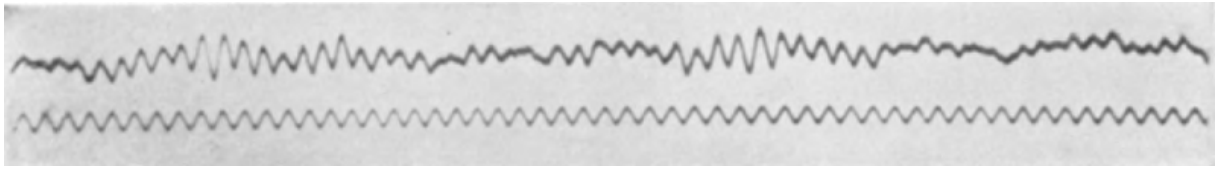
Event related potential

(현대 영어교육학회 2019 워크샵 자료)

대구가톨릭대학교 심리학과
권유안

History

- Hans Berger (1929)

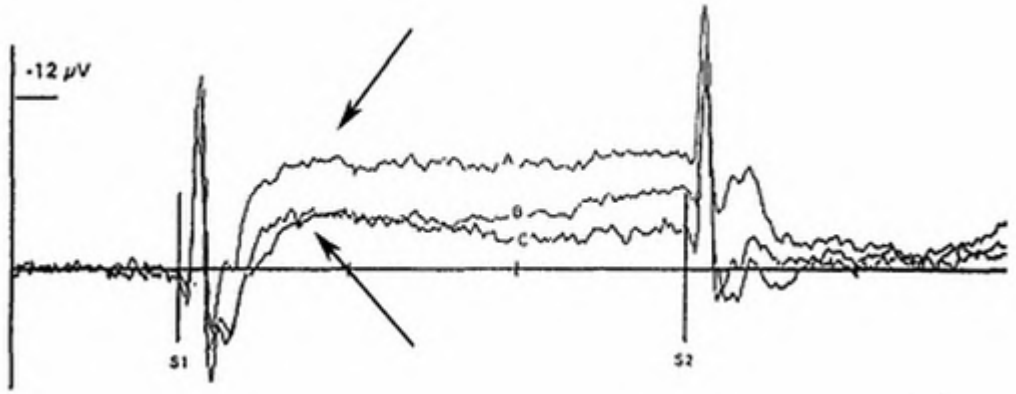


History

- The modern era of ERP (1964)

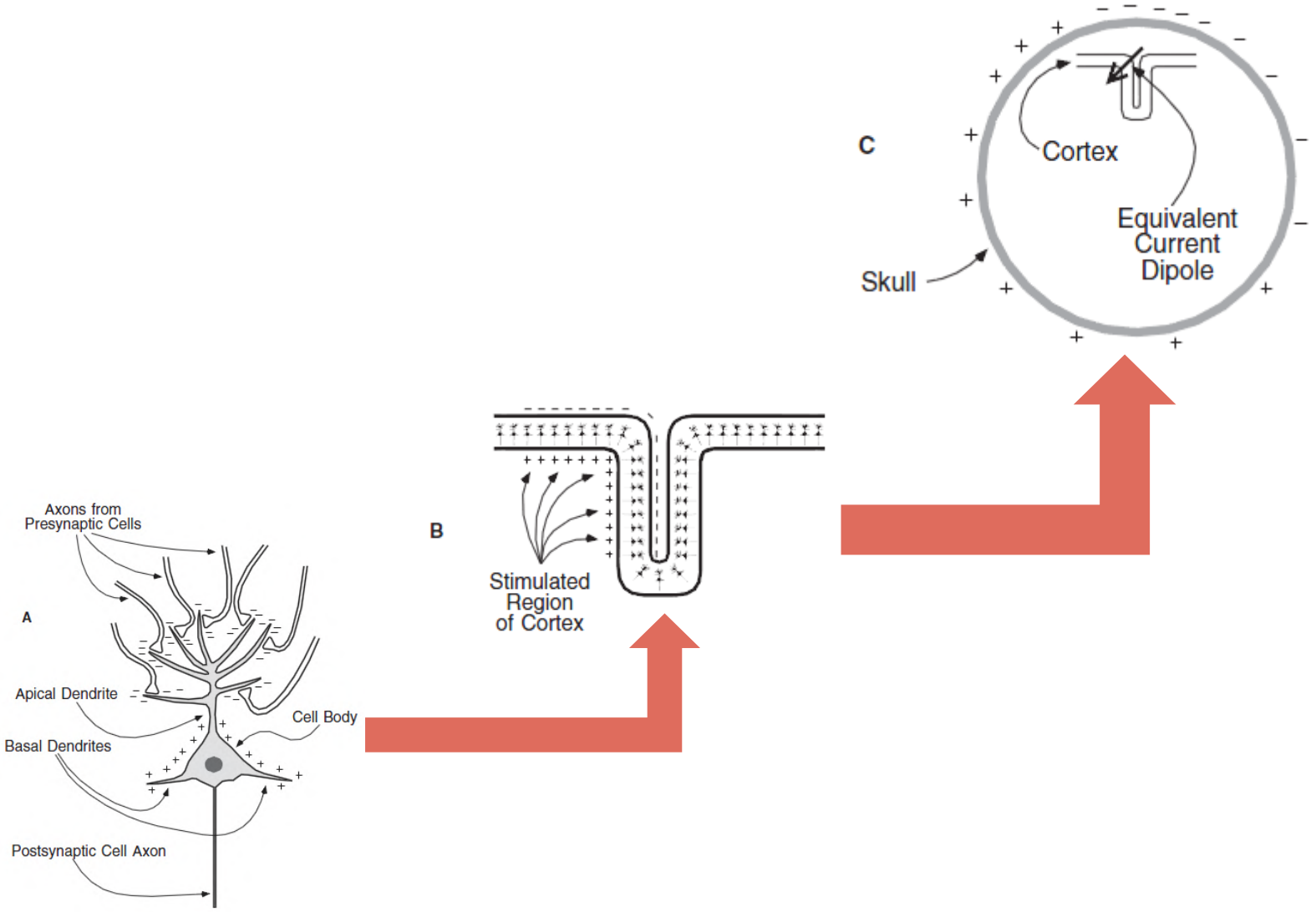
Contingent negative variation (CNV)

