAB-AQ) and scores on the divided attention condition 2 (see previous section for attention task description). The authors reported nonsignificant correlations. Gordon-Pershey and Wadams[25] also reported lack of an association, which was attributed to individual variability. Specifically, multiple case comparisons showed that attention might be differentially affected in PWA and, therefore, the variability in performance did not allow for a trend between measures of language and attention to emerge at a group level. Finally, Yao et al[29] also found no association between WAB-AQ and attention, which was interpreted as an artifact of the scoring procedure, and the authors recommended the use of a more comprehensive battery when assessing attention in aphasia.

The abovementioned studies indicate that the degree to which attentional skills are affected in aphasia is not consistently related to aphasia severity. However, other studies have yielded opposite results. Fonseca et al[31] found a significant correlation between the WAB-AQ and the Symbol Search scores of the Wechsler Adult Intelligence Scale. In a similar vein, Lee et al[35] correlated the confidence index of Conners' Continuous Performance Test-II (a derived summary measure of attention performance with a higher score indicating greater confidence that an impairment is present) with the WAB-AQ. The results revealed a significant negative association indicating that better language skills were associated with better attentional skills. The authors repeated this analysis using the WAB-Revised Language Quotient and showed similar findings. Huang et al[38] reported a significant correlation between aphasia severity and executive control inverse efficiency, an adjusted reaction time measure derived from the Attention Network Test by dividing

Table 3. Studies Investigating the Relationship Between Attention Deficits and Language Deficits in PWA

Study	Participants	Attention assessment	Language assessment	Relevant findings
Attention deficits and overall aphasia severity				
Murray et al[21]	Chronic PWA (n=16) Controls (n=8)	Tone discrimination task	WAB[24]	No association between attention deficits and aphasia severity
Gordon-Pershey et al[25]	Chronic PWA (n=8)	Map search and telephone search while counting subtests of the TEA[26] Mazes and Symbol Trails subtests of the Cognitive Linguistic Quick Test[27] Sustained Attention subtest of Leiter-R[28]	WAB[24]	No association between attention deficits and aphasia severity
Yao et al[29]	Acute PWA (n=45) Acute stroke patients w/out aphasia (n=41) Controls (n=44)	Loewenstein occupational therapy cognitive assessment[30]	WAB[24]	No association between attention deficits and aphasia severity
Fonseca et al[31]	Chronic PWA (n=48)	Symbol Search of the WAIS[32] Letter Cancelation of the Lisbon BLAD[33]	Lisbon Aphasia Assessment Battery[34]	Association between attention deficits and aphasia severity
Lee et al[35]	Chronic PWA (n=14)	CPT-II[36]	WAB-R[37]	Association between attention deficits and aphasia severity
Huang et al[38]	Chronic PWA (n=26) Controls (n=26)	ANT[12]	Chinese version of the WAB[39]	Association between attention deficits and aphasia severity
Meier et al[40]	Acute PWA (n=23)	FICA Test from the NIH Toolbox Cognition Battery[41]	WAB-R[37]	Association between attention deficits and aphasia severity
Attention deficits and specific aspects of language deficits				
Kalbe et al[42]	Chronic PWA (n=154) Controls (n=106)	Attention Task of the Aphasia Check List[42]	Language Task of the Aphasia Check List[42]	Association between attention deficits and reading, listening, and writing
Pérez Naranjo et al[43]	Chronic PWA (n=21) Controls (n=24)	CPT-II[36]	Phonological processing lexical access semantic association	Association between attention deficits and phonological sound discrimination and semantic association
Huang et al[38]	Chronic PWA (n=26) Controls (n=26)	ANT[12]	Subtests of the Chinese version of the WAB[39]	Association between attention deficits auditory comprehension and repetition
Schumacher et al[44]	Chronic PWA (n=32)	TAP[19] TEA[26]	Subtests 1, 2, 8, and 9 of PALPA[45] Word-to-picture matching, naming, and camel and cactus tests of the Cambridge Semantic Battery[46] BNT[47] Synonym judgement[48] Spoken sentence comprehension of the CAT[49] Picture description of the BDAE[50]	Only performance in one TEA subtest associated with overall severity of language impairments No association between attention components and overall severity of language impairments Limited association between attention measures and language components
Frankel et al[51]	Case study with chronic PWA	Forward digit span and bells cancellation tests[52] Stroop color-word interference test[53] Echopraxic tasks[54]	Connected speech	Association between attention deficits and conversational skills

ANT indicates Attention Network Test; BDAE, Boston Diagnostic Aphasia Examination; BNT, Boston Naming Test; CAT, Comprehensive Aphasia Test; CPT-II, Conners' Continuous Performance Test-II; FICA, Flanker Inhibitory Control and Attention; PALPA, psycholinguistic assessments of language processing in aphasia; PWA, patients with aphasia; TAP, test of attentional performance; TEA, test of everyday attention; WAB, Western Aphasia Battery; WAB-R, Western Aphasia Battery-Revised; and WAIS, Wechsler Adult Intelligence Scale.

reaction time by its corresponding percentage accuracy. Finally, Meier et al[40] performed a principal component analysis in which they included scores from several linguistic and cognitive tasks, including the Flanker Inhibitory Control and Attention scores. This analysis revealed 2 components, a linguistic and an executive control one, which were entered in regression models predicting WAB-AQ. The results showed that both linguistic and executive control components were significant predictors of acute aphasia severity.

