

An Introduction to the Event-Related Potential

Ch1.A Broad Overview of the Event-Related Potential Technique

Ch2.A Closer Look at ERPs and ERP Components



연세대학교
YONSEI UNIVERSITY
Biomedical Engineering

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ERP(Event-Related Potential)

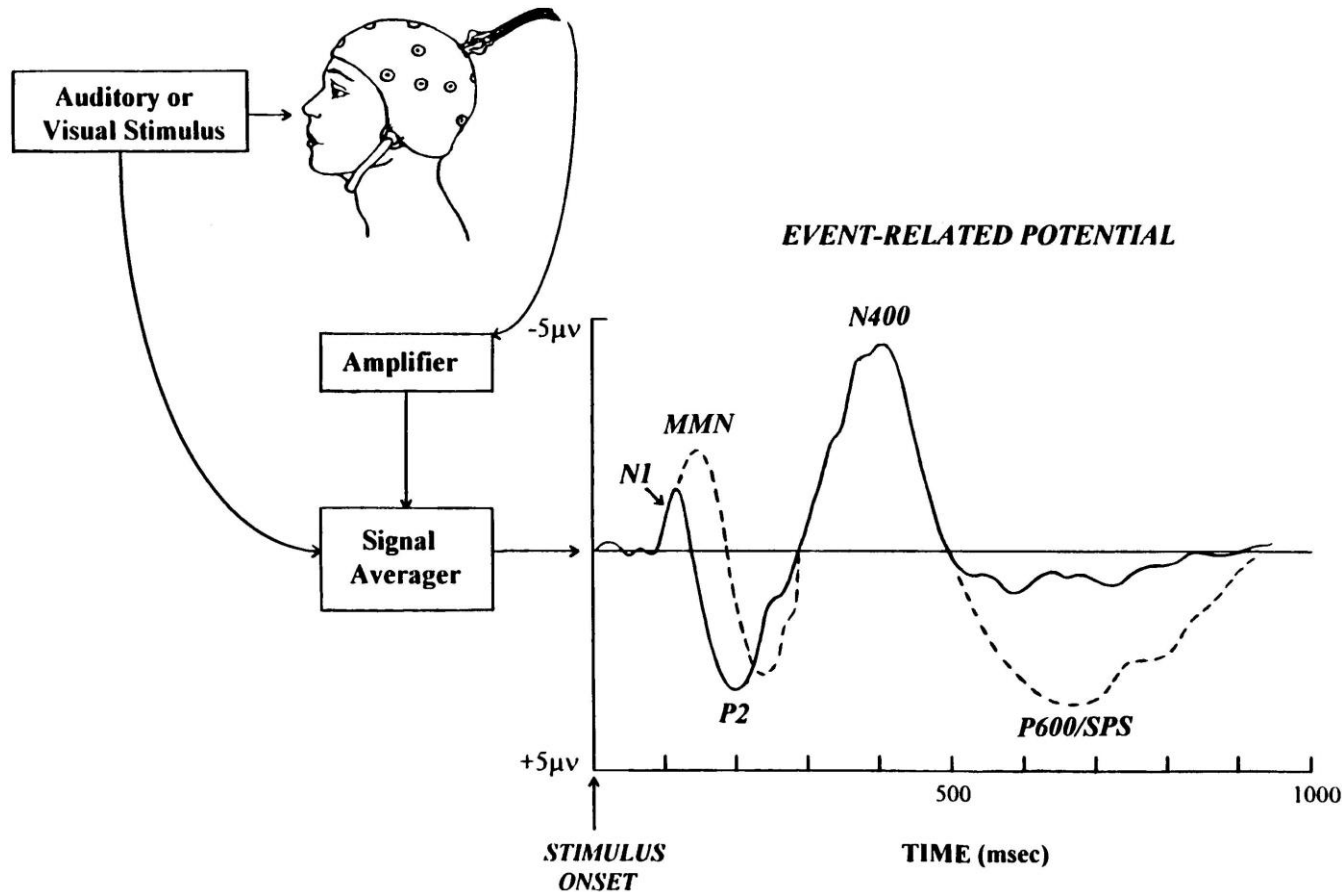
- ERP : Event에 대해서 발생한 뇌파(EEG)
- 뇌파 : 여러개의 Source에서 Cortex, Skull을 지나 Scalp에서 합쳐진 Potential
- Source : Source waveform이 발생하는 곳, 주로 anterior cortex의 pyramid cells
- Source waveform : Anterior cortex의 pyramid cells의 PSP
- Event : 실험자가 피험자에게 가한 자극
- 자극 : 실험자가 피험자의 감각을 유발하는 것
- 감각 : Visual, Olfactory, Auditory, Taste
- EEG는 많은 신경적 요인, 비신경적 요인에 의해 발생한 전압과 Noise가 합쳐진 형태
- ERP component : Event와 관련된 Epoch에 유의미한 지표가 있을 때 부여되는 의미
- 유의미한 지표 : Average technique, Difference wave를 통해 발견된 Amplitude, Latency 등의 차이
- Epoch : ERP component를 포함하여 특정 시간 간격으로 자른 것
- Average technique : trial이 같은 EEG를 평균내는 전처리 방법 → 공통 성분 제거
- Difference wave : 파형 간 차이를 보기 위한 EEG들을 서로 빼서 만든 EEG

