

# It's either a cook or a baker: Patients with conduction aphasia get the gist but lose the trace

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## Abstract

Patients with conduction aphasia have been characterized as having a short-term memory deficit that leads to relative difficulty on span and repetition tasks. It has also been observed that these same patients often get the gist of what is said to them, even if they are unable to repeat the information verbatim. To study this phenomenon experimentally, patients with conduction aphasia and left hemisphere-injured controls were tested on a repetition recognition task that required them to listen to a sentence and immediately point to one of three sentences that matched it. On some trials, the distractor sentences contained substituted words that were semantically-related to the target, and on other trials, the distractor sentences contained semantically-distinct words. Patients with conduction aphasia and controls performed well on the latter condition, when distractors were semantically-distinct. However, when the distractor sentences were semantically-related, the patients with conduction aphasia were impaired at identifying the target sentence, suggesting that these patients could not rely on the verbatim trace. To further understand these results, we also tested elderly controls on the same task, except that a delay was introduced between study and test. Like the patients with conduction aphasia, the elderly controls were worse at identifying target sentences when there were semantically-related distractors. Taken together, these results suggest that patients with conduction aphasia rely on non-phonologic cues, such as lexical-semantics, to support their short-term memory, just as normal participants must do in long-term memory tasks when the phonological trace is no longer present.

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## 1. Introduction

The syndrome of conduction aphasia was first described by Wernicke (1874/1977) after seeing two patients who had relatively good comprehension but paraphasic speech and anomia. Wernicke (1906/1977) later included the symptom of impaired repetition when discussing his revised concept of conduction aphasia:

“Most important of these [criteria for conduction aphasia] are inability to mimic and disintegration or loss of

the word-concept... this form of aphasia results from disruption of the tract which is involved in mimicry of the sounds of words heard (pp. 230–231).”

Since then, repetition deficits have been considered a hallmark of conduction aphasia, along with paraphasic speech and relatively spared comprehension (Goodglass, 1992; Kohler, Bartels, Herrmann, Dittmann, & Wallech, 1998). Numerous studies have attempted to characterize the boundaries of the repetition deficit, but the task demands often require overt repetition, which is problematic in patients who make paraphasic errors. To address this, some studies have utilized pointing responses, so that patients respond by pointing to a series of digits, words,

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etc., rather than having to overtly repeat them (e.g., Tzortzis & Albert, 1974). Regardless of the response employed, patients with conduction aphasia have been shown to have a repetition deficit, suggesting that theirs is a difficulty in processing auditory–verbal information, not simply an output deficit.

Based on such data, it has been suggested that patients with conduction aphasia, or some subset of them, suffer from a type of auditory–verbal short-term memory deficit (Caramazza, Basili, Koller, & Berndt, 1981; Shallice & Warrington, 1977; Warrington, Logue, & Pratt, 1971; Warrington & Shallice, 1969). This deficit has been attributed to a disruption of what Baddeley has termed the *phonological store* (Baddeley & Hitch, 1974, 1994; Vallar & Baddeley, 1984a, 1984b). In Baddeley's model, the phonological store is a mechanism that holds on to an auditory–verbal stimulus very briefly. In order for this information to be maintained in short-term memory, it must be rehearsed (known as *articulatory rehearsal*). If the phonological trace is not intact, the information cannot be rehearsed, and thus patients have difficulty holding onto and repeating auditory–verbal information (Baldo & Dronkers, 2006).

It has been noted that while patients with conduction aphasia are indeed significantly impaired on repetition and other short-term memory tasks, they often retain the gist of what is said to them (Saffran & Marin, 1975). For example, in an attempt to repeat the sentence *The pastry cook was elated*, one of our patients with conduction aphasia responded, *Something about a happy baker* (Dronkers, Redfern, & Ludy, 1998). This patient apparently lost the verbatim information but comprehended the meaning. How is this possible? We propose that this effect is mediated by a lexical-semantic route that does not rely on the auditory–verbal trace. Similar ideas have been put forward previously, suggesting that representations other than purely phonologic codes are activated in short-term memory (Freedman & Martin, 2001; Katz & Goodglass, 1990; Martin & Saffran, 1997; Martin, Saffran, & Dell, 1996; Martin, Shelton, & Yaffee, 1994; Potter, 1993; Saffran & Marin, 1975; Shallice & Warrington, 1970). Even Wernicke's (1906) models predicted the existence of an indirect semantic route via the *concept center*. We would suggest that this same semantic route is activated in the short-term in normal participants, but the more precise phonological trace is relied upon for immediate repetition. Only when the phonological trace is no longer available (i.e., in long-term retrieval) do normal participants have to rely on a more gist-like reconstruction of the information. Patients with conduction aphasia, on the other hand, are forced to rely on this less-than-exact form even in the short-term, due to the degradation of the phonological trace.

