A PET Study of Cerebral Activation Patterns Induced by Verb Inflection

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In the last years, it has become a matter of intense debate whether regular and irregular aspects of language are processed within the same cognitive module as postulated by a number of connectionist models, or whether separate modules have to be assumed, with a word frequency-insensitive symbolic processing module for regular morphology (*cook, cook-ed*), and word frequency-sensitive lexical storage for irregular morphology (*drink, drank*). While single process models predict overlap of the neuronal activation associated with regular and irregular morphological processing, a high degree of non-overlapping activations would favor dual process models.

During four PET scans, we presented subjects with infinitive verb forms, which had to be inserted with appropriate inflection in a neutral sentence frame. In a crossed design, verbs were varied between scans along the dimensions 'regular vs. irregular' and 'high vs. low spoken frequency of past tense/participle forms (HF vs. LF)'. Sentence frames requiring past tense (*He ... something.*) or participle formation (*He has ... something.*) were randomized within scans to avoid response strategies. In two further scans (baseline conditions), HF and LF verbs were presented in their inflected form, so that they could be inserted in the sentence frame without morphological production.

Subjects and Methods

12 healthy, native German-speaking righthanders (6♀, 6♂) participated in the study. Sentence frames were presented on a monitor for 1s. After a 500ms interval, the verb was presented for 600ms. Response sentences were recorded on DAT tape and analyzed for correctness and reaction time (voice onset). The scan sequence was varied. For each PET scan, 40 mCi [^{15}O]-butanol were injected as intravenous bolus. Cerebral tracer accumulation data of 40s were converted into regional cerebral blood flow (rCBF) data as described elsewhere (1). Images were anatomically standardized, and filtered to an image resolution of 14 mm. PET image analysis included pixel-by-pixel t-map calculation, t-thresholding corresponding to $p<0.05$ (uncorrected), and cluster analysis with clusters exceeding 40 pixels (2).

Results and Conclusions

Reaction times (RTs) were fastest in the baseline conditions (HF 517ms, LF 540ms) and faster for regular (HF 557ms, LF 574ms) than for irregular verbs (HF 594ms, LF 611ms). RTs were similar to those obtained in a previous reaction time study using identical but randomized stimuli, indicating that blocking did not severely alter the processing of stimuli. An analysis for areas that were sensitive to the regular-irregular distinction, irrespective of frequency (HF and LF scans collapsed), revealed ten cortical areas with a significant rCBF increase for irregular verbs when directly compared to regular verbs, two areas for the reverse comparison (Table 1). Two areas were sensitive to frequency, irrespective of regularity (regular and irregular scans collapsed), with Broca's area (BA 45) being more active for LF verbs (Table 2). When compared to baseline, both regular and irregular morphological production induced significant rCBF increases in midbrain and cerebellum, but showed no overlap in cortical areas. This study, while avoiding some confounding factors (e.g. fixed scan sequence), confirms the general results of a recent PET study (3). Stronger cortical activation for irregular verbs, and little overlap in activation for regular and irregular verbs are easier to reconcile with dual process models. Our findings, however, are not compatible with the functions the authors attribute to specific areas. The assignment, of regular inflection to the left dorsolateral prefrontal cortex, for example, is at variance with our observation that this area was stronger activated for irregular verbs.

Tab.1: Regularity-sensitive cortical areas

regular vs. irregular verbs	
R. inf. temp. gyr. BA 37	L. angul. gyr. BA 39
irregular vs. regular verbs	
R. inf. front. gyr. BA 47	L. mid. front. gyr. BA 44,6
R. mid. frontal gyr. BA 46	L. sup. front. gyr. BA 10
R. sup. front. gyr. BA 9,32	L. sup. temp. gyr. BA 39,40
R. sup. occ. gyr. BA 18	L. sup. pariet. lob. BA 5
L. mid. front. gyr. BA 46 (dorsolat.prefront. cortex)	L fusiform gyr. BA 37

Tab.2: Frequency-sensitive cortical areas

high vs. low frequency	*low vs. high frequency*
R. middle occ. gyr. BA 19	L. inf. front. gyrus BA 45 (Broca's area)

References

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