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EEG Evidence for a Three-Phase Recurrent Process during Spoken Word Processing

Bin Zhao, Jianwu Dang, Gaoyan Zhang
E-mail: zhaobeiyi@tju.edu.cn;
jdang@jaist.ac.jp; zhanggaoyan@tju.edu.cn

Tianjin key Laboratory of Cognitive Computing and Application,
Tianjin University, Tianjin, China

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Outline

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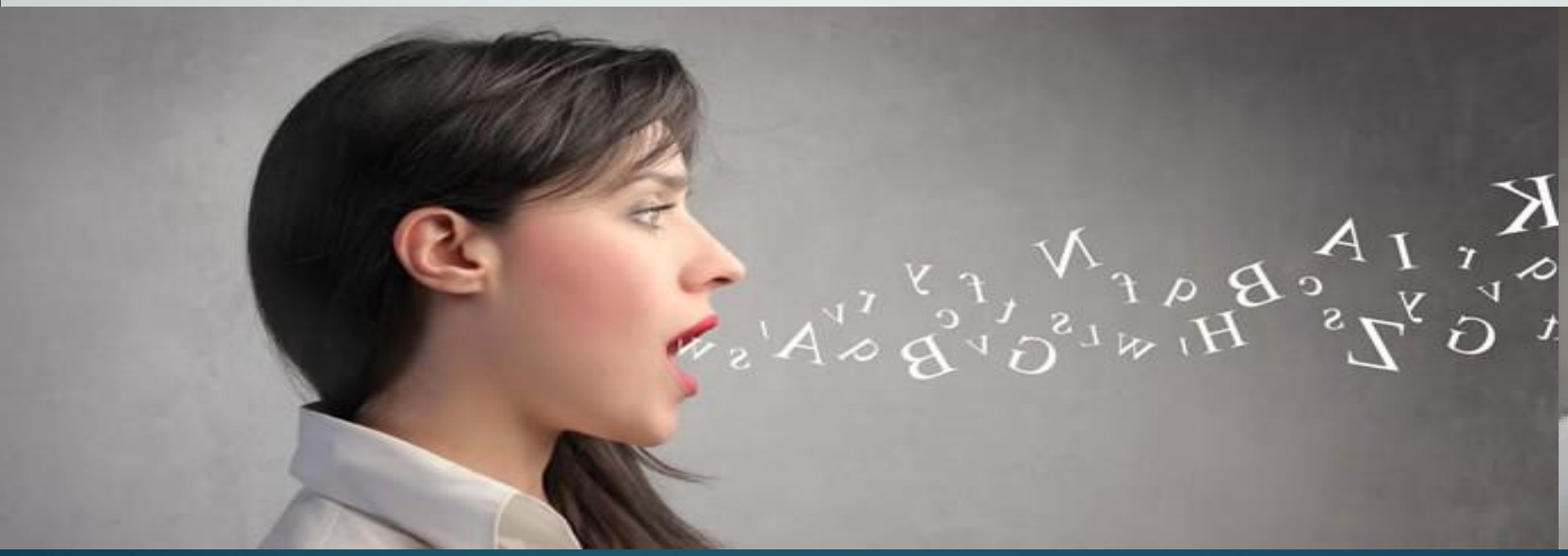
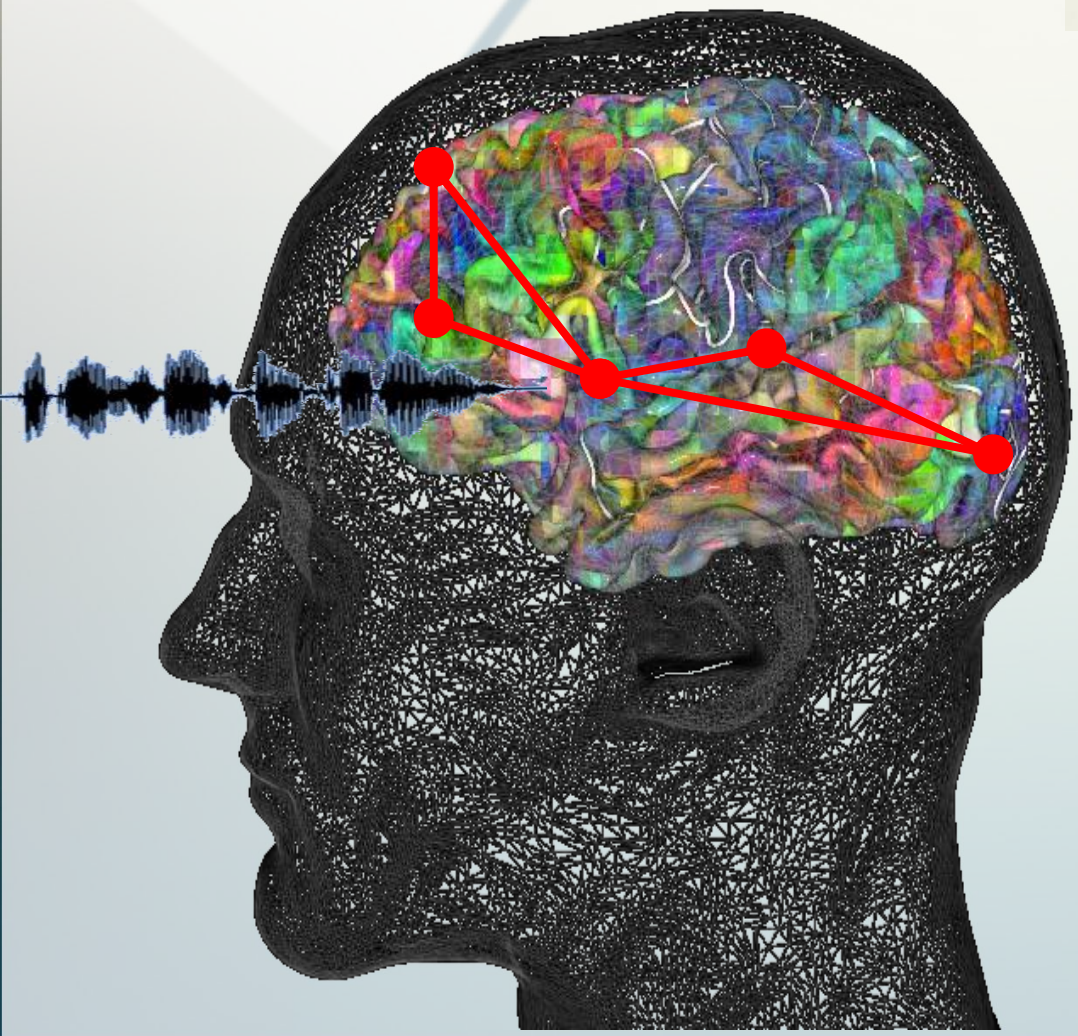
Part One

Introduction

Introduction



Introduction



Two explanations of spoken word processing:

Serial processing model

acoustic-phonetic input -- mental linguistic knowledge involves explicit ordering of information types:
phoneme --- syllable --- morpheme --- semanteme
e.g. [k...]---[kæ...]---[kæt]---cat
J. Morton, "Interaction of information in word recognition," Psychol Rev, vol. 76, pp. 165-178, 1969.