- First cognitive ERP component

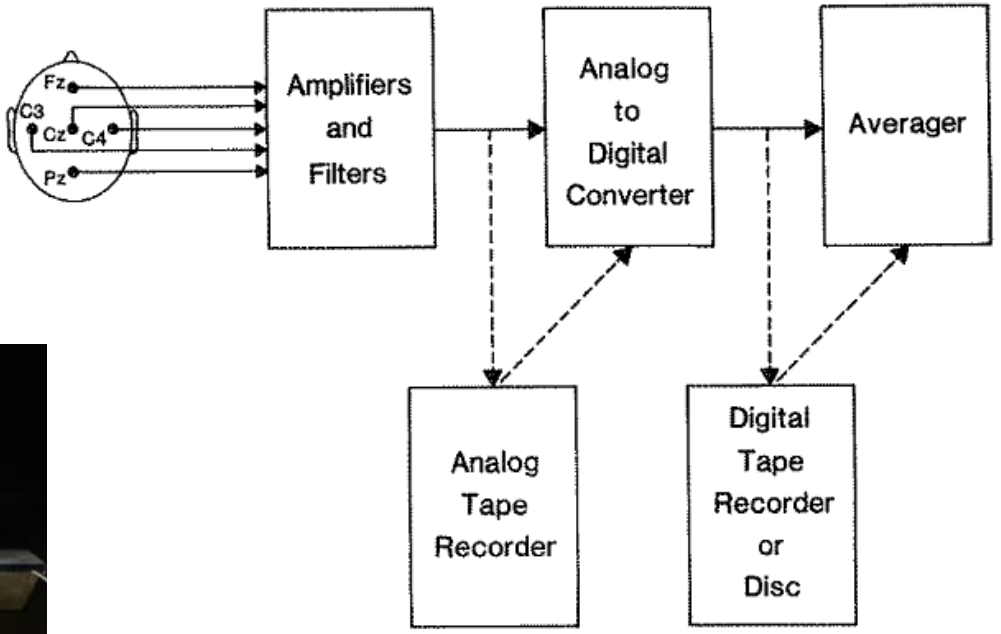


- S2반응의 준비

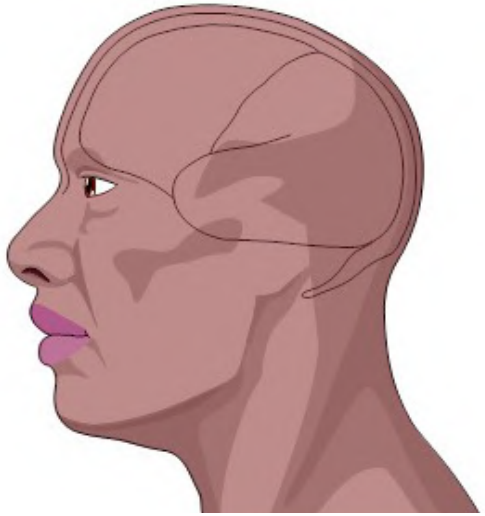
Source of signal

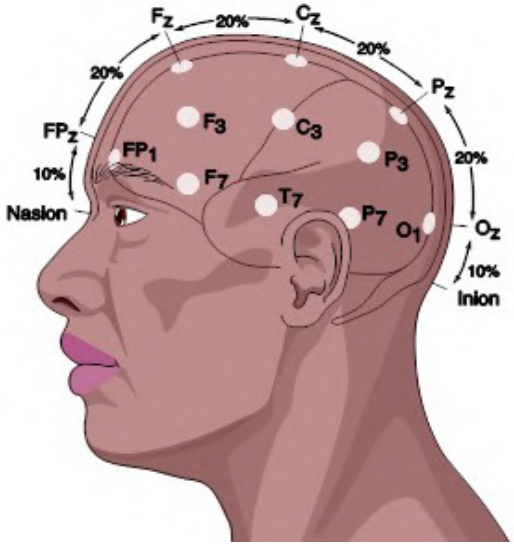


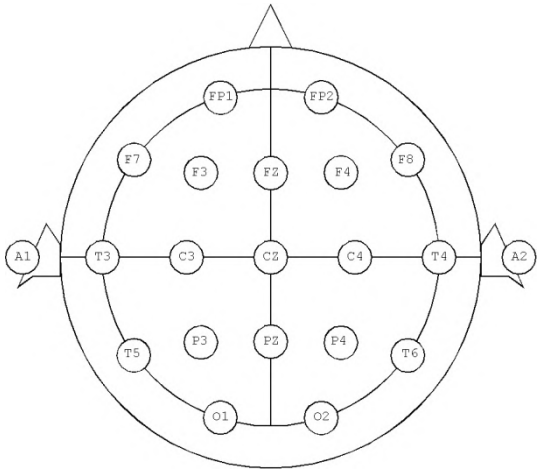
Recording EEG

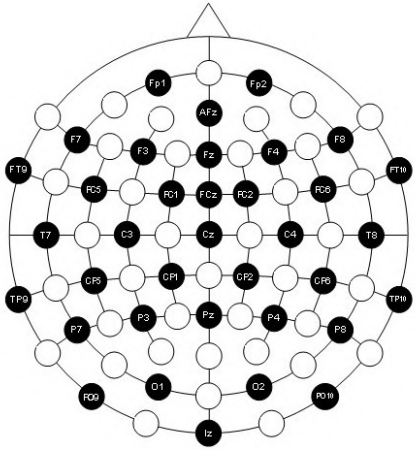


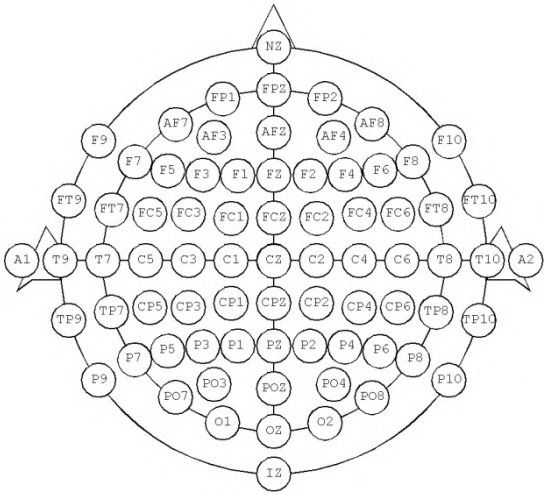
Electrode sites

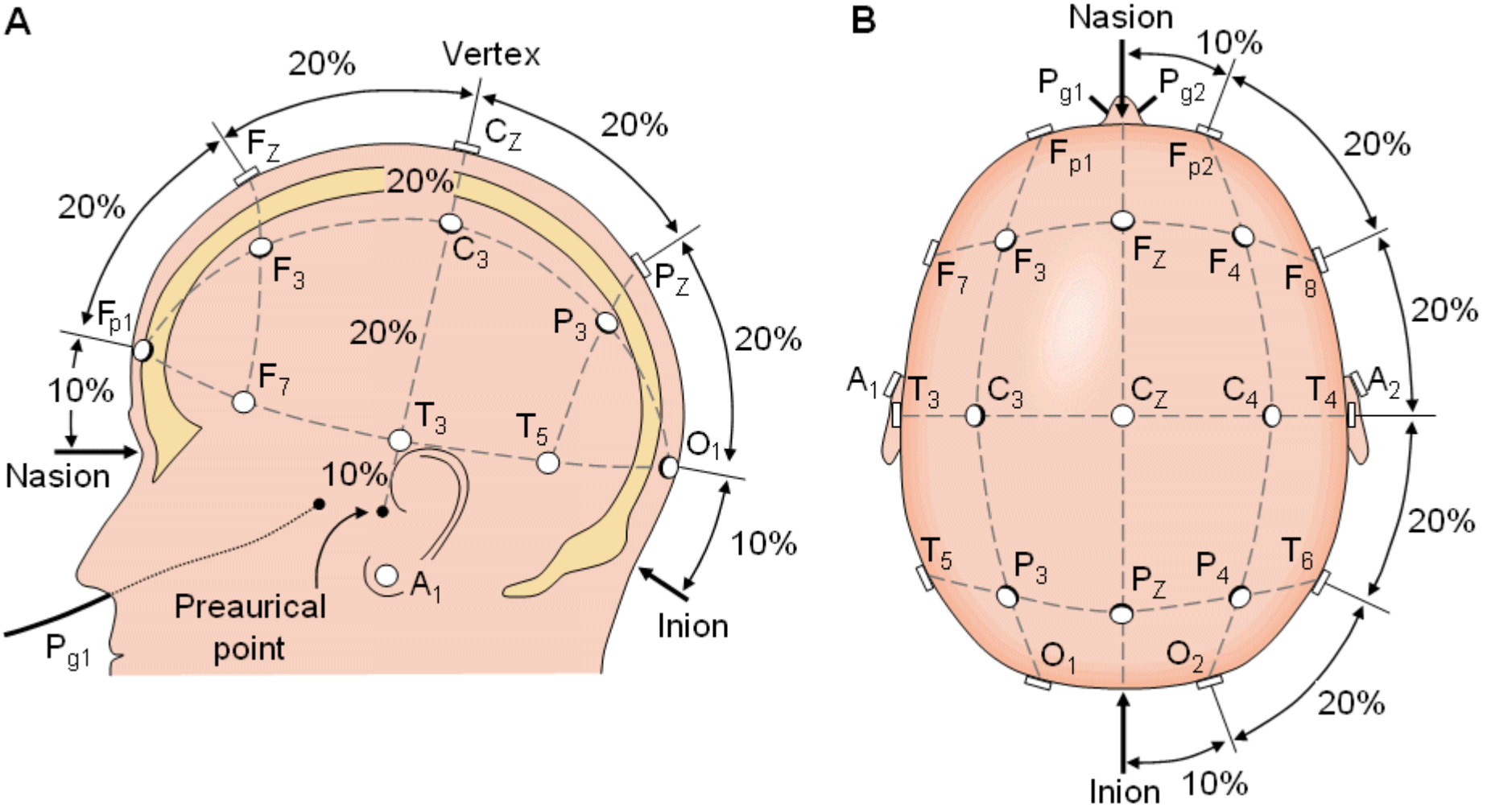






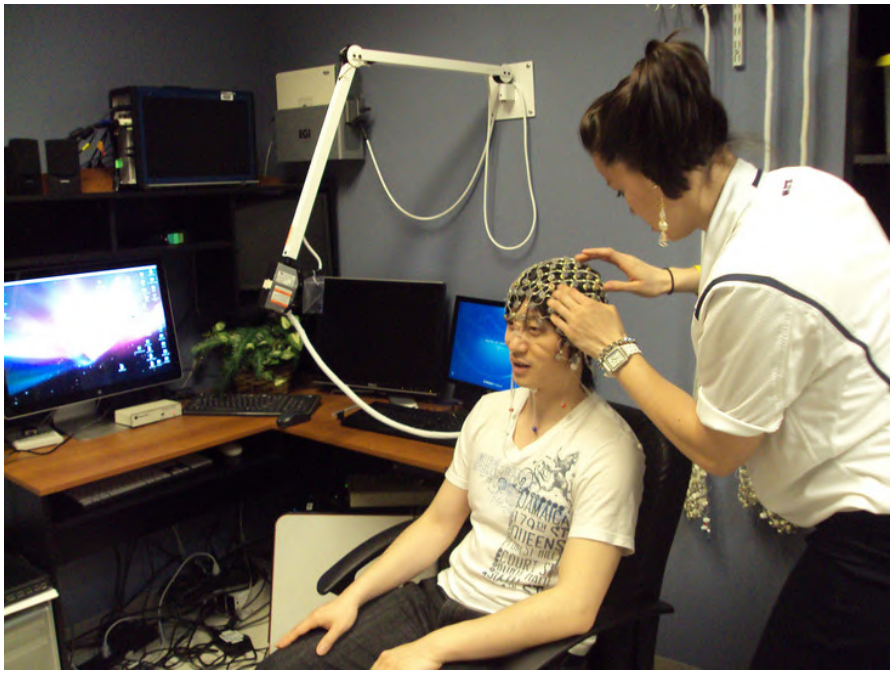




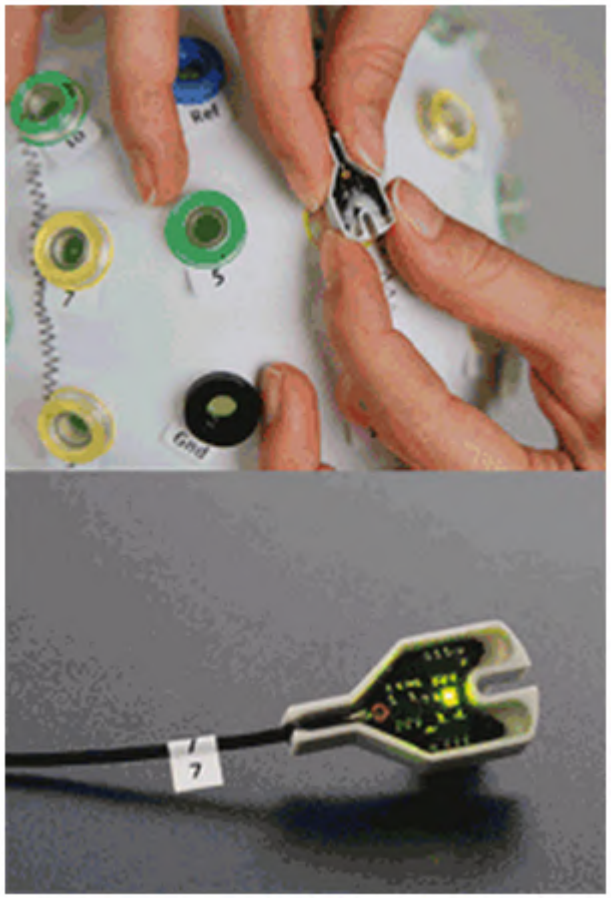

A
Vertex
20%
20%
20%
20%
20%
20%
10%
10%
10%
Nasion
Inion
Preaurical point
F_Z
C_Z
P_Z
F_{p1}
F_3
C_3
P_3
F_7
T_3
T_5
O_1
A_1
P_{g1}
B
Nasion
10%
20%
20%
20%
20%
10%
Inion
P_{g1}
P_{g2}
F_{p1}
F_{p2}
F_7
F_3
F_Z
F_4
F_8
A_1
T_3
C_3
C_Z
C_4
T_4
A_2
T_5
P_3
P_Z
P_4
T_6
O_1
O_2

