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Neural correlates of phonological and semantic-based anomia treatment in aphasia

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Abstract

Most naming treatments in aphasia either assume a phonological or semantic emphasis or a combination thereof. However, it is unclear whether semantic or phonological treatments recruit the same or different cortical areas in chronic aphasia. Employing three persons with aphasia, two of whom were non-fluent, the present study compared changes in neural recruitment associated with phonologic and semantic-based naming treatments. The participants with non-fluent aphasia were able to name more items following both treatment approaches. Although this was not the case for the participant who had fluent aphasia, her naming errors decreased considerably following treatment. Post-treatment fMRI revealed similar changes in neural activity bilaterally in the precuneus among the two non-fluent participants—increased activity was noted in the right entorhinal cortex and posterior thalamus on post-treatment scans for the third participant. These findings imply that cortical areas not traditionally related to language processing may support anomia recovery in some patients with chronic aphasia.

Keywords: Cuing hierarchy; fMRI; Naming; Neuroimaging; Recovery; Therapy

Although the ability to name common objects has limited ecological significance per se, it is commonly targeted in aphasia treatment based on the assumption that it ameliorates lexical-semantic processing deficits, which in turn would drive aphasia recovery. While the underlying cause of anomia varies significantly among patients, most treatment approaches either include a phonological or semantic focus (for a review see Maher & Raymer, 2004; Nickels, 2002).

Previous research has suggested that to be optimally effective, anomia treatment should be tailored to the needs of each patient—for example, patients with primarily semantic deficits should be treated with regimens that emphasize semantic processing. However, other studies have shown that some patients who respond well to semantic-based anomia treatment also respond well to phonologically-based approaches (Fridriksson, Holland, Beeson, & Morrow, 2005; Wambaugh, Cameron, Kalinyak-Fliszar, Nessler, & Wright, 2004). While several cognitive models of lexical processing might explain this effect, a particularly influential 'interactive activation model' has been suggested by Dell and colleagues (Dell & O'Seaghdha, 1991, 1992; Gagnon, Schwartz, Martin, Dell, & Saffran, 1997; Martin, Dell, Saffran, and Schwartz, 1994; Schwartz, Dell, Martin, & Saffran, 1994). This account posits spreading activation within three processing levels with semantic-lexical information being processed at the first two levels and phonological constructions occurring at a third level. However, processing between levels is highly interactive as suggested by mixed semantic and phonological naming errors (as in "cow" for *cat*). Since this model is highly interactive, stimulation at one level (e.g., the phonological level) also stimulates processing at the other (semantic-lexical). This interactive stimulation has been shown in several anomia treatment studies of persons with aphasia (Dell, Schwartz, Martin, Saffran, & Gagnon, 1997; Martin & Laine, 2000; Renvall, Laine, Laasko, & Martin, 2003).

Some recent studies suggest aphasia recovery following stroke is dependent on left hemisphere reorganization while increased right neural activity following stroke represents

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maladaptive disinhibition (Martin et al., 2004). Perhaps even more convincingly, studies by Naeser and colleagues (Martin et al., 2004; Naeser et al., 2005) have shown that repetitive transcranial magnetic stimulation (rTMS) of the pars triangularis in the right hemisphere in non-fluent aphasic patients' results in improved naming. Since rTMS generally leads to tonic inhibition of the stimulated area, this finding suggests that right hemispheric activity is maladaptive, as its inhibition in this study ameliorated symptoms. It is possible that damage to the left pars triangularis leads to transcallosal disinhibition of the homologous area of the right hemisphere, with this activity decrementing performance and that rTMS to the right pars triangularis suppresses activity that normally would be inhibited by an intact Broca's area. The key question is why right hemisphere activity should be maladaptive, and why reduction of this activity should improve symptoms. Heiss and Thiel (2006) suggested that right hemispheric activity may itself suppress left hemisphere activity, and therefore that disrupting right hemisphere function allows the residual regions of the left hemisphere to become more active. Although this work provides substantial evidence suggesting a maladaptive role for the right hemisphere in inhibiting recovery, numerous studies have revealed right hemisphere recruitment associated with recovery of speech production (Crinion & Price, 2005; Crosson et al., 2005; Meister et al., 2006).