ERP(Event-Related-Potential)

ERP : Event에 대해서 발생한 뇌파(EEG)

Event : 실험자가 피험자에게 가한 자극 (visual, auditory...)

EEG는 많은 신경적 요인, 비신경적 요인에 의해 발생한 전압과 Noise가 합쳐진 형태



Name

Positive peak voltage : P

Negative peak voltage : N

Sequence : P1, P2, P3... / N1, N2, N3...

Timing : P300, N170, N400 ...

Waveform

① Peak voltage amplitude

② Latency

- Absolute latency

time interval between stimulus presentation and the point of maximal value (peak) of a defined component

- Relative latency (inter-peak latency)

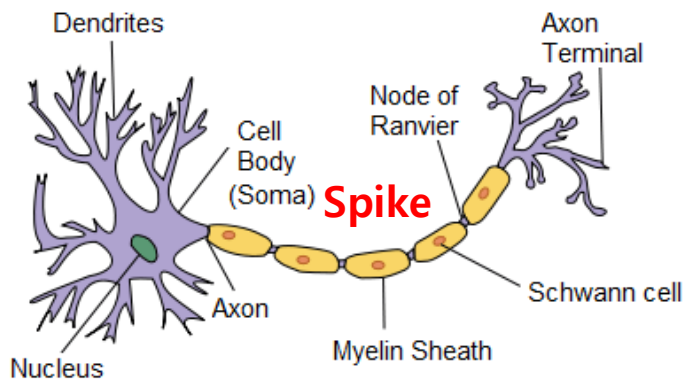
time interval between two components

③ Event code (=Trigger code)

Neural Origin of ERP

Action Potential

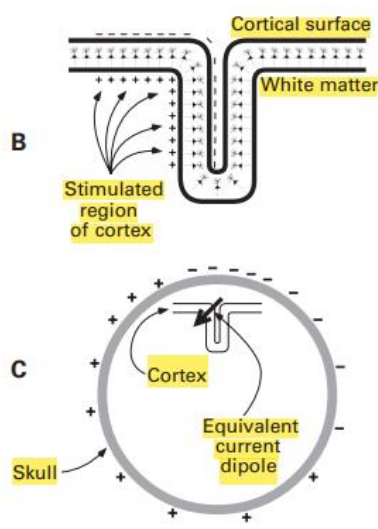
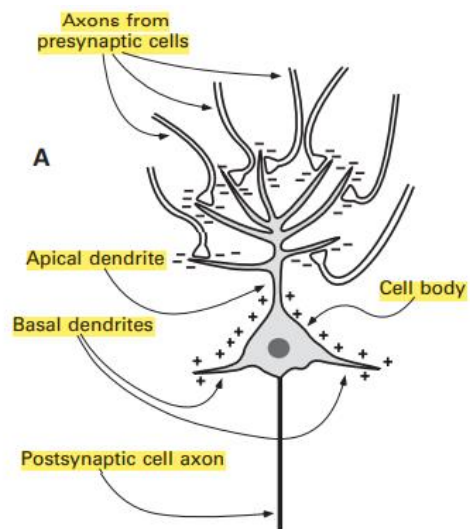
Rising and falling in membrane potential across a axon