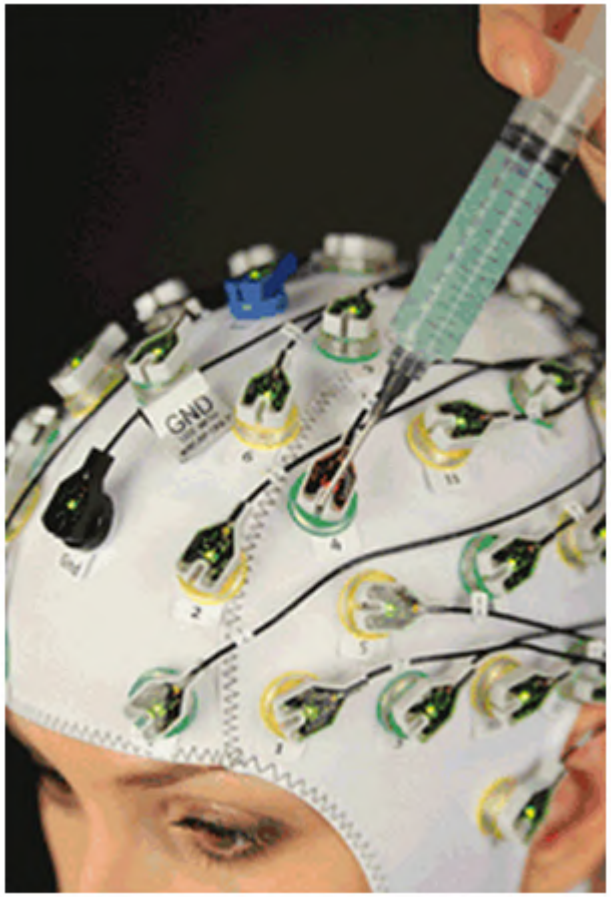
Type of Electrodes

Type of Electrodes

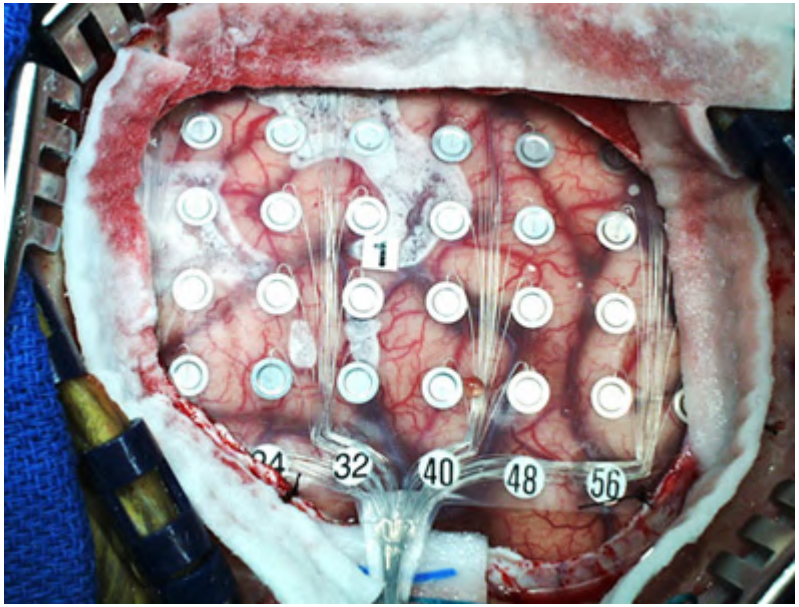


Type of Electrodes



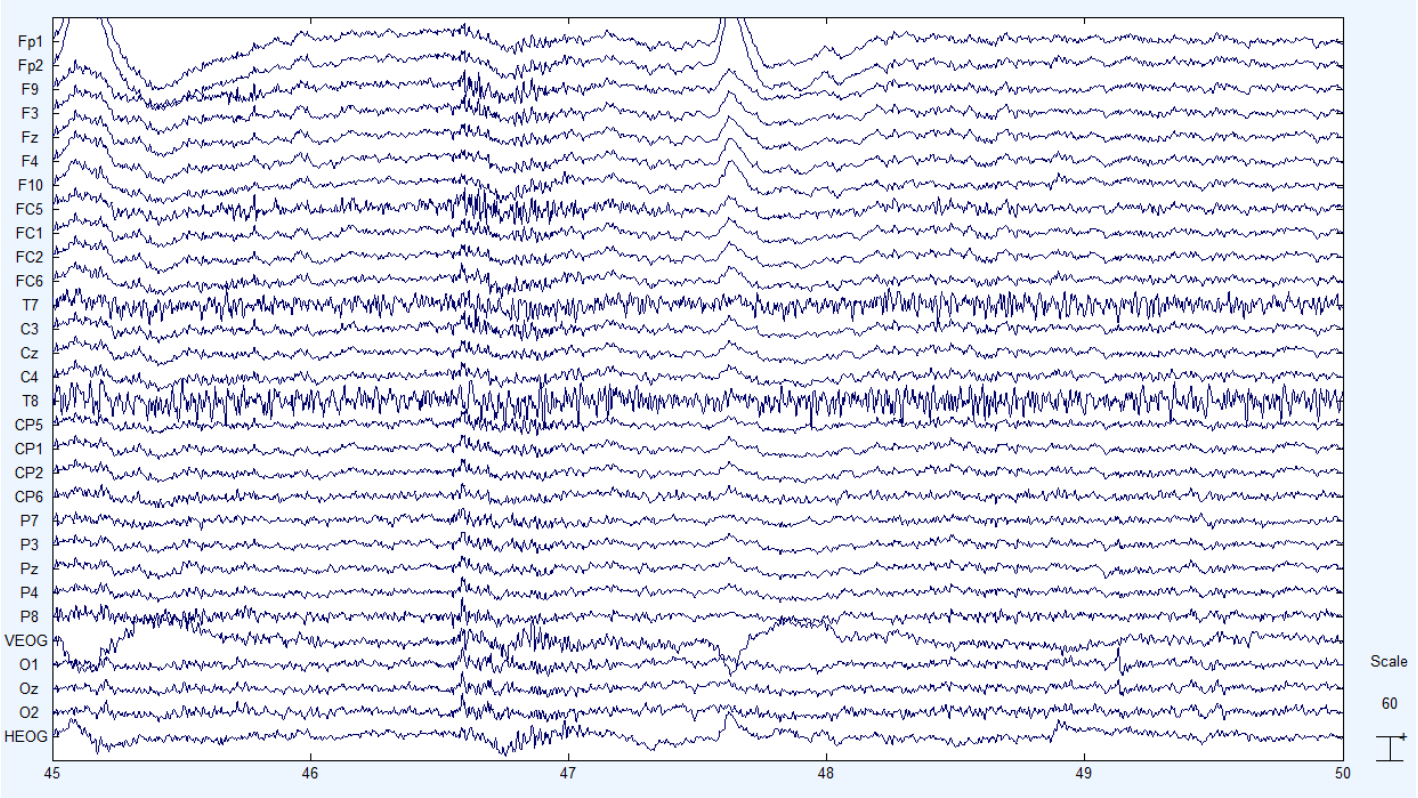


Type of Electrodes



Type of Electrodes

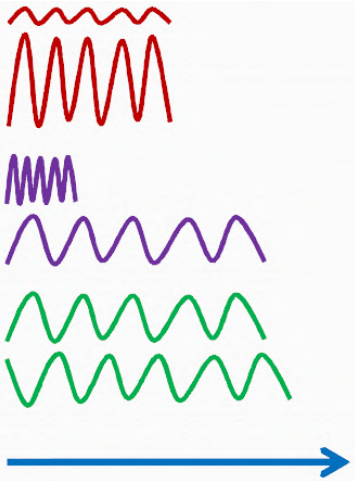
Brain Signal



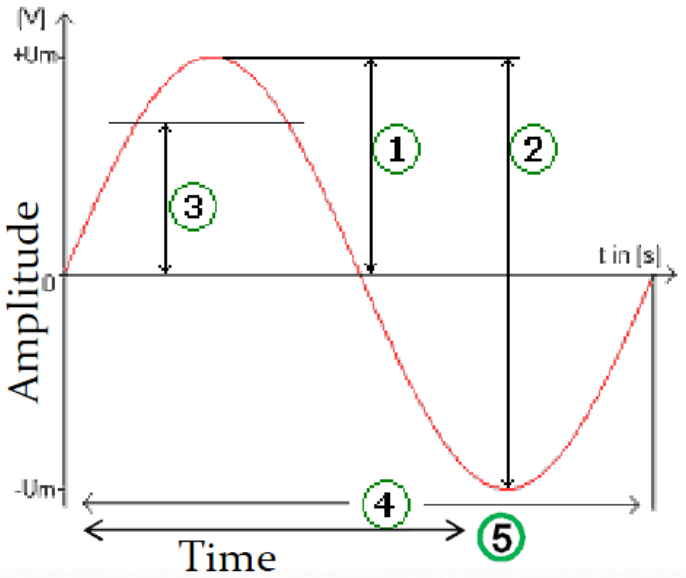
- EEG data

Brain Signal

- **Amplitude** (μV)
  - Magnitude/power
- **Frequency** (Hz)
  - Cycles (wave periods) per second
- **Phase**
- **Time/latency** (ms)

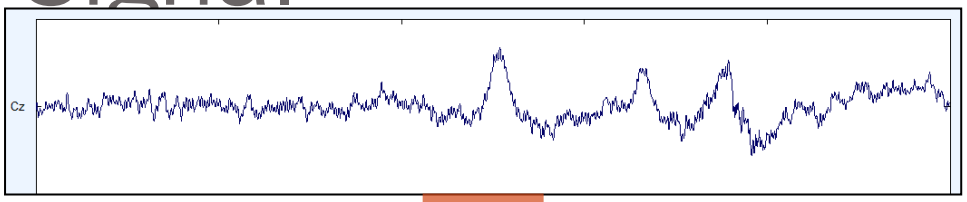


Time and amplitude

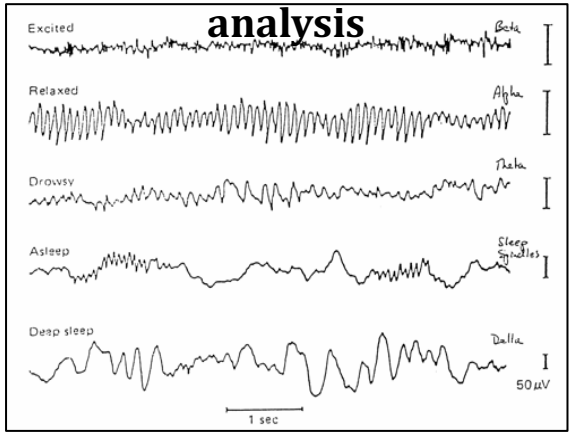


1 = Peak amplitude
2 = Peak-to-peak amplitude
3 = Mean/RMS amplitude
4 = Wave period
5 = Peak latency

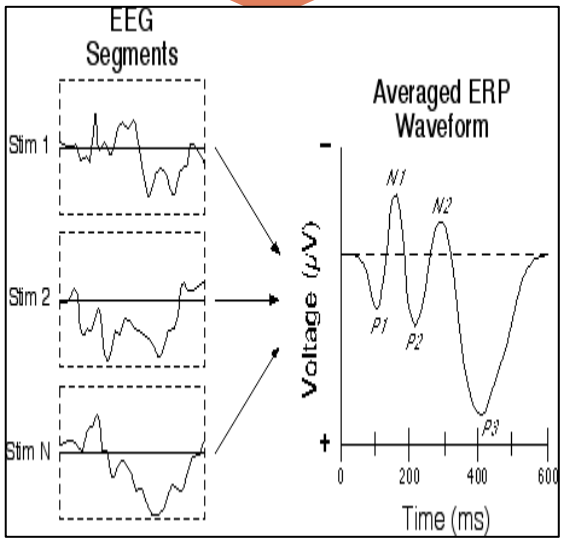
Brain Signal



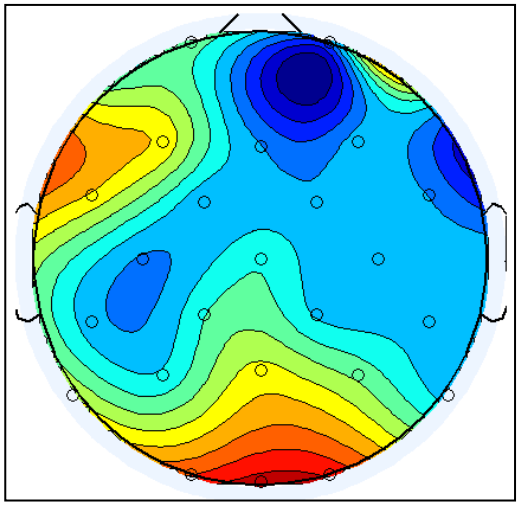
Frequency based analysis



Time based analysis

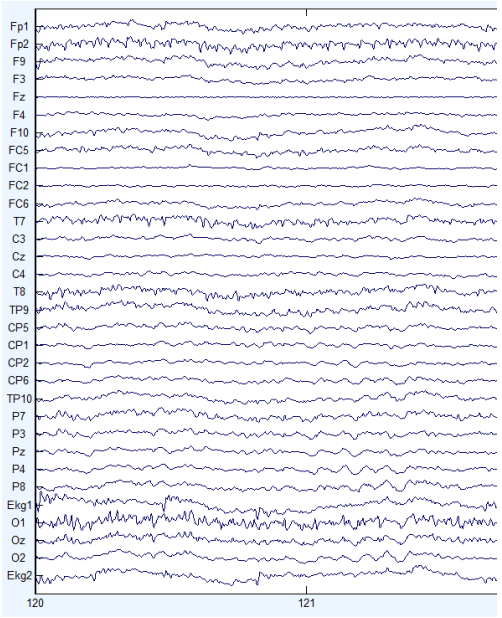


Brain Topography

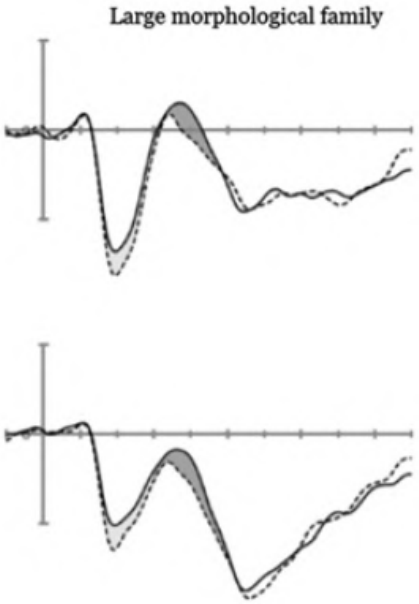


EEG analysis

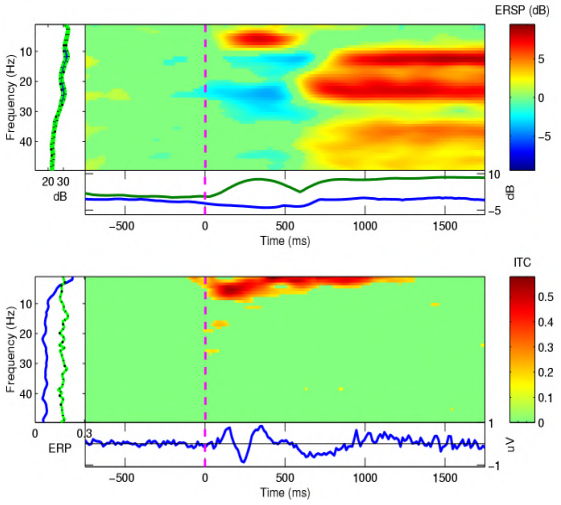
- EEG



- ERP (event-related potential)

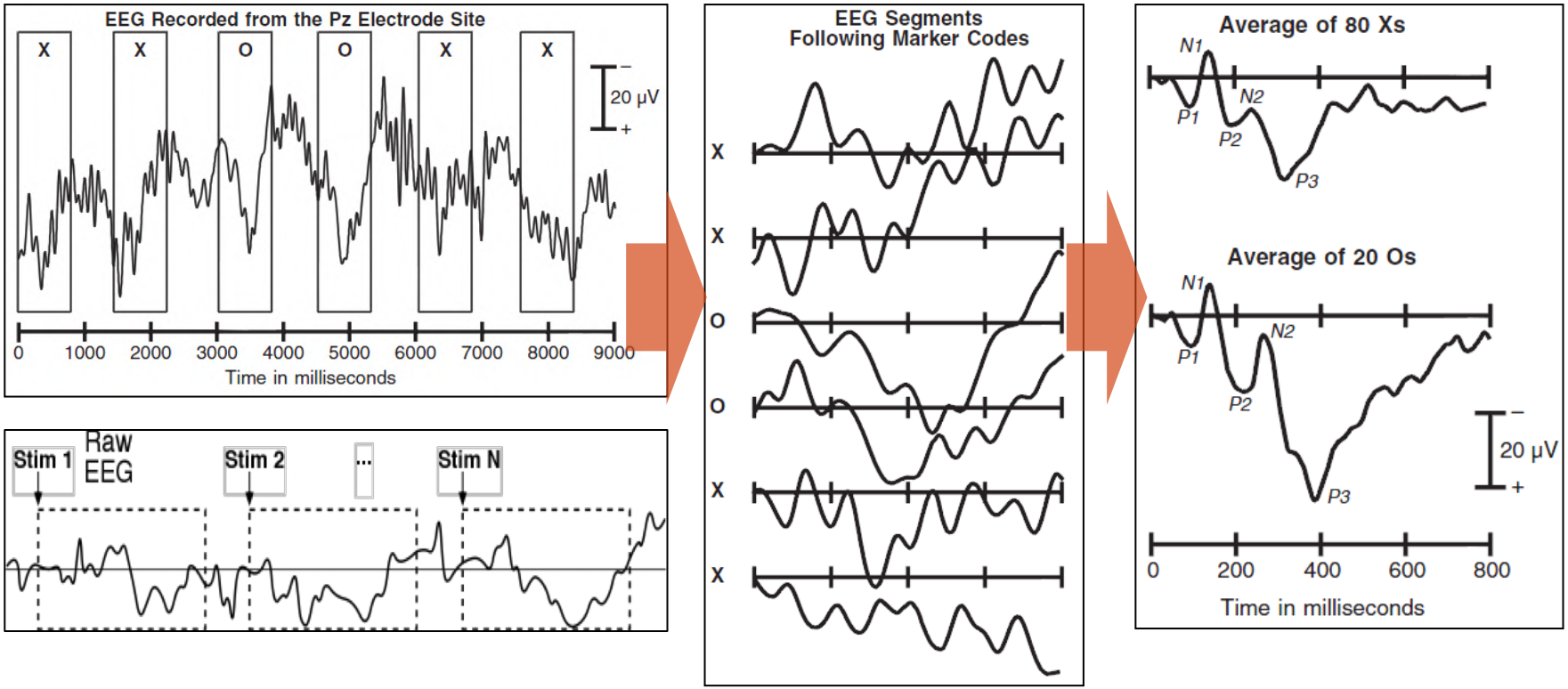


- ERSP (event-related spectral dynamic)