Attention Deficits and Specific Aspects of Language Deficits

The rest of this section is devoted to studies that have investigated the relationship between attention and specific aspects of language processing rather than, or in addition to, the broad aphasia severity index. In the article describing the newly developed Aphasia Check List, Kalbe et al[42] reported significant correlations between scores on the cross-out attention task and scores on several language subtests, including reading aloud, reading comprehension, auditory comprehension, writing to dictation and word generation subtests. Similar results have been reported by Pérez Naranjo et al.[43] Correlation analyses showed significant associations between focused attention indices and performance in phonological sound discrimination and semantic (word knowledge) association tasks. Regression analyses revealed that focused attention predicted language performance even after accounting for performance in related linguistic tasks, indicating that attention has an influence over language deficits shown in PWA. In a more recent study, Huang et al[38] found that measures of alerting and orienting attention were correlated with repetition and auditory comprehension respectively. Stepwise regression analyses controlling for demographic variables revealed that executive control reaction time predicted auditory comprehension, whereas alerting and orienting attention predicted repetition. The authors suggested that in PWA, language is related to specific attention functions and, therefore, disentangling the mechanism of attention deficits in this population may supplement rehabilitation strategies. Finally, in a recently published study, Schumacher et al[44] administered several attention and language tasks in PWA and found that only performance in the Elevator Counting with Distraction task of the Test of Everyday Attention was associated with severity of overall language impairment, whereas no association was observed between attention components derived through principal component analysis and severity of overall language impairment.

The studies presented in the previous paragraphs were group studies reporting associations between several types of attention and word- and sentence-level language deficits in aphasia. A final study, which is a case study by Frankel et al[51] examined if attention deficits impacted conversational difficulties. The authors analyzed connected speech samples using Conversation Analysis procedures,[55] with a focus on turn taking, topic management, and repair. The authors reported that the patient exhibited preserved simple sustained attention, which occurred together with the ability to maintain concentration and track meaning during conversation with 1 interlocutor. On the other hand, shifting attention (reflected in performance on trail making) was impaired, indicating an inability to shift focus. This occurred together with difficulties on tracking meaning during multi-party conversations, in which topics and speakers change rapidly, as well as on conversational repair.

In summary, although the evidence presented in the previous section indicates that PWA demonstrate attention deficits, the evidence for associations between attention deficits and aphasia severity, as reviewed in the first part of this section is mixed. Large-scale studies suggest that severe aphasia is related to attention deficits; however, smaller-scale studies report a lack of association, which may be attributed either to lack of power or the way attention deficits were assessed and scored. On the other hand, the majority of studies that have investigated the relationship between attention and specific aspects of language processing suggest that attention deficits, especially deficits on more complex types of attention, are related to (and in some cases even predict) deficits in various aspects of language processing, including word- and sentence-level processing as well as conversational skills.

ATTENTION TRAINING, LANGUAGE TREATMENT, AND APHASIA RECOVERY

Given the albeit mixed research evidence suggesting a relationship between attention deficits and language deficits, several researchers have attempted to further investigate this relationship within the context of aphasia recovery and treatment outcomes (Table 4). The first set of studies have investigated treatment-induced (n=1) and spontaneous (n=1) aphasia recovery as a function of baseline attention skills. The second set includes studies that have investigated language improvement in PWA as a function of attention treatment (n=4). The third set includes studies that have investigated treatment outcomes using both types of treatment, namely language and attention treatments (n=2). Finally, the fourth set includes a study that has explored attention improvement in PWA as a function of language therapy (n=1).

Aphasia Recovery and Baseline Attention Skills

Lambon Ralph et al[56] examined the relationship between gain after anomia therapy and baseline performance on cognitive tasks, including tasks that assess sustained and divided attention. Correlation analyses with pooled data from 4 previous studies showed a significant association between baseline performance on elevator counting with distraction and therapy gain both immediately after therapy and at follow-up. In a more recent study, Fonseca et al[57] assessed attention skills of PWA during the acute stage of stroke and evaluated how their performance relates to aphasia recovery at 3 months. Contrary to the Lambon Ralph et al[56] study, the authors reported that the average baseline performance on the attention tasks was within normal range and, most importantly, did not predict aphasia recovery.

Language Improvements Following Direct Attention Training

The studies discussed next have implemented a treatment approach that was directed towards improving attentional skills. In an early case study, Coelho[59] reported data from an individual with mild aphasia

Table 4. Studies Investigating the Relationship Between Attention Deficits and Aphasia or/and Attention Recovery in PWA

Study	Participants	Treatment type	Recovery measure	Relevant findings
Aphasia recovery and baseline attention skills				
Lambon Ralph et al[56]	Chronic PWA (n=33)	Language Therapy targeting anomia	Proportion of the potential maximal gain	Association between baseline attention deficits and therapy gain
Fonseca et al[57]	Acute PWA (n=39)	NA	Token Test[58]	No association between baseline attention deficits and aphasia recovery
Language improvements following direct attention training				
Coelho[59]	Case study with chronic PWA	APT-II[8]	Reading comprehension scores and reading rate (ie, words per minute)	Attention training resulted in improved reading abilities
Murray et al[60]	Case study with chronic PWA	APT-II[8]	Paragraph listening accuracy and reaction time	Minimal changes in language abilities following attention training
Lee et al[61]	Chronic PWA (n=6)	APT-III[62]	Maze reading tasks	Attention training resulted in improved reading abilities
Peach et al[63]	Chronic PWA (n=4)	L-SAT[64] APT-III[62]	Improvement on treatment tasks Western Aphasia Battery-Revised Aphasia Quotient (WAB-R AQ)[37] Object and Action Naming Battery[65] Discourse Comprehension Test[66]	Language-specific attention training and domain-general attention training result in language improvement
Language treatment versus language plus attention training				
Zhang et al[67]	Chronic PWA (n=40)	Impairment-specific language therapy Impairment-specific language therapy + gradual attention training[68]	Subtest scores and Aphasia Quotient WAB[24]	Combination of language and attention training is more successful than language training alone
Modarres et al[69]	Case study with chronic PWA	Language therapy targeting anomia Attentive rehabilitation of attention and memory[70]	Naming probes	Combination of language and attention training is more successful than language training alone
Attention improvements following language treatment				
Marinelli et al[71]	Acute-to-chronic PWA (n=20)	Language Therapy targeting auditory and written comprehension and production as well as articulatory difficulties	CoBaGa[71]	Language therapy may result in improved attention abilities

