The influence of sentence context on word categorization: an fMRI investigation
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Introduction
• During language processing listeners integrate various sources of perceptual and contextual information to understand the linguistic message.
• Studies have shown that the perception of speech can be influenced by meaning including word and sentence-level context, especially when the speech input is ambiguous (Borsky, Tuller, & Shapiro, 1998).
• The overall goal of this work is to understand the processes involved in and the neural systems underlying the integration of sentence meaning and acoustic information.

Methods
Stimuli. A continuum was created that varied along the voice onset time (VOT) of the initial stop consonant of the target words ‘goat’ and ‘coat’.
A total of three stimuli were selected from the continuum; two good exemplars, one for [k] and the other for [q], and one boundary stimulus for which the phonetic identity of the initial stop consonant (and hence the word) was ambiguous. These stimuli were appended to three sentence fragment contexts: goat-biased (he wore the _), goat-biased (he fed the _), and neutral (he saw the _).
Participants. 21 participants volunteered for this study and were paid $25/hr for their participation.
Task. Participants listened to the auditory presentation of the stimuli and were instructed to press a button to indicate whether they heard the word ‘goat’ or ‘coat’.

Behavioral Results
• Sentence context influenced categorization for the boundary stimuli with significant differences emerging for goat-biased sentence context (p = .02), and a trend for coat-biased sentence context (p = .07).
• The categorization of the endpoint stimuli was unaffected by sentence context.
• The fMRI analysis focused on the goat-biased and neutral sentence contexts.

Scanning Protocol
• 3 Tesla Tim Trio MRI scanner equipped with 32 receiver channel head coil
• Sparse-sampling design with MR compatible in-ear headphones
• 3 runs consisted of 24 randomly presented trials of each sentence context and stimulus type
• Participants were eliminated due to excessive movement
• Statistical maps were corrected for multiple comparisons by including only clusters that were significant at a group-wise corrected statistical threshold of p < 0.05, as determined by Monte Carlo simulations.

Sentence Context x Target Stimulus Interaction
Voxels thresholded at p = .025, clusters corrected at p < .05

Peak Talairach coordinates (-58, -4, 5) Y extends from -1 to 42
- The largest cluster emerged in left superior temporal cortex (83 voxels).
- For the boundary target stimulus, we found less activation in goat-biased sentence contexts compared to neutral sentence contexts.
- In contrast, for the goat endpoint target stimulus, greater activation was found in goat-biased sentence contexts compared to neutral sentence contexts.
- This interaction suggests that the left superior temporal gyrus is recruited in integrating sentence context information with acoustic phonetic information.
- The integration of sentence context with an ambiguous stimulus results in decreased activation, presumably due to the fact that sentence context resolves phonetic ambiguity.
- In contrast, the integration of sentence context with an endpoint stimulus results in increased activation, presumably due to the congruence of sentence context and phonetic category.
- Other significant clusters at a corrected p < .025 were found in the right superior temporal gyrus, the right middle frontal gyrus, the right cingulate, the left cerebellar hemisphere, and the right cerebellum.

Anatomically-based Region of Interest Analysis
(Regions were defined using the Talairach Daemon built in AFNI)
- We examined whether modulation of phonetic category information occurs early in the speech processing stream, i.e. Heschl’s gyrus.
- To isolate this region, we reduced the voxelwise threshold to p = .05 and examined changes in activity that only fell within Heschl’s gyrus.
- Although only a trend, a similar pattern emerged as was found in the left superior temporal gyrus.

Effect of Acoustic Information in Same Sentence Contexts
Neutral Boundary – Neutral Goat Endpoint
Voxels thresholded at p = .025, clusters corrected at p < .05

Goat-biased Boundary – Goat-biased Goat Endpoint
- In the comparison between boundary and endpoint stimuli in the neutral condition, greater activation was found for the boundary stimulus in the inferior frontal gyrus and greater activation was found for the goat endpoint stimulus in the angular gyrus.
- Consistent with earlier findings, the inferior frontal gyrus and the angular gyrus are recruited in phonetic processing (Blumstein et al. 2005).

Conclusions
- Sentence context and acoustic information are integrated in the left superior temporal gyrus, suggesting that this area is involved in integrating multiple sources of information during language processing.
- Similar patterns emerged in Heschl’s gyrus suggesting that this area may be receiving feedback from the superior temporal gyrus.
- These findings indicate that different neural areas are activated in processing the acoustic properties of stimuli than are recruited for the integration of different sound structure and sentence context information.

References

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