Direct mapping model

low-level (sub-phoneme) --- high-level (lexicon)
Mapping [k...]--- cat, cap, cash, click, kindle .....
Shifting [kæ...]---cat, cap, cash .....
Integration [kæt]--- cat
J. L. McClelland, and J. L. Elman, "The TRACE m... ...n," Cognitive Psychology, vol. 18, pp. 1-86, 1986

Introduction

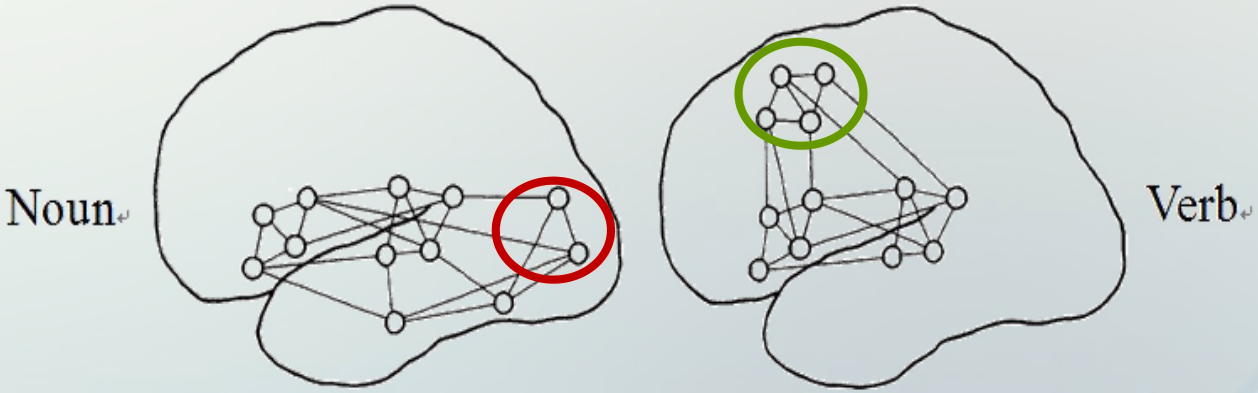
Purpose: to uncover the brain activation dynamics during spoken word processing

Method:

1. Electroencephalograph (EEG)
   high temporal resolution
   to trace the time course of different phases during word processing

2. EEG source reconstruction
   high spatial resolution
   to locate the activated brain sources in response to the words in each phase

Material: nouns and verbs



Nouns (objects)
visual-occipital cortex

Verbs (actions)
motor-fromtal cortex

F. Pulvermüller, B. Mohr, & H. Schleichert, "Semantic or lexico-syntactic factors: What determines word-class specific activity in the human brain?" Neuroscience Letters, vol. 275, no. 2, pp. 81-84, 1999.

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Part two

Methods

Spoken Word Stimuli

Table 1. Mean rating values of psycholinguistic, semantic and emotional features for nouns and verbs

	Familiarity	Concreteness	Vision-relatedness	Motion-relatedness	Arousal	Valence
Noun	5.96	4.04	5.76	1.99	2.60	3.20
Verb	5.65	3.57	3.12	5.62	2.61	3.09

Properties

- **familiar, concrete and neutral two-character (disyllable) words in Mandarin**

Type

- 80 **nouns**
- 80 **verbs**
- 160 white noise segments (filling)

Record Parameters

- Format: Wave PCM (*.wav)
- Sampling rate: 44100Hz
- Sound track: stereo (dual track)
- Bit depth: 16 bit (float)

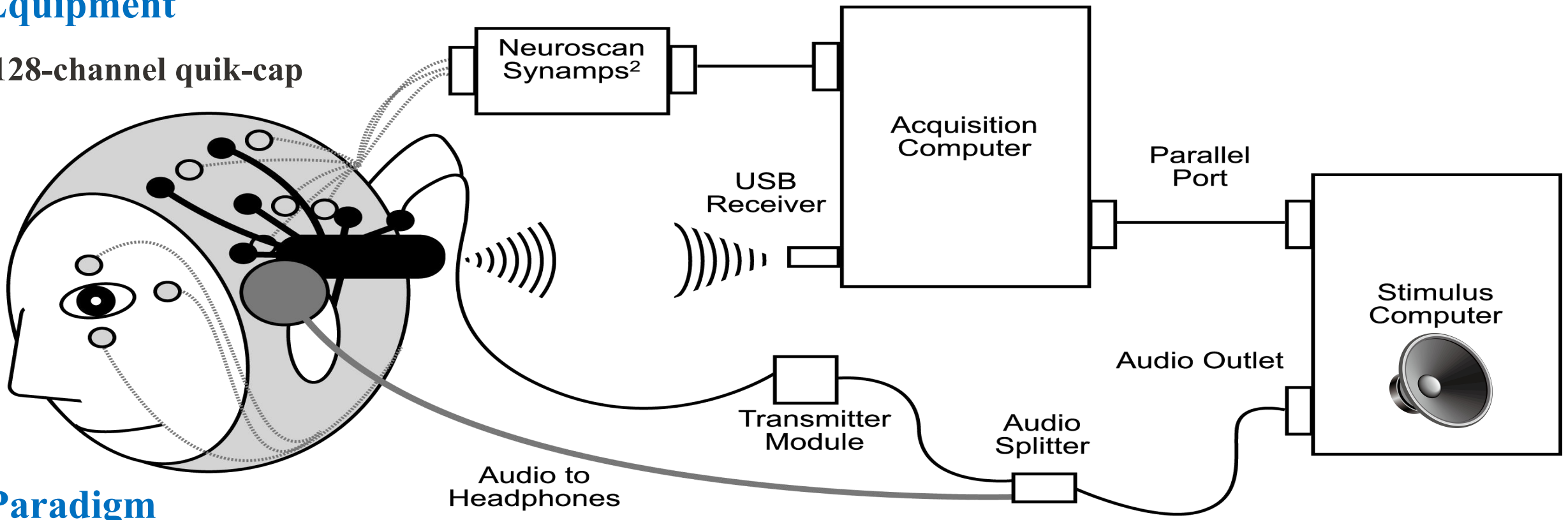
Table 2. Part list of the word stimuli

名词 Noun		动词 Verb	
书本	shuben	矗立	chuli
窗户	chuanghu	追逐	zhuizhu
夕阳	xiyang	打扫	dasao
外衣	waiyi	点燃	dianran