APT-II indicates Attention Process Training-II; APT-III, Attention Process Training-III; CoBaGa, Cognitive Test Battery for Global Aphasia; L-SAT, language-specific attention treatment; PWA indicates patients with aphasia; and WAB, Western Aphasia Battery.

whose primary complaint was difficulties in reading. The patient received attention treatment, during which they were engaged in a series of repetitive tasks addressing sustained attention, in the beginning, and progressing through alternating, selective, and divided attention. Reading abilities were monitored throughout the treatment via reading an article from various magazines and answering comprehension questions, and 2 indices of change were derived, namely reading comprehension scores and reading rate (ie, words per minute). The treatment probe data revealed that the reading comprehension scores gradually improved over the course of the treatment and that increased accuracy was maintained at the follow-up. The reading rate data showed a trend towards decreasing, more stable reading rate. According to Coelho, the patient's reading improvements were attributable to sustained attention, coping with distractions, and increased concentration.

In another case study, Murray et al[60] used the same attention training program as Coelho in a patient with mild aphasia to investigate whether attention improvements would evoke concomitant improvements in auditory comprehension as well as the patient's and their spouse's perception of their daily attention and communication difficulties. Throughout treatment, auditory comprehension was monitored via a paragraph listening task, in which the patient listened to 4 prerecorded passages and then answered prerecorded multiple-choice questions. During the treatment tasks, the patient demonstrated gradual improvements in reaction time, accuracy, or both, and therefore was able to acquire the specific attention skills that the treatment targets. Improved scores on attention tasks tapping into skills like those practiced during treatment were also achieved. Regarding auditory comprehension during the paragraph probe, the authors reported a trend towards improved listening accuracy, which they attributed to exposure effects, and reaction time, which they interpreted as improved speed. Finally, the authors reported minimal change in basic and high-level language abilities as measured with the standardized assessments, and in how the patient and their spouse rated the adequacy of the patient's communication abilities following treatment, and moderate improvements on the attention skills. Based on these findings, Murray and colleagues proposed that structured attention training may result in improvements limited to specific attention skills, whereas positive changes in untrained functions, including language, are less likely.

That is, cross-domain generalization did not occur in this instance.

Lee et al[61] used attention training to treat individuals with chronic mild aphasia and concomitant reading comprehension problems, with an emphasis on the metacognitive component of the treatment. Specifically, the attention training program included 2 features that promote metacognitive behavior, namely effort and motivation self-ratings and presentation of detailed data. Over the course of the treatment and after each attention task, participants were asked to rate their effort and motivation and were shown their accuracy results on a line graph. A battery of assessments was administered prior to and after treatment to characterize attention deficits and evaluate response to intervention. Reading comprehension was monitored with maze reading tasks, during which participants were asked to read maze passages silently and to circle the word in parenthesis that appropriately completes each sentence. The authors reported that 3 of the 6 participants showed a positive change in maze accuracy. The aggregated effect size was statistically significant. Based on these results, the authors argued that the attention training program used in this study has the potential to improve reading skills in PWA.

The studies reported above utilized a domain-general approach for attention training, such that treatment only included nonlinguistic stimuli. The alternative to such an approach is the use of tasks that address language-specific attention skills. Peach et al[63] examined the comparative effectiveness of the 2 diverging attentional approaches to aphasia recovery in a small-scale randomized controlled cross-over single-subject study. Specifically, all participants in their study were exposed to 2 attention treatment programs: a language-specific attention treatment with language-based tasks and stimuli that impose increasing attentional demands on lexical and sentence processing, and a direct attention training program. Steady, linear improvements on the treatment tasks followed the language-specific attention treatment, whereas more variable and unpredictable patterns of performance were associated with direct attention training program. The improvements following the language-specific attention treatment were reliable, as reflected by the statistically significant effect sizes for most of the tasks. The results of the standardized assessments also favored the language-specific attention treatment. Although simple sums of change scores for the 3 standardized language tests showed that either treatment (or both) may result in language improvements, 3 of the 4 participants exhibited reliable improvements on WAB-AQ following the language-specific attention treatment. Peach and colleagues argued that either a language-specific or a domain-general attention training program may produce some language improvements in aphasia; however; a language-specific treatment seems to be a preferable approach for aphasia rehabilitation.

Language Treatment Versus Language Plus Attention Training

Zhang et al[67] conducted a randomized controlled trial, in which the first group received impairment-specific language therapy, whereas the second group received additional gradual attention training.[68] Prior to and after treatment, language function was assessed by components of the WAB, including spontaneous speech, auditory comprehension, repetition, and naming, and WAB-AQ was calculated. The authors reported that both groups had similar language function at the baseline; however, after treatment, the group that received additional gradual attention training exhibited significantly higher scores in the auditory comprehension and naming components of the WAB compared with the group that received language treatment only.

Similar results have also been reported in a case study by Modarres et al.[69] The patient who participated in this study received naming treatment via language-based tasks followed by a combined program in which language-based tasks and attention training were both presented. The language-based tasks included semantic and phonological activities, whereas attention training was delivered via the Attentive Rehabilitation of Attention and Memory[70] program targeting sustained, selective, alternating, and divided attention using nonlinguistic stimuli. According to the authors, the patient exhibited improvements on their naming ability during both treatment programs, however more gains were associated when the language tasks were combined with attention training. Most importantly, this combined treatment protocol resulted in generalization to untrained linguistic items in this participant.