To test this idea experimentally, we employed a repetition recognition procedure, in which patients with conduction aphasia and neurologic controls were presented with a series of sentences. After they heard each sentence, patients were shown three written sentences that differed by only a single word and asked to point to the matching one. On

some of the trials, the target sentence was semantically-distinct from the other two distractor sentences. On other trials, the target sentence was semantically-related to the other sentences. It was predicted that patients with conduction aphasia would only be impaired when the distractor sentences were similar to the target, since they would not be able to rely on the lexical-semantics (or gist) of the sentence to identify it. To further investigate the basis for this effect, we also tested normal elderly participants on the same stimuli, with a 10-min delay between presentation of the sentences and test. It was predicted that this group would perform like patients with conduction aphasia, since the delay would force them to rely on long-term, lexical-semantic memory rather than the phonological trace (Baddeley, 1966; Baddeley & Ecob, 1970). That is, they were also predicted to perform poorly when differentiating target sentences from semantically-related distractors, since the verbatim information would no longer be available.

## 2. Methods

### 2.1. Participants

Fourteen patients who suffered a single, left hemisphere (LH) middle cerebral artery stroke participated in the current study. Patients were selected from a large pool of patients at the Center for Aphasia and Related Disorders, VA Northern California Health Care System (VANCHCS), based on the following criteria: Native English speakers in the chronic phase of stroke (>12 months post-onset) with no premorbid history of psychiatric illness, dementia, or neurologic illness. From this pool, seven patients with conduction aphasia (two female and five male) were identified who were available for testing. The diagnosis of conduction aphasia was made based on the Western Aphasia Battery around the time of testing (WAB; Kertesz, 1982). This diagnosis is made in patients with fluent aphasia who have relatively good comprehension (70–100% correct on the WAB) and relatively poor repetition (0–69% correct; see Table 1 for patient characterization). Spontaneous naming deficits in this group included a mixture of phonemic and semantic paraphasias, both within and across patients. A group of seven age- and education-matched LH patients with mild aphasia (two female and five male) who met the above criteria and were available for testing were tested as controls. These patients had mild aphasic symptoms, which consisted of word-finding difficulties and modestly reduced fluency (see Table 1). All patients were right-handed, except for two left-handed patients with conduction aphasia, but these patients' data were not anomalous. Patients with conduction aphasia and LH controls did not differ in terms of age, Mann–Whitney  $U = 19$ ,  $p = .54$ , education,  $U = 21.5$ ,  $p = .71$ , or months post-stroke,  $U = 12$ ,  $p = .13$ .

Overlays of patients' lesions from each group are shown in Fig. 1, reconstructed from CT and MRI scans acquired around the time of testing and imaged in MNI space using

Table 1  
Patient Characterization

	Lesion site	Gender	Age	Educ. (years)	Aphasia type	AQ	Rep.	Naming	Comp.	Digit span	Word span	Similar cond.
<i>Conduction aphasia</i>												
1063	TP	M	58	14	CA	75	56	72	78	2	2	43
0806	FTP	M	76	14	CA	40	9	2	70	0	0	35
0951	FTP	M	67	20	CA	74	64	78	74	3	2	87
1138	FP	M	72	17	CA	65	16	68	80	2	1	48
1133	FT	F	56	14	CA	70	56	76	90	3	1	56
1015	FTP	F	58	18	CA	67	49	80	84	2	2	52
1137	TP	M	64	12	CA	73	51	83	89	—	—	87
<i>LH controls</i>												
0743	F	M	61	11	WNL	98	100	61	86	5	4	96
0896	TP	M	64	16	WNL	98	92	96	100	6	4	100
0716	SP	M	61	16	Anomic	84	92	74	86	4	4	92
1064	S	M	83	12	Unclass	92	91	93	100	7	5	100
1018	S	F	58	17	WNL	99	98	99	100	6	5	96
1097	FP	M	55	15	WNL	97	100	93	100	7	5	100
0997	S	F	56	17	WNL	97	100	97	100	5	5	100

Notes. CA, conduction aphasia; T, temporal; F, frontal; P, parietal; S, subcortical; AQ, aphasia quotient (out of 100); WNL, within normal limits on WAB; Unclass, unclassifiable on the WAB; Rep., WAB repetition percentage (out of 100); Naming, WAB naming percentage; Comp., WAB comprehension percentage; —, data not available. Similar cond. refers to performance (percent correct) on the semantically-similar condition of the experimental repetition recognition task.