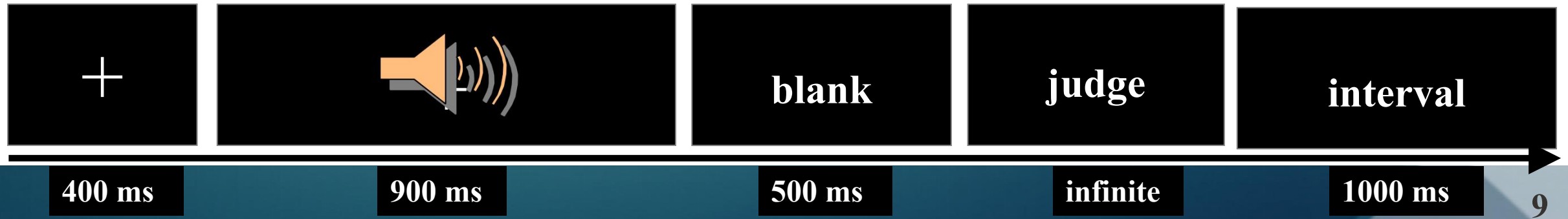
Experimental Procedure

Equipment

128-channel quik-cap



Paradigm

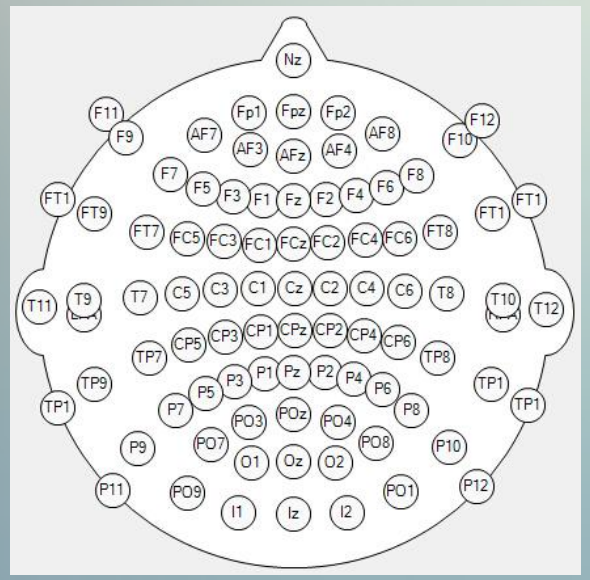


EEG Acquisition Parameters

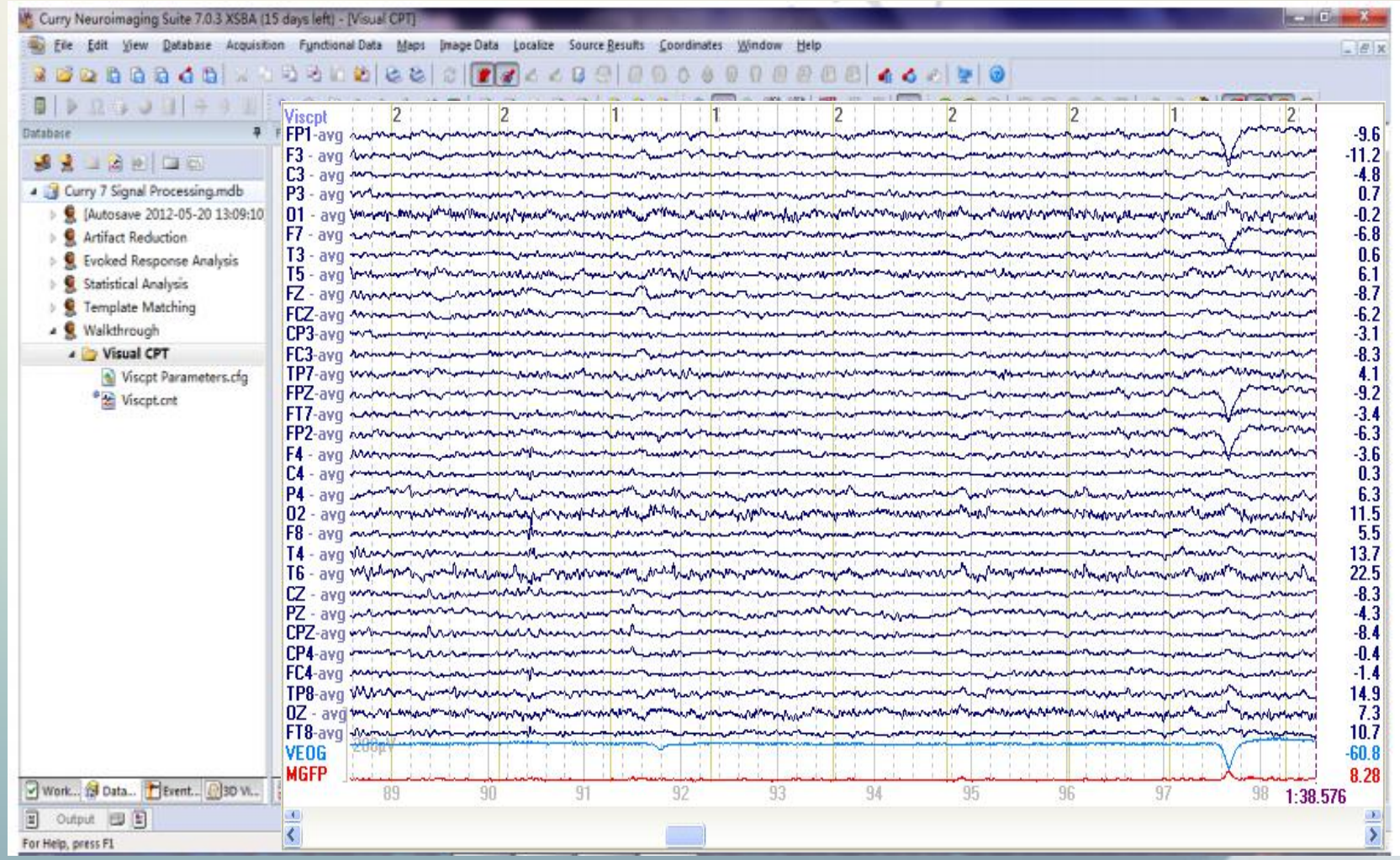
Online Recording Parameters :

