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Verbal memory and sentence comprehension in aphasia: A case series

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ABSTRACT

This case series explores the relationship between verbal memory capacity and sentence comprehension in four patients with aphasia. Two sentence comprehension tasks showed that two patients, P1 and P2, had impaired syntactic comprehension, whereas P3 and P4's sentence comprehension was intact. The memory assessment tasks showed that P1 and P2 had severely impaired short-term memory, whereas P3 and P4 performed within the normal range in the short-term memory tasks. This finding suggests an association between short-term memory deficit and sentence comprehension difficulties. P1 and P3 exhibited impaired comparable working memory deficits, suggesting a dissociation between working memory and sentence comprehension.

Introduction

Language comprehension is a complex task and several aspects of it utilize verbal memory. One such aspect is the construction of the syntactic structure of an input sentence (parsing) and the use of it to determine its meaning (interpretation). This has been called *syntactically based comprehension* and requires the establishment of relations between sentential constituents that may span several words (Caplan, Michaud, & Hufford, 2013). To illustrate, consider the complex sentence in (1) whose parsing and interpretation requires the retrieval of *The dancer* at the point at which *admired* and *practiced* are encountered.

1. The dancer that the choreographer admired at the audition practiced the routine.

Because the time frame over which comprehension takes place is short, most models postulate that sentence comprehension is supported by Short Term Memory (STM), which refers to the temporary maintenance of information, and Working Memory (WM), which refers to both the maintenance and manipulation of information. These models have placed emphasis on different types of linguistic representations that have to be maintained in order for comprehension to take place. Some models have focused on the importance of the retention of phonological information (Friedrich, Martin, & Kemper, 1985; Papagno, Cecchetto, Reati, & Bello, 2007), whereas others have emphasized the importance of the retention of lexical-semantic information (Martin & He, 2004; Martin & Romani, 1994), or the retention of multiple levels of linguistic representations (Martin & Ayala, 2004; Martin & Saffran, 1997).

Despite the differences regarding the linguistic representations that are maintained during sentence processing, many researchers agree that individual differences in verbal STM/WM play a significant role in sentence comprehension. Specifically, it has been suggested that individuals with high memory capacities, as measured by traditional span tasks, perform better on more resource demanding sentences (e.g. object relative clauses), relative to individuals with low memory capacities, but these two span groups perform similarly on less resource demanding sentences (e.g. subject relative clauses) (for empirical evidence, see Gordon, Hendrick, & Levine, 2002; Just & Carpenter, 1992; Miyake, Carpenter, & Just, 1994). However, a number of neuropsychological results has challenged the view that the comprehension of syntactically complex sentences requires high memory capacities. To illustrate, many studies have shown that patients with Alzheimer's disease are able to understand syntactically complex sentences, despite their severely limited STM (Rochon, Waters, & Caplan, 1994; Waters, Caplan, & Hildebrandt, 1991). The same patients have also exhibited normal on-line sentence parsing, as measured by increases in self-paced listening times at points of increased complexity (Almor, Kempler, MacDonald, Andersen, & Tyler, 1999; Kempler, Almor, & MacDonald, 1998). In addition, studies of people with aphasia (PWA) have revealed dissociations between performance on STM/WM and sentence comprehension tasks, indicating that intact STM/WM functions are not necessary for sentence comprehension and vice versa (Caplan et al., 2013; Friedmann &

Gvion, 2003; Gvion & Friedmann, 2012). Finally, many studies of neurologically intact individuals have shown that individual differences in verbal STM are not correlated with individual differences in on-line measures of sentence processing (Caplan, Dede, Waters, Michaud, & Tripodis, 2011; DeDe, Caplan, Kemtes, & Waters, 2004; Traxler, Morris, & Seely, 2002; Traxler, Williams, Blozis, & Morris, 2005).

