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Neural activity associated with semantic versus phonological anomia treatments in aphasia

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ABSTRACT

Naming impairments in aphasia are typically targeted using semantic and/or phonologically based tasks. However, it is not known whether these treatments have different neural mechanisms. Eight participants with aphasia received twelve treatment sessions using an alternating treatment design, with fMRI scans pre- and post-treatment. Half the sessions employed Phonological Components Analysis (PCA), and half the sessions employed Semantic Feature Analysis (SFA). Pre-treatment activity in the left caudate correlated with greater immediate treatment success for items treated with SFA, whereas recruitment of the left supramarginal gyrus and right precuneus post-treatment correlated with greater immediate treatment success for items treated with PCA. The results support previous studies that have found greater treatment outcome to be associated with activity in predominantly left hemisphere regions, and suggest that different mechanisms may be engaged dependent on the type of treatment employed.

1. Introduction

Difficulty naming objects is one of the most common impairments in people with aphasia post-stroke, irrespective of aphasia classification (Goodglass & Wingfield, 1997). Thus, remediation of naming impairments is often a focus of treatment in the rehabilitation of language. Treatments for naming impairments in aphasia typically employ a semantic and/or phonological approach, in order to target the major cognitive components of word retrieval that may be impaired (Nickels, 2002). Although naming impairments can be remediated using phonological and semantic-based techniques, the relationship between a person's locus of deficit in word retrieval and their response to a particular type of treatment approach is not always clear (Howard, Patterson, & Franklin, 1985; Lorenz & Ziegler, 2009). As the use of a specific treatment approach is often guided by identifying and targeting an individual's locus of deficit, such inconclusive findings suggest that methods other than behavioural measures are required to determine what type of treatment may be more beneficial for a particular individual. One such method is neuroimaging, which has been employed to investigate the neural mechanisms underlying the recovery of language in the acute stages, as well as treatment-induced changes in the chronic stage post-stroke.

Activation within peri-lesional regions, as well as recruitment of right hemisphere homologues, has been observed following left hemisphere damage (Crosson et al., 2007; Price & Crinion, 2005). Some studies suggest that restitution of left hemisphere regions is associated with greater recovery (e.g. Cao, Vikingstad, George, Johnson, & Welch, 1999; Heiss & Thiel, 2006; Szaflarski, Allendorfer, Banks, Vannest, & Holland, 2013). The role of the right hemisphere is more complex; some studies suggest that right hemisphere activity can be maladaptive and may hinder language recovery (e.g. Rosen et al., 2000), whereas others have found right hemisphere activity to be associated with greater recovery (e.g. Elkana, Frost, Kramer, Ben-Bashat, & Schweiger, 2013). A study conducted by Saur et al. (2006) suggests that right hemisphere involvement in recovery may be dynamic, with up regulation of the right hemisphere in the acute stage, followed by a normalisation of left hemisphere perilesional activity associated with greater recovery in the chronic stage post-stroke. However, studies

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investigating the neural mechanisms underlying recovery of language post-stroke are limited by the variability across participants in terms of lesion site/size, severity and type of language impairment, as well as the type of task used to examine neural activity, and therefore need to be interpreted with some caution.

In terms of treatment-induced recovery, some studies have investigated the relationship between lesion site/size and treatment outcome. For example, Parkinson, Raymer, Chang, Fitzgerald, and Crosson (2009) found larger anterior lesions to be associated with greater treatment success, although this was dependent on whether the basal ganglia remained intact. Additionally, Meinzer et al. (2010) found the degree of damage to the hippocampal formation and surrounding white matter to correlate with treatment responsiveness. Other studies have investigated the relationship between naming impairments and patterns of brain activity. Some studies have found functional reorganisation in the right hemisphere associated with improvements following certain treatments (Crosson et al., 2005; Peck et al., 2004), whereas others have found greater treatment outcome to be associated with activity in left hemisphere perilesional regions (see Meinzer & Breitenstein, 2008; Meinzer, Harnish, Conway, & Crosson, 2011 for reviews). However, studies investigating the relationship between an individual's pattern of brain activity, lesion site, and their response to treatments targeting either semantic or phonological processing are scarce.

With respect to semantic-based treatments, the results of a case study conducted by Davis, Harrington, and Baynes (2006), suggest that treatments employing semantic techniques may engage inferior frontal and inferior temporal regions typically associated with semantic processing. However, as the fMRI task (covert verb generation) differed from the therapy task (semantic judgements), and in-scanner performance could not be monitored, the relationship between brain activation changes and improvements following this therapy remains unclear.