Quik-Cap: 128 electrodes
Configuration: Extended 10-10 system
Amplifier: Synamps 2/RT
Sample rate: 1kHz
Impedance: below 5kΩ

128 electrodes: 10-10 system



online EEG signals



EEG Pre-processing Parameters

Offline Analysis Parameters :

Filter Parameters: 0.1Hz - 30Hz (brainwave range)

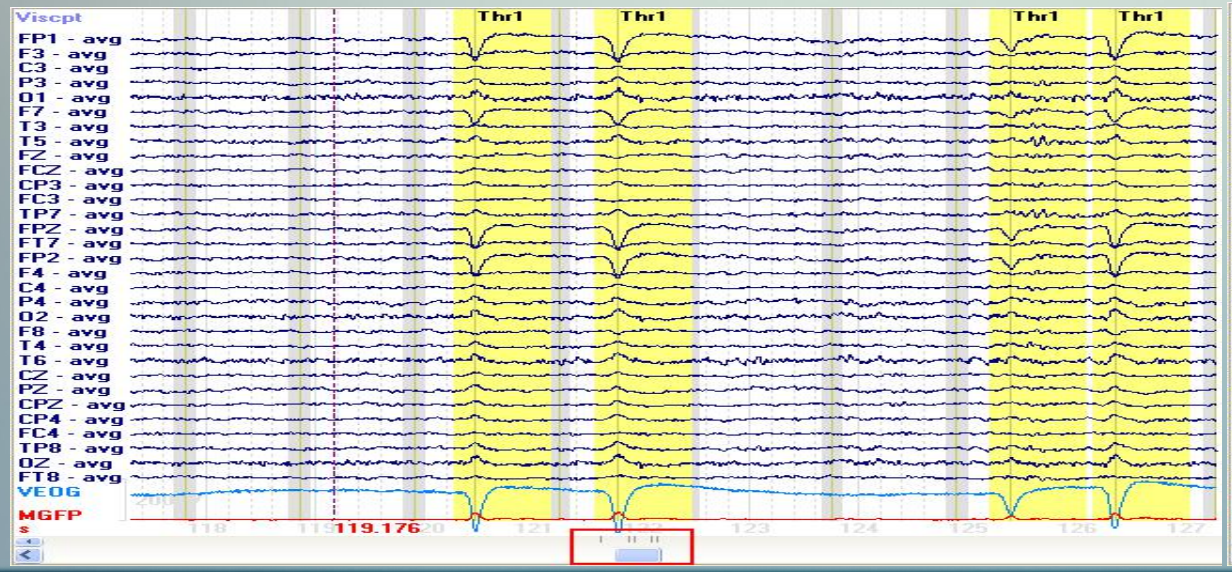
Reference electrode: Common Average Reference (CAR);

Baseline correction: remove a constant or linear DC offset from the data

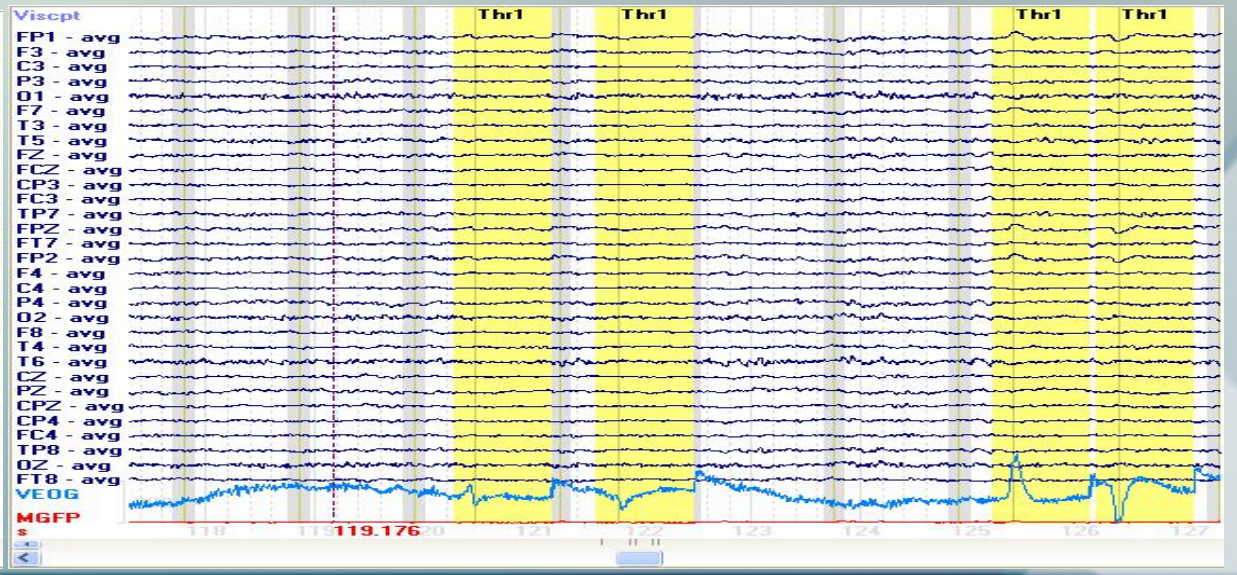
Artifact Reduction: Covariance analysis

1. eye blink reduction: threshold (VEOG): ±200 uv, time range: -200-200 ms
2. bad block reduction: threshold : ±100 uv, time range: -200-500 ms