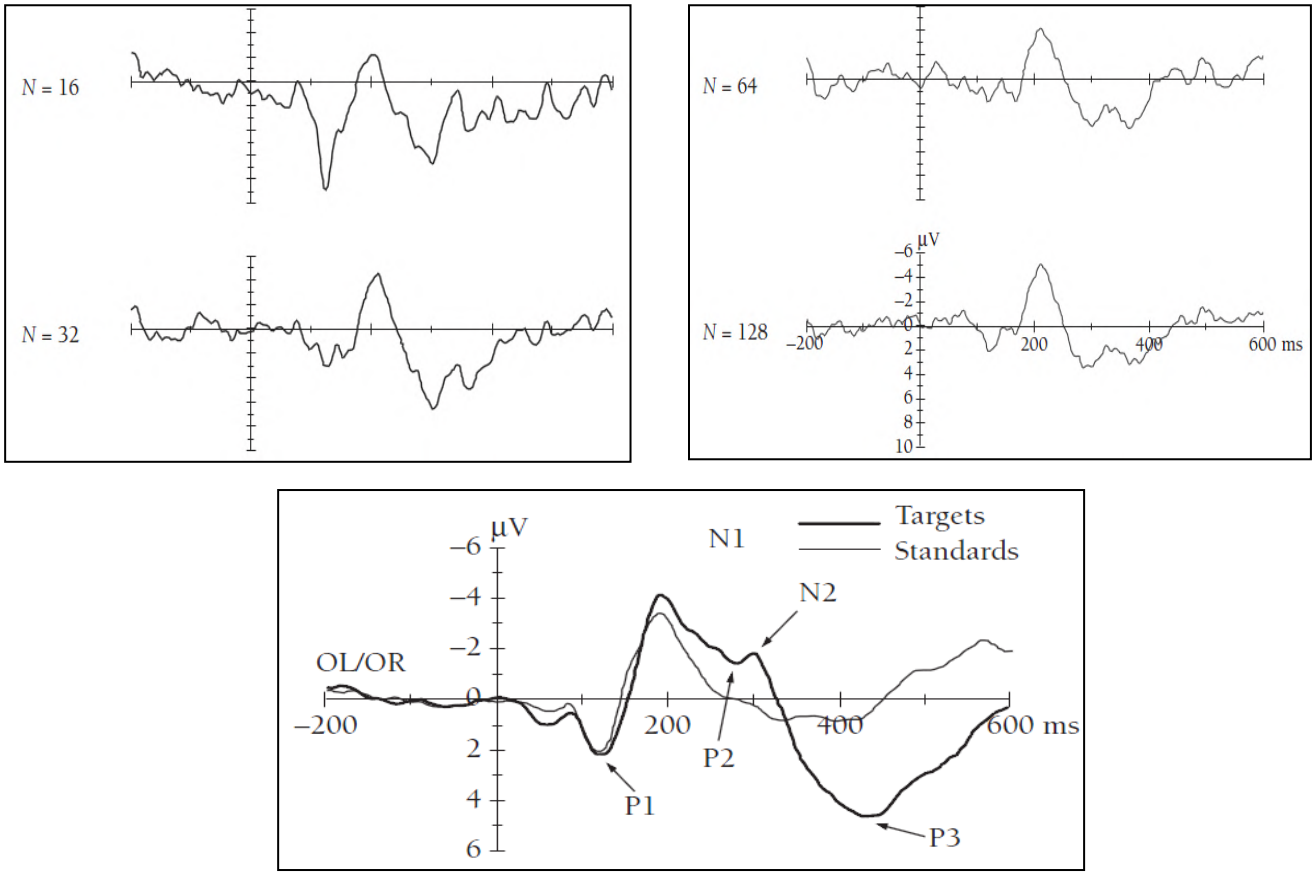
Analysis EEG

- ERP (event-related potential)



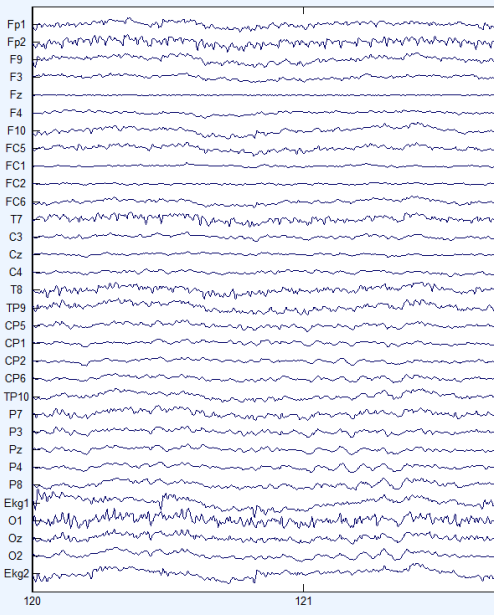
Analysis EEG

- Averaged ERP

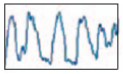
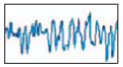
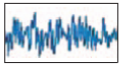
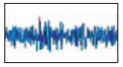
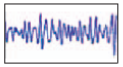


Analysis EEG

- Event related spectral Dynamics

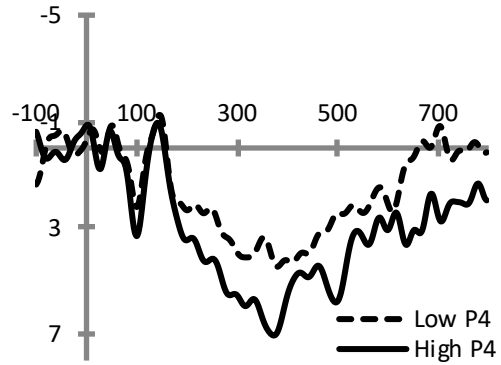


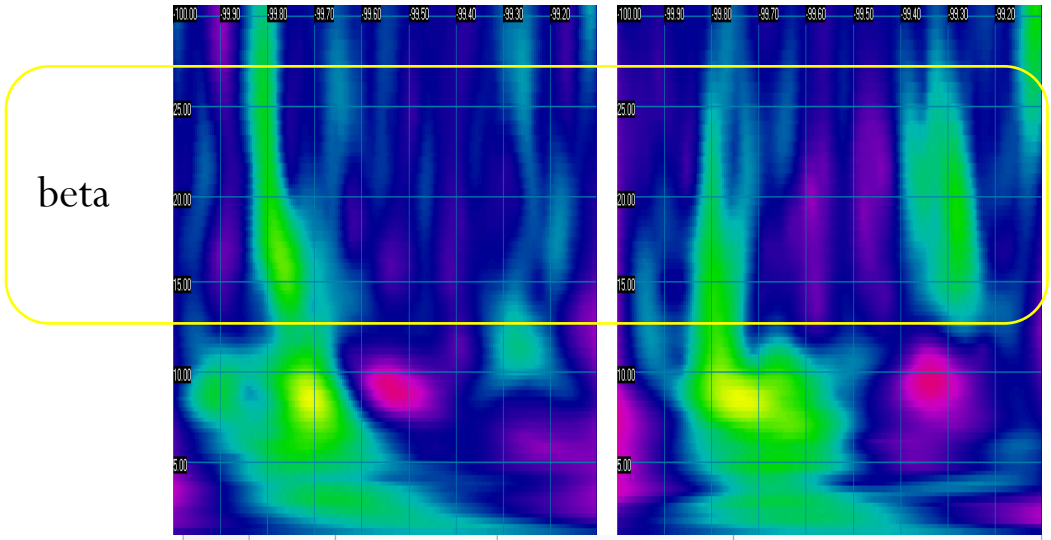
FFT

Name and example	Description
Delta 	Delta is the slow wave characteristic of deep, unconscious sleep. It is less than 4 Hz, and similar EEG frequencies appear in epileptic seizures and loss of consciousness, as well as some comatose states. It is therefore thought to reflect the brain of an unconscious person. The Delta frequency tends to be the highest in amplitude and the slowest waves. Delta waves increase in relation to our decreasing awareness of the physical world.
Theta 	Theta activity has a frequency of 3.5 to 7.5 Hz. Theta waves are thought to involve many neurons firing synchronously. Theta rhythms are observed during some sleep states, and in states of quiet focus, for example meditation. They are also manifested during some short term memory tasks, and during memory retrieval. Theta waves seem to communicate between the hippocampus and cortex in memory encoding and retrieval.
Alpha 	Alpha waves are those between 7.5 and 13Hz that arise from synchronous and coherent (in phase) electrical activity of large groups of neurons in the human brain. They are also called Berger's waves in memory of the founder of EEG. Alpha waves are predominantly found to originate from the occipital lobe during periods of relaxation, with eyes closed but still awake. Conversely alpha waves are attenuated with open eyes as well as by drowsiness and sleep.
Beta 	Beta activity is 'fast' irregular activity, at low voltage (12–25 Hz). Beta waves are usually associated with normal waking consciousness, often active, busy, or anxious thinking and active concentration. Rhythmic beta with a dominant set of frequencies may be associated with various pathologies and drug effects. Beta is usually seen on both sides of the brain in symmetrical distribution and is most evident frontally. It may be absent or reduced in areas of cortical damage.
Gamma 	Gamma generally ranges between 26 and 70Hz, centered around 40Hz. Gamma waves are thought to signal active exchange of information between cortical and subcortical regions. It is seen during the conscious waking state and in REM dreams (Rapid Eye Movement sleep). Note that gamma and beta activity may overlap.

Analysis EEG

- ERSP

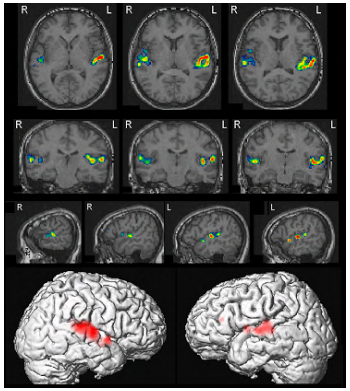




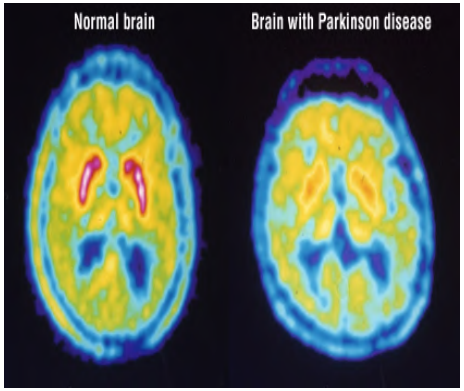
Beta	>13 – 30	both sides, symmetrical distribution, most evident frontally; low amplitude waves	• alert/working • active, busy or anxious thinking, active concentration	• benzodiazepines