Attention Improvements Following Language Treatment

The studies presented in the previous parts of this section suggest that direct attention training alone or combined with language treatment may result in language improvements. In this last part, we review a study that investigates the opposite relationship, that is whether language treatment may generalize to improvements in the attention domain. Specifically, Marinelli et al[71] reported data from patients with severe aphasia who received language treatment focusing on auditory and written comprehension and production as well as on rehabilitation of articulatory difficulties. All participants also completed standardized attention tasks. The results showed a significant improvement for comprehension and repetition, and, most importantly, a significant improvement for attention. The authors interpreted this finding as evidence for a strong relationship between language impairments and general cognitive functioning.

THE NEURAL BASIS OF THE ATTENTION-LANGUAGE RELATIONSHIP IN APHASIA

The evidence reviewed in the previous sections indicate a high prevalence of attention deficits in aphasia. It is also important to note emerging evidence that the status of the attention skills of PWA affect the extent of aphasia recovery. This behavioral relationship is likely to have a neural basis as well. To illustrate, domain-general attention is thought to be subserved by different brain regions comprising the dorsal attention network and ventral attention network. The dorsal attention network, organized bilaterally and comprising the intraparietal sulcus and the frontal eye fields of each hemisphere, is considered a goal-driven or "top-down" attentional system.[72] The Ventral attention network is thought to be a stimulus-driven or "bottom-up" attentional system largely right lateralized and comprising the temporoparietal junction and the ventral frontal cortex.[72] Several studies have investigated the activation patterns of these networks (or regions that belong to these networks) in stroke survivors (with or without aphasia) compared with healthy adults and have addressed their role in attention skills and/or aphasia recovery.

Carter et al[73] reported that, within 4 weeks after stroke, decreased interhemispheric connectivity of homologs within the dorsal attention network (eg, left and right intraparietal sulcus) correlated with worse performance on a spatial attention task. Sandberg[74] reported that chronic PWA have decreased connectivity within the dorsal attention network compared with controls. Interestingly, in the same study, comparisons within the PWA group showed that higher connectivity in the dorsal attention network was associated with less severe aphasia. Duncan and Small[75] reported that imitation-based treatment resulted in increased functional connectivity within resting-state networks, including the dorsal attention network, and decreased functional connectivity between the networks. These findings indicate that modularity, a key organizational principle in resting-state networks, increased as a function of treatment. The authors also found that this increased modularity was positively correlated with improvement in post-treatment narrative production. Siegel et al[76] found that stroke survivors had lower modularity than healthy adults in the 2 attention networks 2 weeks poststroke. Interestingly, their modularity increased over the first year, and this increase was associated with better recovery of language and attention. Barbieri et al[77] found greater upregulation in a group receiving treatment in regions within the dorsal attention network, and the upregulation was positively related with behavioral gains resulting from treatment. Finally, several studies have reported changes in activation or connectivity—following treatment—in regions implicated in attentional processing, including the middle frontal gyrus,[78–80] and the superior parietal lobule,[80,81] reflecting increased engagement of top-down attentional mechanisms.[82]

CONCLUSIONS

This narrative review includes 28 behavioral studies that investigated the relationship between attention and language in PWA using various methods and approaches. Despite the methodological differences, the studies reviewed in this article indicate that attention, a domain-general cognitive skill that is fundamental for more complex tasks and operations, is critical to examine in aphasia. The relationship between attention and language in aphasia varies from concomitant deficits to highly interrelated deficits. All studies included in this review showed that PWA suffer from impairments to various degrees in their attentional skills. Several studies also showed that these limitations may be associated with language deficits in this population, and, more importantly, may predict the degree of language recovery. Finally, treatment studies showed that training attention in PWA may result in language improvements and that PWA exhibit more treatment gains when the treatment protocol targets both domains.

Following Villard and Kiran,[9] we argue that the relationship between attention and language deficits in aphasia should be considered within the broader context of the brain status and other factors that are known to affect aphasia recovery. The schema suggested by Villard and Kiran[9] allows for a strong influence of attention on language but also takes into account the selective effects of brain damage on attention and language. In a similar vein and as shown in the Figure, we suggest that factors such as the stroke lesion characteristics (ie, lesion volume and/or location), and overall brain damage (eg, the presence and severity of other white matter lesions affecting the brain network topology) may affect both attention and language in PWA, and therefore individuals' brain status plays a role in the attention-language relationship. Other factors, including individuals' demographic characteristics, aphasia severity, and treatment-related factors (eg, time and intensity) should also be considered.

Collectively, the studies reviewed here indicate an important link between attention and aphasia. They also underly the applicability of several nonverbal attention tests to PWA. This further suggests that evaluation of attention abilities in aphasia is feasible and, therefore, PWA should not be excluded from studies of vascular or other dementia due to their language impairment alone. However, there are several limitations that need to be considered. First, only few studies were large-scale studies, whereas a convenience sample was used in most of the cases (ie, no sample size justification was provided). In addition, in several cases, participants were not able to complete all tasks, reducing even more the data available. Another limitation is the lack of information on PWA's brain lesions in most of the studies. As a result, the possible relationship patterns among aphasic symptoms and attentional skills as a function of the damage to different