before



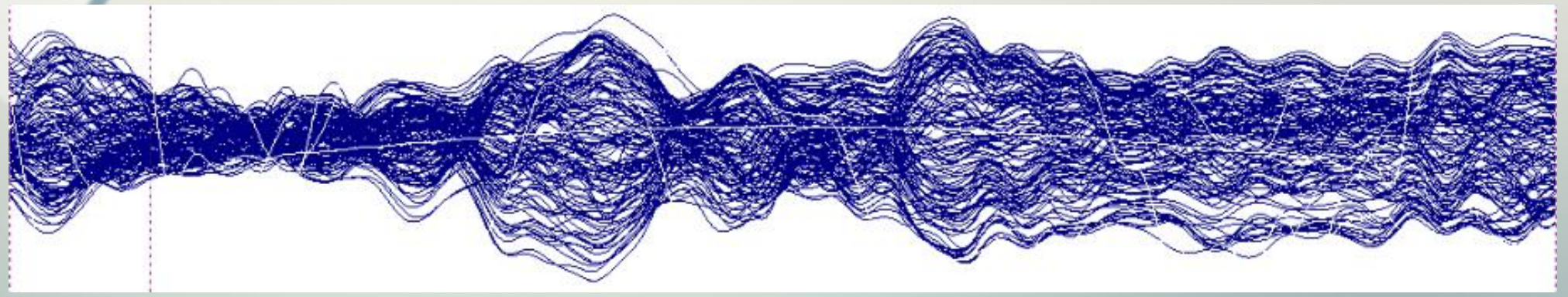
after



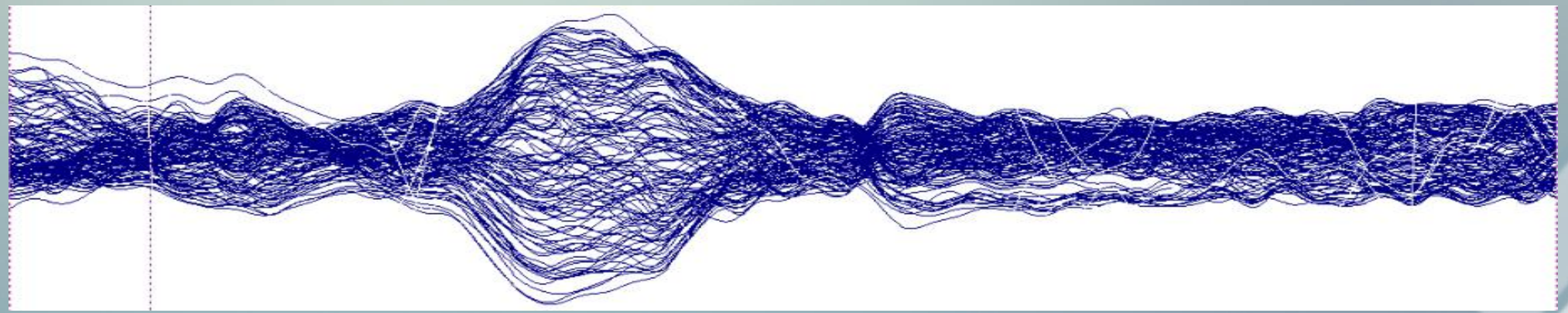
EEG Functional Data

Epoch/Averaging (Event Related Averaging): -100-1000 ms

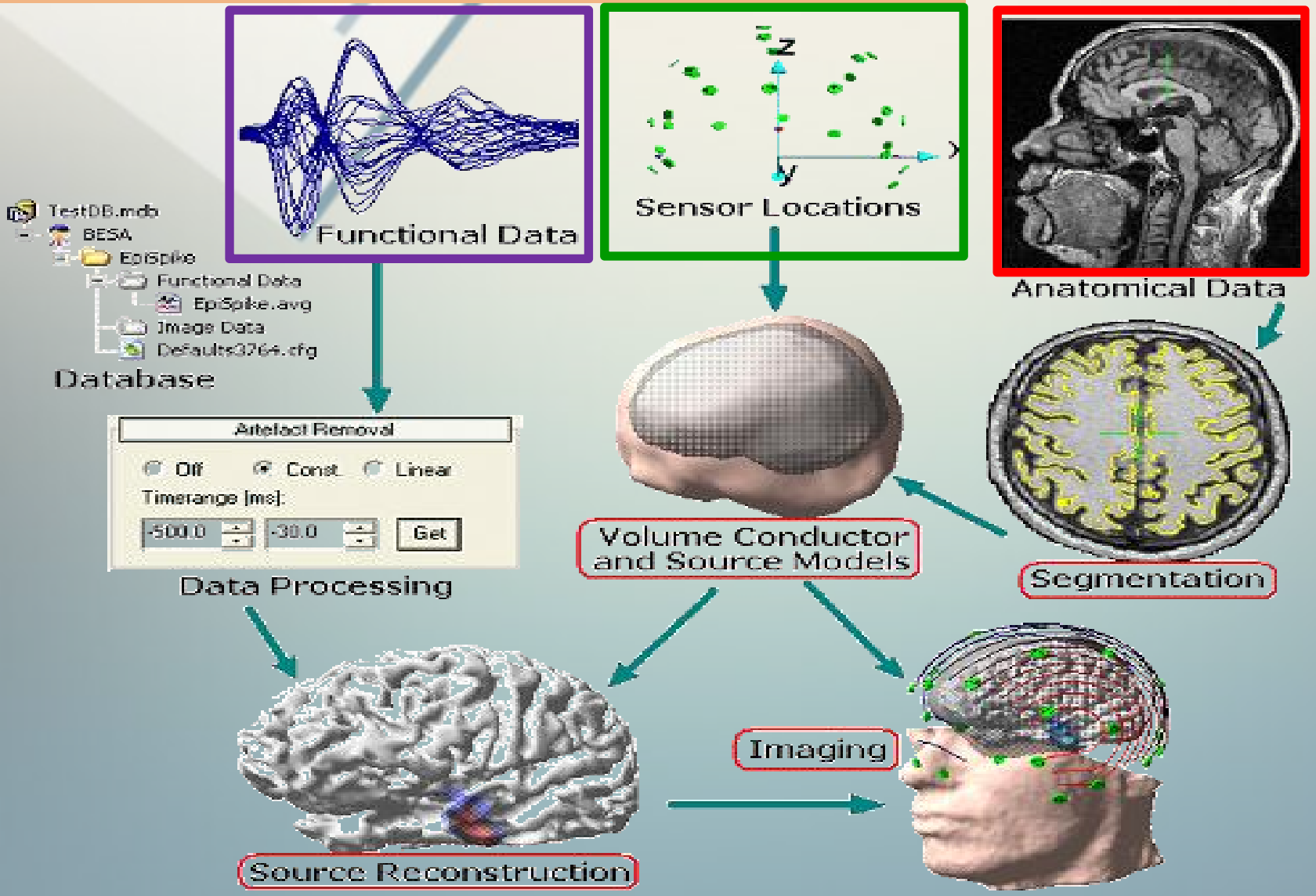
Noun-related event



Verb-related event



EEG Source Reconstruction



Purpose:

To construct the brain sources that may contribute to the noun and verb processing.

Procedure:

Functional Data: inversely calculate for the localization of activity sources

Sensor Locations (128 electrodes): Boundary Element Method (BEM) construct volume conductor and source models

Anatomical Data: segment brain structure Head model: standard MRI template

EEG Source Reconstruction

Functional Data - data processing

Noise Estimation Timerange : -40-0 ms
Noise Estimation limitation: signal-to-noise ratio (SNR) >10

PCA (Principle Component Analysis) to determine the possible source numbers.
It ia assumed for certain signals recorded on the scalp, there are one or more sources in the brain where the activities originates.

