Short-term and working memory treatments for improving sentence comprehension in aphasia: a review and a replication study

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Short-Term and Working Memory Treatments for Improving Sentence Comprehension in Aphasia: A Review and a Replication Study

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ABSTRACT

Although the roles of verbal short-term and working memory on spoken sentence comprehension skills in persons with aphasia have been debated for many years, the development of treatments to mitigate verbal short-term and working memory deficits as a way of improving spoken sentence comprehension is a new avenue in treatment research. In this article, we review and critically appraise this emerging evidence base. We also present new data from five persons with aphasia of a replication of a previously reported treatment that had resulted in some improvement of spoken sentence comprehension in a person with aphasia. The replicated treatment did not result in improvements in sentence comprehension. We forward recommendations for future research in this, admittedly weak at present, but important clinical research avenue that would help improve our understanding of the mechanisms of improvement of short-term and working memory training in relation to sentence comprehension.

KEYWORDS: Aphasia, sentence comprehension, treatment, short-term memory, working memory

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Learning Outcomes: As a result of this activity, the reader will be able to (1) discuss the impact of phonological short-term deficits on sentence comprehension in persons with aphasia; (2) describe a range of tasks used in short-term and working memory treatment studies; (3) evaluate the evidence base of short-term and working memory treatments for sentence comprehension in persons with aphasia.

In addition to the core linguistic deficits, persons with aphasia present with concomitant deficits in verbal short-term memory (STM) and working memory (WM).[1–6] Spoken sentence comprehension is one such linguistic deficit that has been linked to the relative integrity of STM/WM functioning.[5] STM and WM are related cognitive abilities. They are related in that both are responsible for the temporary storage and retrieval or recognition over a few seconds of verbal stimuli.[7] STM is often tested using word span tasks that involve serial recall, and sometimes recognition of verbal stimuli, usually lists of words or digits. STM can also be tested without the need to recall stimuli serially, but in any order (i.e., free recall). A crucial difference between STM and WM is that STM is not involved actively or majorly in the mental manipulation of verbal stimuli, whereas WM (hence the term *working*) is responsible for active mental manipulation for executing a particular goal or plan.[7] In comparison to STM, WM is more closely related to particular aspects of attention and executive functioning such as updating, shifting, and inhibiting verbal information.[2,5] The development of treatments of STM/WM functioning in persons with aphasia is recent. In this article we discuss the presently small evidence base of STM/WM treatments that explicitly sought to improve sentence comprehension through STM/WM training in persons with aphasia. We also present new evidence from a replication of a STM treatment study we performed. We conclude with a critical discussion of the current evidence base and highlight areas for future studies to help improve our understanding of the mechanisms of STM/WM training in relation to sentence comprehension.

CONTRIBUTIONS OF STM TO SENTENCE COMPREHENSION DEFICITS IN APHASIA

Sentence comprehension deficits in aphasia can be caused by impairments to linguistic processing abilities such as word comprehension, syntactic comprehension, and assignment of thematic roles to syntactic structures.[4] They can also be caused by STM deficits.[4,8] Historically, the role of STM in sentence comprehension (especially sentences with complex syntax) has drawn upon evidence from word span tasks. Such tasks rely on repetition, and engage input and output phonological processes, particularly if nonwords are involved in comparison to real words. Real words involve both phonological and semantic processing. Impaired performance in span tasks (recalling three or fewer words from word lists), often in addition to other aspects of phonological processing, have led researchers to postulate a particular STM subsystem (phonological STM) responsible for storing temporarily the sound form of words.[5–7] The words in tasks that may test the integrity of phonological STM are manipulated for length (i.e., number of syllables), phonological similarity (i.e., words that rhyme versus words that do not), and lexicality (i.e., words versus nonwords). Studies of patients with deficient phonological STM have shown that phonological STM can support sentence comprehension by keeping the phonological form of the sentence active in STM so that the person can refer back to aspects of that phonological form, aiding sentence interpretation.[8] So, the pattern of co-occurring deficits in phonological STM and sentence comprehension in the same patients has provided evidence for a role of phonological STM in sentence comprehension. However, a severely impaired phonological STM does not always lead to sentence comprehension deficits.[4] Dissociations between normal STM performance and impaired sentence comprehension have been reported.[4]

