



## Facilitation of naming in aphasia with auditory repetition: An investigation of neurocognitive mechanisms



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### ARTICLE INFO

#### Article history:

Received 16 March 2012

Received in revised form

19 January 2013

Accepted 7 May 2013

Available online 16 May 2013

#### Keywords:

Aphasia

Auditory repetition

fMRI

Overt picture naming

Phonology

### ABSTRACT

Prior phonological processing can enhance subsequent picture naming performance in individuals with aphasia, yet the neurocognitive mechanisms underlying this effect and its longevity are unknown. This study used functional magnetic resonance imaging to examine the short-term (within minutes) and long-term (within days) facilitation effects from a phonological task in both participants with aphasia and age-matched controls. Results for control participants suggested that long-term facilitation of subsequent picture naming may be driven by a strengthening of semantic–phonological connections, while semantic and object recognition mechanisms underlie more short-term effects. All participants with aphasia significantly improved in naming accuracy following both short- and long-term facilitation. A descriptive comparison of the neuroimaging results identified different patterns of activation for each individual with aphasia. The exclusive engagement of a left hemisphere phonological network underlying facilitation was not revealed. The findings suggest that improved naming in aphasia with phonological tasks may be supported by changes in right hemisphere activity in some individuals and reveal the potential contribution of the cerebellum to improved naming following phonological facilitation. Conclusions must be interpreted with caution, however, due to the comparison of corrected group control results to that of individual participants with aphasia, which were not corrected for multiple comparisons.

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### 1. Introduction

Word retrieval difficulty, referred to as anomia, is clinically the most common symptom of language impairment following brain damage and is often measured by picture naming performance (Laine & Martin, 2006). Naming performance can be improved in individuals with post-stroke aphasia (Best, Herbert, Hickin, Osborne, & Howard, 2002; Hickin, Best, Herbert, Howard, &

Osborne, 2002; Howard, Patterson, Franklin, Orchard-Lisle, & Morton, 1985a), however, the neural basis of training-induced improvement remains uncertain.

Successful naming begins with the conceptual-semantic stage of word production, with activation and selection of the meaning of a picture from within an individual's semantic system (Levelt, 1999). This is followed by conceptually driven activation and selection of the appropriate lexical entry. Finally, the phonological components associated with this abstract lexical unit are prepared for articulation (Levelt, 1992). Connections must also exist between these processing levels, enabling a mapping operation linking word meaning and word form (Nickels, 2001). However, such a simplified explanation belies the complexity underlying word retrieval and production processes. Competing theoretical models exist which attempt to provide detailed accounts of a functional architecture for each processing component and the interactions between them (Dell, Schwartz, Martin, Saffran, & Gagnon, 1997; Martin, Dell, Saffran, & Schwartz, 1994; Morton,

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1969, 1979; Seidenberg & McLelland, 1989). The majority of these models assume that components of the system are interconnected to a certain degree, that some components operate relatively independently and that some components can be localized to different parts of the brain (Coltheart, 2001). Functional neuroimaging studies have identified the cortical regions that mediate these word retrieval and production processes, with various large-scale meta-analyses showing that the semantic and phonological components of naming engage different neural regions (Indefrey, 2011; Indefrey & Levelt, 2004; Price, Devlin, Moore, Morton, & Laird, 2005; Vigneau et al., 2006). While the exact role of specific regions in language processing remains under debate, some consensus has been reached regarding the localization of broad linguistic functions. By way of brief summary, the anterior and mid-portions of the inferior frontal gyrus, the mid- to posterior portions of the middle and inferior temporal gyri, the anterior temporal lobe region, and the angular gyrus of the parietal lobe have been consistently linked to semantic processing (Abrahams et al., 2003; Binder et al., 1997; Bookheimer, 2002; Demonet et al., 1992; Demonet, Thierry, & Cardebat, 2005; Vigneau et al., 2006; Visser, Jefferies, & Lambon Ralph, 2010). Phonological processing, on the other hand, has implicated the posterior portion of the inferior frontal gyrus, the posterior portion of the superior temporal gyrus and the supramarginal gyrus of the parietal lobe (Abrahams et al., 2003; Bookheimer, 2002; Hickok & Poeppel, 2004; Indefrey & Levelt, 2004; Moore & Price, 1999; Vigneau et al., 2006).