ICA (Independent Component Analysis) to extract independent components for word processing
Current Density Reconstruction (CDR): an independent analysis that allowes distributed sources to be concurrently observed at a certain time point and could provide the activation extent on a regular 3D grid or on the cortex.

sLORETA (standardized Low Resolution Electromagnetic Tomography) : inverse operation constraints required to settle the non-uniqueness between surface topography and underlying sources..
(a modification of MNLS, Minimum Norm Least Squares)

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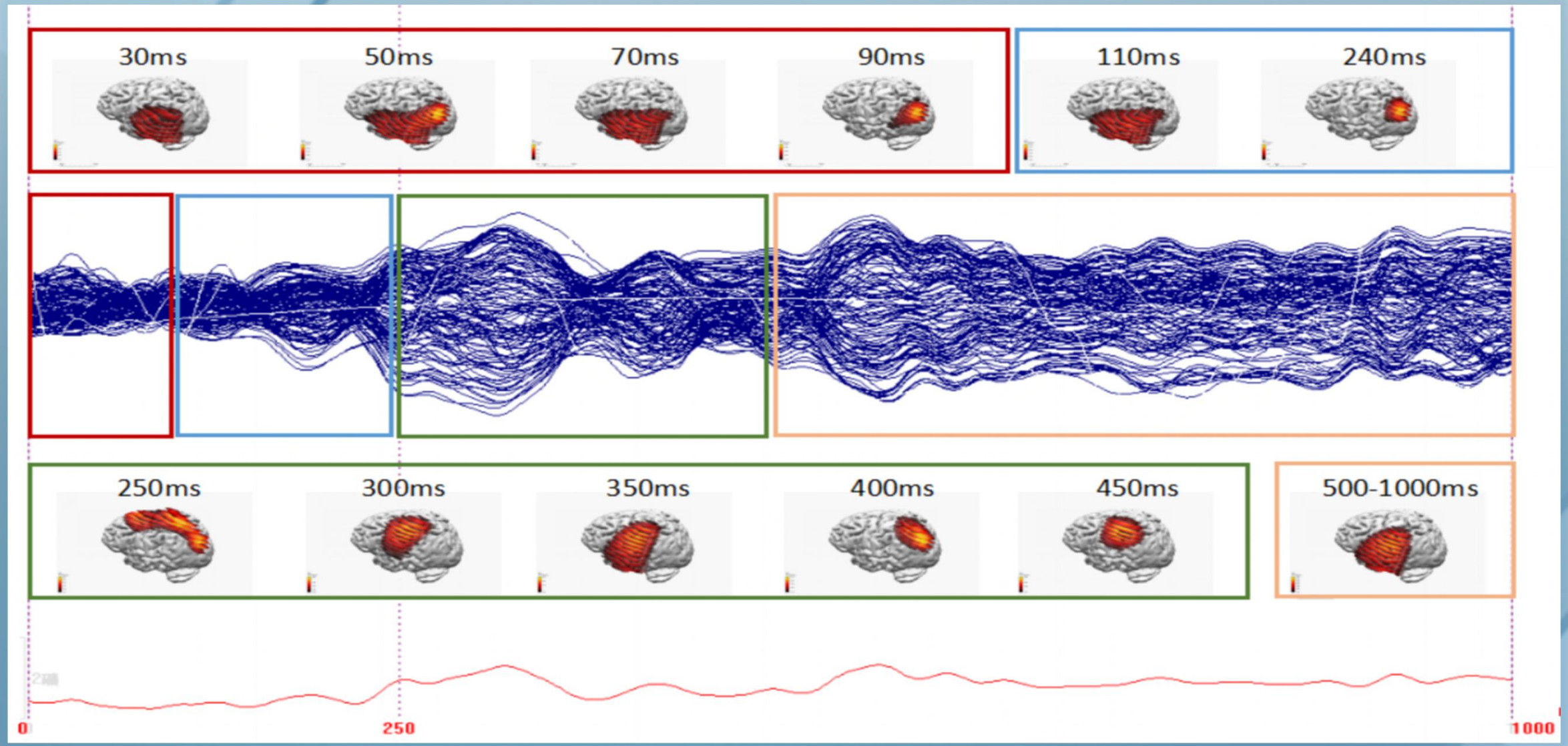
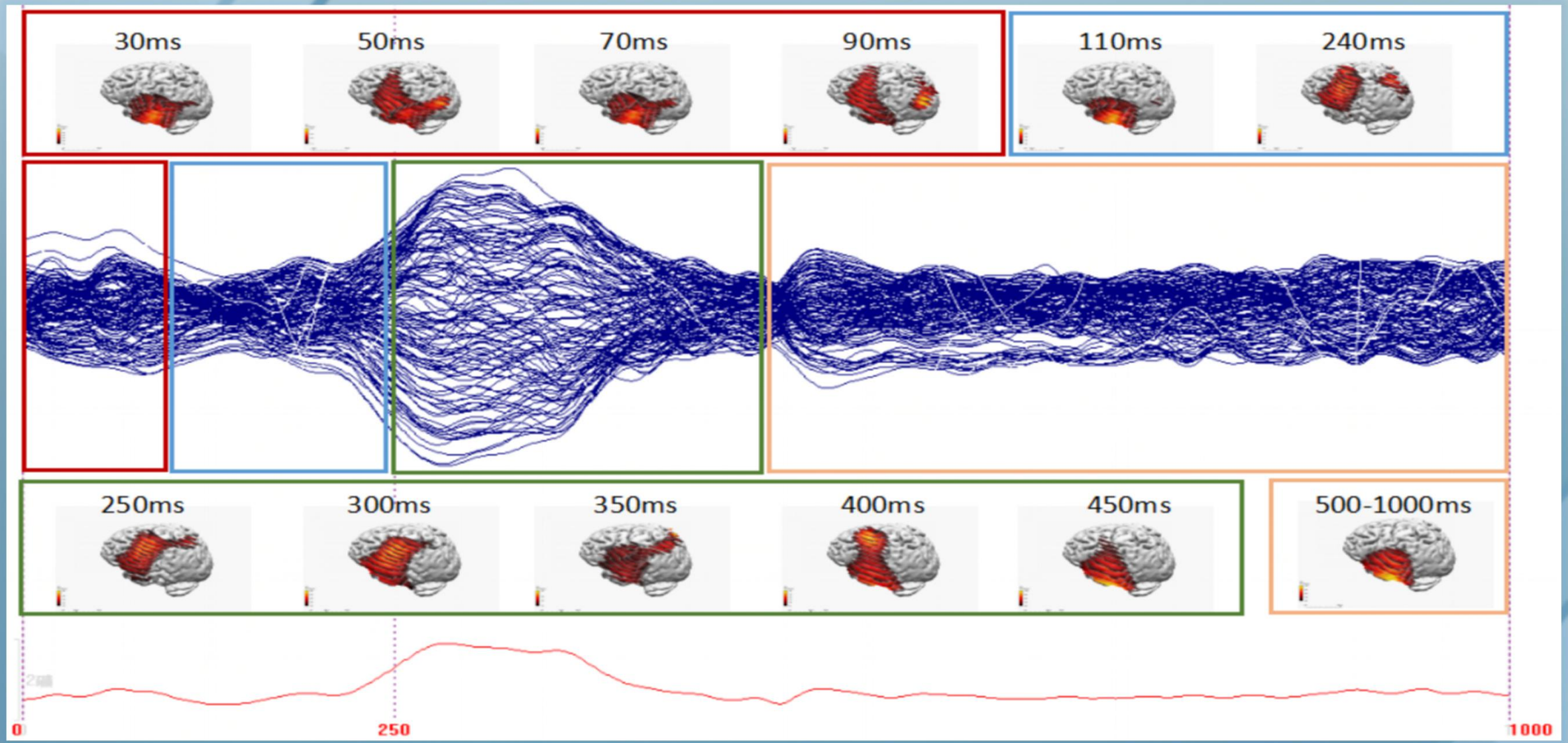
Part three