A more recent development about the contribution of STM to sentence comprehension in aphasia goes beyond phonological processing and emphasizes lexical semantic abilities. The differential contribution of phonological and semantic abilities is based on the hypothesis that performance in STM would vary according

Table 1 Diagnostic Features of Phonological and Semantic STM Impairments[5]

Phonological STM impairment	Semantic STM impairment
Better at semantic probe than rhyme probe tasks	Better at rhyme probe than semantic probe tasks
Better recall of short than long words	Similar recall of short and long words
Better recall of words than nonwords	Similar recall of words and nonwords
Better at written than spoken modality	Better at spoken than written modality

Abbreviation: STM, short-term memory.

to the nature of word processing abilities in terms of phonology and semantics (i.e., aspects of the aphasia itself).[5,6] In relation to sentence comprehension, some persons with aphasia can have particular difficulties with either semantic or phonological aspects of STM, in the context of relatively intact single-word processing abilities.[5] The diagnostic features of phonological and semantic STM deficits are summarized in Table 1. In this line of research, persons with semantic STM deficits were shown to have sentence comprehension deficits, whereas persons with phonological STM deficits had relatively spared sentence comprehension.[5]

OVERVIEW OF STM AND WM TREATMENTS FOR IMPROVING SENTENCE COMPREHENSION

Unlike many traditional aphasia treatments that use the same stimuli from session to session, the use of different stimuli within and across sessions, aiming to improve a person's ability to maintain temporarily sequences of spoken words is a distinguishing feature of STM/WM treatments. The words can be similar from session to session but the order in which words appear in treatment stimuli is different. Pre- and posttreatment testing of STM/WM would show if STM/WM has improved (i.e., near transfer effects). In examining wider generalization (i.e., far transfer of treatment benefits), standard language measures are used, which for sentence comprehension are mainly spoken sentence-picture matching tasks. In this section we describe (in chronological order of publication) STM/WM treatments that sought to improve sentence comprehension, which has taken the form of primarily single case studies. Biographical information of the participants reported in these studies is shown in Table 2 with information about treatment. We also present new evidence from a replication of a previous study.[9] All participants reported in this section presented with stroke-induced chronic aphasia (>8 months).

The treatment in Francis et al was based on repetition of phrases and sentences, which were read out by the person's husband, and the person had to repeat verbatim.[10] There was also weekly joint supervision by a speech-language pathologist and a neuropsychologist. In terms of treatment feedback, the authors state that the person's husband was not providing

Table 2 Summary of Published Treatment Studies of STM/WM Involving Persons with Sentence Comprehension Deficits

Studies	Participants	Treatment information
Francis et al[10]	$n = 1$, female, age = 69	Repetition of 12–20 sentences twice a day, 5 d a week, over 17 wk; plus 12 supervision sessions
Harris et al[14,*]	$n = 2$, both male, ages = 73, 74	One 1.5-h session per week, over 10 wk; plus self-administered homework
Salis[9]	$n = 1$, female, age = 73	26 sessions, each ~ 30 min, over 13 wk
Zakariás et al[16]	$n = 3$, two male (K.K., B.L.), one female (B.B.), ages = 57 (K.K.), 63 (B.L.), 64 (B.B.)	13 sessions, each ~ 20 min, over 4 wk

Abbreviations: STM, short-term memory; WM, working memory.
*Although two persons were included, only one patient presented with sentence comprehension deficits. The sentence comprehension abilities of the second person were at the ceiling.