Another semantic-based treatment that has been examined using fMRI is Semantic Feature Analysis (SFA), a task that involves analysing the features of an object using a matrix of cue words (e.g. group, use, action, properties, etc.) to facilitate retrieval of semantic information required for word retrieval (Boyle, 2004; Boyle & Coelho, 1995; Coelho, McHugh, & Boyle, 2000). Marcotte et al. (2012) examined a group of nine participants with aphasia using SFA and found a correlation between improved naming and activation in the left precentral gyrus both pre- and post-treatment, as well as activity in the left inferior parietal lobe post-treatment. Further, the more successful responders were found to recruit fewer brain areas post-treatment compared to successful naming pre-treatment, with no additional right hemisphere activity, providing some further evidence that restitution of left hemisphere regions may be associated with greater treatment-induced recovery.

With respect to phonologically-based treatments for anomia, Vitali et al. (2007) employed a phonological cueing treatment with two participants with aphasia, where one participant with a large lesion of Broca's area showed activation in right hemisphere language homologues following therapy. In contrast, the second participant with a smaller lesion that partially spared Broca's area, showed activation predominantly in the left hemisphere following therapy. Interestingly, the participant with a smaller anterior lesion and peri-lesional activation following therapy also showed a greater change in naming accuracy than the participant with a larger lesion and right hemisphere activation following therapy. These results are in contrast to Parkinson et al.'s (2009) study, which found greater treatment success in the presence of larger anterior lesions. Such discrepancies may relate to the type of therapy provided. Parkinson et al.'s study pooled participants who had undergone either an intentional non-symbolic gesture training task in combination with word retrieval tasks or a combined semantic/phonological treatment, whereas Vitali et al.'s (2007) study focused specifically on phonological cueing.

Another phonologically-based technique examined using fMRI is Phonological Components Analysis (PCA). Modelled on the structure of SFA, PCA involves the generation of phonological features of a target word such as the initial phoneme, initial phoneme associates, final phoneme, number of syllables, and rhyming words (Leonard, Rochon, & Laird, 2008). Rochon et al. (2010) examined the effect of PCA with two people with aphasia using fMRI. Changes in cortical activation during semantic and rhyme judgement tasks were greater in left hemisphere perilesional areas post-treatment for both participants, activating frontal and temporal regions as well as the supramarginal gyrus and inferior parietal regions. However, despite improved naming performance following treatment, there was no significant change in performance for the fMRI judgement tasks. Thus, as the treatment task differed from the task employed in the scanner, altered neural activity during the judgement tasks may not have reflected improvements in naming following treatment.

While the above studies have attempted to target different components of word retrieval, there is debate regarding whether such treatments are selective in targeting a particular processing component or, alternatively, if these differences have been overstated (see Howard, 2000). This issue may also be examined by considering the neural mechanisms underpinning treatments that assume different targets. However, very few studies have directly compared phonological and semantic approaches to naming therapy. Fridriksson et al. (2007) examined phonological and semantic cueing hierarchies, where two participants who showed improved naming following treatment showed increased activation in the left inferior frontal gyrus, left and right motor and premotor regions, right middle temporal gyrus, as well as the precuneus bilaterally. When phonological and semantic approaches were contrasted, one participant showed increased activation in the right anterior superior frontal gyrus for the semantic cueing, whereas the other showed increased activation in the precuneus bilaterally for the phonological cueing approach. However, in addition to the process targeted, the type of tasks used when comparing different approaches may also be critical with respect to the level of difficulty and response demands required (Hickin, Best, Herbert, Howard, & Osborne, 2002). For example, the sentence completion cue employed by Fridriksson et al. (2007) may be more difficult and require different response demands than an initial phoneme cue, which in turn may affect treatment outcome and influence differences in brain activity between tasks.

It is evident that the literature contains inconsistent findings regarding the neural mechanisms responsible for treatment-induced aphasia recovery. Such inconsistencies may relate to the heterogeneity of subjects, in terms of lesion size/site, time post-onset and language symptoms, the type of task used to examine brain activation, as well as variation in the type of treatments investigated. In addition, while recent studies have begun to examine whether activity in a group of individuals pre-treatment, or changes in activity post-treatment, is associated with outcome (Fridriksson, Richardson, Fillmore, & Cai, 2012; Menke et al., 2009), investigations of this type directly contrasting two distinct treatments are lacking. The aim of this study was to examine brain activity before and after two techniques, namely PCA and SFA that target different word retrieval components yet employ similar formats and response demands. Given that individuals respond differently to these treatment approaches, and the primary locus of impairment does not always predict treatment outcome, it is important to investigate the neural mechanisms that may underlie successful treatment. Specifically, we investigated (a) if naming-related brain activity pre-treatment was associated with successful outcomes for each treatment, and (b) whether treatment-induced