일반적으로 많은 수의 Neuron이 정확히 같은 시간에 Spike 발생 X
→ Action Potential은 Scalp에서 기록되기 어려움

PSP(PostSynapticPotential)

- ① Neurotransmitters bind to receptors on the membrane of the postsynaptic cell
- ② Ion channels open or close → Voltage across the membrane



ERP is almost always reflect PSP

Neurotransmitter : Excitatory / Inhibitory

Synapse : Cellbody / Apical dendrite / Basal dendrite

Site transmits signals from presynaptic cell to postsynaptic cell

Equivalent current dipole = Sum of unit dipoles
Single functional brain region

ERP Localization

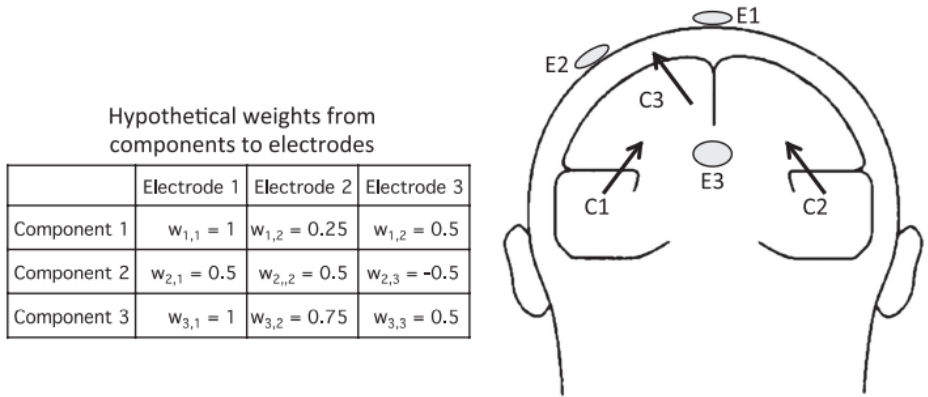
ERP Localization : Where is the ERP source?
What is the right source waveform combination?

<Superposition>

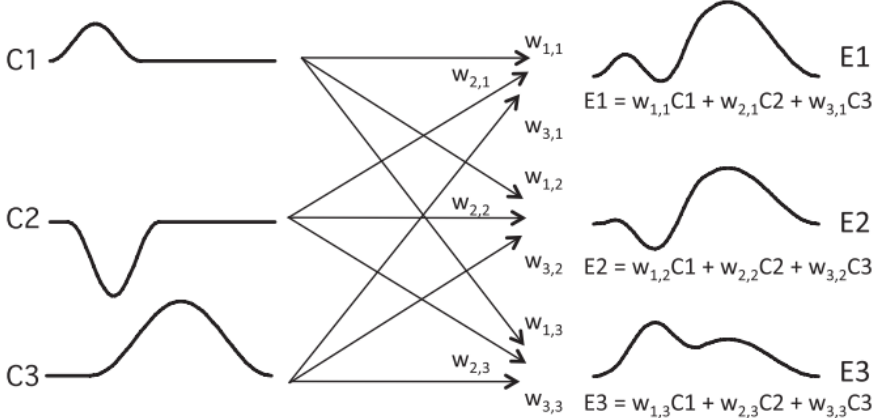
EEG : waveform mixed-up several source of brain activity