With regard to treatment-induced anomia recovery in aphasia, changes in neural activity have been reported in the left hemisphere (Cornelissen et al., 2003), right hemisphere (Peck et al., 2004), and both (Fridriksson, Morrow, Moser, Fridriksson, & Baylis, 2006). Employing two non-fluent and one fluent aphasic participant, the study by Cornelissen et al. (2003) used magnetoencephalography (MEG) to reveal anomia treatment-related changes in neural modulation in the left perilesional parietal lobe. In contrast, the results by Peck et al. (2004) showed primarily right hemisphere changes in the temporal aspects of the hemodynamic response (HDR) in three patients who underwent anomia treatment. More recently, Fridriksson et al. (2006) also employed three participants who received naming treatment and pre- and post-treatment fMRI. This study employed three fMRI scanning sessions before and after anomia treatment focused on errorless learning of a closed set of words. The results revealed a bilateral increase in neural activity associated with improved naming ability in two participants, while the third did not respond to treatment. These three studies included participants with a wide range of aphasia severity and type as well as different anomia treatment approaches; nevertheless, some gross similarities in treatment-related neural modulation were noted. For example, one of the fluent participants in the Fridriksson study also showed left parietal perilesional modulation associated with anomia recovery, much as the three participants studied by Cornelissen et al. (2003).

The purpose of the present study was to investigate the neural correlates of phonological and semantic-based treatments of anomia in three persons with chronic aphasia. Each participant received five 2-hr treatment sessions with a phonological focus and five 2-hr sessions with a semantic focus. Treatment sessions for each of the two approaches were completed within a 1-week period and the order of approaches were counter-balanced, where two participants first received the phonological treatment and the third participant first received the semantic approach. Because only limited evidence exists to support the test-retest reliability of fMRI data in persons with aphasia (Kurland et al., 2004), two fMRI sessions testing picture naming were acquired before and after each treatment approach was completed. Thus, neurological activity associated with treatment was assessed in a higher-level fMRI analysis within each participant.

1. Methods

1.1. Participants

This study included three persons with aphasia who regularly attend aphasia groups at a university clinic. The first participant – NS – was a 63-year-old woman who retired as a librarian following a left hemisphere ischemic stroke approximately 1 year prior to study inclusion. To classify aphasia type and assess specific language problems, the Western Aphasia Battery (WAB; Kertesz, 1982) was administered to each participant. NS' overall score on the WAB suggested that her language impairment was most consistent with conduction aphasia. Her speech was marked by frequent phonemic paraphasias and hesitant attempts at self-correction; she was very aware of her speech errors, something that is common in conduction aphasia (Table 1). She scored 33 out of 100 on the confrontation naming subtest of the WAB; errors consisted of both phonemic and semantic paraphasias while tactile and phonemic cues provided minimal support in naming attempts. During the word fluency task, she was able to name three animals (i.e., dog, cat, and zebra). Repetition on the single-word level was moderately impaired, and her performance worsened at the phrase and sentence levels. Auditory comprehension was relatively spared although she had mild difficulty following two- and three-step directions. To more specifically test naming performance, the Philadelphia Naming Test (PNT; Roach, Schwartz, Martin, Grewal, & Brecher, 1996) was administered. The PNT includes 175 picturable nouns that were selected from a word frequency list compiled by Frances and Kucera (1982). Pictures are presented on a computer screen and responses are video recorded and later scored by two clinicians. The mean number of correctly named pictures by NS on two baseline PNT sessions was 24. She also produced frequent semantic and phonemic (formal) paraphasias as well as non-words (Table 1).

Table 1
Biographical and language-related information for each of the three participants with aphasia

	NS	EG	CH
Gender	Female	Female	Male
Age	63	42	63
Time post onset	12 months	22 months	98 months
Current aphasia type	Conduction	Broca's	Broca's
Western aphasia battery			
Spontaneous speech	16/20	11/20	7/20
Comprehension	140/200	140/200	141/200
Repetition	24/100	12/100	76/100
Naming	33/100	25/100	37/100
Aphasia quotient	57.4	43.4	50.7
Philadelphia naming test[a]			
Correct response	24	46	38
Semantic paraphasia	23	10	22
Phonemic paraphasia	18	9	3
Mixed paraphasia	2	1	1
Unrelated	10	1	4
Non-word	12	3	0
No response	86	105	107

[a] Scores represent a mean performance on the first two PNT sessions before treatment initiation.