To summarize, the data from both neurologically intact individuals and neuropsychological cases are contradictory regarding the role of STM and WM in sentence comprehension. This case series aimed to provide neuropsychological data on this topic by exploring memory capacity and complex sentence comprehension in four chronic stroke patients with aphasia. The logic behind the study was as follows. If STM and/or WM supports syntactically based comprehension, then the PWA with limited STM and/or WM should exhibit impaired sentence comprehension. Conversely, if STM and WM functions and sentence comprehension are unrelated, then dissociations between STM/WM and comprehension performance should be observed. A dissociation was considered to be present if a patient with impaired sentence comprehension performed within the normal range on the STM and/or WM tests, or vice versa. In order to explore the neural correlates of the associations or dissociations observed, the PWA's MRI scans were analyzed and an estimation of lesions' volume was calculated. Neuropsychological and neuroimaging research suggests that multiple regions of the left hemisphere are involved in both sentence comprehension (Caplan, Waters, DeDe, Michaud, & Reddy, 2007; Pettigrew & Hillis, 2014; Thothathiri, Kimberg, & Schwartz, 2012) and STM/WM, including the supramarginal gyrus (Race, Ochfeld, Leigh, & Hillis, 2012), Broca's area (Romero, Walsh, & Papagno, 2006), dorsolateral prefrontal area (Race et al., 2012), superior temporal gyrus (Leff et al., 2009) and angular gyrus (Baldo, Katseff, & Dronkers, 2012). We therefore hypothesized that damage to this network may be associated with both short and/or working memory and sentence comprehension deficits. We further hypothesized that patients with the highest volumes of ischemia will generally exhibit the worst performance. We did not have a specific hypothesis regarding the neural correlates of any observed associations and/or dissociations.

Methods

Participants

Four Greek-speaking chronic PWA due to stroke participated in the study. All participants were males, (premorbidly) right-handed, with normal or corrected-to-normal vision. They had an average age of 55 years (range: 42–62 years) and an average of 13 years of education (range: 12–16 years). They were diagnosed as having aphasia by the second author on the basis of their performance on the Greek version of the Boston Diagnostic Aphasia Examination – Short Form (BDAE-SF; Goodglass & Kaplan, 1972; adapted in Greek by Tsapkini, Vlahou, & Potagas, 2009). They all presented non-fluent and effortful speech output. Nevertheless, their performance on the Automatized Sequences BDAE-SF subtest suggests no dysarthria; they were able to recite the days of the week and count to 21, with only minor errors in counting for P1 and P3. Single-word repetition was moderately impaired in P1 and P3, whereas P2 and P4 exhibited normal performance. P4 also exhibited intact responsive naming, that is he responded accurately to questions like *What do we tell time with?*, whereas the other three patients presented moderate impairments. P4 exhibited intact naming abilities, as revealed by his performance on the Boston Naming Test (BNT), whereas the other three patients presented moderate naming difficulties. Finally, all patients' single-word comprehension was intact; they were able to point to pictures corresponding to spoken words accurately and fast. Table 1 presents demographic data along with scores on initial language assessment of the PWA that participated in this study.

The PWA's MRI scans were obtained on a Philips 3T scanner. Scans were analyzed without knowledge of language and memory assessment results. Chronic ischemic lesions were outlined semi-automatically on axial FLAIR sequences using MRICron (Rorden, Karnath, & Bonilha, 2007). Manual outlining was followed by intensity threshold yielding two-dimensional lesion maps. Three-dimensional (3D) models were built from those lesion maps using the Model Maker Module (Joint Smoothing, 5 iterations, Sinc Filter, Split Normals, 0.25 decimation) in 3D slicer version 4.6.2 (Fedorov et al., 2012). Each patient's T1 was co-registered to the Montreal Neurological Institute (MNI) template using a six-dimension affine registration. The resulting transform matrices were used to co-register the abovementioned 3D models to the MNI template. The visual representation of the 3D lesions was superimposed on the 3D reconstruction of the cortex surface under the MNI template.

P1 had chronic infarct involving the left temporal lobe, the insula, the foot of the third frontal convolution, the posterior internal capsule, the external capsule, and a large portion of the parietal lobe (including supramarginalis and angular gyri). P2 had chronic infarct involving the left temporal pole, the inferior superior and middle temporal gyri, the inferior frontal gyrus, part of the angular gyrus, supramarginal gyrus as well as part of the lobule parietalis superior. P3 had chronic infarct involving the insula, the dorsolateral prefontal cortex, the inferior frontal gyrus, the external capsule and the most superior part of the superior temporal gyrus. P3 had chronic left infarct involving the left insular cortex, external capsule, inferior frontal gyrus

Table 1. PWA's demographic and background language assessment data.