<Weight>

Position, Direction of underlying component / Conductance



Source waveform at the generator location for each component

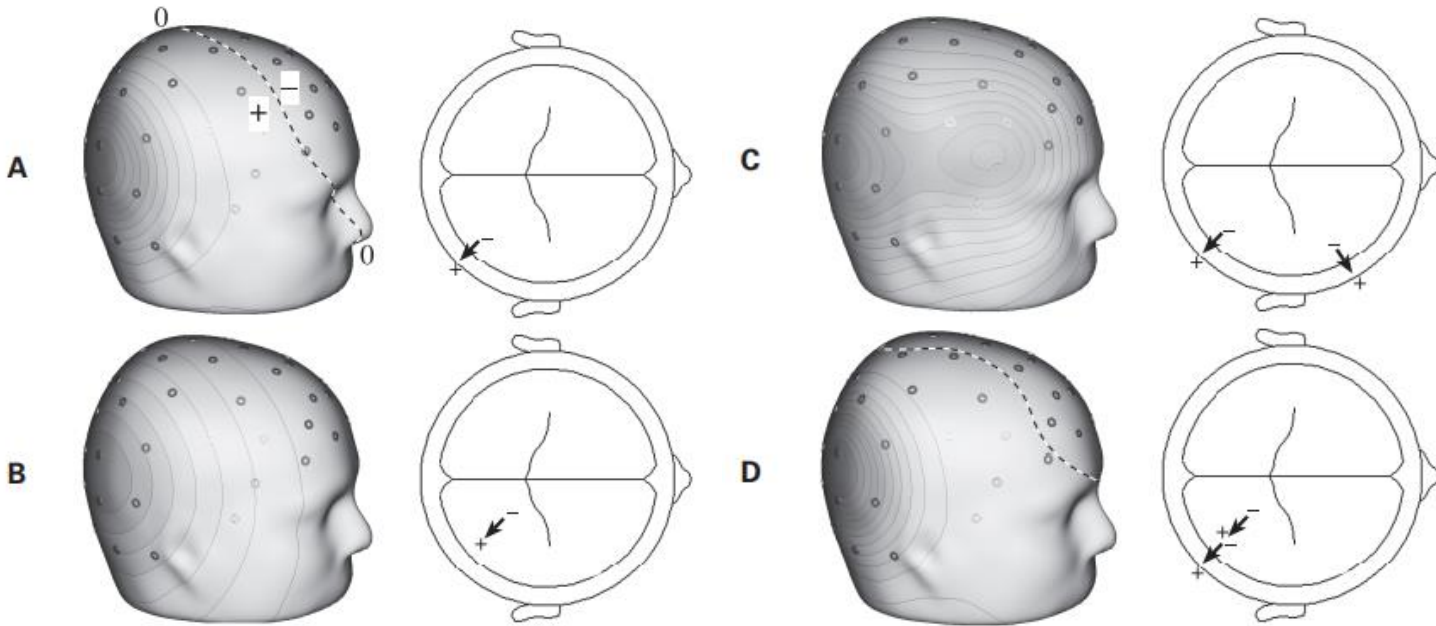


Forward / Inverse problem

Scalp Voltage Distribution



Internal underlying brain component



- ① Deep & Focal dipole = Superficial & Wide dipole
- ② A voltage distribution = D voltage distribution
- ③ Assumption X

External constraints

(Non-uniqueness problem solve)

