

# Comparing Cortical Activation of Regular and Irregular Inflection in German

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## Abstract

The symbol-manipulating approach to the cognitive processing of language predicts distinct neural activation patterns for the production of irregular and regular inflections, whereas the associative approach expects no distinct patterns of activation. An event-related fMRI study of German nominal and verbal inflections shows that the total extent of cortical activation was significantly greater for irregulars than regulars, an outcome consistent with the symbol-manipulating account.

## Introduction

The associative approach to the cognitive processing of language maintains that regular and irregular inflections are accomplished by the same single process [1]. In contrast, the symbol-manipulating approach claims that two different processes are implicated [2]. Although it agrees with the associative approach that irregular inflection is accomplished by associative memory, the symbol-manipulating approach believes that regular inflection involves the application of rules that combine stems with inflections. If the symbol-manipulation account is correct, distinct neural activation patterns should be observed for the production of irregular and regular inflections. Alternatively, there should be no neural differentiation between regular and irregular inflection if both are processed within a single mechanism, as in the associative account. In this study we tested these predictions on German nominal and verbal inflections, using event-related fMRI.

## Methods and Materials

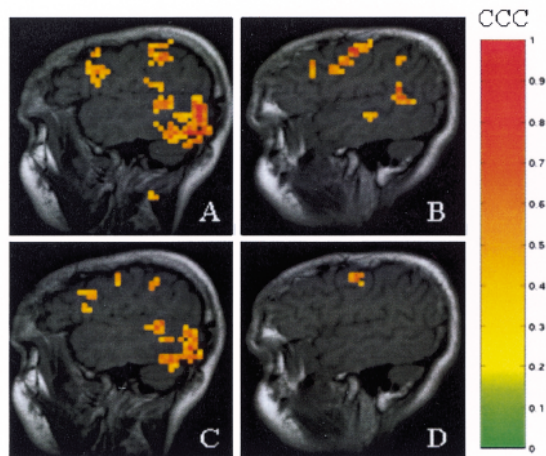
Eight normal right-handed native German speakers (4 female, 4 male, aged from 24 to 45 years) participated in the study. Each subject performed two paradigms: (1) silently generating the plural of nouns; and (2) silently generating the past participle of verbs. Twelve regular and twelve irregular nouns were used in paradigm 1. In paradigm 2, 12 regular and 12 each of two different irregular classes of verbs were used. Regular and irregular words were matched for frequency. Sagittal T2\*-weighted images of a whole head were acquired on a GE 1.5 T clinical scanner using a gradient echo Echo-Planar-Imaging pulse sequence (field of view 24 cm, TE/TR = 50/2000 ms, flip angle 90°, matrix size 64×64, slice thickness 7 mm). For paradigm 1, 168 images per anatomic section were acquired during 24 14-s long event-related trials presented in a random fashion. During each trial, the subject silently spoke the plural of the visually presented noun, which was visible for 1 sec followed by a 13 sec rest period. For paradigm 2, 252 images were acquired during 36 trials. The subject silently produced the past participle of the visually presented verb in each trial.

## Data Analysis

Images were assessed and corrected for possible in-plane translation and rotation. The signal intensity time course was corrected for possible slow baseline drifts. Images associated with regular and irregular forms were then sorted out. To explore the main effect of regularity, noun and verb images were collapsed to obtain an average regular and irregular image for each subject. Time courses of images were analyzed by cross-correlation (cc) with a gamma reference function [3-5] to yield activation maps (estimated  $p < 0.01$ ). The total activated volumes in the cortical regions except the occipital lobe and fusiform gyrus were compared between regular and irregular words.

## Results and Discussions

Significant activation was located primarily in the left and right Broca's area, precentral gyrus, dorsal-lateral frontal cortex, inferior frontal gyrus, anterior cingulate cortex, insula, postcentral gyrus, supramarginal gyrus, angular gyrus, superior parietal lobule, and posterior temporal lobe (superior, middle, and inferior gyri). The total extent of cortical activation was significantly greater for irregulars than regulars ( $p < 0.005$ ). For regulars, the left hemisphere was activated to a greater extent than right hemisphere ( $p < 0.02$ ). In contrast, irregulars activated left and right cortical tissue to approximately the same degree. The significant increases in the activated volumes during irregular inflection were located in the right precentral gyrus, the left frontal lobe except Broca's area, the left and right supramarginal gyrus, angular gyrus and superior parietal lobule, and the left and right posterior temporal lobe, compared with regular inflection. This observation of different patterns of activation between regulars and irregulars is consistent with the symbol-manipulating account.



Activation in the left and right hemispheres during regular and irregular inflection in a single subject. (A: average activation of irregular nouns and verbs in the left hemisphere; B: average activation for irregulars in the right hemisphere; C: average activation for regulars in the left hemisphere; and D: average activation for regulars in the right hemisphere.)

## References

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