feedback on accuracy, but the person herself was aware when she did not repeat accurately. It is not clear if the professionals provided feedback in the supervision sessions, and what form that feedback took. In terms of STM improvement, digit span improved from two (impaired) to six digits (normal). Sentence repetition measured as number of words also improved but sentence repetition measured as whole sentence correct did not. Improvements in sentence comprehension (token test) did not show change.[11] There was no change in a spoken sentence-picture matching test of active sentences.[12] There was no change in another spoken sentence-picture matching test involving a larger range of syntactic structures.[13]

The treatment task in Salis was a recognition STM task (matching listening span), that required the judgment of whether word-list pairs comprising spoken nouns were the same or different (no spoken output was necessary).[9] In one half of the word-list pairs, the words were identical in order. In the other half two of the words in the second list would be transposed. For example, the list pair *sink, frame, sleeve, loom—sink, frame, sleeve, loom* is the same, whereas the list pair *spoon, disk, pad, boy—disk, spoon, pad, boy* is different. In terms of feedback, if the person's response was correct, acknowledgment was given and the next word-list pair was presented. If a response was incorrect, the word-list pair was repeated and the clinician wrote down the words. Then, the clinician pointed out the words that were dissimilar in order. A speech-language pathologist delivered the treatment in clinic. The person's daughter also delivered part of the treatment at home. The daughter had been provided with training and was present in all treatment sessions. Digit span improved from four to six and digits; matching listening span improved from four to seven. Sentence comprehension in the token test did not improve,[11] but there was a statistical improvement in sentence-picture matching.[13]

In the study by Harris et al,[14] the person (D.S.) presented with a semantic STM deficit (Table 1), and two treatments were compared in relation to sentence comprehension. The authors predicted that D.S.'s sentence comprehension would improve following a phonological-semantic STM treatment, but not after a phonological treatment. A neuropsychologist delivered the treatment. In the phonological treatment (delivered first), D.S. had to repeat lists of nonwords serially that were read out by the clinician. The phonological-semantic treatment that followed involved serial repetition of real words. D.S. was also encouraged to think about the meaning of the words as he repeated them. In terms of feedback, in both treatments, if a repetition contained errors, the clinician provided the correct list at the end of each trial. It is not clear if the person had another opportunity for repetition, following feedback. Self-administered homework was also provided in terms of written word lists that tapped into STM recognition (nonwords for the phonological; real words for the phonological-semantic). After phonological STM treatment, phonological STM (i.e., nonserial repetition of lists of four nonwords) improved (from 53 to 87%) but phonological-semantic STM (i.e., nonserial repetition of lists of four real words) remained almost the same (83 to 80%), possibly because of ceiling effects. After phonological-semantic STM treatment, phonological STM was 62% (a decline from 87%) and phonological-semantic STM remained the same. Two sentence processing measures were taken before and after treatments. The first was a semantic anomaly sentence judgment task in which the person judged if spoken sentences made sense or not. After the phonological treatment, there was no improvement in this task. However, after the semantic-phonological treatment, there was an improvement. The second measure was a spoken sentence-picture matching test,[15] in which an improvement was noted only after the phonological-semantic treatment, not after the phonological.

Unlike the previous treatments that trained STM, the treatment described by Zakariás et al trained WM.[16] It used the *n*-back task, a WM task that has been used to measure WM capacity in aphasia.[3,17] There were two related *n*-back versions, a standard one and one with "lures" (i.e., distractors). In both versions the visual-verbal stimuli comprised letters that were presented on a computer screen, one at a time. In the standard version, the person had to press the space bar, if the same letter appeared at a predetermined position earlier in the sequence. So, in 2-back with a given sequence of *C, F, C, S, L, S, K,* the person would be expected to press the spacebar upon seeing *C* and *S* (underlined). In the "lure" version, the person had to ignore the "lure." So, given the sequence *C, F, S,* **C**, *L, K, L, N,* the person would be expected to press the spacebar when they saw only *L* (underlined; the "lure" is the bold **C**). Two speech-language pathologists and a nurse delivered the treatments, training for whom had been provided. It is not clear which professional delivered the treatment to each person. Written and spoken feedback was presented but it is not clear if the computer, the clinicians, or both presented it. In WM measures (near transfer), only two subjects, K.K. and B.B., improved in one-back with letters. No person improved in two-back with letters. No person improved in one- and two-back with pure tones. In spoken sentence-picture matching,[18] only K.K. and B.L. improved statistically when the scores were calculated as numbers of correct responses. When the scores were calculated as "blocks" correct, only B.L. and B.B. showed improvement.