	Non-fluent PWA			
	P1	P2	P3	P4
Age	42	58	62	59
Years of education	14	12	16	12
Time post onset (years)	4.1	5.5	0.6	4.8
Hemiplegia	Right	No	No	No
Auditory comprehension – BDAE-SF				
Word comprehension (16)	15.5	15.5	16	15.5
Oral expression – BDAE-SF				
Automatized sequences (4)	3	4	3	4
Single word repetition (5)	3	5	3	5
Responsive naming (10)	6	4	5	10
BNT (45)	25	28	30	43
Words per minute	13.32	12.00	16.78	22.63

and posterior part of the dorsolateral prefrontal cortex. Individual patient lesions along with lesion volumes are shown in Figure 1.

Neurologically intact adults also participated in the study as controls. Those that participated in the two language tasks performed at ceiling (i.e., 100% accuracy) and therefore their data are not discussed here. The healthy adults (n = 10, four males) that participated in the memory tasks had an average age of 48 years (range: 40–57 years) and an average of 14 years of education (range: 12–17). Any human data included in this paper was obtained in compliance with the regulations of the Eginition Hospital ethics committee.

Procedure

All participants were administered a battery of tasks whose aim was to assess their language and memory abilities. In order to be able to control for task effects, sentence comprehension was assessed in two different tasks, namely a sentence-picture matching task and a truth-value judgment task (see Caplan et al., 2007 for a discussion about dissociations of performance on specific sentence types over tasks in aphasia). PWA completed testing in three sessions with each session lasting roughly 1 hour. Testing took place in a quiet room, after participants gave informed consent.

STM and WM span tasks

Six memory tests were administered. Four were simple tests of immediate serial recall assessing STM: 2-syllable word span; 4-syllable word span; 2-syllable nonword span; forward digit span. Two tests required both retention and manipulation of items: digit ordering; backwards digit span.

The procedure for the word and nonword span tasks was the same: participants heard a series of unrelated words and nonwords at the rate of one word per minute and asked to

