Neural differentiation within the language system: the past tense

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Introduction
A key issue in cognitive neuroscience concerns the functional and neural architecture of the systems underlying human language, and whether they should be characterised in terms of a uniform computational and neural process, or whether multiple distinct underlying mechanisms are involved. The regular and irregular past tense has become a main focus in this debate. The regular past tense [played] is the paradigmatic example of a predictable, rule-like process whereas the irregular past tense [made] represents the converse case of an unpredictable and idiosyncratic process. A critical issue is whether processing regular and irregular forms can be accommodated within a single underlying system, or whether separate and specialised processes are required to handle the regular past tense. In support of the latter position, previous neuropsychological studies suggest that regular past tense forms invoke morpho-phonological parsing processes which do not play the same critical role for irregular past tense forms or other simple words [Tyler et al, 2002]. We claim that these parsing processes engage the left inferior frontal cortex [LIFG], a region which is damaged in non-fluent aphasic patients who have difficulties processing regularly inflected past tense forms. This predicts that the LIFG should be preferentially activated for regular past tense forms compared to matched control items in imaging studies with healthy volunteers. We tested this is a sparse imaging fMRI study where patients with LIFG damage had shown selective difficulties with the regulars [Tyler et al, 2002]. 18 subjects heard pairs of regularly [blessed-bless] and irregularly [teach-taught] inflected forms together with pairs of simple words phonologically matched to the regulars [crest-cress] and irregulars [peach-port], together with various sets of control pairs, and made a same-different judgement on each pair.

Method
Scans were corrected for slice timing and were realigned, spatially normalised and smoothed with an isotropic 12 mm FWHM Gaussian kernel. Each subject’s data was analysed using the GLM (Friston et al., 1995), and combined into a RFX analysis. Three sessions and nine event types were entered into the model.

Results
Regular past tense pairs differentially activated a widespread network of sites including the LIFG, anterior cingulate and bilateral superior temporal gyrus. Subsequent analysis of
the lesion extents from aphasic patients with LIFG damage and deficits for the regulars showed that they had damage overlapping with all three of these sites.

Discussion
This combination of behavioural and neural evidence from normal and impaired populations is strong evidence for a specialised system that is necessary for processing regular verb inflection. The role of this system may be to link access processes in the temporal lobe to information provided by inferior frontal processes that parse inflected forms into stems and affixes.

**Fig 1:** Significant activations for the contrast of real regulars minus real irregulars. Significant clusters were found in the RSTG, LSTG, LAC and LIFG. Activation peaks are displayed in brackets. The colour bars indicate the range of T values for each activation. The plots show effect size in arbitrary units. L=L. The activations are superimposed on the mean T1 image of the 18 volunteers.