Sublexical processing in left inferior frontal gyrus depends on word intelligibility

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Introduction

The left pars triangularis (PTr) is responsive to high *phonotactic frequency* (PF) words (Vaden, Piquado, Hickok, *submitted*), or words that are composed of speech sounds that co-occur with high frequency in the English language (Vitevitch & Luce, 1999). Two explanations for this PF effect are:

1. Sublexical representations activated passively by auditory-motor **associations**, or
2. Sublexical representations **recruited** to aid lexical access when speech intelligibility is low.

Our aim was to further characterize the relation of PF to left PTr activity by manipulating spoken word intelligibility and varying age.

Predictions

Association hypothesis	Recruitment hypothesis
PF effects increase as intelligibility increases.	PF effects increase as intelligibility decreases.
No age-related differences.	PF effects increase with increasing age.

Method

Manipulating Phonotactic Frequency

Stimuli: 120 CVC word recordings (Dirks et al., 2001) selected using controlled ranges of word frequency (WF), neighborhood density (ND), and phonotactic frequency (PF) from the Irvine Phonotactic Online Dictionary (Vaden, Halpin, Hickok, 2009).

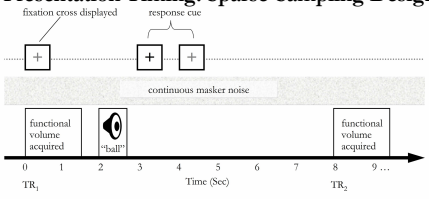
Manipulating Speech Intelligibility and Varying Age

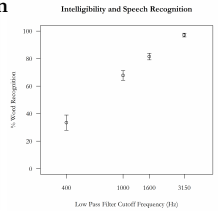
1. Intelligibility: 400 Hz, 1000 Hz, 1600 Hz, 3150 Hz low-pass filter cutoff frequencies.
2. Age: 36 participants between 19-79 years (m = 50.5, sd = 21.0).

Participants: 23 females, native English speakers, right handed. Continuous broadband noise was presented (62.5 dB SPL) with words (75 dB SPL) to reduce the confounding effects of differences in audibility among participants. Pure tone thresholds were positively correlated with age, $R^2 = 0.62$, $p < 0.001$.

Task: Listen, then press a button to indicate whether or not the word is recognizable.

Presentation Timing: Sparse-Sampling Design





Imaging Protocol (3T Philips)

Anatomical: T1 weighted, voxel = [1 × 1 × 1mm].

Functional: 131 images, 17 min 42s; TR = 8s; voxel = [3 × 3 × 3.25mm].

Synchronized presentations used Eprime, IFIS-SA control system, Sensimetrics piezzoelectronic insert earphones.

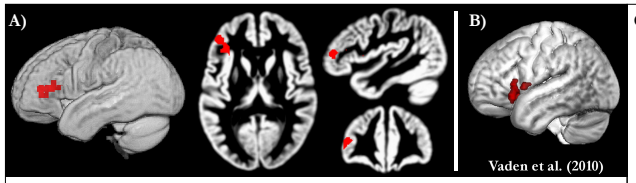
Analysis

Preprocessing: realignment, co-registration, DARTEL normalization, smoothing (8mm FWHM), de-trended using Linear Model of the Global Signal (Macey et al., 2004) using SPM5.

Individual Analyses: Stimulus events were entered into the general linear model separately by intelligibility condition, which was convolved with the haemodynamic response function, each had a PF and ND parameter.

Group Analyses: (1) Did the PF of words modulate responses during speech recognition? (*eg.* PF effect)
(2) ROI: PF effect related to (a) individual age or (b) intelligibility condition?

Results



High PF words elicited the greatest response in the left PTr.

A) Significant, positive correlation between responses to speech and PF of words shown in red voxels. Statistic map was thresholded at $t(29) = 3.35$, $p = 0.001$, cluster-corrected $p < 0.001$.

B) Replication of Vaden, Piquado, Hickok (*submitted*).

C) Significant impact of intelligibility on PF effect, $F(3,105) = 6.3$, $p < 0.001$; greatest PF effect for the most intelligible words (p's < 0.05).

D) PF was not related to age, $R^2 = 0.05$, $p = 0.2$.

Performance Summary

Logistic regression demonstrated significant effects of intelligibility ($p < 0.001$), PF ($p = 0.004$; 3150 Hz only), and ND (p's < 0.006; 400 Hz and 1000 Hz only). Factors that did not account for significant variance: **age**, pure tone thresholds, WF.

High PF words were recognized less often than low PF words in the most intelligible condition.

Conclusions

Our findings are consistent with auditory-motor associations driving sublexical activity in left PTr.

1. Positive correlation in left PTr using sparse-sampling design, replicated Vaden, Piquado, Hickok (*submitted*).
2. Phonotactic frequency effects were greatest when intelligibility was the highest.
3. Phonotactic frequency effects were not related to age in this cross-sectional study.

Association could provide the basis for PTr recruitment in tasks that rely on sublexical representations.

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