Matlab software. A summary of lesion sites is provided in Table 1. The patients with conduction aphasia generally had more posterior lesions that overlapped in the superior temporal gyrus and inferior parietal cortex, but lesions also extended anteriorly in some cases. The LH controls' lesions were widely distributed with no common area of overlap.

Seven normal age- and education-matched elderly participants (two female and five male) were also tested. They were recruited from the control participant pool at the VANCHCS. All elderly controls were right-handed, reported English as their first language, and were screened for history of psychiatric illness, dementia, and neurologic illness.

All participants read and signed consent forms prior to research participation. The study was approved by the Institutional Review Board at the VANCHCS and was in compliance with the Helsinki Declaration for treatment of human research participants.

2.2. Materials and procedures

Patients' speech and language status was assessed with the Western Aphasia Battery (WAB). The WAB consists of a series of subtests that separately measure a range of abilities, including speech fluency, comprehension, repeti-

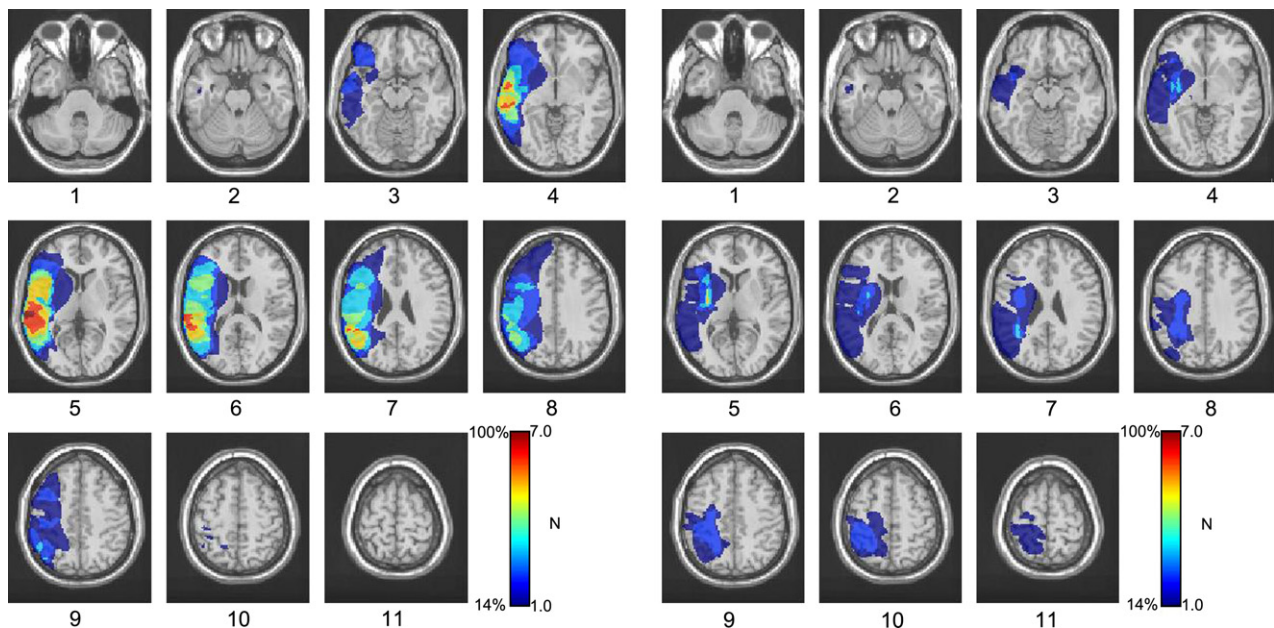


Fig. 1. Lesion overlays of patients with conduction aphasia (left) and LH controls (right). Color bar at right shows degree of lesion overlap across patients.

tion, and naming. The repetition subtest from the WAB was used as a measure of overt repetition ability to correlate with performance on the experimental measure. It consists of both single word and sentence repetition. In addition, digit span and word span were tested using an in-house measure of repetition. Span was scored as the longest string of digits or words the patient could repeat, given two trials at each length (see Table 1).