Results

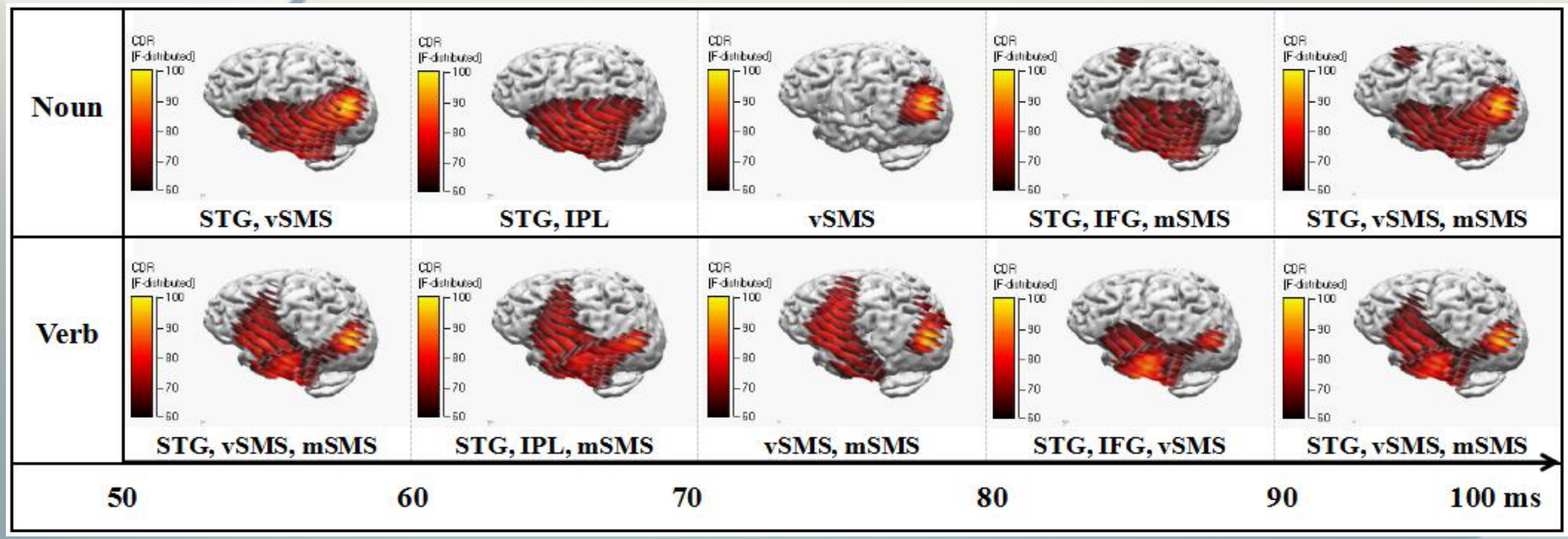
Reconstruction Results (noun)



Reconstruction Results (verb)

