Investigation of the Spatiotemporal Dynamics of the Brain during Perceiving Words

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Abstract: To investigate the temporal dynamics and spatial representations in speech perception and processing, electroencephalograph (EEG) signals were recorded when subjects listening Chinese words and pseudo words. According to the source reconstruction, the early neural activations were observed in wider areas from the Spt (an area in the Sylvian fissure at the parietotemporal boundary) to the premotor cortex and posterior frontal gyrus during 35ms to 80ms, while the areas from posterior middle temporal gyrus to anterior middle temporal gyrus were activated during a time period from 110ms to 180ms. These activation patterns are consistent with the dual-stream model, where the former one corresponds to the dorsal stream and the latter one belongs to the ventral stream. These two streams interacted after 180ms and showed recurrent activation after 300ms. This phenomenon was not observed for the pseudo words. Our findings demonstrate a quite early stage of speech cognitive process and present the dynamics of interaction between the two streams during perceiving words. The results are essential for the construction of connectivity model in further studies.

Experiment and Method

Participants: 16 Mandarin native speakers (8 males, 8 females) with the mean age of 23.9 years. All the subjects were right-handed with normal vision and hearing without psychiatric disorders or neurological deficit.

Materials: 50 Chinese verbs(e.g. 打击) and 50 pseudo words(e.g. 禁咚). Each contained auditory and visual stimuli.

Task: Judge the consistency of the auditory and visual words.
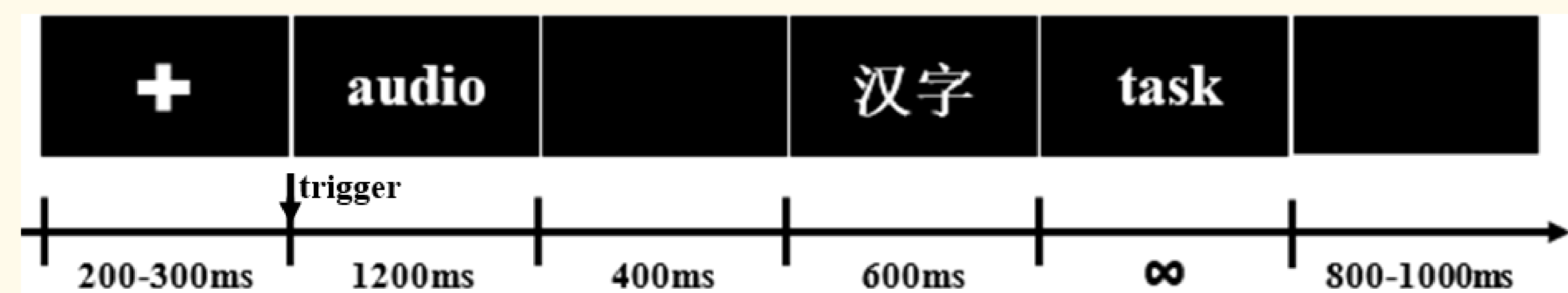
EEG recording: Neuroscan Synamps system with 128 electrodes at a sampling rate of 1000 Hz.

Offline Analysis:
Reference electrode: CAR (Common Average Reference).
Baseline correction: Constant.   Filter: 0.1 Hz – 30 Hz.
Artifact reduction.   Event Related Averaging.