Other Neuro-image

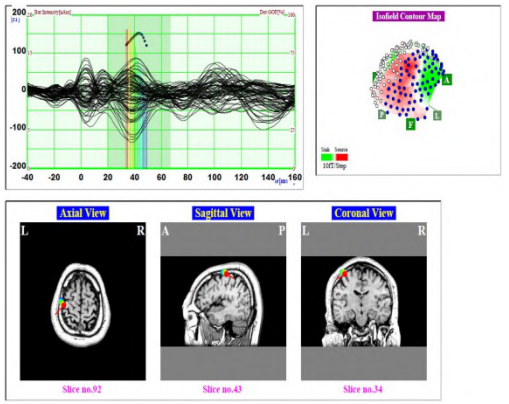
- fMRI



- PET



- MEG



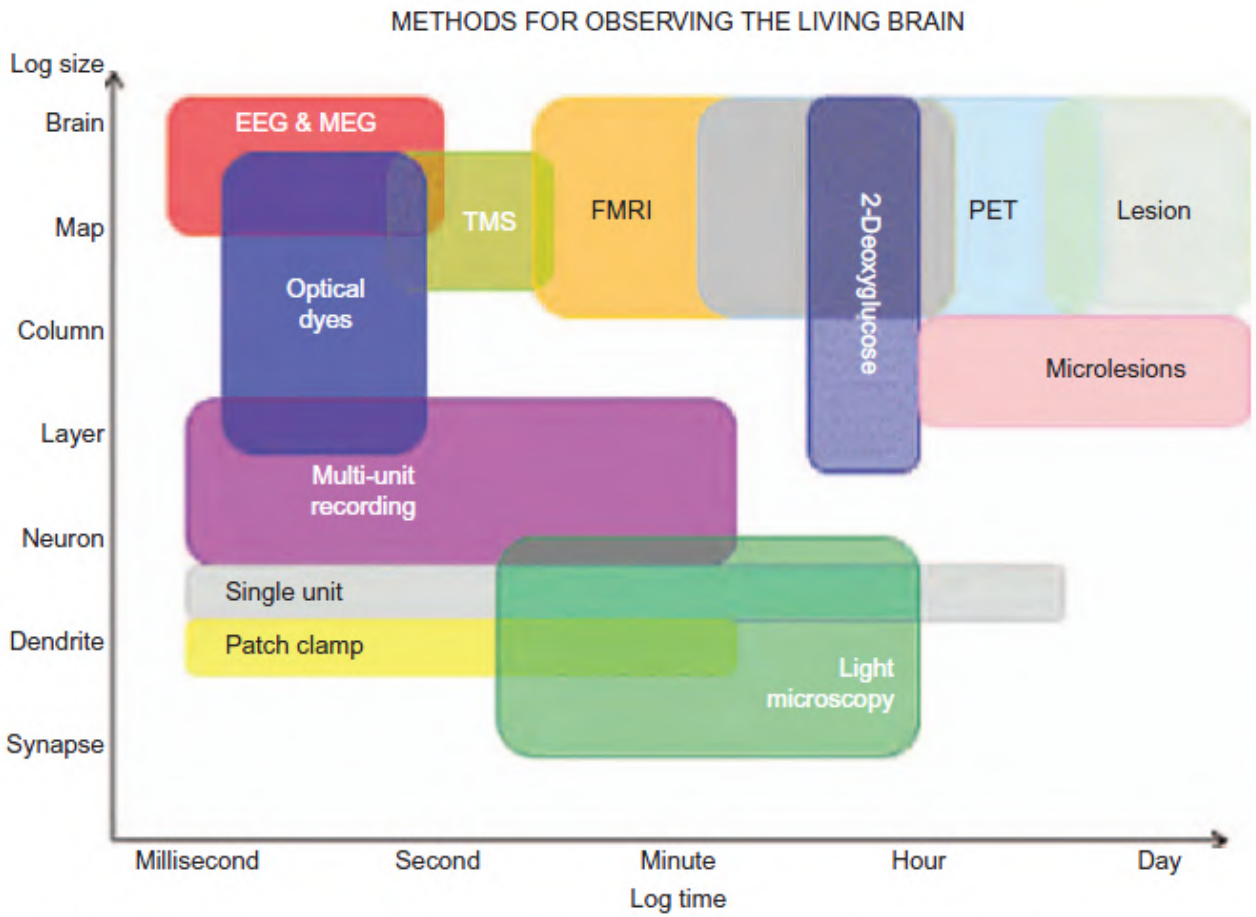


FIGURE 4.2 Pros and cons of imaging techniques. Different imaging modalities have different resolution. While some approaches have a very high temporal resolution but a low spatial resolution, other modalities have an opposite relation.

Area

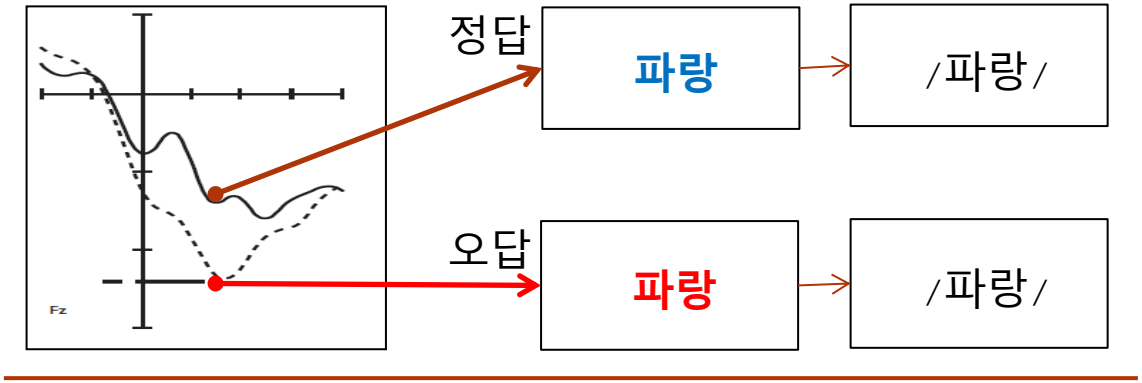
- 순수학문
  - Perception
  - Attention
  - Memory
  - Language process

- 응용분야
  - Addiction
  - Counseling
  - HCI
  - Learning
  - Neuro-feedback

Examples

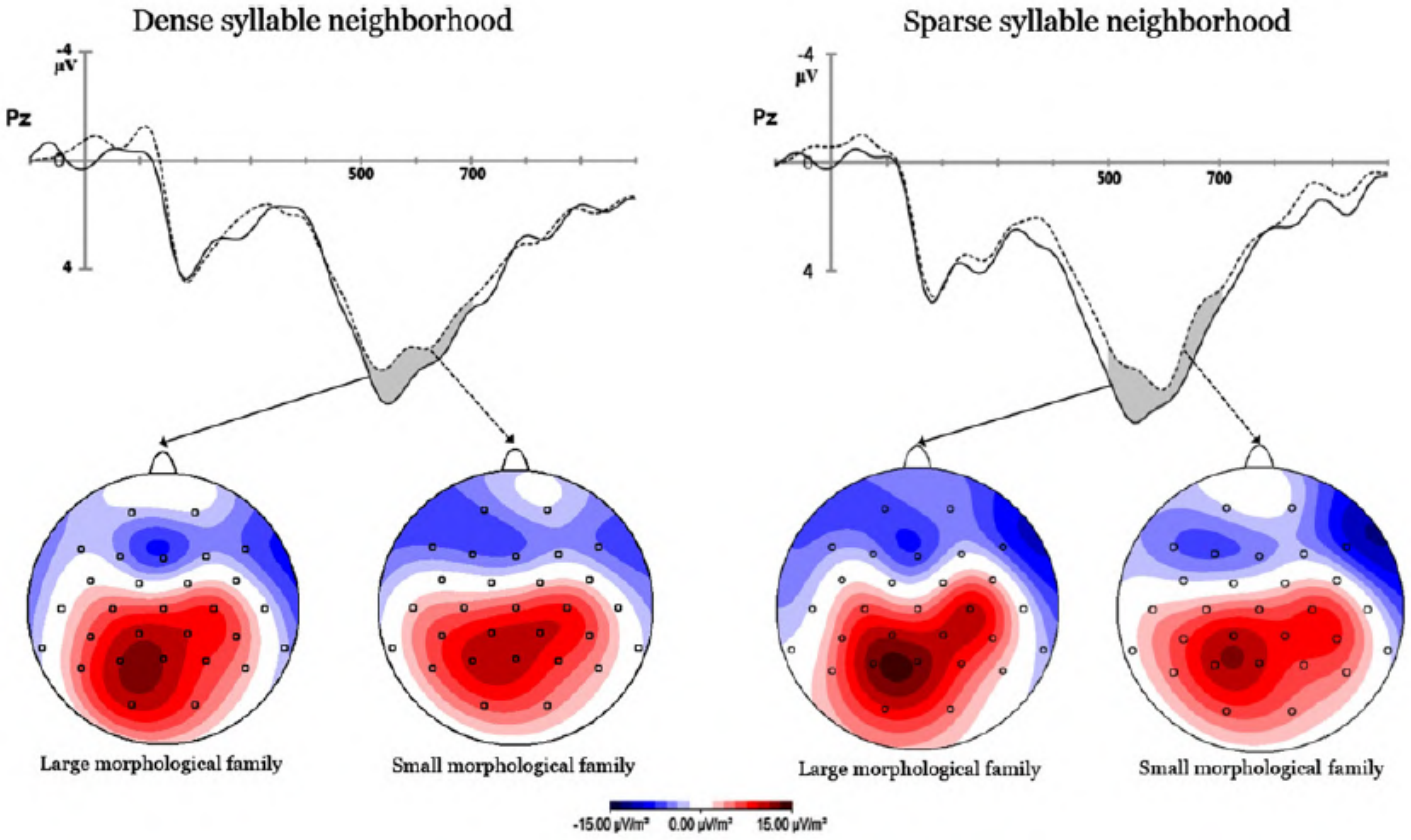
- Attention

Stroop color-word paradigm



Examples

- Language processing



Examples

- NeuroMarketing
  - http://www.youtube.com/watch?v=8Qo4FKvpE0c#t=40

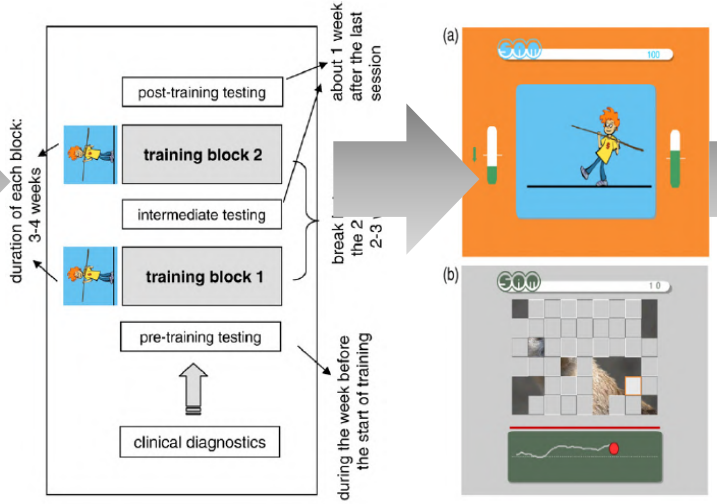
- Game
  - http://www.youtube.com/watch?v=WDgkZZYSVPo&list=PL8C99DAEAEA2FCEC1

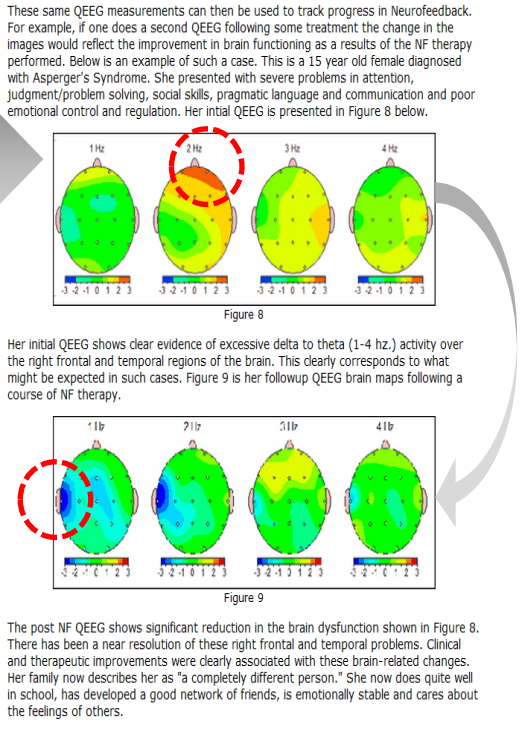
Examples

- BCI (Brain computer interface)
  - http://www.ted.com/talks/tan_le_a_headset_that_reads_your_brainwaves.html
  - http://www.youtube.com/watch?v=yff20TlHv34

Examples

- qEEG: neurofeedback



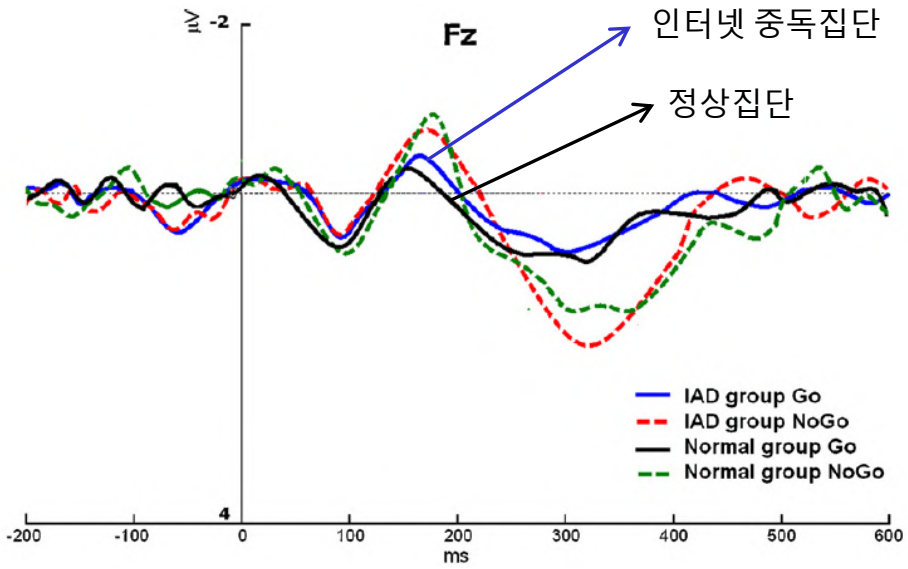


아스퍼거 신드롬 아동이 Neurofeedback game으로 자신의 theta wave와 delta wave (1-4Hz)의 적정수준을 유지하는 훈련을 받음