We will now discuss the replication study. The primary purpose of this study was to replicate the original treatment in case series using a more robust design that involved computerized delivery, treatment fidelity measures, as well as treatment-related control probes.[9] At the time of the study no previous published STM/WM study in aphasia had employed a case series design involving several persons with aphasia. As well as examining far transfer to sentence comprehension, the replication determined if the treatment would have a positive impact on psychosocial measures of communication, which none of the previous treatments reviewed so far assessed. As in the original study,[9] the key sentence comprehension outcome measures were performed "blind" by a speech-language pathologist, training for whom was provided. Computerized delivery ensured consistency and precision of timing of treatment content and elimination of prosodic cues, which affect STM.[19] The participants were five persons with stroke-induced chronic aphasia. Background biographical information is presented in Table 3. Their language profiles are presented in Table 4. None of the persons were involved in any other treatment although they all attended social groups for persons with aphasia. The Sunderland NHS Research Ethics Committee gave ethical approval for the study.

The matching listening span tasks were created and delivered with a bespoke computer program.[20] This program was used to assemble digital sound files of individual words (prerecorded in live voice) into pairs of word lists for the matching span tasks. The interword intervals within the lists were set to 1 second, and the interval between the two word lists in each trial was either 1 or 2 seconds, based on the person's preference. These temporal parameters remained constant throughout the treatment. A tablet touchscreen computer with an external mini speaker was used to deliver five pretreatment baselines and also the treatment itself at a volume level comfortable for each person.

Each baseline comprised 20 different word-list pairs. Ten pairs contained words that were in the same order in the two lists. The other 10 contained words that were in a different order, whereby two adjacent words

Table 3 Biographical Information of Participants and Communication Characteristics

	Patient 1	Patient 2	Patient 3	Patient 4	Patient 5
Age	55	60	47	86	68
Gender	M	M	M	M	F
Formal education (y)	12	16	12	8	12
Months since aphasia onset	180	48	8	84	108
Impression of severity (0–5)	2	1	1	3	4
MLU	2	1	1	2	7
Apraxia of speech	Mild	Mild	Moderate	Moderate	Mild

Abbreviation: MLU, mean length of utterance (in words).
Note: Impression of severity is based on the Boston Diagnostic Aphasia Examination aphasia severity rating scale.[33]
Severity of apraxia of speech based on performance in the Apraxia Battery for Adults.[34]

Table 4 Language Profiles of Participants on Subtests of the Comprehensive Aphasia Test[35]

	Patient 1	Patient 2	Patient 3	Patient 4	Patient 5
Word comprehension	100%	100%	93%	93%	100%
Sentence comprehension	56%	50%	44%	82%	50%
Paragraph comprehension	100%	75%	75%	100%	100%
Word repetition	100%	69%	94%	100%	75%
Complex word repetition	100%	67%	67%	100%	100%
Nonword repetition	80%	20%	60%	60%	20%
Sentence repetition	50%	0%	17%	50%	83%
Naming	67%	41%	46%	92%	92%

were transposed in the second list. The same–different ordered pairs were presented in pseudorandom order. The words were monosyllabic, concrete nouns and were matched for frequency.[21] In each word list they were also semantically unrelated to prevent chunking. After listening to each pair, participants had to indicate (verbally or nonverbally) if the two lists were the "same" or "different" by touching a corresponding button on the computer screen placed in front of the person. Examples and practice trials were provided to ensure understanding of the task and consistency of response. The number of words in the list pairs was informed by performance in a digit matching listening span test (Table 5).[15] No feedback on accuracy was provided in the baseline testing.