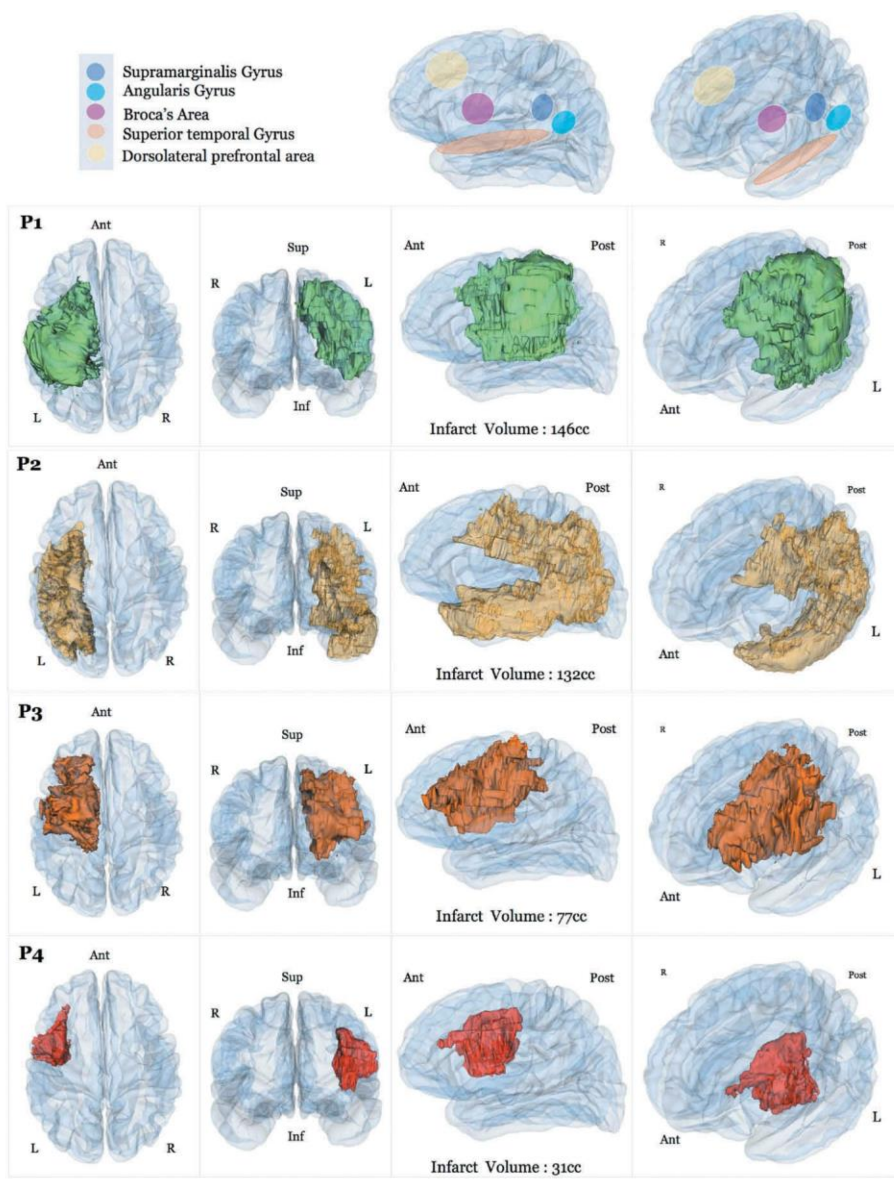

Figure 1. Reconstruction of patient's chronic ischemic lesions depicted on 3 dimensional transparent templates of cortical surface using (each row, left to right) superior, anterior, left lateral and left cranial oblique angles.

report them back in the same order. There were five difficulty levels (2, 3, 4, 5 and 6 word sequences) with five sequences each. The words included in the 2-syllable and 4-syllable word span tasks were selected from a larger pool of words on the basis of ratings on imageability made by 29 neurologically intact Greek speakers. The statistical comparison (Cumulative Link Mixed Model fitted with the Laplace approximation) showed that the two lists were matched in imageability ($z = -0.029$, $p = .98$), which was high across lists. Nonwords differed from 2-syllable words by a single phoneme.

The procedure for the tasks including digits was as follows: sequences of digits were verbally presented at the rate of one digit per second and participants were instructed to report them back in the same order for the forward span task, in ascending order for the digit ordering task, and in backwards order for the backwards digit span task. Participants responded by pointing to a written 1–9 digit list provided on individual note cards.

Performance of each individual patient in the WM tasks was compared to the performance of the control group using Crawford and Howell t-test. This test addresses the question whether or not a patient exhibits a statistically significant deficit (Crawford & Howell, 1998). For the control group, paired *t*-tests were used to compare conditions and check for length and lexicality effects. The small number of participants in the patients groups did not allow for group comparisons. Finally, because of the differences in response mode between (non)word- and digit-based tasks (i.e., verbal response versus digit pointing), we could not calculate composite scores for STM and WM capacity.

Sentence-picture matching task

In the sentence-picture matching task, participants saw two pictures on a computer screen, while simultaneously hearing a sentence. Participants pressed a key to indicate which of the two pictures matched the sentence. This task contained 40 trials, with 10 sentences in each of the following categories: active (e.g. *The boy is chasing the girl*), passive (e.g. *The girl is chased by the boy*), center embedded subject relative (e.g. *The boy who is kicking the man has black hair*) and center embedded object relative (e.g. *The boy who the man is kicking has black hair*). All sentences were semantically reversible (i.e., the foil picture depicted reversed thematic roles – in case of relative clauses, both the boy and the man had black hair). There were an equal number of left-to-right and right-to-left action depictions.

Truth-value judgment/sentence verification task

In this task participants saw one picture on a computer screen, while simultaneously hearing a sentence. Participants pressed a key to indicate whether the picture correctly depicted the sentence or not. This task contained 80 trials, with the same sentences used in the sentence-picture matching task. In half of the trials, sentences were paired with matching pictures, whereas in the other half they were paired with mismatching pictures (i.e. foil sentences depicting reversed thematic roles). There were an equal number of left-to-right and right-to-left action depictions.

Results

STM and WM measures

Participants' performance on the STM and WM tasks is presented in Table 2. For the control group, the average span for two-syllable words was 4.5 (range 4–5), for four-syllable words 3.6 (range 3–5) and for nonwords 2.8 (range 2–4). To test for a length effect, the span obtained in the two-syllable span task was compared to that obtained in the four-syllable span task. This comparison revealed that short words were recalled significantly better than long words ($t(9) = 4.07$, $p < 0.01$). To test for a lexicality effect, the span obtained in the two-syllable span task was compared to that obtained in the nonword span task. Words were recalled better than nonwords, however the difference between the two tasks did not reach statistical significance ($p > 0.05$).