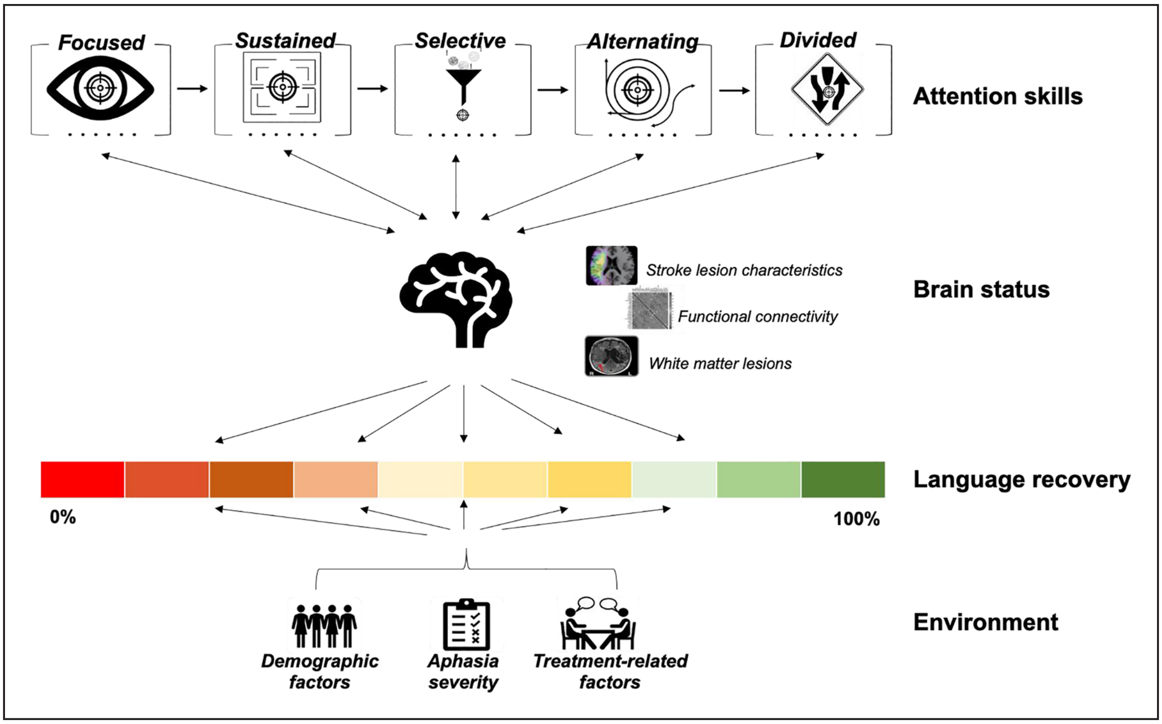

Figure. Schema of attention and language in aphasia.

brain areas and networks cannot be addresses. A third limitation concerns the methodology followed in the studies. Specifically, previous research[1] has confirmed patterns of intra-individual variability in attention tasks among PWA. Given that most data come from single timepoints, the reliability of PWA's attentional skills is not ascertained. In addition, although most studies report an association between attention and language, no conclusions toward causation can be drawn due to the cross-sectional nature of the studies. A fourth limitation is that, despite the careful selection of tests with a minimal verbal load, one cannot guarantee that the tests are entirely nonverbal; the instructions were verbal, and one cannot rule out verbalization of the resolution strategies.

Future work could take several directions. For instance, given that most (if not all) of the attention tests that were used in the studies reviewed here have not been developed for PWA, best practice recommendations for assessing attention in this population are needed. We suggest that the tasks assessing attentional skills in PWA should include multiple subtests evaluating different aspects of attention as well as different modalities (ie, auditory and visual modalities). In addition, researchers should choose assessments with strong construct validity, to minimize involvement and, therefore, interference from other cognitive processes beyond attention. For instance, TEA may not be appropriate for this population given the linguistic demands and need for verbal responses. We also suggest that the assessments should be administered in multiple timepoints to account for intra-individual variability and that objective scoring methods should be use to allow for replicability and reproducibility of the results. Despite the encouraging evidence that training attention in PWA may result in language improvements, the reports are sporadic and mostly case reports or self-controlled studies. Therefore, language-specific treatments remain the standard approach in treatment-induced aphasia recovery. Large-scale clinical trials are needed to evaluate the therapeutic effect of attention training and inform clinical practice. Such studies would also allow us to explore whether there is a causal relationship between attention and language deficits in aphasia through appropriate mediation analyses. Longitudinal studies are also needed to evaluate the dynamic changes in language and attention impairments in aphasia as well as to check for further decline over time towards a dementia stage. Finally, we encourage the combination of neuropsychological and neuroimaging data providing information regarding participants' brain status (eg, stroke lesion characteristics, white matter lesions, activation, and connectivity patterns). This combination will allow us to explore how attentional skills are related to various aphasic symptoms and neural damage.

ARTICLE INFORMATION

Affiliations

Aphasia Research Laboratory, Department of Speech, Language and Hearing Sciences, Sargent College of Health and Rehabilitation, Boston, MA (M.V., S.K.). Edith Cowan University and Sir Charles Gairdner Hospital, Perth, Australia (E.G.).

Sources of Funding

This work was supported by NIH-NIDCD under grant 1R01DC016950.

Disclosures

Dr Kiran is a co-founder of Constant Therapy Health and owns stock options in the company; however, there is no scientific overlap in the scientific content of this article and the financial entity.

