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Task-demand modulation of activation in Broca's area

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A number of brain imaging studies of sentence comprehension have reported evidence of activation in Broca's area correlated with the processing of syntactically complex sentential material in both FMRI and PET studies (e.g., Caplan, 1995). This finding fits well with several decades of evidence concerning the effects of lesions on Broca's area. Independent FMRI and PET investigations of working verbal memory (WVM) (e.g., Smith & Jonides, 1999) have also found evidence of activation of Broca's area correlated with increased memory load. One hypothesis to consider based on these two pieces of evidence is that Broca's area is involved in verbal working memory operations, and that complex structural processing employs this same resource. However, the experimental evidence does not easily reconcile with such a hypothesis. There is, for example, evidence suggesting that individuals with working memory deficits caused by brain lesions have no significant language processing difficulties, and, simultaneously, that individuals with language comprehension difficulties caused by lesion have no deficits in standard tests of WVM (e.g., Martin, 1990). In addition, studies of memory load in language have traditionally failed to find convincing demonstrations that the memory that is standardly examined in 'working memory' tests is the same memory employed in language processing (see, e.g., Caplan & Waters, 1999).

One potential basis for the apparent inconsistency and conflict in this literature may lie in a little-considered aspect of these studies: the tasks (and their relevant 'demands') that have been employed in the study of both language and memory. Task demands have long been cited as prime candidates for non-reliability and non-replicability across both laboratories and techniques in neuro-imaging work (e.g., Ojemann et al, 1998). In the current fMRI study, we were interested in teasing apart the additional processing demands that standard sentence comprehension-tasks bring to the study of language processing from issues of sentence complexity per se. We undertook this study to attempt to resolve the potential conflict in the literature on the role of Broca's area in cognitive and language processing.

Methods

Subjects

Ten right handed native English speakers from UCSD participated for payment.

Stimuli

1. Two English sentence constructions which are standardly reported to differ in processing difficulty but which are matched on all other grounds were examined:
   Subject relative construction [SR] (relatively easy to process): e.g., The girl who saw the boy went into the classroom."
   Object relative construction [OR] (relatively difficult to process): e.g., The girl who the boy saw went into the classroom."
2. Three levels of *Task Condition* were employed while participants comprehended samples of each sentence type. Each task had task demands requiring different levels of task-related cognitive/memory processes. In order of increasing demand, the tasks (which all required button press responses to each sentence) were:
   Passive comprehension (listen and understand sentences, alternating button-press responses).
   Post-sentential probe (indicate if a word which follows the sentence was in the sentence or not).
   Thematic specification (indicate if the 1st NP was the actor/agent' of the first verb).

FMRI Information

Imaging was performed on a Seimens 1.5T clinical MRI scanner fitted with a three axis local head gradient coil (Wong, Bandettini, & Hyde, 1992). During one scanning session both structural functional images were obtained**.** Structural MPRAGE T2 -weighted image parameters included: echo time (TE) of 5.2 min at 1.0 mm thick for a total of 180 slices. Functional run parameters included: 17 contiguous slices at 6 mm thick ($4 \times 4 \times 6$), field of view of 256; flip angle 90°**.** The design parameters were: 30 s off/30 s on; three cycles; total run time = 210 s; TR = 2000; 92 reps. In this within subjects design, there were a total of 12 runs per subject with 7 sentential stimuli presented per cycle, totaling 21 stimuli per run.

Analysis

Using the statistical software AFNI (Cox, 1996), data from each subject were first corrected for motion and other artifacts and then converted to Tailarach space. All 10 subjects were then combined for group analysis (3dANOVA) and contrast comparisons. Only processing taking place while the sentence was being heard was analyzed.

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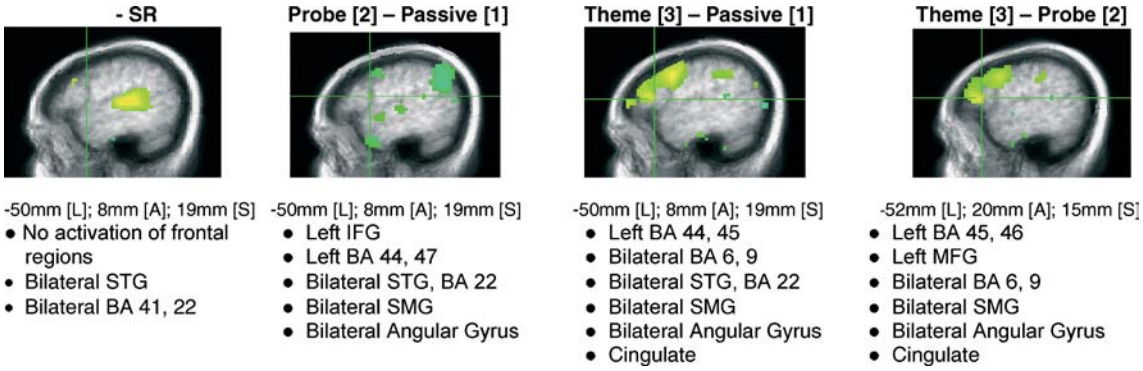

Fig. 1. Sample slices for four contrast comparisons $N = 10$, $t = 2.019$, $p < .05$.

Results

Each level of task difficulty was compared against each other level for both sentence types. Comparisons collapsing across each of these variables were also performed. The overall results are briefly described here followed by sample slices from the collapsed analyses. Overall, (and as can been seen in Fig. 1) increases in sentence complexity (OR vs. SR) did NOT produce differential activation in Left frontal regions (e.g., Broca's area). However, increases in task demand, analyzed across sentence difficulty, clearly demonstrated increases in activation in frontal regions, notably including Broca's area.

Conclusions

The results demonstrate a strong main effect for task demand but none for structural complexity during comprehension. This suggests that literature implicating Broca's area in structural processing may well have been confounded with task demand (which, in turn, may have involved WM). While the Broca's area may play a role in structural processing, these results suggest that task demand (including memory) may account for much of Broca area involvement in language studies.

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