Patients were also administered an experimental repetition recognition test in a separate session that included other testing. The repetition recognition test included 32 declarative sentences that were read aloud by the examiner. Following each sentence, a page was presented with three sentences written in a large black font, and participants were asked to point to the sentence they had just heard. On two-thirds of the trials, the three sentences included the target sentence (e.g., *The van was dirty*) and two distractor sentences that differed by a single, semantically-related word (e.g., *The truck was dirty* and *The van was messy*). The related word was either a synonym (e.g., *cook* for *chef*) or a categorically-related associate (e.g., *clock* for *watch*). On the other trials, the three sentences included the target sentence (e.g., *The prize was hidden*) and two distractor sentences that differed by a single, semantically-distinct word (e.g., *The prize was ugly* and *The lane was hidden*). The substituted words in this control condition still created meaningful sentences. Thus, both the experimental and control conditions had distractor sentences that differed by a single word, but only in the control condition was the substituted word unrelated to the target. In both conditions, the substituted word came from the same word class (i.e., noun, adjective, etc.).

The sentences in the two conditions were matched for number of words (both mean = 5.6 words/sentence). An independent group of five neurologically normal adults rated the target sentences for imageability and familiarity on a scale from 1 to 5 (five being very imageable/familiar). The sentences in the related and the distinct sentence conditions were rated as being high on imageability (4.1 vs. 4.4, respectively) and familiarity (4.2 vs. 4.2), and did not differ significantly,  $ps > .10$ .

The procedure differed for the elderly control participants. The target sentences were all read in succession by the examiner, without any explicit instructions to remember the sentences for later. Next, they were administered a filler task for approximately 10 min that involved making decisions about pictures. Following the filler task, the elderly controls were presented with the target and distractor sentences in the booklet and asked to point to the target sentence that they had heard 10 min previously. They were told to guess if they could not remember the sentence.

Performance for all participants was calculated as percent correct in the two different conditions, semantically-similar versus semantically-distinct distractor sentences. Chance performance was 33.3% correct.

#### 4. Results

Performance of patients with conduction aphasia (CA) and LH controls on the repetition recognition task was analyzed with two-tailed Mann–Whitney  $U$ -tests for non-parametric data. As predicted, patients with conduction aphasia and LH controls did not differ in their ability to identify target sentences with distinct distractors (94.7% vs. 100%, respectively),  $U = 17.5$ ,  $p = .38$ . However, patients with conduction aphasia were significantly worse than LH controls at identifying target sentences with semantically-similar distractors (58.3% vs. 97.7% correct, respectively),  $U = 0$ ,  $p = .001$  (see Fig. 2). A related samples test (Wilcoxon Signed Ranks test) comparing only the CA patients' performance on the two conditions also revealed significantly poorer performance on the similar condition relative to the distinct distractor condition,  $Z = -2.37$ ,  $p = .02$ . These results suggest that patients with conduction aphasia are poor at immediate recognition when the information is semantically confusable. Importantly, the same patients were not impaired on sentences when the substituted word was semantically-distinct, so that basic reading or hearing deficits could not explain their impaired performance.

In order to determine whether performance on the repetition recognition task was related to spoken repetition, a Pearson product-moment correlation was used to assess