REFERENCES

1. Villard S, Kiran S. Between-session intra-individual variability in sustained, selective, and integrational non-linguistic attention in aphasia. *Neuropsychologia*. 2015;66:204–212. doi: 10.1016/j.neuropsychologia.2014.11.026
2. Lang CJG, Quitz A. Verbal and nonverbal memory impairment in aphasia. *J Neurol*. 2012;259:1655–1661. doi: 10.1007/s00415-011-6394-1
3. Gilmore N, Meier EL, Johnson JP, Kiran S. Nonlinguistic cognitive factors predict treatment-induced recovery in chronic poststroke aphasia. *Arch Phys Med Rehabil*. 2019;100:1251–1258. doi: 10.1016/j.apmr.2018.12.024
4. Vallila-Rohter S, Kiran S. Non-linguistic learning and aphasia: Evidence from a paired associate and feedback-based task. *Neuropsychologia*. 2013;51:79–90. doi: 10.1016/j.neuropsychologia.2012.10.024
5. Kahneman D. *Attention and effort. Englewood Cliffs*, NJ: Prentice-Hall; 1973
6. Mirsky AF, Anthony BJ, Duncan CC, Ahearn MB, Kellam SG. Analysis of the elements of attention: a neuropsychological approach. *Neuropsychol Rev*. 1991;2:109–145. doi: 10.1007/BF01109051
7. Posner MI, Rothbart MK. Research on attention networks as a model for the integration of psychological science. *Annu Rev Psychol*. 2007;58:1–23. doi: 10.1146/annurev.psych.58.110405.085516
8. Sohlberg MM, Mateer CA. *Cognitive rehabilitation: An integrative neuropsychological approach*. New York, NY: Guilford Press; 2001.
9. Villard S, Kiran S. To what extent does attention underlie language in aphasia?. *Aphasiology*. 2017;31:1226–1245. doi: 10.1080/02687038.2016.1242711
10. Hula WD, McNeil MR. Models of attention and dual-task performance as explanatory constructs in aphasia. *Semin Speech Lang*. 2008;29:169–87; quiz C 3. doi: 10.1055/s-0028-1082882
11. LaCroix AN, Baxter LC, Rogalsky C. Auditory attention following a left hemisphere stroke: comparisons of alerting, orienting, and executive control performance using an auditory attention network test. *Audit Percept Cogn*. 2020;3:238–251. doi: 10.1080/25742442.2021.1922988
12. Fan J, McCandliss BD, Sommer T, Raz A, Posner MI. Testing the efficiency and independence of attentional networks. *J Cogn Neurosci*. 2002;14:340–347. doi: 10.1162/089892902317361886
13. Robin DA, Rizzo M. The effect of focal cerebral lesions on intramodal and cross-modal orienting of attention. *Clinical Aphasiology*. 1989;18:61–74.
14. Hunting-Pompon R, Kendall D, Bacon Moore A. Examining attention and cognitive processing in participants with self-reported mild anomia. *Aphasiology*. 2011;25:800–812. doi: 10.1080/02687038.2010.542562
15. Posner MI, Cohen Y. Covert orienting of visuospatial attention task. In: Stelmach GG, Requin J, eds. *Tutorials in motor behavior*. Amsterdam: North-Holland Publishing Company; 1980:243–258.
16. Erickson RJ, Goldinger SD, LaPointe LL. Auditory vigilance in aphasic individuals: Detecting nonlinguistic stimuli with full or divided attention. *Brain Cogn*. 1996;30:244–253. doi: 10.1006/brcg.1996.0016
17. Grant DA, Berg EA. *Wisconsin card sorting test*. Odessa, FL: Psychological Assessment Resources; 1981.
18. Spaccavento S, Marinelli CV, Nardulli R, Macchitella L, Bivona U, Piccardi L, et al. Attention deficits in stroke patients: The role of lesion characteristics, time from stroke, and concomitant neuropsychological deficits. *Behav Neurol*. 2019;2019:1–12. doi: 10.1155/2019/7835710
19. Zimmermann, P, Fimm B. Test for attentional performance (TAP). Herzogenrath, Germany: *PsyTest*; 1995.
20. Laures J, Odell K, Coe C. Arousal and auditory vigilance in individuals with aphasia during a linguistic and nonlinguistic task. *Aphasiology*. 2003;17:1133–1152. doi: 10.1080/02687030344000436
21. Murray Laura L, Holland Audrey L, Beeson Pelagie M. Auditory processing in individuals with mild aphasia. *J Speech Lang Hear Res*. 1997;40:792–808. doi: 10.1044/jslhr.4004.792
22. Hula WD, McNeil MR, Sung JE. Is there an impairment of language-specific attentional processing in aphasia?. *Brain Lang*. 2007;103:240–241. doi: 10.1016/j.bandl.2007.07.023
23. Posner MI, Petersen SE. The attention system of the human brain. *Annu Rev Neurosci*. 1990;13:25–42. doi: 10.1146/annurev.ne.13.030190.000325
24. Kertesz A. *Western aphasia battery*. New York: Grune and Stratton; 1982.
25. Gordon-Pershey M, Wadams A. The relationship of language and attention in elders with nonfluent aphasia. *Cogent Medicine*. 2017;4:1356063. doi: 10.1080/2331205x.2017.1356063