Overall, PWA exhibited lower performance on the STM and WM tasks compared to controls. Their forward digit span was smaller than that of the control group, however the difference did not reach statistical significance for any of them. As for word and nonword span tasks, two patterns were observed. P1 and P2 exhibited significantly smaller word and nonword span than controls, whereas P3 and P4's performance on the 4-syllable word span and nonword span did not significantly differ from that of controls. P3 and P4's 2-syllable word span, although significantly smaller than that of controls, was higher than that of P1 and P2. All PWA evinced a lexicality effect; their performance on the two-syllable word span task was better than their performance on the nonword span task. P1 also presented a length effect; his performance on the two-syllable word span task was better compared to the four-syllable word span task. WM measures revealed that PWA performed significantly worse than controls in the digit ordering task, whereas

Table 2. Recall spans of individual PWA compared with the age and education matched controls.

	Control sample (n = 10)		P1			P2			P3			P4		
Task	Mean	*SD*	Score	*t*	*p*	Score	*t*	*p*	Score	*t*	*p*	Score	*t*	*p*
STM measures														
2-syllable word span	4.5	0.47	2.0	−5.07	0.001	2.0	−5.07	0.001	3.0	−3.04	0.01	3.0	−3.04	0.01
4-syllable word span	3.6	0.70	0.5	−4.22	0.002	2.0	−2.17	0.05	3.0	−0.81	0.43	3.0	−0.81	0.43
2-syllable nonword span	2.8	0.59	0.0	−4.52	0.001	0.0	−4.52	0.001	2.0	−1.29	0.22	2.0	−1.29	0.22
Digit span – forward	6.1	1.29	4.0	−1.55	0.15	5.0	−0.81	0.43	4.5	−1.18	0.26	4.0	−1.55	0.15
WM measures														
Digit ordering	5.9	0.32	4.0	−5.66	0.000	5.0	−2.68	0.02	4.5	−4.17	0.002	4.0	−5.66	0.000
Digit span – backwards	4.7	1.16	2.0	−2.21	0.05	3.0	−1.39	0.19	2.5	−1.80	0.05	4.0	−0.57	0.57

P1 and P3 also exhibited significantly smaller backwards digit span (the difference did not reach significance for P2 and P4).

Syntactic comprehension measures

As shown in Table 3, P1 and P2 exhibited impaired syntactic comprehension; their comprehension of syntactically complex sentences was roughly at chance level in both sentence-picture matching (SPM) and truth-value judgment (TVJ) tasks. On the other hand, P3 and P4 performed well above chance across conditions and tasks.

Discussion

The aim of this case series was to look for theoretically interesting associations and/or dissociations between verbal memory capacity and sentence comprehension in PWA. In line with memory capacity accounts of sentence comprehension, we hypothesized that if STM and/or WM support syntactic comprehension, then (a) the PWA with limited STM and/or WM should exhibit impaired sentence comprehension, and (b) no sentence comprehension difficulties should appear in the PWA with intact STM and/or WM. To explore this hypothesis, we developed two sentence comprehension tasks and a series of STM and WM tests which were administered to four Greek-speaking PWA. Despite the limited number of participants, our results showed a STM-sentence comprehension association and a WM-sentence comprehension dissociation. Both are discussed in the following paragraphs in light of previous relevant studies.

With regards to sentence comprehension, P1 and P2 presented the typical profile of the non-fluent PWA and agrammatism: their comprehension of syntactically complex sentences (i.e., passives and object relative clauses) was impaired, performing roughly at chance level in both sentence-picture matching and truth-value judgment tasks. In contrast, P3 and P4 exhibited intact syntactic comprehension across conditions in both tasks. Considering their memory capacity, P1 and P2 exhibited severely impaired STM, as revealed by the word and non-word span tasks. Their performance on the forward digit span task did not statistically differ from that of controls. However, we suggest that this cannot be interpreted as intact recall of item and order information. We rather attribute this performance pattern to the fact that in this task the response mode for the PWA was digit pointing which might have helped them to encode the digit lists spatially. P3 and P4, on the other hand, exhibited relatively preserved STM. The only task in which they presented significantly lower performance than controls was the 2-syllable word span task. Note that their performance in this task was higher than that of P1 and P2 though. Taken together, these results seem to suggest that P1's and P2's sentence comprehension deficits are somehow associated with their STM deficit. A similar association has been reported by Wilson and Baddeley (1993). In their case study, a patient with limited digit span exhibited impaired comprehension of long sentences. When retested after years, the same patient exhibited normal digit span and sentence comprehension. In a more recent study, Thothathiri and Mauro (2018) also reported a patient with impaired STM and sentence comprehension deficits.