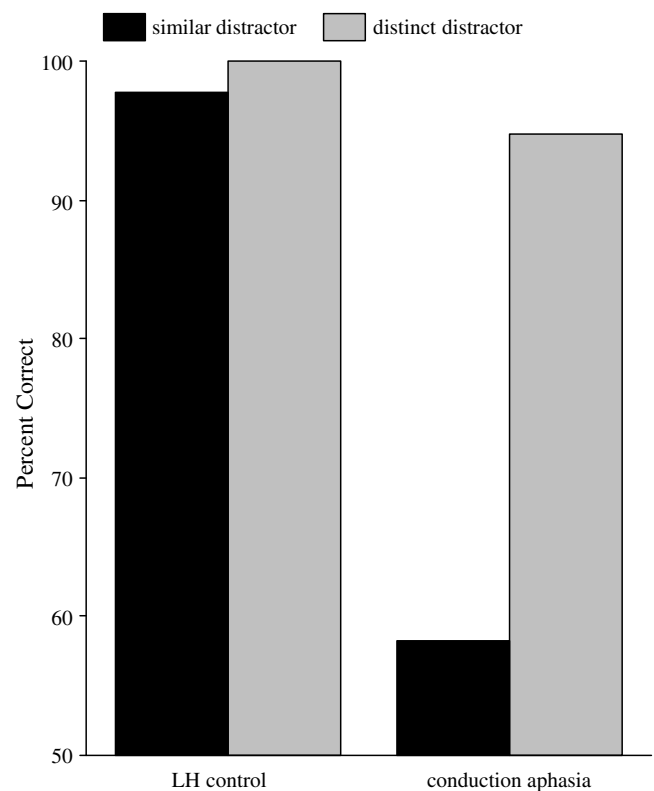


Fig. 2. Performance of patients with conduction aphasia and LH controls on the repetition recognition task. Patients with conduction aphasia were only impaired on the semantically-similar distractor condition.

the relationship between patients' accuracy on the semantically-similar sentence condition and their repetition performance on the WAB. This relationship was significant,  $r(14) = .67, p < .01$ , suggesting that patients' ability to distinguish the semantically-similar sentences was associated with their capacity for overt repetition.

Next, we analyzed performance of the elderly control participants on the same repetition recognition stimuli, with a delay period between study and test. Performance on the semantically-related and semantically-distinct sentence conditions were compared, using a paired-samples Wilcoxon Signed Ranks test. As predicted, the elderly controls performed more poorly at recognizing target sentences among semantically-similar distractors relative to the semantically-distinct target sentences (61.3% vs. 87.7% correct),  $Z = -2.37, p = .02$  (see Fig. 3). This pattern is similar to that of patients with conduction aphasia and suggests that the elderly controls relied to some extent on lexical-semantic information that was easily confused in the former condition.

## 5. Discussion

In the current study, patients with conduction aphasia (CA) were impaired on a forced choice, sentence repetition recognition task but only when the distractors were semantically-related to the target. When the distractors were semantically-distinct, patients with conduction aphasia were easily able to identify the matching sentence. These results suggest that patients with conduction aphasia are unable to rely on the verbatim phonological trace to identify/repeat information but rather rely more heavily on a separate route that registers lexical-semantic information. This alternative route allows them to encode semantically-distinct information. In order to further test this idea,

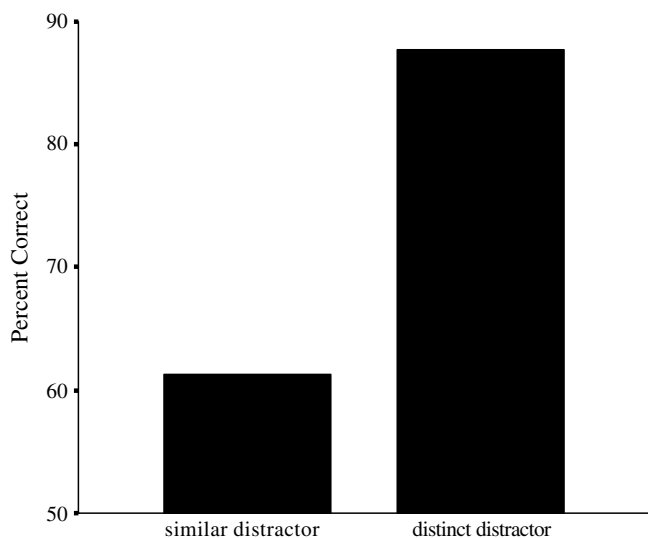


Fig. 3. Performance of elderly control participants on the repetition recognition task following a 10-min delay. Participants showed significantly worse performance on the semantically-similar distractor condition.

we also administered the same stimuli to normal elderly controls, except that a 10-min delay was inserted between presentation of the sentences and the recognition procedure. The elderly participants also showed a significant dissociation, with much poorer performance on trials when semantically-related distractors were present. Because they were forced to rely on long-term memory, rather than the phonological trace, they were more prone to confuse semantically-related sentences. We would argue, then, that patients with conduction aphasia are similarly forced to rely on lexical-semantics in short-term memory tasks because the phonological trace is degraded.

The patients with conduction aphasia in the current study also demonstrated this phenomenon of semantic confusability in a more qualitative way during the task procedures. In the semantically-similar condition, two CA patients repeatedly pointed at the related words in the target and distractor sentences (e.g., *boy* vs. *man*, *chef* vs. *cook*), stating that they could not decide between them—“*Could be either one.*” Again, this highlights the fact that CA patients process the information they hear at a semantic level but do not have the verbatim trace available to them in order to discriminate between related items. For this reason, information that does not carry a lot of semantic context, such as a person's name or a phone number, is almost impossible for such patients to repeat in everyday situations.