그 결과 우측 전두엽에서 정상아동에 비해 많은 delta wave가 사라지고 언어를 통제하는 좌측 측두엽에서 alpha wave가 증가함

Examples

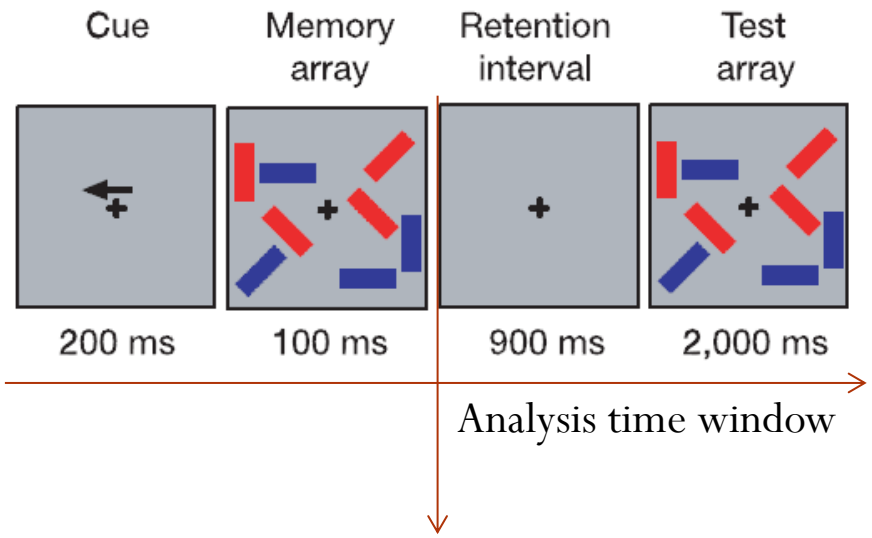
- 중독 검사



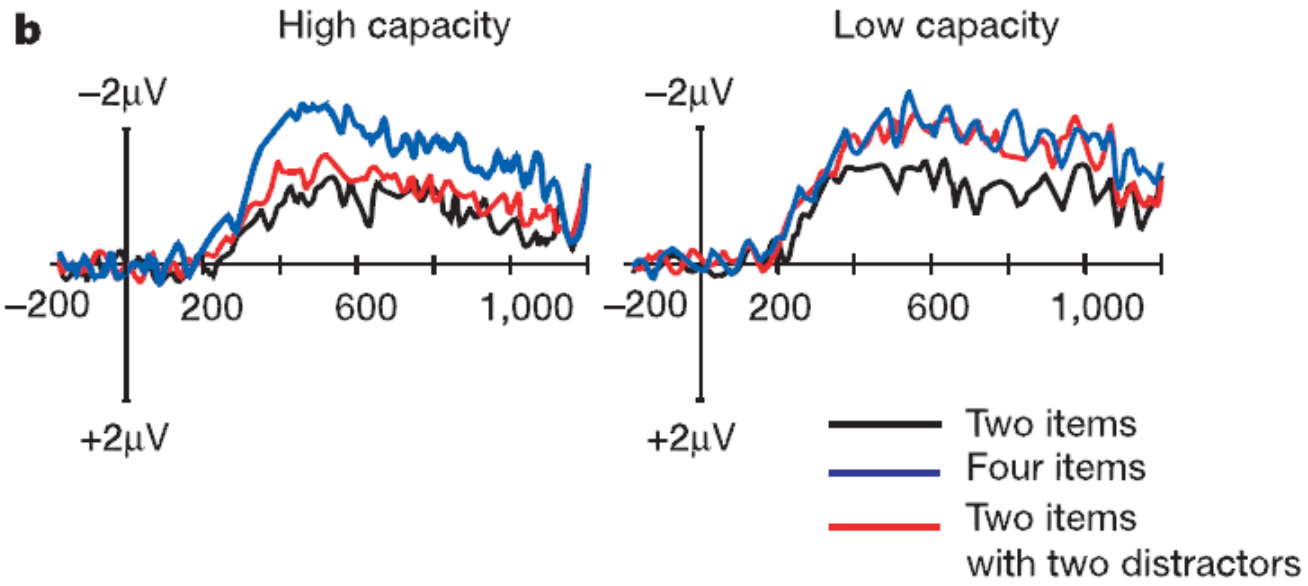
Examples

- **Memory efficiency**
  - **High capacity vs. Low capacity**

Group	Condition		
High capacity	Two items	Four items	Two items with two distractors
Low capacity			



- Results
  - High capacity의 경우 two items with two distractors의 CDA (contralateral delay activity)가 two items에 유사하고 반대로 low capacity의 경우 four items와 유사함



- Conclusion
  - Low capacity는 쓸데없이 모든 것을 기억하려하는 경향이 있음

매체의 몰입도를 반영하는 ERP

- 특정 ERP로 사용자가 매체에 얼마나 몰입을 하는지를 알아낼 수 있는가?
- 몰입을 방해할 때 발생하는 ERP로 측정이 가능

매체의 몰입도를 반영하는 ERP

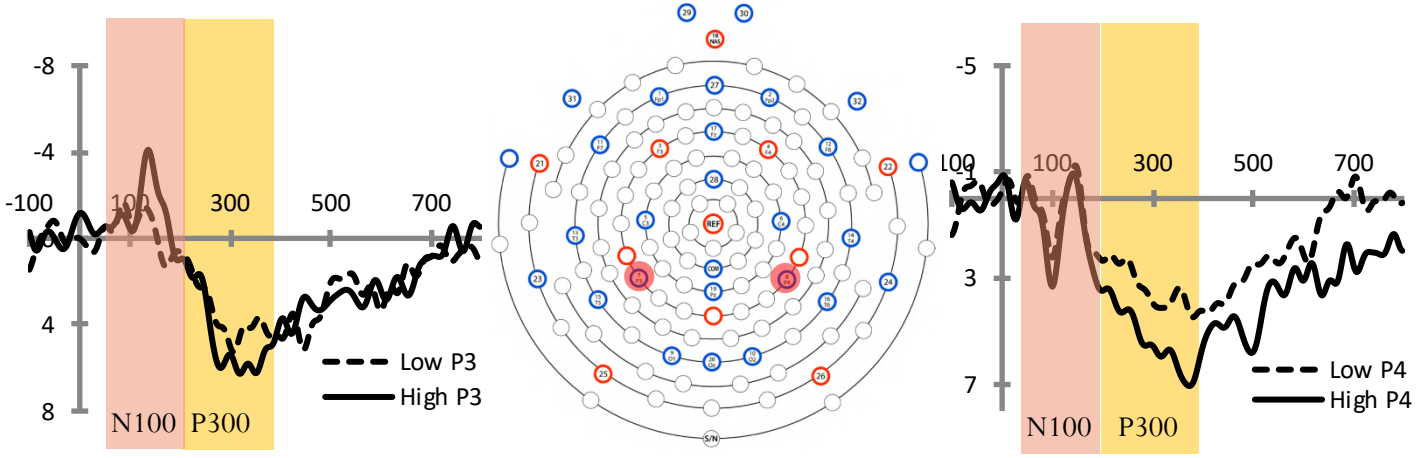
Dual Task: 만화를 보다가 '삑' 소리를 듣자마자 버튼을 누르기

Button Press

몰입의 정도가 강할 수록 "삑"소리에 대한 버튼 반응은 느려질 것임

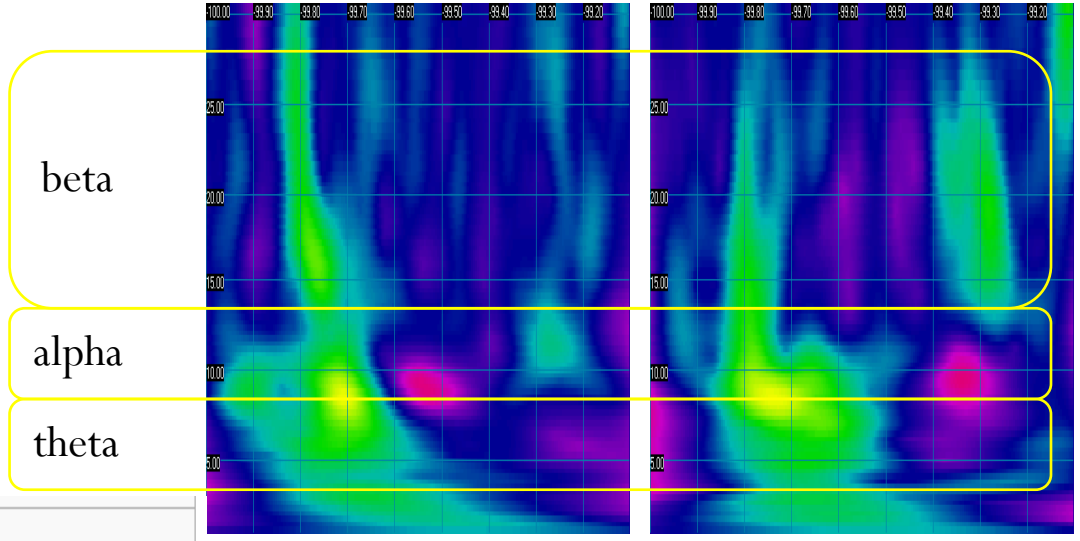
- Attention shift

매체의 몰입도를 반영하는 ERP



N100 (P3 vs. P4)
High vs. Low: $p = .55$
Left vs. Right: $p < .01$
Interaction: $p < .03$

P300 (P3 vs. P4)
High vs. Low : $p < .05$
Left vs. Right : $p = .56$
Interaction: $p = .65$



Beta	>13 – 30	both sides, symmetrical distribution, most evident frontally; low amplitude waves	• alert/working • active, busy or anxious thinking, active concentration	• benzodiazepines

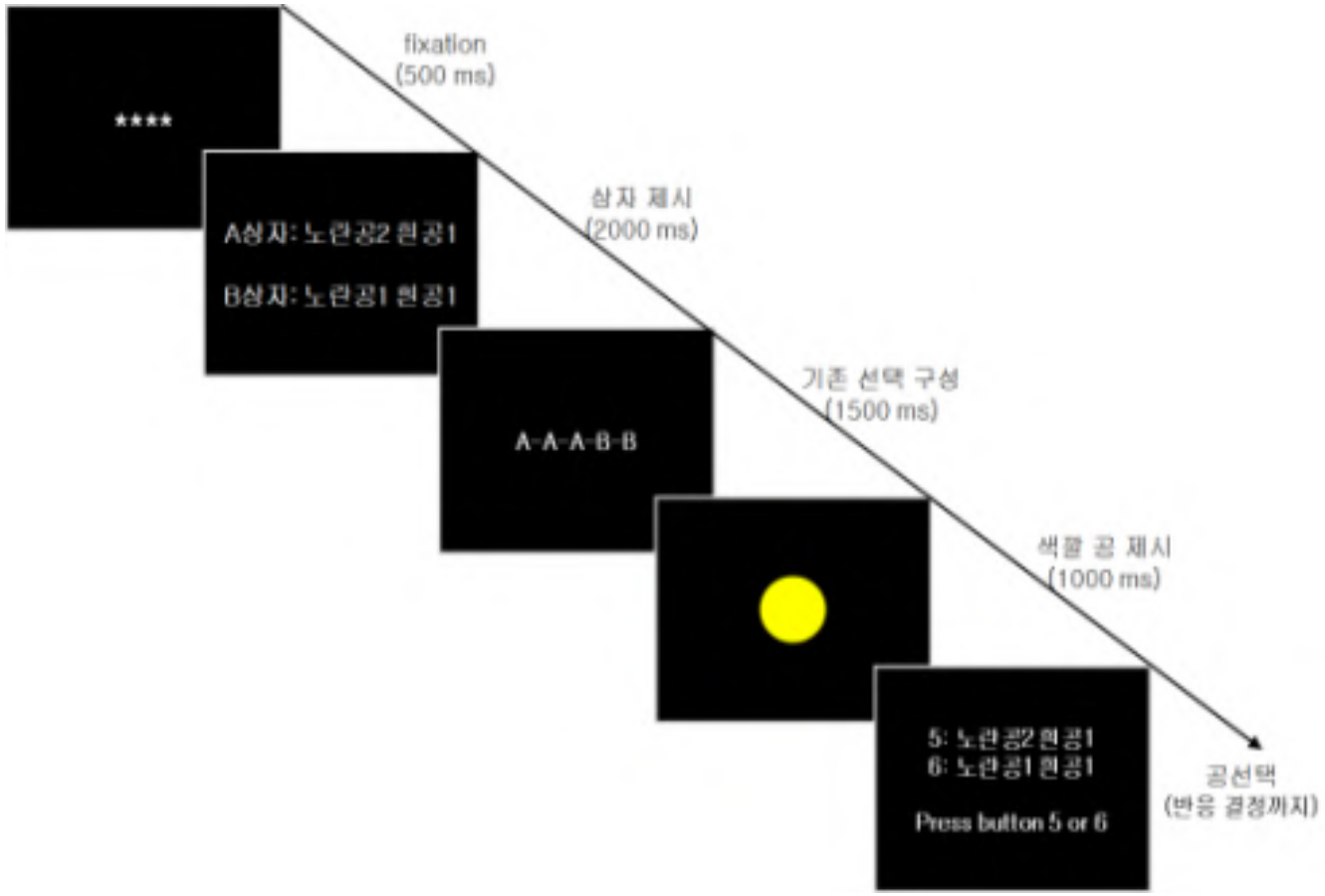
개인의 성격이 의사결정에 미치는 영향: ERP study

- 군중추종적 성향에 영향을 미치는 개인적 특성에 따라 구분한 집단 간에 뇌파의 차이가 존재하는가?