To the best of our knowledge, the vast majority of previous studies that explore the association between STM and sentence comprehension in aphasia, including both case series and large scale studies, either do not report lesion data (e.g., Bartha & Benke, 2003; Caplan et al., 2013; Friedmann & Gvion, 2007; Ivanova & Hallowell, 2012; Martin, 1987; McCarthy & Warrington, 1987a, 1987b; Sung et al., 2009) or do not discuss lesion data in relation to STM and/or sentence comprehension deficits (e.g., Caramazza, Basili, Koller, & Berndt, 1981; Martin & Feher, 1990; Martin & He, 2004; Vallar & Baddeley, 1984; Wright, Downey, Gravier, Love, & Shapiro, 2007; Zakariás, Keresztes, Marton, & Wartenburger, 2016). The only study that approaches the relationship between STM and sentence comprehension from a lesion-based perspective is a recent study by Pettigrew and Hillis (2014). Specifically, they explored memory capacity and sentence comprehension in acute stroke patients with aphasia. They also analyzed their MRI scans for lesions in the STM/WM network. Their results indicate an association between damage to the STM/WM network and impaired comprehension of syntac- tically complex sentences. They also report that STM is a significant predictor of syntactic comprehension. Our study is of course limited by the small number of partici- pants, but may still contribute to this topic by providing supporting data from chronic patients with aphasia. We will, therefore, attempt a brief speculation on the lesion substrate of the observed deficits. P1 and P2 had massive lesions affecting posterior regions, including the posterior parietal cortex and the superior temporal gyrus, although leaving prefrontal areas relatively spared. P3 and P4 had lesions affecting such anterior regions, including the dor- solateral prefrontal cortex. Evidence from brain imaging studies support the notion that the posterior parietal cor- tex and the dorsolateral prefrontal cortex are involved in information manipulation and monitoring respectively (Champod & Petrides, 2007, 2010), and thus can be con- sidered as fundamental neural correlates of WM. On the other hand, STM has been linked to temporal cortices by several studies (Leff et al., 2009; for a review, see also Petrides, 2015). In this context, the presence of WM deficits could be attributed to damage to dorsolateral frontal regions and/or posterior parietal cortices, evident in all patients. However, only P1 and P2 had lesions that severely affected temporal areas, which have been associated with STM. Moreover, their lesions included the

Table 3. Proportions of correct responses in comprehension of syntactically complex sentences.

	Non-fluent PWA			
	P1	P2	P3	P4
Sentence-picture matching				
actives	0.85	0.90	0.90	0.95
passives	0.40	0.30	0.90	0.80
subject relative clauses	0.10	1.00	0.90	0.90
object relative clauses	0.40	0.30	0.90	0.90
Truth value judgment				
passives	0.45	0.55	0.90	0.95
subject relative clauses	0.50	0.55	0.90	0.80
object-relative clauses	0.40	0.45	0.90	0.80

superior temporal gyrus, which has been suggested to be a common neural substrate for short-term memory and speech comprehension (Leff et al., 2009). Based on the above, the observed association could be lesion-based, meaning that damage to the superior temporal gyrus could be crucially detrimental for both STM and sentence comprehension. In any case, specific lesion-deficit associations are beyond the scope of this study, since our focus is on the associations derived from behavioral findings and not imaging data.

Apart from lesion-based, the observed association between STM and sentence comprehension may be functional, in the sense that STM directly supports sentence comprehension. This support can be interpreted in two ways. The first interpretation is that STM plays a role in the assignment of linguistic structure and the use of that structure to determine meaning (i.e., role in parsing and interpretation). The second interpretation is that STM supports the use of the products of those processes to perform a task (i.e., post-interpretive role). To disentangle the two roles, one should investigate real-time sentence processing using online paradigms such as self-paced listening and eye tracking measures. Such techniques will allow us to explore whether and how individual differences in STM capacity affect online measures at points of cognitive load when processing syntactically complex sentences and how this interacts with end-of-sentence accuracy measures (for a similar discussion, also see Caplan et al., 2013; Pettigrew & Hillis, 2014) (Thothathiri & Mauro, 2018).