These experimental findings are consistent with a number of patients described in the literature. Saffran and Marin (1975) studied a patient with a repetition disorder who performed STM tasks as if they were LTM tasks (e.g., showing primacy but no recency effects). Similar to what we have observed, they also reported that the patient could paraphrase sentences that he was unable to repeat. Similarly, Butterworth, Campbell, and Howard (1986) described a patient who showed excellent comprehension for auditory sentences that she could not repeat. They also described her errors as preserving the meaning of what she heard. She performed much better on tasks when context was provided but was very poor when sentences were abstract/arbitrary (e.g., on the Token Test).

The current data lend further support to the idea of an additional, semantic component in the traditional working memory model (Freedman & Martin, 2001). Potter (1993) has described what she terms *conceptual short-term memory* as a processing stream that runs parallel with the phonological store and allows for the integration of conceptual/contextual information from long-term memory into on-line processing. These ideas are also related to a new component in Baddeley's model, the episodic buffer (Baddeley, 2000). He has proposed that information processed via the episodic buffer activates related nodes in long-term memory to *create and manipulate novel representations ... providing the basis for planning future action* (Repovs & Baddeley, 2006; p. 15). Dell and colleagues (Dell, Martin, & Schwartz, 2007; Dell, Schwartz, Martin, Saffran, & Gagnon, 1997; Schwartz, Dell, Martin, Gahl, & Sobel, 2006)

have also examined the role of lexical-semantics in both repetition and naming using bi-directional connectionist models to predict aphasic performance. They found that repetition performance could be predicted by the model given separate lexical-semantic and lexical-phonological processes (Dell et al., 2007). The CA pattern was associated with relatively low phonological weights and stronger semantic weights in their model, thus explaining how semantic confusability could occur in this patient group.

The notion of a semantic route has also been used in part to explain the pattern of repetition performance in so-called deep dysphasia (Butterworth & Warrington, 1995; Katz & Goodglass, 1990; Martin, 1996; Martin et al., 1996; Michel & Andreewsky, 1983). The term *deep dysphasia* has been used to describe a rare repetition disorder marked by difficulty with non-word repetition and semantic errors in single-word repetition. The patients tested in the current study did not routinely exhibit semantic substitutions in single-word repetition and thus did not meet these criteria. Deep dysphasia cases often meet criteria for conduction aphasia but sometimes have anomic or Wernicke's aphasia.

Lesion site was not a focus in the current study—patients were chosen on the basis of a pattern of language deficits. Not surprisingly, though, the lesions in the patients with conduction aphasia tended to be centered in posterior cortex, specifically, the superior temporal gyrus and inferior parietal cortex. We have recently shown that patients with lesions in inferior parietal cortex (not necessarily all meeting criteria for conduction aphasia) were disrupted on tasks that tap the phonological store, such as span and rhyming tasks (Baldo & Dronkers, 2006; see also Vallar, Di Betta, & Silveri, 1997). We have also shown that lesions to these areas result in poor performance on sentence comprehension tasks that rely on auditory short-term verbal memory, such as holding a sentence in mind while choosing a corresponding picture from an array of semantically-similar distractors (Dronkers, Wilkins, Van Valin, Redfern, & Jaeger, 2004). Together, these results help confirm the importance of posterior superior temporal and inferior parietal regions in supporting a phonological store, while semantic information can be accessed via a distinct neural network.

The sample size in the current study was limited, despite several years of recruitment. Patients with chronic, persistent conduction aphasia (>1 year) have been relatively rare in our medical setting, especially given our strict selection criteria (i.e., single CVA, no neurologic/psychiatric history, etc.). Nonetheless, the experimental condition of interest showed a clear dissociation between the two groups of patients. Further testing is planned with a larger group of patients with a wide array of semantic and phonologic deficits to further explore the parameters of the observed dissociation.

The current findings, along with previous studies, suggest that a number of representations are activated in working memory (e.g., lexical-semantic) in addition to

the phonological store and that these representations are used for long-term encoding/retrieval. These findings have implications for models of the interaction between short-term memory and language in patients with aphasia and contribute to our understanding of their interaction in the normal mind (Martin & Saffran, 1997).

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