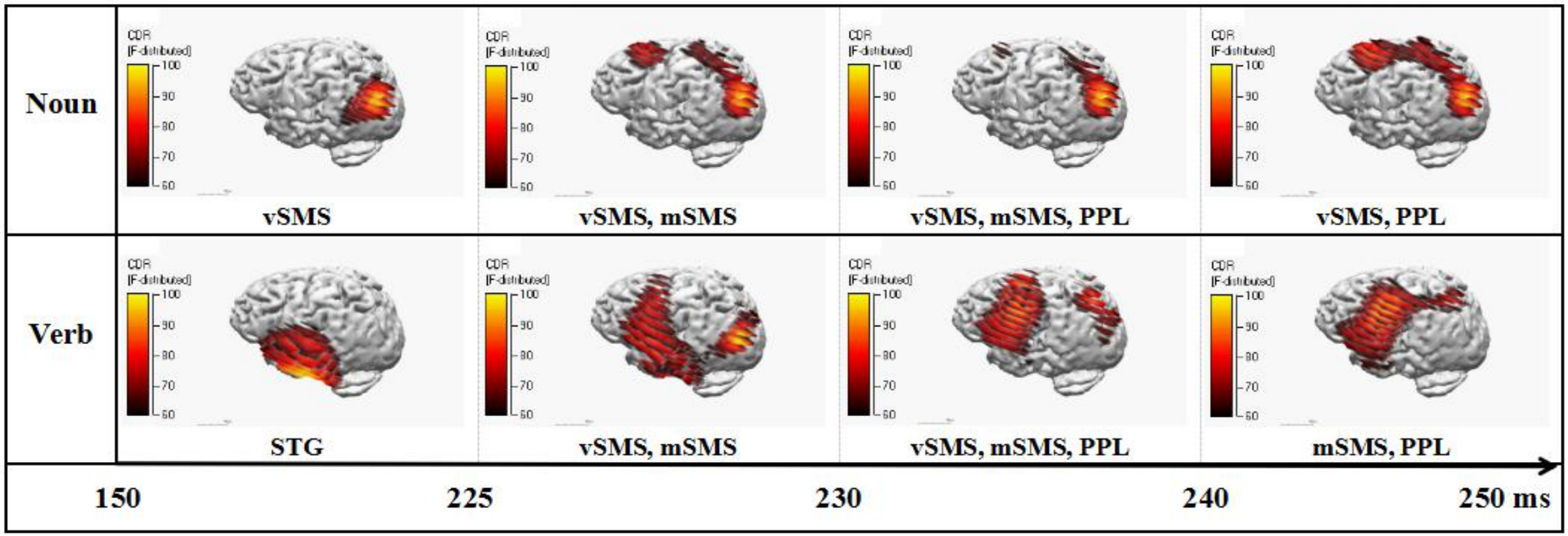


First Phase



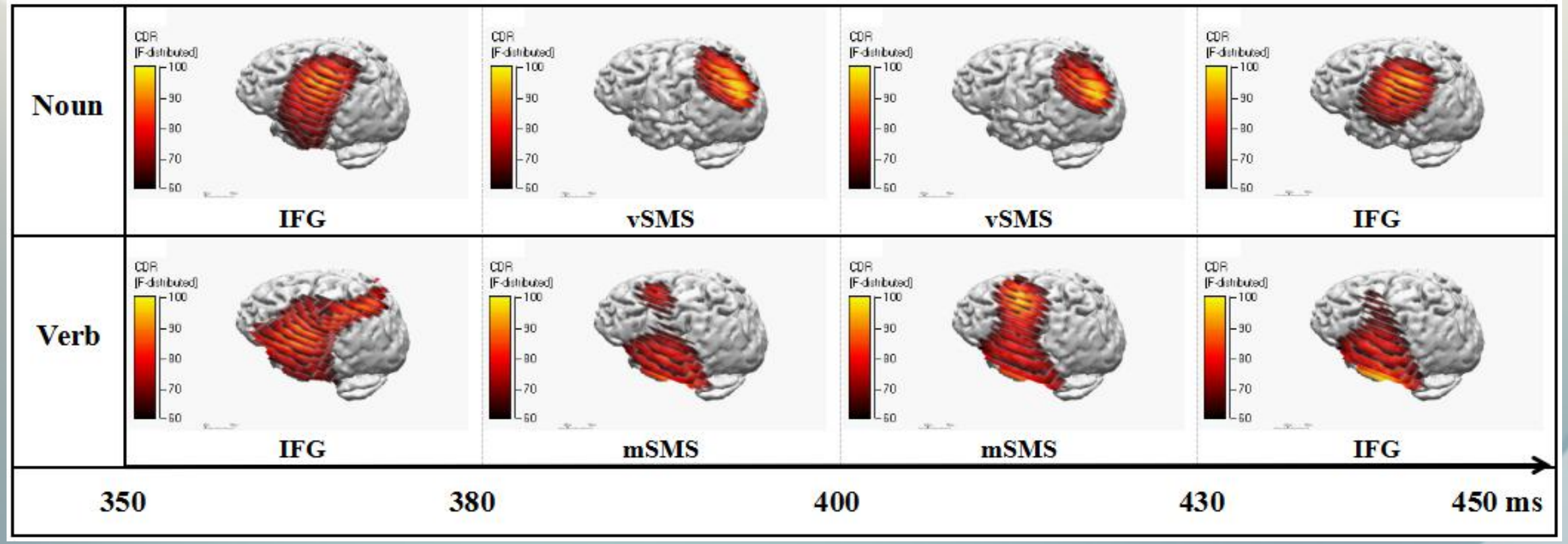
STG = superior temporal gyrus; IFG = inferior frontal gyrus; IPL = inferior parietal lobe;
vSMS = visual-related sensory and motor systems; mSMS = motor-related sensory and motor systems

Second Phase



STG = superior temporal gyrus; IFG = inferior frontal gyrus; IPL = inferior parietal lobe; PPL = posterior parietal lobe; vSMS = visual-related sensory and motor systems; mSMS = motor-related sensory and motor systems

Third Phase



IFG = inferior frontal gyrus;
vSMS = visual-related sensory and motor systems; mSMS = motor-related sensory and motor systems

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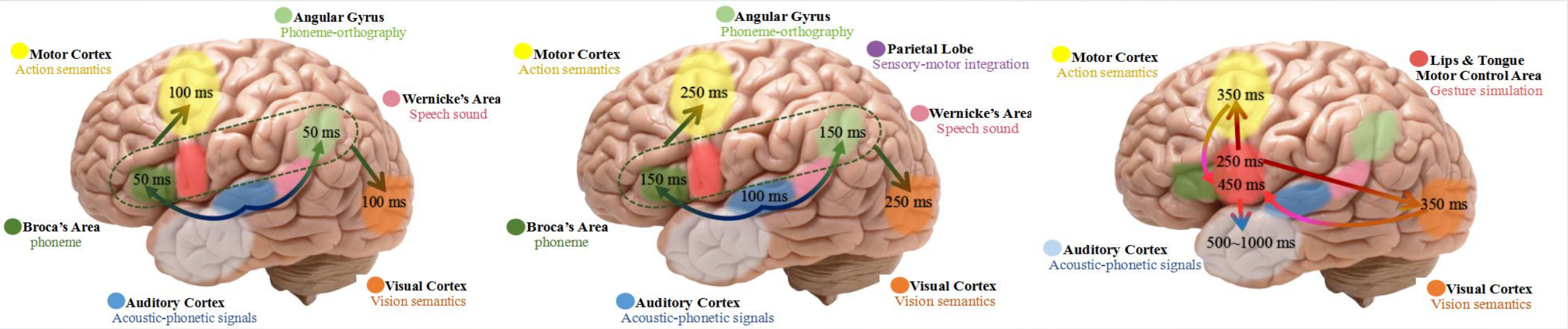
Part Four

Conclusions

Three-phase recurrent phase (TPRP)



The tentative phase	The primary phase	The advanced phase
50-100 ms	150-250 ms	350-450 ms
vSMS and mSMS are both activated in noun and verb condition.	noun-elicited vSMS verb-elicited mSMS noun-verb dissociation	noun-elicited vSMS verb-elicited mSMS noun-verb dissociation (most significant)
Searching for potential words including both nouns and verbs in visual and motor cortex exhaustively.	A continuing word searching and shifting process discriminatethe best match.	High-level information integration and word identification process.

Conclusions

The sound-meaning transformation during spoken word processing is processed in functionally hierarchical time phases, which matches well with the **direct mapping model**.

Spoken word processing can be regarded as a **three-phase recurrent process (TPRP)** : tentative access phase, primary selection phase, and advanced integration phase.

End

Thank You