Statistical method

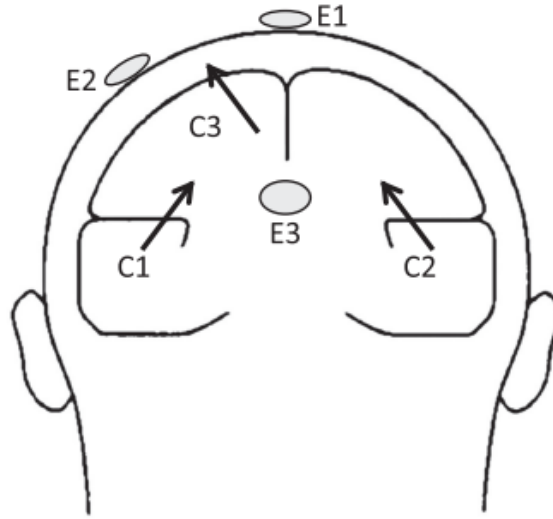
(Hypothetico-deductive approach : HD)

Forward problem

Internal underlying brain component → Scalp Voltage Distribution(=EEG)

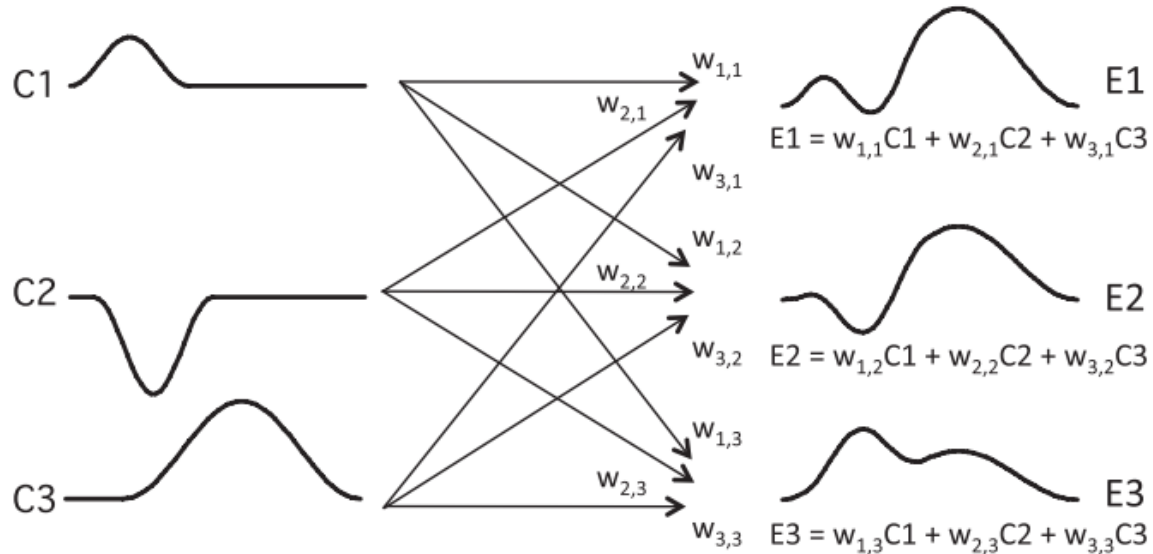
Hypothetical weights from components to electrodes

| | Electrode 1 | Electrode 2 | Electrode 3 |
|-------------|-----------------|------------------|------------------|
| Component 1 | $w_{1,1} = 1$ | $w_{1,2} = 0.25$ | $w_{1,3} = 0.5$ |
| Component 2 | $w_{2,1} = 0.5$ | $w_{2,2} = 0.5$ | $w_{2,3} = -0.5$ |
| Component 3 | $w_{3,1} = 1$ | $w_{3,2} = 0.75$ | $w_{3,3} = 0.5$ |