26. Robertson IH, Ward T, Ridgeway V, Nimmo-Smith I. *The test of everyday attention*. Edmunds: Thames Valley Testing; 1994.
27. Helm-Estabrooks N. *Cognitive linguistic quick test (clqt)*. London: Harcourt Assessment; 2001.
28. Roid GH, Miller LJ. Leiter international performance scale - revised: Examiner's manual. In: Roid GH, Miller LJ, eds. *Leiter international performance scale - revised*. Wood Dale, IL: Stoelting Co; 1997.
29. Yao J, Liu X, Liu Q, Wang J, Ye N, Lu X, Zhao Y, Chen H, Han Z, Yu M, et al. Characteristics of non-linguistic cognitive impairment in post-stroke aphasia patients. *Front Neurol*. 2020;11:1038. doi: 10.3389/fneur.2020.01038
30. Katz N, Itzkovich M, Averbuch S, Elazar B. Loewenstein occupational therapy cognitive assessment (lotca) battery for brain-injured patients: Reliability and validity. *Am J Occup Ther*. 1989;43:184184192–184184192. doi: 10.5014/ajot.43.3.184
31. Fonseca J, Raposo A, Martins IP. Cognitive functioning in chronic post-stroke aphasia. *Applied NeuropsychologyAdult*. 2019;26:355364. doi: 10.1080/23279095.2018.1429442
32. Wechsler D. *Wechsler memory scale - iii*. San Antonio: Psychological Corp.: Harcourt Brace Jovanovich; 1987.
33. Garcia C. *Doença de alzheimer. Problemas de diagnóstico clínico [alzheimer's disease. Problems of clini- cal diagnosis]*. Lisbon, Spain: Faculdade de Medicina de Lisboa; 1984.
34. Castro-Caldas A. Diagnóstico e evolução das afasias de causa vascular [diagnosis and evolution of vascular aphasia]. *Lisbon Faculty of Medicine*. 1979;
35. Lee JB, Kocherginsky M, Cherney LR. Attention in individuals with aphasia: Performance on the conners' continuous performance test – 2nd edition. *Neuropsychol Rehabil*. 2020;30:249–265. doi: 10.1080/09602011.2018.1460852
36. Conners CK. *Conners' continuous performance test ii*. Toronto: Multi-Heath Systems Inc; 2000.
37. Kertesz A. *Western aphasia battery (revised)*. San Antonio, TX: Psychological Corp.; 2007.
38. Huang Q, Shu T, Xu W, Chen Z. Alerting, orienting, executive control and language function in post-stroke aphasia patients. *Rehabilitation*. 2022;7:5–15. doi: 10.11648/j.rs.20220701.12
39. Gao SR, Chu YF, Shi SQ, Peng Y, Dai SD, Wang YH. A standardization research of the aphasia battery of Chinese. *Chinese Mental Health Journal*. 1992;125–128.
40. Meier EL, Kelly CR, Hillis AE. Dissociable language and executive control deficits and recovery in post-stroke aphasia: An exploratory observational and case series study. *Neuropsychologia*. 2022;172:108270. doi: 10.1016/j.neuropsychologia.2022.108270
41. Gershon RC, Wagster MV, Hendrie HC, Fox NA, Cook KF, Nowinski CJ. Nih toolbox for assessment of neurological and behavioral function. *Neurology*. 2013;80:S2–S6. doi: 10.1212/WNL.0b013e3182872e5f
42. Kalbe E, Reinhold N, Brand M, Markowitsch HJ, Kessler J. A new test battery to assess aphasic disturbances and associated cognitive dysfunctions -- german normative data on the aphasia check list. *J Clin Exp Neuropsychol*. 2005;27:779–794. doi: 10.1080/13803390490918273
43. Pérez Naranjo N, Del Río Grande D, González Alted C. Individual variability in attention and language performance in aphasia: A study using conner's continuous performance test. *Aphasiology*. 2018;32:436–458.
44. Schumacher R, Halai AD, Lambon Ralph MA. Attention to attention in aphasia – elucidating impairment patterns, modality differences and neural correlates. *Neuropsychologia*. 2022;177:108413. doi: 10.1016/j.neuropsychologia.2022.108413
45. Kay J, Lesser R, Coltheart M. *Palpa. Psycholinguistic assessment of language processing. Introduction*. Hove: LEA; 1992.
46. Bozeat S, Lambon Ralph MA, Patterson K, Garrard P, Hodges JR. Non-verbal semantic impairment in semantic dementia. *Neuropsychologia*. 2000;38:1207–1215. doi: 10.1016/s0028-3932(00)00034-8
47. Kaplan E, Goodglass H, Weintraub S. *Boston naming test*. Pro-Ed; 2001.
48. Jefferies E, Patterson K, Jones RW, Lambon Ralph MA. Comprehension of concrete and abstract words in semantic dementia. *Neuropsychology*. 2009;23:492–499. doi: 10.1037/a0015452
49. Swinburn K, Porter G, Howard D. *Comprehensive aphasia test*. Psychology Press; 2004.
50. Goodglass H, Kaplan E. *The assessment of aphasia and related disorders*. Philadelphia: Lea & Febiger; 1983.