The treatment sessions began immediately after the baselines. Twenty different word-list pairs were used in each treatment session, with the same temporal parameters as in the baselines. The key difference between baseline and treatment sessions was the inclusion of visual and auditory feedback on persons' response accuracy. If a person's response in each trial was correct, the visual feedback was a smile from a face cartoon (called Memo). In addition, auditory feedback that acknowledged the person's response as correct was also presented simultaneously. If a person's response was incorrect, Memo presented with a neutral expression. The auditory feedback stated that the response was incorrect and the word-list pair was repeated. If after the second presentation the person's response was correct, the visual and audio feedback acknowledging the correct trial was presented (as previously described). If the response was incorrect, the program repeated the word-list pair and the speech-language pathologist (who delivered baseline and treatment sessions) would write down the word list and explain which words had (or not) been in the same order as in the first word list before moving on to the next trial. Level of difficulty

Table 5 STM Abilities Pre- and Posttreatment

	Patient 1	Patient 2	Patient 3	Patient 4	Patient 5
Digits forward—spoken[36]	2–3	2–2	2–3	0–2	4–4
Digits backward—spoken[36]	n.a.	n.a.	n.a.	0–2	2–2
Digits forward—pointing	2–3	4–5	3–3	2–3	4–4
Digits backward—pointing	n.a.	4–5	n.a.	2–2	2–2
Digit matching listening span[15]	3–5	3–4	3–5	5–4	4–4
Words forward—spoken*	2–3	1–1	2–3	2–2	2–3
Visual tapping forward[36]	4–4	5–4	3–3	4–3	4–3
Visual tapping backward[36]	3–3	5–4	2–2	4–3	3–3

Abbreviation: n.a., person not able to attempt task; STM, short-term memory.
Note: First number in each cell refers to pretreatment, second number to posttreatment.
*Monosyllabic words, matched for frequency.

(defined as number of words in word-list pairs) was determined by the person achieving 80% correct (at first attempt) or above on two consecutive training sessions. Level of difficulty increased by one word in the word-list pairs. Participants received a roughly equal number of treatment sessions (27 to 30), delivered either at their homes or at Newcastle University.

Every fourth session, the same speech-language pathologist who delivered the treatment presented control probes. The control probes involved a word span task comprising lists of four disyllabic concrete nouns, which were different from session to session. In each list the words were semantically unrelated to each other and were matched for frequency.[21] The person was required to repeat the words serially.

The outcomes of treatment in terms of STM (near transfer) are shown in Table 5. In summary, very few improvements were found, particularly in the digit matching listening span, which in comparison to the treatment tasks is the closest measure of near transfer effects. Patients 1, 2, and 3 improved either by one or two items. The outcomes in terms of sentence comprehension and psychosocial functioning are shown in Table 6. McNemar chi-square tests (one-tailed) were used to evaluate changes. None of the comparisons showed statistically significant changes (i.e., $p < 0.05$). The Communication Outcome After Stroke (COAST) is a measure of a person's perception of how aphasia affects their psychosocial functioning.[22] The Communication Effectiveness Index (CETI) evaluates spouses' perceptions of the communication skills of the person with aphasia.[23] Ratings in both measures were converted to proportions of percentages. In the case of patient 4, a close friend completed the CETI, and in the case of patient 3, his sister. Chi-square tests (one-tailed) were used to evaluate changes in both COAST and CETI. The only statistically significant change that was found was for person patient 3 in the CETI (chi-square $= 12.5113$, $p = 0.000$). None of the other comparisons were significant. Finally, performance in the control probes (not reported here) showed very minor fluctuations of minus/plus one word in some participants.

