INTRODUCTION

There is ample evidence for implicit (automatic) semantic processing following presentation of meaningful linguistic stimuli in both the auditory and visual modalities (e.g., the Stroop effect; MacLeod, 1991).

Nonetheless, whether words are processed obligatorily remains uncertain mainly due to inconsistent reports regarding differences in brain activation between word and nonword sounds.

Subjects performing a nonlinguistic visual feature detection task produced activations in language areas suggesting implicit visual word processing (Price et al., 1996).

The current study employed fMRI to study the effects of attention (task demands) and stimulus type (auditory words, nonwords) on brain areas implicated in language processing.

Task demands were manipulated such that subjects were engaged in a bimodal selective attention task where sounds were either attended to or ignored. To hold attention constant and away from the sounds, in the ignore condition subjects focused on a demanding visual task.

METHODS

Subjects: 28 healthy, right-handed, native English speakers.

Auditory Stimuli:

- Words: 140 concrete monosyllabic nouns
- Pseudowords: 140, matched to words in number of phonemes, phonological neighborhood size, average biphone log frequency
- Rotated Speech: 70 spectrally rotated words, 70 rotated pseudowords chosen randomly from the lists above
- Mean Duration = 667 ms

Visual Stimuli: Single Japanese characters (Kana; e.g. ｱ) in middle of screen.

Paradigm:

- SOA of sounds = 2, 4, or 6 s. SOA of visual stimuli = 0.5 s. Auditory or visual repetition = 17%
- Each of 7 runs included 12 blocks of randomized: Attend Auditory (ignore visual and ignore auditory) conditions.

Task: Participants performed a 1-back matching task in the assigned attended modality. In the attend auditory, subjects were instructed to keep their eyes focused on the screen while ignoring the visual characters.

MRI Procedures:

- GE Sigma 1.5T scanner (GE Medical Systems, Milwaukee).
- Functional data: T2*-weighted, gradient-echo EPI (TR = 2 sec, TE = 40 ms, flip angle = 90°, slice thickness = 3.75 x 3.75 x 4.50 mm voxels).
- Anatomical data: 3-D spoiled gradient-echo sequence. Whole brain, 0.94 x 0.94 x 1.2 mm3 voxels.
- Image analysis used AFNI software package (Cox, 1996). FWHM = 6 mm. Random effects analysis.
- Cluster size threshold (641 ul, p < .05 corrected) was applied to the group-t-maps thresholded at p < .001.

RESULTS

Auditory Behavioral Performance

The auditory matching task was performed wall. overall d’ = 3.20 (words = 3.35, pseudowords = 3.31, rotated speech = 2.95).

The visual task proved to be very demanding: d’ = 2.72.

ATTEND AUDITORY > ATTEND VISUAL (ignore auditory)

Pseudowords activated very similar to those activated by words.

Rotated Speech activated very similar areas to those words and pseudowords. There was somewhat more activation in right ventrotemporal areas and less activation in left OFC.

ATTEND VISUAL > ATTEND AUDITORY (ignoring visual)

Pseudowords: No above threshold activations.

ATTEND VISUAL > ATTEND PSEUDOWORDS (in Orange).

Attentional vs. non-attentional conditions:


DISCUSSION

Regardless of stimulus type, attended sounds activated the STS, SMG and DPC more than unattended sounds. These areas are associated with auditory working memory which is necessary for performing the 1-back task.

Regardless of task demands (attend, ignore), words and pseudowords did not differ in activation, suggesting similar processing.

Rotated speech activated dorsal temporal areas (HG, PT) more than either words or pseudowords, regardless of task demands. These results suggest additional pre-attentive acoustic analysis of these unfamiliar sounds.

Rotated speech also activated SMG and DPC more than either words or pseudowords during the attend auditory task. This suggests greater demands on auditory working memory, consistent with the behavioral data showing poorer performance on the 1-back task for rotated speech.

Conversely, attended words and pseudowords activated more ventral temporal areas (STS, MTG, ITG, fusiform), suggesting linguistic/semantic analysis.

A large region in the medial occipital lobe (cuneus, lingual gyrus) showed stronger activation in the attend auditory task than in the visual task. We speculate that this pattern may represent active inhibition of the ongoing visual stimulation.

Taken together, these results suggest that attention modulates linguistic processing of words and pseudowords. Rotated speech appears to be processed mainly at a prephonemic auditory level regardless of attentional state. Attentional processing engages auditory working memory, especially for rotated speech.