독립변인		종속변인
집단간 요인 (between-subject)	집단내 요인 (within-subject factor)	
군중신호 추종 경향 군중신호 추종(N=15) 군중신호 비추종(N=13)	뇌영역 전측 중앙 후측 보상유형 일반보상 추가보상	각 피험자가 해당 조건의 자극을 보았을 때 각 시점(time-point)별로 유발된 뇌파의 전위값들을 평균(예, 100 ms에서 8 μV, 101 ms에서 7 μV 등등의 평균)하고, 이 값을 분석하려는 시간대별(100-200 ms, 200-400 ms, 400-600 ms)과 뇌영역별로 구분하여 종속치로 사용
자아존중감 성향 자아존중감 높음(N=11) 자아존중감 낮음(N=10)		
성격특징 내향성(N=11) 외향성(N=10)		
오류성향 오류 높음(N=14) 오류 낮음(N=14)		

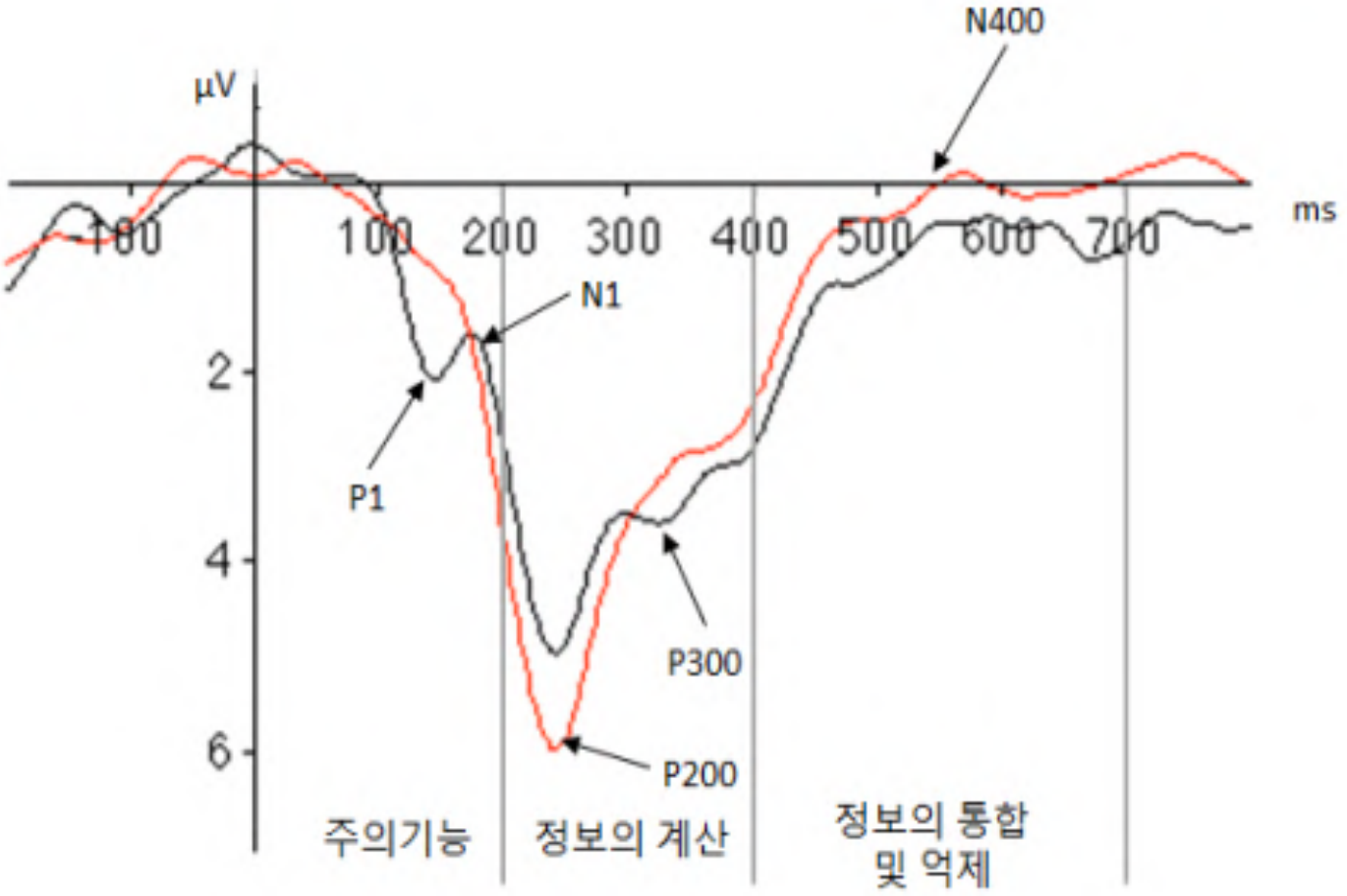
개인의 성격이 의사결정에 미치는 영향: ERP study

- 방법



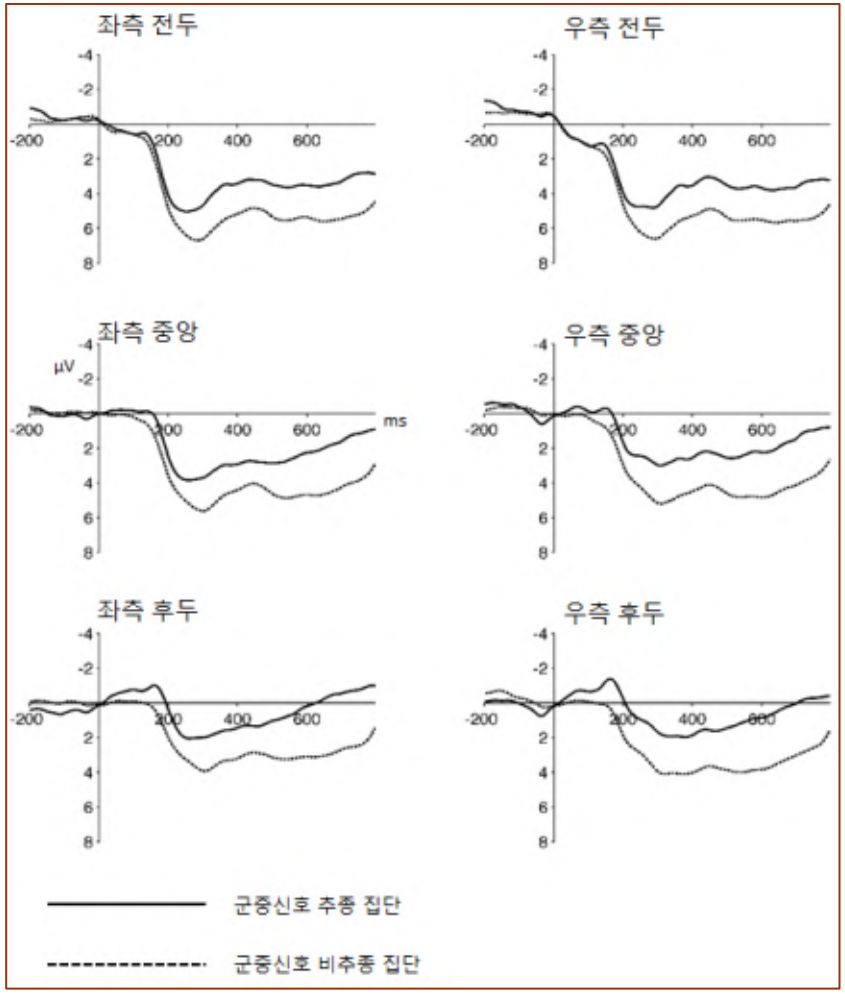
개인의 성격이 의사결정에 미치는 영향: ERP study

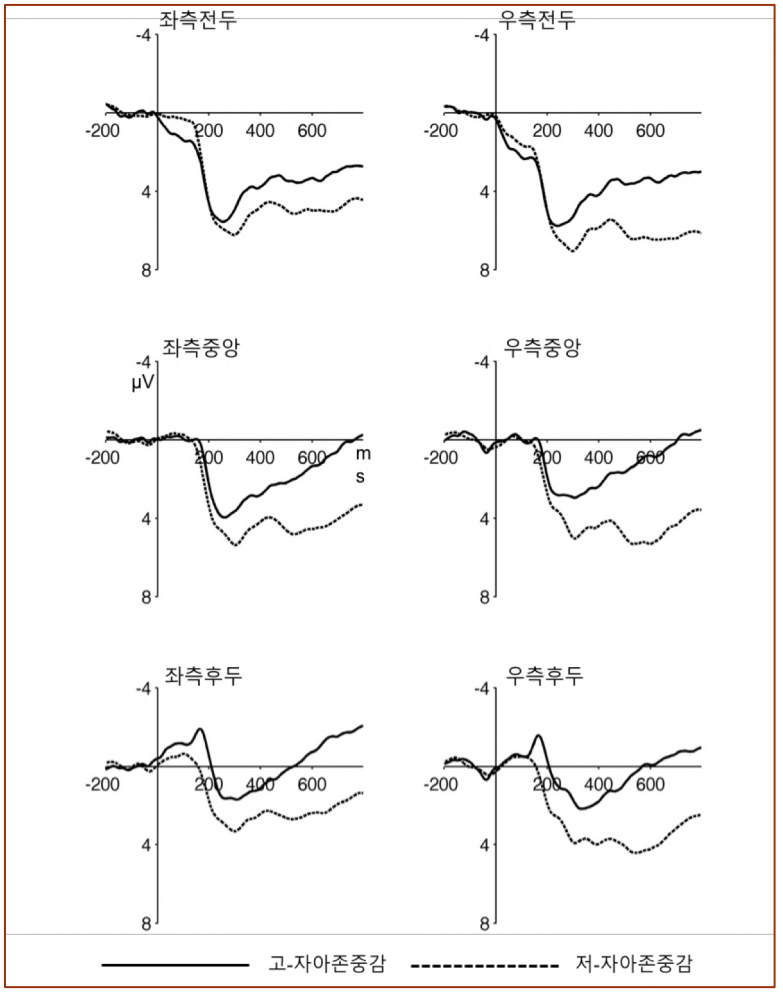
- 시간대별 인지처리



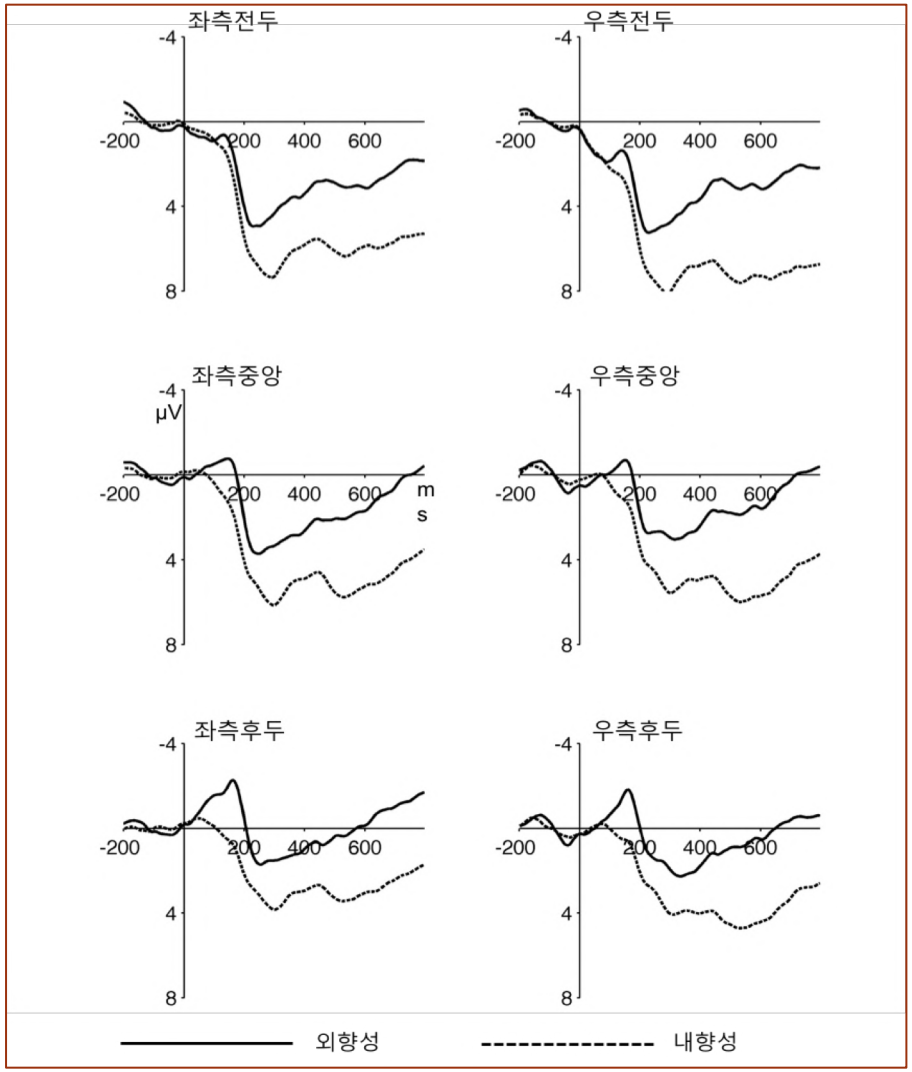
개인의 성격이 의사결정에 미치는 영향: ERP study

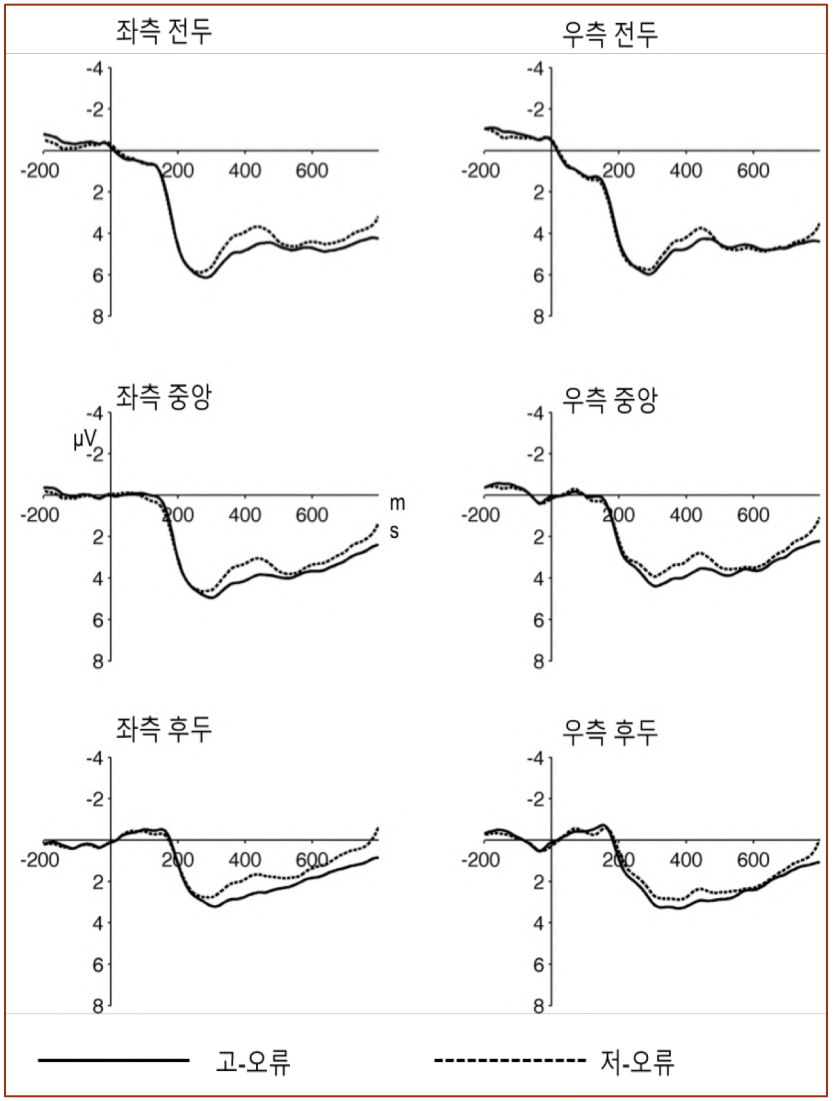
- 결과





개인의 성격이 의사결정에 미치는 영향: ERP study





개인의 성격이 의사결정에 미치는 영향: ERP study

주요 집단 요인	주의집중 단계 (100-200ms)	정보의 계산 단계 (200-400ms)	정보통합 및 부적절한 정보의 억제 단계 (400-600ms)
군중추종 집단차이	군중추종 집단이 더 주의집중함	군중추종 집단이 정보계산을 더 적게함	군중추종 집단이 정보통합 및 불필요한 정보를 더 많이 억제함
자아존중감 집단차이	차이없음	자아존중감 높은집단이 정보계산을 더 적게함	자아존중감 높은집단이 정보통합 및 불필요한 정보를 더 많이 억제함
내외향성 집단차이	외향성 집단이 더 주의집중함	외향성 집단이 정보계산을 더 적게함	외향성 집단이 정보통합 및 불필요한 정보를 더 많이 억제함