To evaluate treatment fidelity all sessions were audio-recorded. A speech-language pathologist who had not been involved in the study carried out the treatment fidelity analyses. A sample of 30% randomly selected treatment sessions for each person was used. The treatment fidelity protocol was informed by recent views on treatment fidelity and comprised two parts.[24] The first part scrutinized the word lists used in terms of word frequency, semantic relatedness of the words comprising the word lists, number of word list and words in each

Table 6 Sentence Comprehension and Psychosocial Measures Pre- and Post-treatment

	Patient 1	Patient 2	Patient 3	Patient 4	Patient 5
TROG[13]					
Pre-treatment	50%	74%	64%	78%	66%
Post-treatment	56%	61%	56%	85%	71%
Token Test[11]					
Pre-treatment	50%	35%~	n.a.	60%	40%
Post-treatment	54%	10%~	n.a.	60%	50%
COAST[22]					
Pre-treatment	39%	49%	42%	39%	46%
Post-treatment	49%	54%	46%	38%	49%
CETI[23]					
Pre-treatment	26%	55%	36%	36%	36%
Post-treatment	32%	58%	61%	35%	46%

Abbreviations: n.a., person not able to attempt task; TROG, Test for Reception of Grammar.
~Only subtests 1 and 2 were attempted (i.e., 20 items).

word list. Consistency in these parts of the protocol was 100% for all categories, apart from the semantic relatedness. This was 78%. The second part scrutinized aspects of the execution of the tasks and consistency of providing feedback (both by the program and speech-language pathologist). Overall consistency in this part was 95%.

DISCUSSION OF ISSUES RAISED BY STM/WM TREATMENT STUDIES

Of the 11 persons discussed in this article and across different STM and a WM treatment, four showed some improvement in sentence comprehension whereas seven did not. We focus on the possible reasons for the lack of improvements, starting from the findings of the replication study.

None of the persons in the current replication improved in sentence comprehension. The hypothesized prediction did not materialize possibly because we did not assess if aspects of phonological or semantic STM were differentially impaired across participants. However, the evidence supporting contrastive distinctions of semantic versus phonological STM and their respective role in sentence comprehension in aphasia is relatively small, particularly for semantic STM. In a study of 20 persons with aphasia where an attempt was made to distinguish phonological and semantic STM deficits, most patients exhibited concurrent semantic and phonological STM deficits, albeit to different degrees of relative severity.[25] The focus of this study was not on sentence comprehension and, consequently, sentence comprehension was not evaluated. This means that a relationship between phonological and semantic STM deficits and sentence comprehension remains unclear. Other studies attempted to characterize the functional impairments of phonological and semantic STM using different criteria from those listed in Table 1.[6,14,26] Such discrepancies make the distinction of phonological and semantic STM nebulous at present, especially in relation to sentence comprehension. Descriptions of persons with mixed profiles of phonological and semantic STM deficits whose sentence comprehension deficits are documented in larger scale studies, and ideally across sentence comprehension tasks and sentence structures to discern task effects,[27] are needed to bolster this important theoretical development in relation to sentence comprehension.

Another possibility for the lack of improvement in our current replication may have to do with the nature of the sentence comprehension deficits themselves. The deficits may not have been uniform across persons despite similar scores in standard tests of sentence comprehension, even in a test that sampled a fairly wide range of syntactic structures.[13] A recent study of sentence comprehension with a focus on syntax in a relatively large sample of persons with aphasia ($n = 61$) found that slow processing in terms of lexical access and syntactic processing as well as increased susceptibility to interference were contributing factors to sentence comprehension.[27] In the new data we presented and the other studies we reviewed, the underlying nature of the sentence comprehension deficit was largely unknown. In fact, there tended to be greater discussion about STM/WM than the nature of the sentence comprehension deficits. A more balanced view is needed. Consequently, future studies of STM/WM training should provide more detailed information about the nature of sentence comprehension deficits, especially in relation to interference control and processing speed. Susceptibility to interference is a mechanism that has been linked to efficient WM capacity in aphasia.[5,25] Similarly, slow processing speed has been shown to be a modifying factor of STM in healthy older adults.[28] It is possible that processing speed modifies STM/WM in aphasia but this hypothesis has not been systematically investigated as yet.

