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The role of left inferior frontal gyrus (LIFG) in semantic short-term memory: A comparison of two case studies

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Introduction

Semantic short-term memory (sSTM) deficits have been traditionally defined as an inability to maintain lexical-semantic representations over a delay (Martin, Shelton, & Yaffee, 1994). Yet patients with sSTM deficits make numerous intrusions of items from previously presented lists. Why should an inability to maintain semantic representations produce an *increase* in intrusions from earlier words? Hamilton and Martin (2005) offered an alternative account: performance may be reduced on sSTM tasks because of an inability to inhibit previously presented items. They supported this with evidence that sSTM patient ML demonstrated exaggerated interference effects on various tasks, consistent with a lesion that included LIFG. This intriguing co-occurrence of behavioral and behavioral-anatomical effects merits further investigation. Here, we compare two patients and ask: (i) Are sSTM deficits (but not pSTM deficits) associated with damage to the LIFG and (ii) Are sSTM deficits (but not pSTM deficits) associated with impairments in interference resolution?

Clinical history

Patient CAC, a right-handed, 46-year-old female with 13 years of education, suffered a left-hemisphere CVA in March 2002. Currently, her speech is fluent, contains phonemic paraphasias, and she demonstrates impaired repetition and naming abilities. Phonological processing at the single word level is above normal, and semantic processing is nearly one standard deviation below normal.

Patient TB, a right-handed, 37-year-old female with 12 years of education, suffered a left-hemisphere CVA in September of 2002. Currently, her speech is mildly nonfluent, marked by word finding problems and impaired repetition, but she has intact naming abilities and comprehension. Phonological processing at the single word level is above normal, and semantic processing is within two standard deviations of normal (standard score on the Peabody Picture Vocabulary Test is 75).

Methods

STM assessment

Subjects performed six STM tests [four immediate serial recall (ISR), two delayed-probe] that have proven effective in distinguishing pSTM from sSTM deficits (Freedman & Martin, 2001; Martin et al., 1994). Administration and span calculation followed Martin et al. (1994).

Interference resolution assessment

Four tasks that enabled a within-task contrast between high- and low-interference resolution were administered following prior methods: Stroop (Friedman & Miyake, 2004); a variant of the hayling sentence completion test (Robinson, Shallice, & Cipolotti, 2005); verb generation (Thompson-Schill et al., 1998); and a variant of the recent-negatives item-recognition task (Hamilton & Martin, in press).

Lesion assessment

For patient CAC, we obtained a high resolution MRI scan. Scanning parameters: T1-weighted spoiled gradient-recalled-echo (MPRAGE; 35/7, 45 flip angle, one signal acquired) transverse images, 1-mm slice thickness, no gap, 1 mm in-plane resolution with a 128192×256 matrix. For patient TB, who could not undergo an MRI, we obtained a research-quality CT scan. Scanning parameters were 44 contiguous axial slices covering the entire brain (2.5 mm slice thickness) without contrast. Under supervision of a behavioral neurologist, a trained observer used MRIcro (Rorden & Brett, 2000) to manually draw lesion boundaries onto a standard MNI template. We also used MRIcro's automated anatomical labeling map to calculate the percent damage to relevant Brodmann areas (BA).

Results

The STM tasks show that patient CAC has a weaker sSTM store relative to patient TB: Fig. 1, (A) illustrates CAC's smaller lexicality effect relative to TB (Word–Nonword Span: .2 versus 1.2), and smaller category probe span (3 versus 3.32). In contrast, patient TB has a weaker pSTM store relative to patient CAC: TB had a smaller phonological similarity effect than CAC (Nonrhyme–Rhyme Span: 1.4 versus 1.6), and smaller rhyme probe span (4.62 versus 5.19). (B) distinguishes TB's lesion (which