51. Frankel T, Penn C, Ormond-Brown D. Executive dysfunction as an explanatory basis for conversation symptoms of aphasia: A pilot study. *Aphasiology*. 2007;21:814–828. doi: 10.1080/02687030701192448
52. Lezak MD. *Neuropsychological assessment*. New York: Oxford University Press; 1995.
53. Golden JC. *Stroop color and word test*. Illinois: Stoelting Company; 1978.
54. Strauss E, Sherman EMS, Spreen O. *A compendium of neuropsychological tests: administration, norms, and commentary*. Oxford University Press; 2006.
55. Ten Have P. *Doing conversation analysis*. London: Sage Publications; 1999.
56. Lambon Ralph MA, Snell C, Fillingham JK, Conroy P, Sage K. Predicting the outcome of anomia therapy for people with aphasia post cva: Both language and cognitive status are key predictors. *Neuropsychol Rehabil*. 2010;20:289–305. doi: 10.1080/09602010903237875
57. Fonseca J, Raposo A, Martins IP. Cognitive performance and aphasia recovery. *Top Stroke Rehabil*. 2018;25:131–136. doi: 10.1080/10749357.2017.1390904
58. De Renzi E, Vignolo LA. The token test: A sensitive test to detect receptive disturbances in aphasics. *Brain*. 1962;85:665–678. doi: 10.1093/brain/85.4.665
59. Coelho C. Direct attention training as a treatment for reading impairment in mild aphasia. *Aphasiology*. 2005;19:275–283. doi: 10.1080/02687030444000741
60. Murray LL, Keeton RJ, Karcher L. Treating attention in mild aphasia: Evaluation of attention process training-ii. *J Commun Disord*. 2006;39:37–61. doi: 10.1016/j.jcomdis.2005.06.001
61. Lee JB, Sohlberg MM, Harn B, Horner R, Cherney LR. Attention process training-3 to improve reading comprehension in mild aphasia: A single-case experimental design study. *Neuropsychol Rehabil*. 2018;30:430–461. doi: 10.1080/09602011.2018.1477683
62. Sohlberg MM, Mateer CA. *Attention process training apt-3: A direct attention training program for persons with acquired brain injury*. Wake Forest, NC: Lash & Associates; 2010.
63. Peach RK, Beck KM, Gorman M, Fisher C. Clinical outcomes following language-specific attention treatment versus direct attention training for aphasia: A comparative effectiveness study. *J Speech Lang Hear Res*. 2019;62:2785–2811. doi: 10.1044/2019_jslhr-l-18-0504
64. Peach RK, Nathan MR, Beck KM. Language-specific attention treatment for aphasia: Description and preliminary findings. *Semin Speech Lang*. 2017;38:5–16. doi: 10.1055/s-0036-1597260
65. Druks J, Masterson J. *An object and action naming battery*. London, United Kingdom: Psychology Press; 2000.
66. Brookshire RH, Nicholas LE. *Discourse comprehension test: Test manual*. Minneapolis, MN: BRK Publishers; 1997.
67. Zhang H, Li H, Li R, Xu G, Li Z. Therapeutic effect of gradual attention training on language function in patients with post-stroke aphasia: A pilot study. *Clin Rehabil*. 2019;33:1767–1774. doi: 10.1177/0269215519864715
68. Hui-li Z, Xiao-ping Y, Ming-ming G, et al. Efficacy of rehabilitation on attention deficits. *Chinese Journal of Rehabilitation Theory and Practice*. 2011;17:535–538.
69. Amin Modarres Z, Azar M, Shohreh J, Vahid N, Ahmad Reza K. The effect of combining attention training program into language-based treatment of anomia on word retrieval: a case report. *J Modern Rehabilitation*. 2020;14:253–260. doi: 10.18502/jmr.v14i4.7723
70. Nejati V. Cognitive rehabilitation in children with attention deficit- hyperactivity disorder: Transferability to untrained cognitive domains and behavior. *Asian J Psychiatr*. 2020;49:101949. doi: 10.1016/j.ajp.2020.101949
71. Marinelli CV, Spaccavento S, Craca A, Marangolo P, Angelelli P. Different cognitive profiles of patients with severe aphasia. *Behav Neurol*. 2017;2017:3875954. doi: 10.1155/2017/3875954
72. Vossel S, Geng JJ, Fink GR. Dorsal and ventral attention systems: Distinct neural circuits but collaborative roles. *Neuroscientist*. 2014;20:150–159. doi: 10.1177/1073858413494269
73. Carter AR, Astafiev SV, Lang CE, Connor LT, Rengachary J, Strube MJ, Pope DLW, Shulman GL, Corbetta M. Resting interhemispheric functional magnetic resonance imaging connectivity predicts performance after stroke. *Ann Neurol*. 2010;67:365–375. doi: 10.1002/ana.21905
74. Sandberg CW. Hypoconnectivity of resting-state networks in persons with aphasia compared with healthy age-matched adults. *Front Hum Neurosci*. 2017;11:91. doi: 10.3389/fnhum.2017.00091
75. Duncan ES, Small SL. Increased modularity of resting state networks supports improved narrative production in aphasia recovery. *Brain Connect*. 2016;6:524–529. doi: 10.1089/brain.2016.0437
76. Siegel JS, Seitzman BA, Ramsey LE, Ortega M, Gordon EM, Dosenbach NUF, Petersen SE, Shulman GL, Corbetta M. Re-emergence of modular brain networks in stroke recovery. *Cortex*. 2018;101:44–59. doi: 10.1016/j.cortex.2017.12.019
77. Barbieri E, Mack J, Chiappetta B, Europa E, Thompson CK. Recovery of offline and online sentence processing in aphasia: language and domain-general network neuroplasticity. *Cortex*. 2019;120:394–418. doi: 10.1016/j.cortex.2019.06.015
78. Sandberg CW, Bohland JW, Kiran S. Changes in functional connectivity related to direct training and generalization effects of a word finding treatment in chronic aphasia. *Brain Lang*. 2015;150:103–116. doi: 10.1016/j.bandl.2015.09.002
79. Kiran S, Meier EL, Kapse KJ, Glynn PA. Changes in task-based effective connectivity in language networks following rehabilitation in post-stroke patients with aphasia. *Front Hum Neurosci*. 2015;9:316. doi: 10.3389/fnhum.2015.00316
80. Thompson CK, den Ouden D-B, Bonakdarpour B, Garibaldi K, Parrish TB. Neural plasticity and treatment-induced recovery of sentence processing in agrammatism. *Neuropsychologia*. 2010;48:3211–3227. doi: 10.1016/j.neuropsychologia.2010.06.036
81. Thompson CK, Riley EA, den Ouden DB, Meltzer-Asscher A, Lukic S. Training verb argument structure production in agrammatic aphasia: behavioral and neural recovery patterns. *Cortex*. 2013;49:2358–2376. doi: 10.1016/j.cortex.2013.02.003
82. Geranmayeh F, Brownsett SLE, Wise RJS. Task-induced brain activity in aphasic stroke patients: What is driving recovery?. *Brain*. 2014;137:2632–2648. doi: 10.1093/brain/awu163