Source waveform at the generator location for each component

Observed waveform at each electrode site



<Superposition>

EEG : waveform mixed-up several source of brain activity

<Weight>

Electrode에서 기록되는 EEG에 대한 underlying component의 전파 비율 → 추정 가능

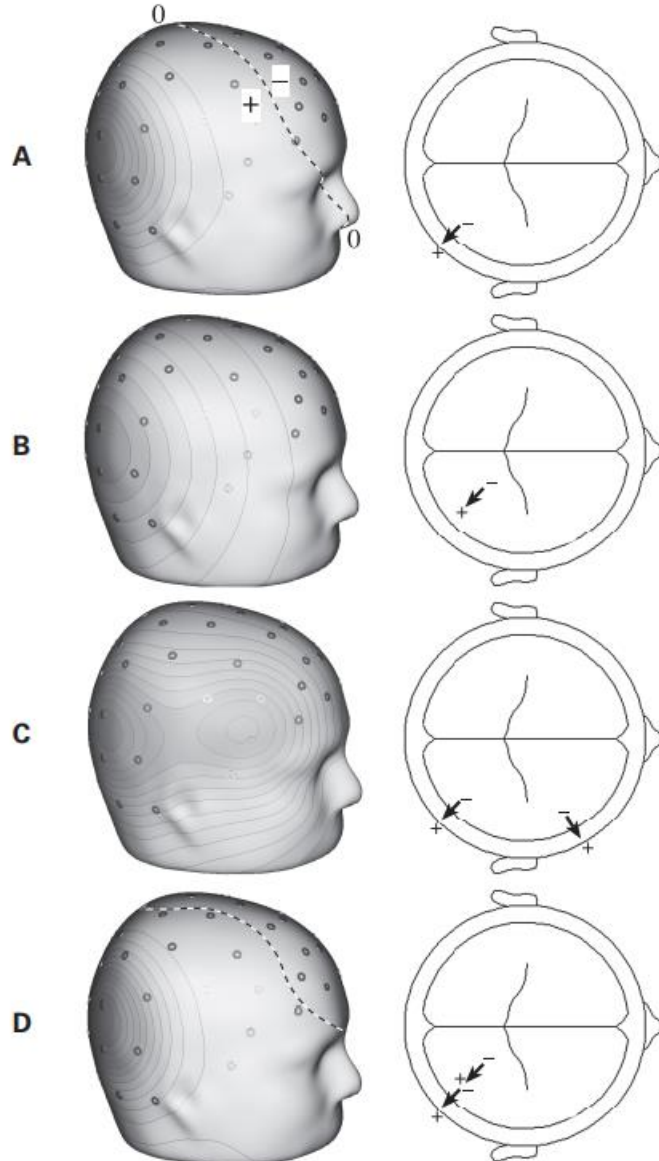
Position, Direction of underlying component / Conductance

$W_{x,y}$: Weight (Underlying component X → Electrode Y)

각 Electrode의 ERP underlying component는 같음
Weight는 다름

ERP Localizaiton / Inverse problem

Scalp Voltage Distribution → Internal underlying brain component



<A> Superficial Radial dipole : focal voltage distribution on the scalp
Voltage distribution → Unit dipole assumption → Simulation → Localization O