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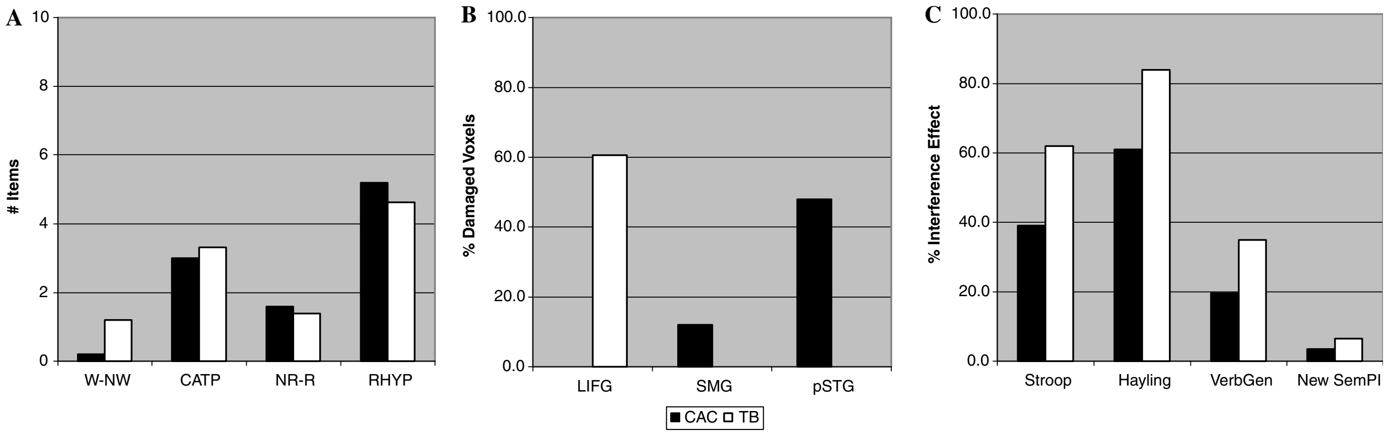

Fig. 1. Span tasks, percent lesion damage, and magnitude interference effects are plotted for patients CAC and TB. Note differences in unit size per each panel. (A) W–NW, difference of Word and Nonword spans (the lexicality effect in STM); CATP, category probe span; NR–R, difference of Nonrhyme and Rhyme spans (the phonological similarity effect in STM); RHYP, rhyme probe span. The lexicality effect and category probe span represent the strength of the *sSTM* store. The phonological similarity effect and Rhyme Probe span represent the strength of the *pSTM* store. (B) Percentage of damaged voxels reported within three regions: LIFG = BA 44 and 45; SMG (supramarginal gyrus) = BA 39 and 40; pSTG (posterior superior temporal gyrus) = BA 41, 42 and 22. (C) For each interference task, we calculated an effect size, corrected for slowing. For example, on the verb generation task each subject's effect size score would be: mean RT (high interference)−mean RT (low interference) / mean RT(all trials).

encompassed a large portion of the LIFG while sparing the posterior temporal and parietal cortices) from CAC's (which included posterior superior temporal gyrus and supramarginal gyrus, but completely spared the frontal lobe). Finally, (C) highlights patient TB's exaggerated interference effects relative to patient CAC; a pattern that was consistent across all four tasks.

Discussion

Hamilton and Martin's (2005) case study of patient ML led to a radical reinterpretation of his sSTM deficit: rather than a problem in maintaining information in a specialized buffer, ML had difficulty resolving interference from irrelevant information. Critical to this alternative account was his lesion, which included LIFG. The present findings, considered alongside Hamilton and Martin's, suggest that while lesions to LIFG do associate with interference resolution deficits, they do not associate with a particular STM deficit. This result is consistent with a theory of LIFG function wherein LIFG supports a *domain-general* cognitive control mechanism that resolves competition between linguistic representations. What is left open is whether and how this LIFG mechanism contributes to performance on STM tasks. This, in turn, leads to interesting questions pertaining to the testing of STM itself.

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