Functional neuroimaging studies have also highlighted the mechanisms that may be involved in the reorganization of language processing following neural injury. This research has provided considerable evidence in support of neural plasticity within the language network following treatment (Thompson & den Ouden, 2008). Treatment strategies that aim to improve naming performance often incorporate multiple exposures to repeated stimuli. However, a single application of a language related task, referred to as 'facilitation', can improve subsequent naming performance in individuals with aphasia (Best et al., 2002; Hickin et al., 2002; Howard et al., 1985a; Patterson, Purell, & Morton, 1983). Unimpaired speakers also benefit from facilitation, with previous behavioural research showing that naming a picture once can speed subsequent naming of that same picture, even up to 48 weeks later (Cave, 1997; Mitchell & Brown, 1988). This performance enhancement in healthy controls is a form of repetition priming—a widely studied phenomenon fundamental to implicit memory and learning mechanisms (Henson, 2003; Tulving & Schacter, 1990). It is thought that facilitation and treatment effects in individuals with aphasia may be acting through repetition priming mechanisms (Nickels, 2002a). While symptom profiles and underlying deficits vary significantly across individuals with aphasia, facilitatory techniques generally take either a phonological or semantic approach (Fridriksson et al., 2007; Maher & Raymer, 2004; Nickels, 2002b). This is due to the commonly held view that these phonological and semantic tasks target distinct components of the impaired word retrieval process (Hillis & Caramazza, 1994; Howard, Patterson, Franklin, Orchard-Lisle, & Morton, 1985b). It has been widely argued, for example, that semantically based tasks that focus on word meanings, such as semantic verification (e.g., "Does it bark?") or picture matching, are the most effective for individuals whose primary area of deficit involves the semantic level of processing. Similarly, phonological tasks like word repetition and rhyming are proposed to be more effective for individuals with a phonological level deficit (Laine & Martin, 2006).

However, some authors propose that the difference between such phonological and semantic techniques has been overemphasized, given that both types of processing usually occur to some

degree with most language related tasks (Howard, 2000; Nickels, 2002b). The facilitatory effects of these techniques may also differ in terms of longevity. Behavioural research in healthy controls has indicated that tasks targeting the phonological level of processing result in only short-term benefits, while tasks incorporating both semantics and phonology work to strengthen the links between the two levels of processing and can be associated with longer lasting facilitation (Wheeldon & Monsell, 1992). Differences have also been identified in individuals with aphasia, with phonological facilitatory tasks resulting in only short-term benefits to naming (up to 15 min) and semantic tasks associated with longer lasting facilitation (up to 24 h later) (Howard et al., 1985a). However, recent research suggests that phonological tasks can also invoke more durable facilitation effects in people with aphasia (Best et al., 2002).

Other factors are thought to influence the improvement of naming ability in aphasia. It has been suggested that reorganization of function and recovery is dependent upon the modulation of neural activity in spared left hemisphere language related regions (Fridriksson, Bonilha, Baker, Moser, & Rorden, 2010; Saur et al., 2006). The role of right hemisphere activity, however, remains a matter of debate. Some research points toward maladaptive functional reorganization to the right hemisphere language homologues (Martin et al., 2004; Rosen et al., 2000) and other studies propose that both right and left hemisphere mechanisms contribute to language recovery (Crosson et al., 2007). It has also been posited that hemispheric contributions may depend on the nature of the treatment, with more language-based treatments targeting ipsilesional left hemisphere language networks and other non-linguistic (e.g., intention/attention or melodic) interventions that improve language targeting primarily right hemisphere mechanisms (Fridriksson et al., 2010).

The literature indicates that the nature of relateralization may also vary depending upon the size of the lesion. Changes in activity in the right hemisphere have been observed in patients with poor recovery and large lesions, while better outcomes can be associated with activity in left language related regions in individuals with smaller lesions (Blasi et al., 2002; Sebastian & Kiran, 2011). Additionally, non-linguistic areas have also been shown to support recovery from anomia in some individuals (Fridriksson et al., 2007). Clearly there is a growing body of literature attempting to identify the neural mechanisms underlying language recovery. The majority of this research has taken the form of traditional treatment studies, which often utilize fMRI to examine neural changes before and after a phonologically or semantically-based intensive treatment (Rochon et al., 2010; Vitali et al., 2007). For example, Vitali et al. (2007) examined the reorganization of cortical activity in two participants with differing lesion type and site who received intensive, phonologically-based treatment. Improved naming performance was associated with either restitution of function in the phonological region of the left inferior frontal gyrus, where it had been spared, or with activation in a right hemisphere homologue where the left inferior frontal gyrus was damaged.

Other researchers have proposed that cortical areas not normally associated with either phonological or semantic processing may support anomia recovery in some individuals. More specifically, Fridriksson et al. (2007) explored the neural correlates of improved naming for both a phonological and semantic treatment in three individuals with aphasia. All three participants benefited behaviourally from both techniques to varying degrees and showed increased activity within cortical regions not typically associated with language processing. The authors proposed that this finding represents cortical adaptation of a compensatory nature, and that aphasic recovery may depend upon the utilization of brain regions that were not part of the pre-morbid language network (Fridriksson et al., 2007, 2010; Musso et al., 1999).

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