A final point to comment on is the role of STM/WM in relation to established linguistically focused treatments for sentence comprehension that do not involve STM/WM training such as mapping therapy.[29] The implication for persons whose sentence comprehension deficits may stem from (wholly or in part) impaired aspects of STM/WM is that linguistically focused treatments may not be the optimum treatment choice.

The person reported by Harris and colleagues improved in sentence comprehension.[14]

This was based on the hypothesis that semantic STM relates to sentence comprehension. As the authors rightly point out, the person's sentence comprehension may have improved not because of the exposure to the semantic-phonological STM treatment but because of an augmentative effect of the phonological treatment that had been given earlier. In other words, an order effect evoked by the design of the study may have triggered the change rather than the treatment per se. Greater control in study design would need to be exercised in future studies.

Although the present article focused on far transfer effects of STM/WM training on sentence comprehension, we should highlight that treatments did not result in near transfer effects of training on all STM/WM measures across all persons, even in treatments that used STM/WM measures that were very closely related to the treatments tasks.[10,16] Although in some cases authors provided thorough discussion of the expected mechanisms of change,[14] the choice of near transfer measures may not have been the most appropriate. For example, Harris and colleagues assessed repetition of nonwords and words in a nonserial manner, although both treatments focused on serial recall. Overall, there has been relatively little discussion of expected near transfer effects and the specificity of these effects in relation to choice of STM/WM measures. It is important to understand both near and far transfer effects as they both may relate to sentence comprehension.

Another important issue is the psychometric quality of the tests. This relates to both assessment of the nature of STM/WM deficits and outcome measures. A recent systematic review of STM/WM in aphasia research found that only a very limited number of standardized tests had robust psychometric properties.[30] Standardization samples to elicit normative data were often small, and most measures exhibited poor validity and reliability properties. Typically, studies describing the STM/WM abilities of persons with aphasia involve experimental tasks and give little consideration to the psychometric properties of these tasks, especially the issue of reliability of performance.

Although improvements in sentence comprehension were noted in two of the three persons reported by Zakariás and colleagues,[16] one person did not improve. This person's progress in the *n*-back tasks was not as good as the progress reported for the other two persons. Also, the progress trajectory in the *n*-back tasks was different. It could be that more training may have been needed for that person. Another reason could be variation in feedback. It is possible that the agents delivering the treatment may have deviated from the feedback protocol and may not have provided the required feedback. In other studies details on feedback and number of practice attempts have generally been underspecified.[10,14] Future studies should take into account recent developments on more detailed documentation of actual treatment procedures and feedback.[24,31] Homework practice tasks featured in three studies.[9,10,14] Although homework increases the intensity of treatment, and persons involved in treatment studies are often keen to practice at home, unsupervised homework practice can jeopardize procedural fidelity. The researcher would not know if the person practices the task in the intended way.

Repetition of words in the form of sentences and word lists were the basis of treatment in two studies.[10,14] Although both tasks place demands on STM it is unclear at present which of these tasks relates to better chances of improving sentence comprehension. Intuitively, sentence repetition would facilitate transfer to sentence comprehension because of the involvement of event concepts, morphological as well as syntactic processing components that repetition of word lists would not trigger. However, sentence repetition is particularly difficult for persons with aphasia. The choice of the matching listening span task had originally been used to avoid spoken output, which had been difficult for the person in the original study.[9] Comparatively little is known about this task in relation to repetition tasks, especially word span. Because matching listening span does not involve speech output, it may not involve rehearsal.[32] Rehearsal is a mechanism known to boost STM capacity.[7] It is possible that practicing matching listening span tasks may have had an undesired effect, which dampened the ability to rehearse and mitigated retention of the phonological structure of the sentence that could have aided comprehension.

To conclude, the potential for far transfer effects of STM/WM training to sentence comprehension is the exciting and potentially promising aspect of STM/WM treatments. Given the small evidence base, the lack of transfer effects on sentence comprehension does not constitute evidence of absence of these effects. Other treatment paradigms and publications of replicated STM/WM treatments, ideally as case series, even in the absence of null findings are needed, provided the design of studies is of good quality.

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