Source Location:
Noise Estimation Limitation: SNR >10.
PCA: sort out the components which might be noise.
ICA: link the components to spatial information.
Head models: BEM & standard MRI template.
Source Location: sLORETA based on the CDR.
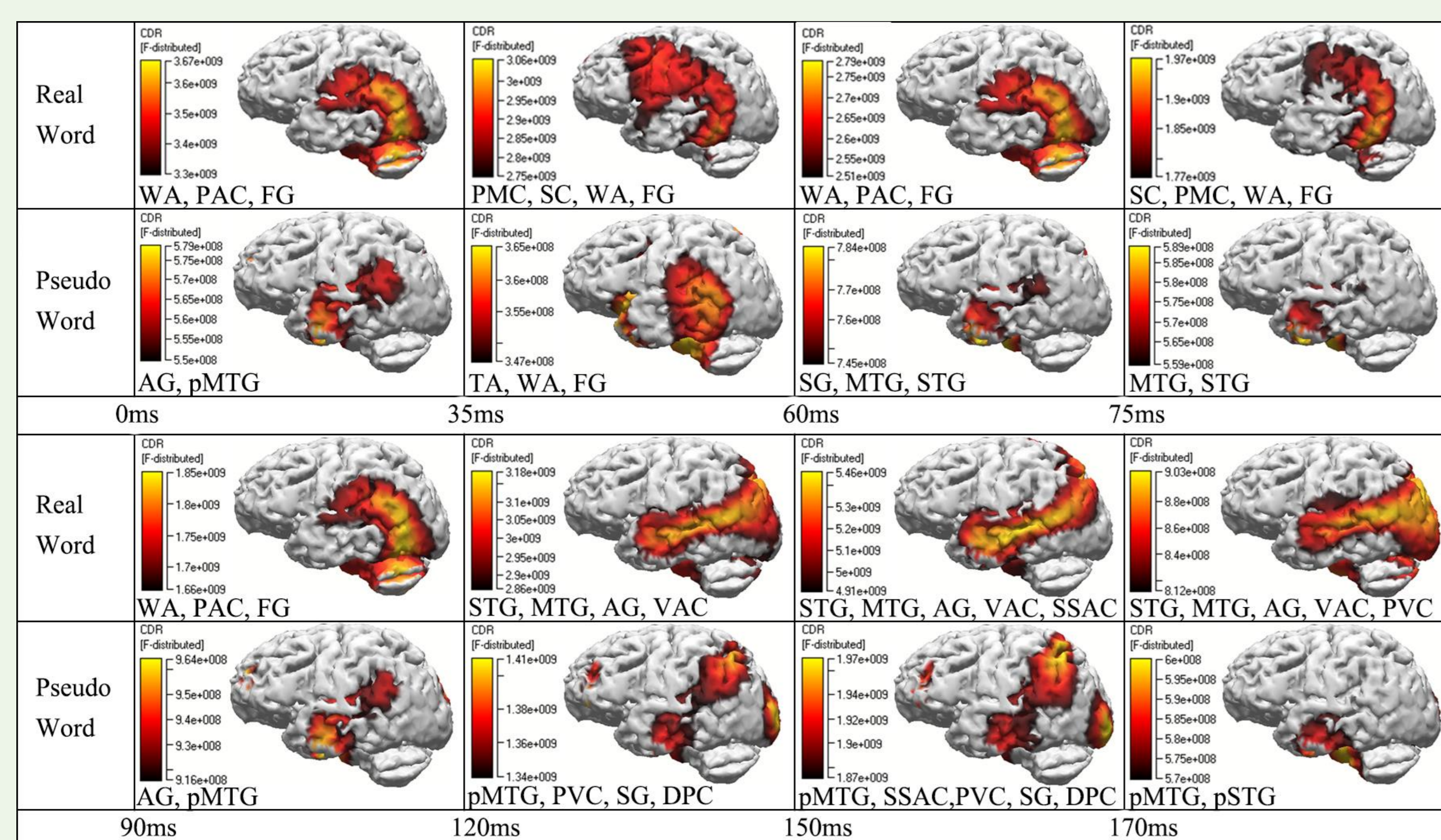
Results and Discussions

