Neural basis of syllable frequency effects in speech perception and production

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INTRODUCTION

•Several models of language propose that frequent syllables are easier and faster to produce because they are pre-compiled as holistic motor routines, whereas infrequent syllables must be assembled online from smaller units (i.e. phonemes). The neural networks supporting the processing of the statistical properties of single syllables and sequences of syllables, however, remain unclear.

•The objective of this study was to examine the impact of syllable distributional statistics on brain activity associated with speech perception and production. We evaluated the impact of statistical features of single-syllables (syllable frequency) and pairs of syllables (mutual information). We expected to find a negative correlation between syllable frequency and brain signal reflecting decreased processing for frequent syllables. We also expected to find decreased brain signal for syllable pairs with high mutual information.

MATERIAL AND METHODS

•20 right-handed healthy participants (mean age = 24.45±4.6 years) were asked to (1) passive listen to 225 nonwords one at a time, and (2) listen to and repeat 225 nonwords.

•The stimuli were 450 meaningless disyllabic Italian nonwords (CV-CV). The frequency of the first syllable (FS1) and second syllable (FS2) and the pointwise mutual information (MI =log[P(syl2 | syl1)/P(syl2)]) of the syllables were calculated. FS1, FS2 and MI were uncorrelated.

•Images were collected on UNITN's 4T Bruker MRI (EPI sequences: 37 axial slices, 3x3x3.45 mm voxels; TR = 3.74 sec, delay = 2 sec). All stimuli and response occurred during the delay in TR. Our statistical model included the categorical factor TASK (perception, production) as well as three parametric regressors: logFS1, logFS2 and MI modeled as Amplitude Modulation (AM regression; AFNI). All analyses were corrected ($p < .01$, FWE $p < 0.01$).

DISCUSSION AND CONCLUSIONS

•The overall effects of speech perception and production are show in Fig 1.

•Different areas (mainly cortical) tracked FS1, FS2 and MI, with different patterns of interaction with task (Fig. 2-4).

•Most of the observed correlations had the expected negative direction (i.e. more freqent syllables and frequent pairs were associated with decreased BOLD signal) but a few positive correlations were found for FS2 in the left postcentral sulcus and cingulate gyrus.

•Significant interactions between statistics and tasks were found across the cortical sensorimotor system (Fig. 5).

•This is the first demonstration that the distributional properties of syllables influence both speech perceptual and motor processes, and that syllable position has an effect on the effect of frequency on BOLD signal.

RESULTS

Fig 1. Overall task effects

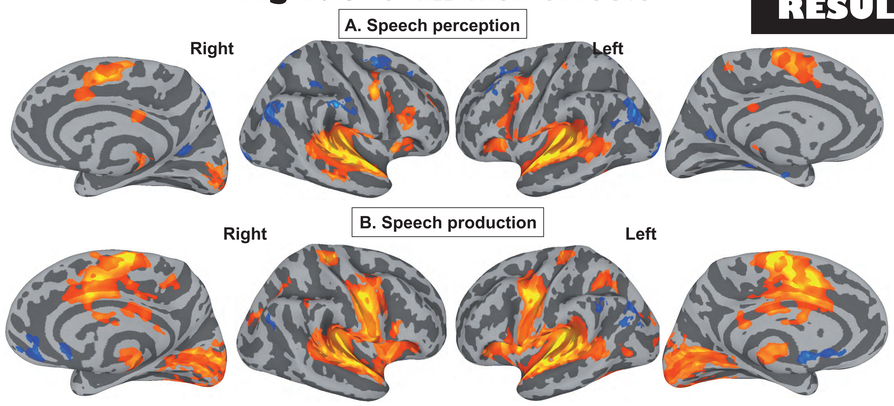

Fig 2. FS1 effects

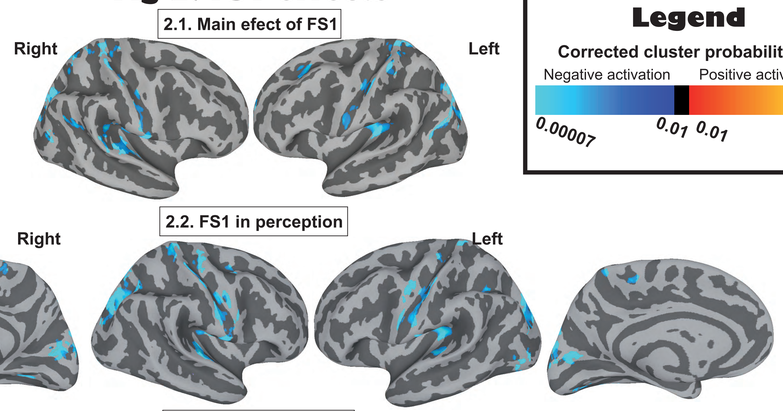

Fig 3. FS2 effects

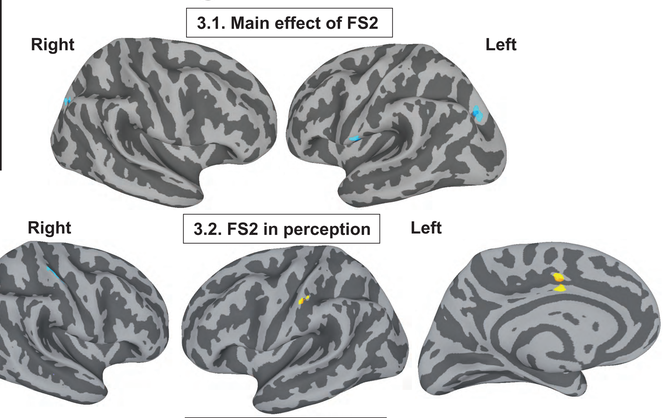

Fig 4. MI effects

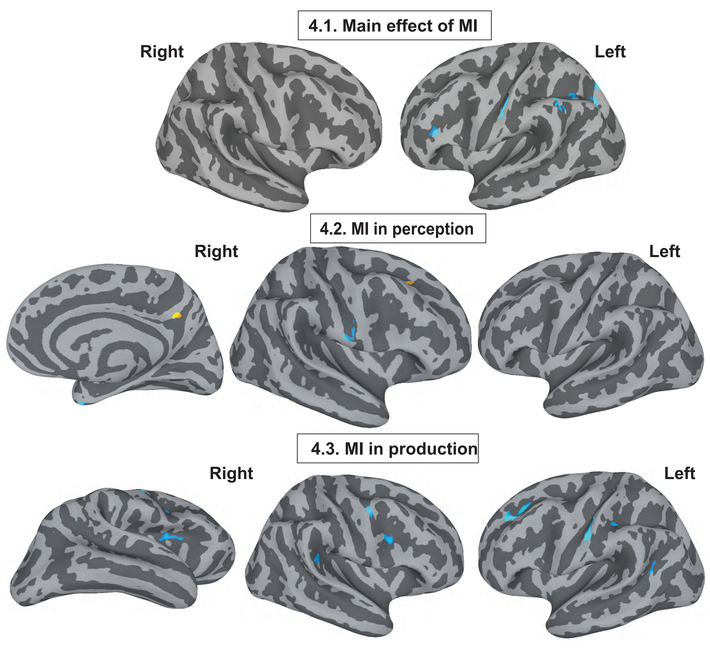

Fig 5. Statistics x Tasks interactions