One problem with accepting the association between STM and sentence comprehension observed in P1 and P2's data as true without any further discussion is that this association could be driven by independent deficits to other linguistic factors that might interact with STM and/or sentence processing in a number of ways. Such a factor is lexical-semantic access. That is, P1 and P2's low performance on word and nonword span tasks could be attributed to impairment in accessing stored lexical-semantic information for words. The fact that P1 and P2 performed better in the forward digit span task could actually provide further evidence towards this hypothesis, given that digits have more constrained semantic representations. To rule out this possibility, we looked at PWA's scores on several BDAE-SF subtests: word comprehension, responsive naming, Boston Naming Task (BNT), and picture-word matching. These subtests were hypothesized to measure aspects of lexical-semantic processing, not redundant with STM and/or sentence comprehension. We found that all participants exhibited a similar performance pattern in these subtests, except BNT where P4 perform almost at ceiling. This provides at least preliminary support for the notion that P1 and P2's deficits in word and nonword span tasks are due to a deficit in the maintenance of verbal representations, rather than deficits in lexical-semantic processing per se.

Another factor that could affect participants' performance on the STM tasks is verbal fluency and/or dysarthria, given that words and nonwords span tasks, contrary to digit span tasks, required verbatim recall. To rule out the possibility of dysarthria being a confound, we looked at participants' performance on the BDAE-SF automatized sequences subtest. P2 and P4 performed at ceiling, whereas P1 and P3 exhibited only mild difficulties. As for their fluency, the two agrammatic participants (i.e., P1 and P2) produced the least words per minute. In general, assessing patients with aphasia with STM/WM tasks that require a verbal response could raise problems, in the sense that limited speech fluency could serve as a confound, and thus provide misleading results. In other words, a low score on an STM/WM task could be due to the inability of the patient to produce speech. Previous studies have attempted to resolve this issue by imple- menting specific exclusion criteria, such as minimum score on a word repetition task (e.g., Kasselimis et al., 2013; Potagas, Kasselimis, & Evdokimidis, 2011). In our study, this criterion was met, since all patients were able to repeat at least 3 single words. In addition, performance between the two subgroups (P1 & P2 vs. P3 & P4) in the repetition task was comparable. The fact that performance on the forward digit span task was similar across patients could be considered an indication of fluency involvement in the STM/WM tasks that required a verbal response. Although we cannot rule out the possibility that reduced span is due to slow rate of articulation, the fact that P3 exhibited a large difference in words per minute from P4 without differing in span tasks suggests that P1 and P2's low performance on word and nonword span tasks is (at least partially) due to STM limitations. Moreover, we argue that the STM/WM tasks that are used in our study may pose differential cognitive demands. For example, the sin- gle word repetition BDAE subscale was used simply as part of background clinical testing and not as a strong indicator of STM capacity. On the other hand, the forward digit span task is interpreted as an index of verbal STM, but it may require limited cognitive resources compared to the word and nonword spans. This notion is further supported by a recent study by Ivanova, Kuptsova, and Dronkers (2017), which showed that there are discrepan- cies between performances of patients with aphasia in different tasks that are thought to engage STM/WM. Interestingly, the authors report different patterns of asso- ciations between the various memory tasks used and measures of language comprehension.

With regards to the relationship between WM and sentence comprehension, we found a clear dissociation: P3 presented intact sentence comprehension despite his WM impairments that were very similar to that of P1 who had difficulties in sentence comprehension. A less clear dissociation was observed in P2 data: his performance on at least one WM task was close to normal in the presence of impaired sentence comprehension. These results seem to suggest that, at least for these patients, WM contributes only minimally in sentence comprehension, in the sense that WM deficits do not necessarily result in comprehension deficits, as in P3, and, on the other hand, relatively preserved WM does not necessarily guarantee intact comprehension, as in P2. This is against the main finding of work with neurologically intact adults showing an association between WM and end-of-sentence comprehension measures (e.g., Caplan & Waters, 2005; DeDe et al., 2004). It is also against the idea that WM deficit can be extended to account for sentence comprehension deficits in aphasia (Miyake et al., 1994). However, similar dissociations have been reported in the aphasia literature (see, Caplan et al., 2013; Pettigrew & Hillis, 2014).

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