Speech perception in noise, SNR dependent activity

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Introduction

For an individual with normal hearing the information extraction from auditory language stimuli in a noise free environment is implicit and automatic. On the other hand, if the signal is disturbed by noise, the information may be incorrectly or only partially coded and explicit decoding by central cognitive processes are needed to decode the signal. This leads to increased cognitive demands and sometimes to an incorrect interpretation of the auditory signal. One part of this work is to identify brain areas whose activity is affected by the degradation speech signals.

Methods

fMRI data was collected on a Philips 1.5 T MR-scanner using a sparse imaging protocol (TR 10s, acquisition time 3s). During the silent intervals the subjects were presented with short sentences degraded by frequency modulated noise at different SNR levels through the MR-system head phones. The design included 25 each of the following conditions; clear speech, speech at 0, -4 and -8 dB relative to the noise level, pure noise and baseline (no stimuli) resulting in a total of 150 items. After each item the test subjects were told to indicate which one of two visually presented words was included in the sentence.

SPM8 was used to apply motion correction, to normalize the data into the MNI space and to find activity related to the speech conditions. Data from the speech related areas was used as input into a search-light classification analysis using the MVPA toolbox[1]. The classifier was trained to tell whether the data came from a high or low SNR condition (clear speech and 0dB vs. -4 and -8 dB).

Results

The classifier was able to correctly label the data as high or low SNR in ~72% of the tested items. The regions that contributed the most the classification were bilateral auditory cortex and lingual gyrus, right insula, bilateral premotor area, middle frontal gyrus and dorsolateral prefrontal cortex (see Figure 1). By extracting the regression weight from the SPM analysis it was seen that the activity was reduced in the auditory cortex and the lingual gyrus when the noise level increased. In contrast the activity seems to be increased in the insular and prefrontal regions when the noise level increases.

Figure 1. Some of the most important areas for the outcome of the classification algorithm.

Conclusions

The functional activity in several areas was affected by the noise level in which the sentences were presented. Reduced activity in auditory cortex and lingual gyrus with increased noise level is consistent with less lingual information being readily available in the signal. The increased activity in prefrontal areas is consistent with the idea that under difficult listening conditions the cognitive demands increase in order to retrieve the speech information presented.
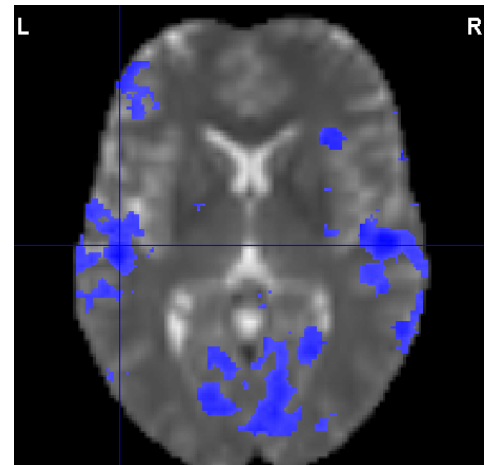
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[1] The Multi-Voxel Pattern Analysis (MVPA) toolbox (2006) Detre et al. http://www.csbmb.princeton.edu/mvpa/