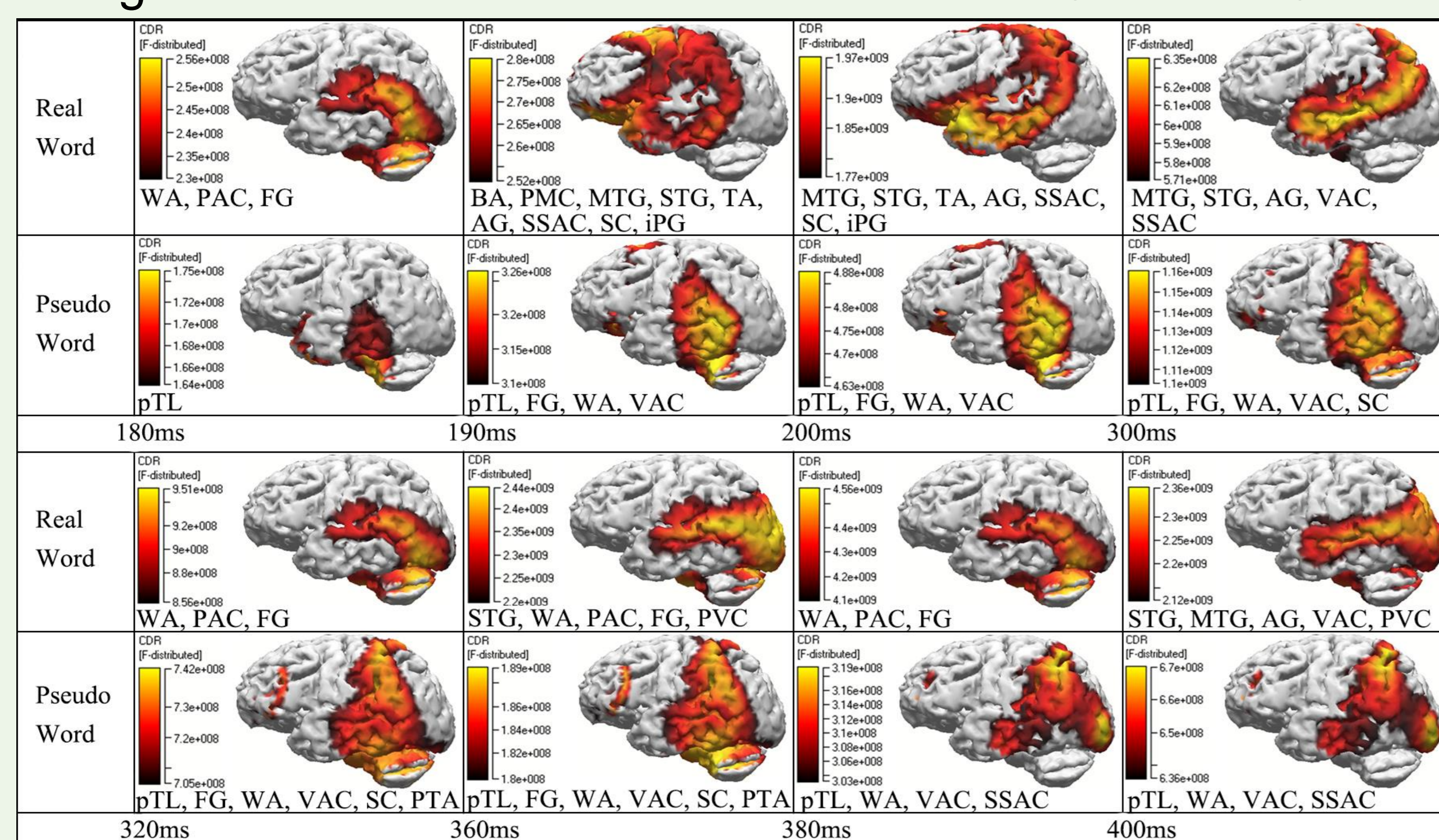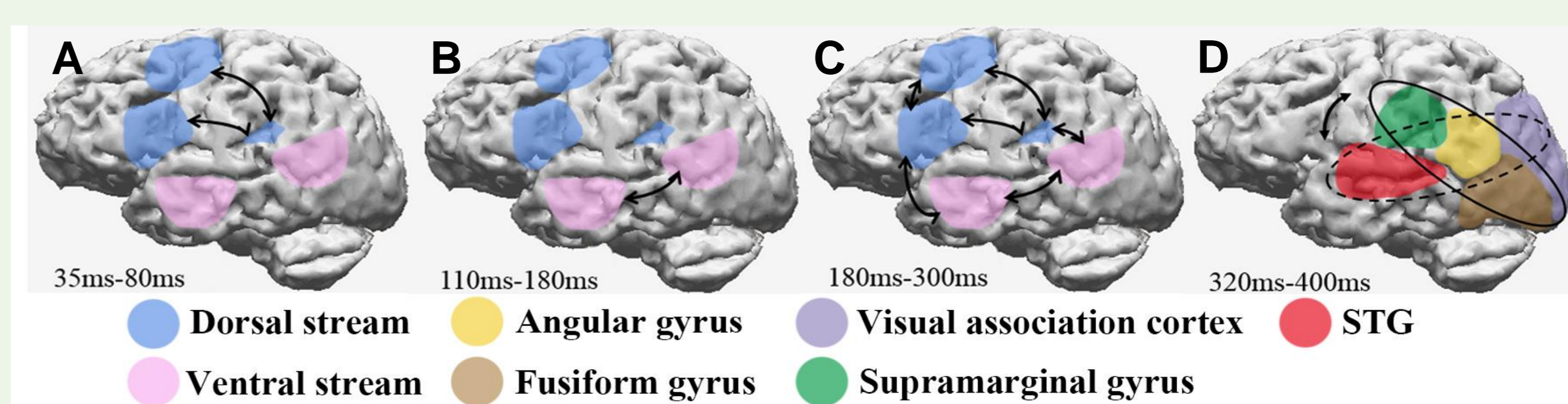Fig. The source reconstruction results from 0ms to 170ms

Fig. The source reconstruction results from 180ms to 400ms

Stage A: Our result showed activations in the Broca's area and a part of PMC with fast reaction. The dorsal stream might be involved in the mirror neuron system during the action mapping processing. Besides, this early stage activation is in line with an unconscious processing period for the brain to collect information according to a conceptual framework of perception. Due to the high temporal resolution of EEG, this study clarified that the activation of the dorsal stream led that of the ventral stream in 75ms.

Stage B: the pattern of brain activations is in line with the role of the ventral stream. We propose that the middle temporal lobe is possibly the more important area in the ventral stream instead of FG.

Stage C: Two streams are connected through the inferior prefrontal gyrus, temporopolar area and Broca's area, which functionally is due to some degree of executive control and working memory during speech perception task. The interaction between them can be regarded as an information integration process.

Stage D: the data showed a recurrent activation between the solid line area and dashed line area, which might agree with the verification model.