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Research report

Distinct loci of lexical and semantic access deficits in aphasia: Evidence from voxel-based lesion-symptom mapping and diffusion tensor imaging

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ABSTRACT

Naming pictures and matching words to pictures belonging to the same semantic category negatively affects language production and comprehension. By most accounts, semantic interference arises when accessing lexical representations in naming (e.g., Damian, Vigliocco, & Levelt, 2001) and semantic representations in comprehension (e.g., Forde & Humphreys, 1997). Further, damage to the left inferior frontal gyrus (LIFG), a region implicated in cognitive control, results in increasing semantic interference when items repeat across cycles in both language production and comprehension (Jefferies, Baker, Doran, & Lambon Ralph, 2007). This generates the prediction that the LIFG via white matter connections supports resolution of semantic interference arising from different loci (lexical *vs* semantic) in the temporal lobe. However, it remains unclear whether the cognitive and neural mechanisms that resolve semantic interference are the same across tasks. Thus, we examined which gray matter structures [using whole brain and region of interest (ROI) approaches] and white matter connections (using deterministic tractography) when damaged impact semantic interference and its increase across cycles when repeatedly producing and understanding words in 15 speakers with varying lexical-semantic deficits from left hemisphere stroke. We found that damage to distinct brain regions, the posterior versus anterior temporal lobe, was associated with semantic interference (collapsed across cycles) in naming and comprehension, respectively. Further, those with LIFG damage compared to those without exhibited marginally larger increases in semantic interference across cycles in naming but not comprehension. Lastly, the inferior fronto-occipital fasciculus, connecting the LIFG with posterior temporal lobe, related to semantic interference in naming, whereas the inferior longitudinal fasciculus (ILF), connecting posterior with anterior temporal regions related to semantic interference in comprehension. These

Abbreviations: ATL, anterior temporal lobe; AF, arcuate fasciculus; AWPV, auditory word-picture verification task; FA, fractional anisotropy; IFOF, inferior fronto-occipital fasciculus; ILF, inferior longitudinal fasciculus; LIFG, left inferior frontal gyrus; MTG, middle temporal gyrus; PNT, Philadelphia Naming Test; PPT, Pyramid and Palm Trees test; UF, uncinate fasciculus; WAB, Western Aphasia Battery; VLSM, voxel-based lesion-symptom mapping.

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neuroanatomical-behavioral findings have implications for models of the lexical-semantic language network by demonstrating that semantic interference in language production and comprehension involves different representations which differentially recruit a cognitive control mechanism for interference resolution.

1. Introduction

Producing a word is sometimes difficult, as evidenced by the fact that people say the wrong word or hesitate when speaking. Likewise, errors also occur when understanding a word. Investigating the way in which language processes fail has a long-standing tradition in informing models of the language system. The prevalence of semantic errors in patients with language impairments due to stroke (i.e., aphasia) (e.g., Dell, Schwartz, Martin, Saffran, & Gagnon, 1997; Forde & Humphreys, 1995) along with the finding that naming pictures (e.g., Kroll & Stewart, 1994) or matching words to pictures (Campanella & Shallice, 2011) belonging to the same semantic category hinders healthy participants' performance demonstrates that language production and comprehension are semantically driven processes. However, semantic interference in naming and word comprehension has been, for the most part, investigated separately, which has led to different assumptions about the locus of semantic interference in each language modality. By most accounts, semantic interference during picture naming arises when accessing the lexical representation for an intended meaning (at a lexical level) (e.g., Howard, Nickels, Coltheart, & Cole-Virtue, 2006; Oppenheim, Dell, & Schwartz, 2010; see also Damian & Als, 2005), whereas semantic interference during word-picture matching occurs when accessing the semantic representation for a given word form (at a semantic level) (e.g., Gotts & Plaut, 2002; see also Campanella & Shallice, 2011; Forde & Humphreys, 1997, 2007; Warrington & Cipolotti, 1996). Yet, neuropsychological evidence demonstrates that damage to neural regions involved in cognitive control results in exaggerated increases in semantic interference when items repeat across cycles regardless of language modality (i.e., language production or comprehension) (Jefferies, Baker, Doran, & Lambon Ralph, 2007), suggesting a shared mechanism serves to resolve interference arising at different loci. However, to our knowledge, previous research has yet to explore these hypotheses by investigating language production and comprehension performance using both behavioral and high-resolution neuroimaging approaches in the same participants with lexical-semantic processing deficits due to left-hemisphere stroke. Thus, the goal of this research was to examine the extent to which language production and comprehension processing stages overlap by exploring how, as a result of stroke, damage to neural regions and their white matter connections affect semantic interference and its increase across cycles in picture naming and word-picture matching tasks.

It is surprising that semantic interference in language production and comprehension is thought to arise at different levels in the language system (Campanella & Shallice, 2011; Forde & Humphreys, 1997, 2007; Gotts & Plaut, 2002; Howard et al., 2006; Levelt, Roelofs, & Meyer, 1999; Oppenheim et al., 2010; Roelofs, 1992, 2003; Warrington & Cipolotti, 1996; Warrington & McCarthy, 1983, 1987) given that one must access a shared semantic system (e.g., Shelton & Caramazza, 1999) both to produce the word for a given meaning and to comprehend the meaning for a given word (see Fig. 1). For example, subjects are slower and/or make more errors when naming pictures and matching words to pictures when trials are blocked in groups depicting items belonging to the same categories (related context: e.g., DOG, CAT, BEAR, COW) versus different categories (unrelated context: e.g., DOG, TRAIN, SHIRT, DESK; e.g., Damian, Vigliocco, & Levelt, 2001; Biegler, Crowther, & Martin, 2008). Both naming and understanding words in these semantic blocking tasks are sensitive to semantic manipulations, where close versus distant categorical relationships among items (e.g., DOG and CAT *vs* DOG and WHALE) results in greater semantic interference in naming (Vigliocco, Vinson, Damian, & Levelt, 2002) and word-picture matching tasks (Crutch & Warrington, 2005; Warrington & Cipolotti, 1996, Experiment 5). Likewise, semantic interference generalizes to novel category exemplars previously not named (Belke, Meyer, & Damian, 2005, Experiment 3) or comprehended (Forde & Humphreys, 1995, Experiment 12), providing evidence that semantic interference results from spreading activation across category members. These findings indicate that semantic interference in production and comprehension originates at the semantic level (see also Belke, 2013), where naming a picture (DOG) or comprehending a word ("dog") activates its semantic representation, which then spreads activation to related representations sharing semantic features with the target (e.g., CAT/"cat"; e.g., Collins & Loftus, 1975; Levelt et al., 1999).

However, it is generally assumed that semantic interference in language production occurs at the lexical level (e.g., Levelt et al., 1999) while semantic interference in language comprehension occurs at the semantic level (e.g., Gotts & Plaut, 2002), despite the assumption that producing and comprehending words make use of shared lexical and semantic representations (reviewed in Howard, 1995; Levelt, 1999; cf. Caramazza, 1997; see Fig. 1). In naming, semantic interference does not occur for tasks which tap the lexical level without access to semantics (i.e., written word naming; Belke, Brysbaert, Meyer, & Ghyselinck, 2005; Kroll & Stewart, 1994; Vitkovitch & Humphreys, 1991) or the semantic level without lexical access (i.e., manually categorizing pictures; Belke, 2013; Damian et al., 2001). Evidence against an output level of interference in naming comes from the finding that