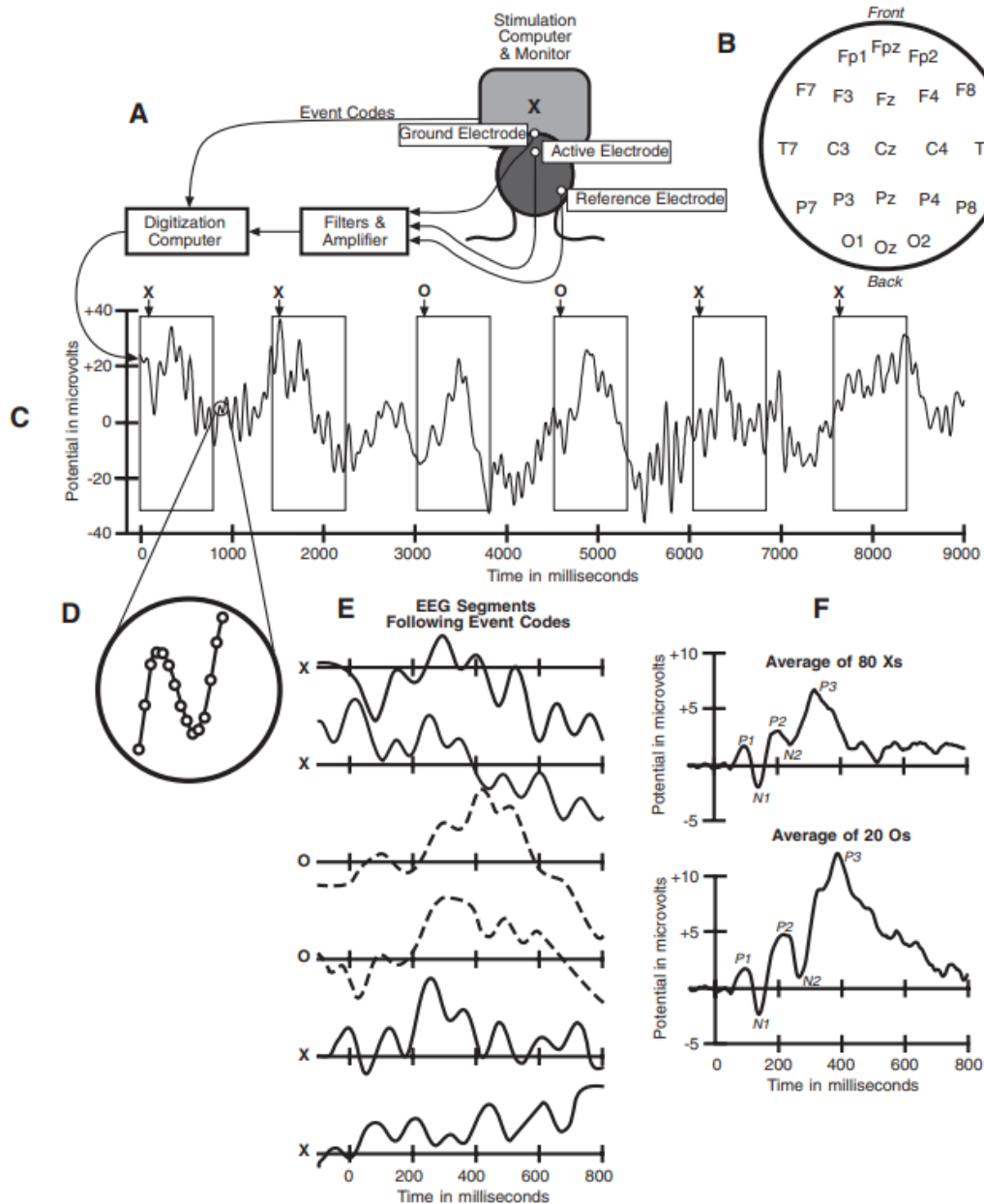
 Deep Radial dipole : Wide voltage distribution, Amplitude ↓ → Localization ↓
① **Deep & Focal dipole = Superficial & Wide dipole**

<C> Two Superficial dipole : Sum of each voltage distribution
Noise X, Two dipole activation O → Localization O

<D> Two dipole : One Superficial dipole + One Deep dipole
② **A voltage distribution = D voltage distribution**
③ **Assumption X**

External constraints (Non-uniqueness problem solve)
Statistical method(Hypothetico-deductive approach : HD)

Oddball task



Experiment object

Rare stimulus와 Frequent stimulus에 따른 ERP component 발견

Event(visual stimulus) : Monitor에 X와 O를 각각 100ms간 표시
X는 80%, O는 20% 비중, 각 trial마다 1400ms의 시간 공백을 둠

Trial : Event를 발생시키는 것 (ex. X 80번, O 20번)

Epoch(=EEG segment)

prestimulus 100ms ~ poststimulus 900ms (1000ms)

Event code : EEG segment onset time 정렬

Average waveform

→ Cancellation component unrelated to the stimulus

ERP component : ERP에 부여된 의미

Result

Os P3 peak amplitude > Xs P3 peak amplitude

→ P3 ERP component : Stimulus의 frequency 차이 반영

Difference wave

→ Os P3 component와 Xs P3 component 정량적 비교