오류정도 집단차이	차이없음	차이없음	차이없음

Story PPL의 효과: ERP study

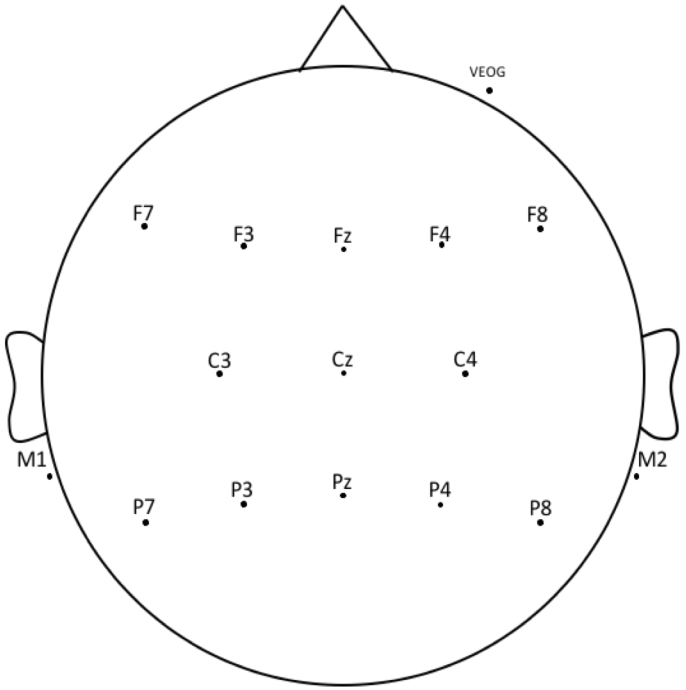
- Story PPL과 일반 PPL의 광고 효과가 무의식적 처리에서 다른 처리를 보이는가?

Story PPL

일반 PPL

Story PPL의 효과: ERP study

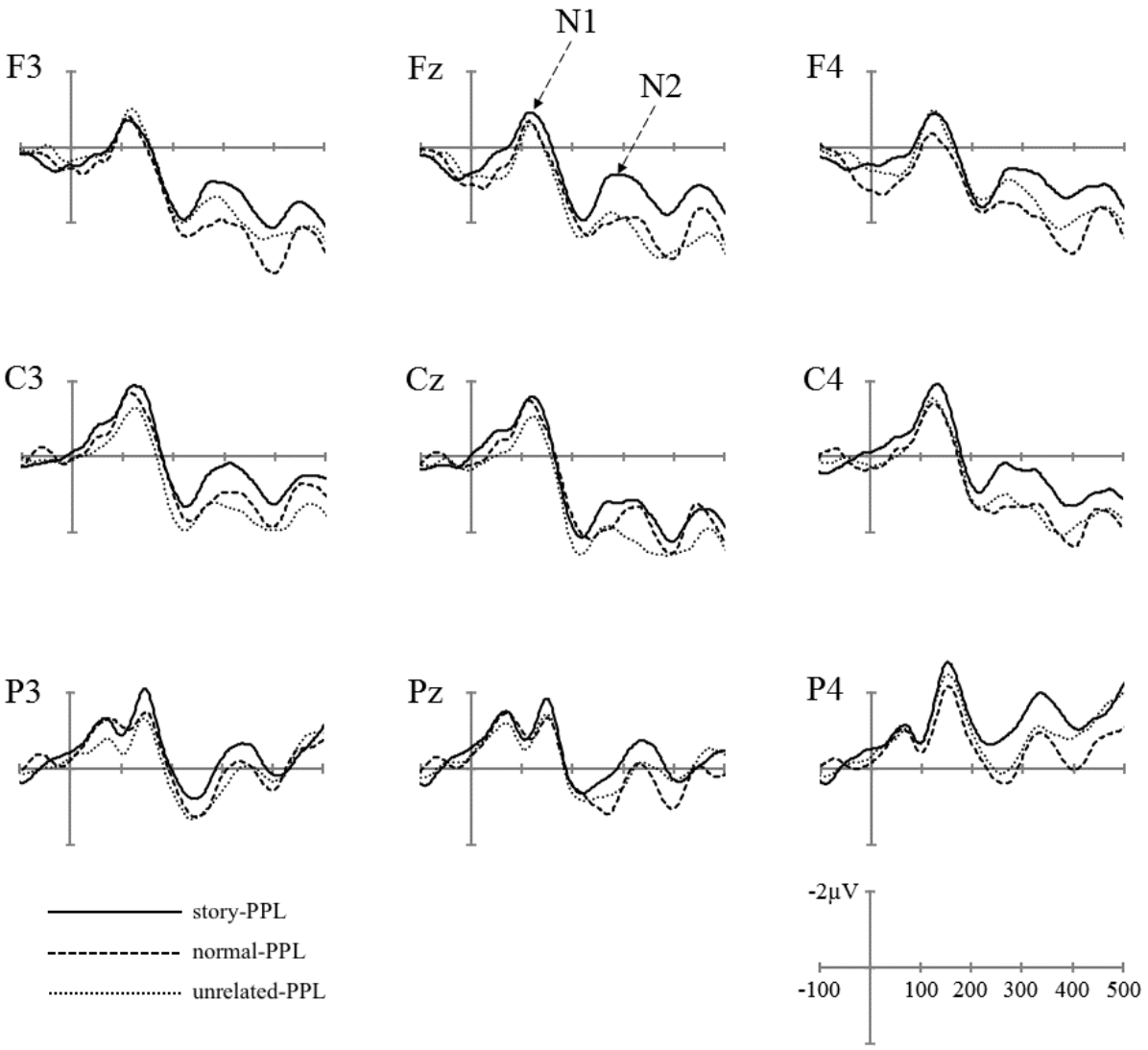
- 과제
  - 표적 자극에 나타난 상품의 범주 판단
  - 1.전자 2.의류 3.식품 4.기타 5.없음
- 피험자
  - 31명
- RT and error rates



	RT (SD)	Error rate (SD)
Story-PPL	1395 (261.5)	9 (5.5)
Normal-PPL	1399 (257.7)	11 (6.1)
Unrelated-PPL	1192 (200.1)	14 (9.9)

Story PPL의 효과: ERP study

- ERP 결과



Story PPL의 효과: ERP study

- N2
  - it reflect the next processes of attended stimuli.
  - the size of the N2 amplitude is closely linked to the difficulty of target discrimination among attended stimulus (Folstein & Van Petten, 2007; Patel & Azzam, 2005; Senkowski & Hermann, 2002)

언어 처리

표기 부호와 음운 부호의 상호작용

한국어는 표기 부호 주도적 처리?

- 박권생(1996, 1999, 2002)
  - 같이 → 평가 vs. 가치 → 평가
  - 동음이의어가 표적 단어를 유의하게 점화시키지 못함
- RT는 인지적 처리의 최종 결과물(Carreiras et al., 2014)
- 표기 심도가 매우 얕고 시각적 음절 경계가 명확한 언어인 한국어의 경우 음운의 역할이 과소평가될 수 있음(Kwon, Lee, & Nam, 2011; Kwon, Nam, & Lee, 2012)

시각적 단어재인에서 음운부호의 활성화 시점: 동음이의어의 사건관련 뇌전위 연구 (2016, 언어과학연구. 76, 1-21)

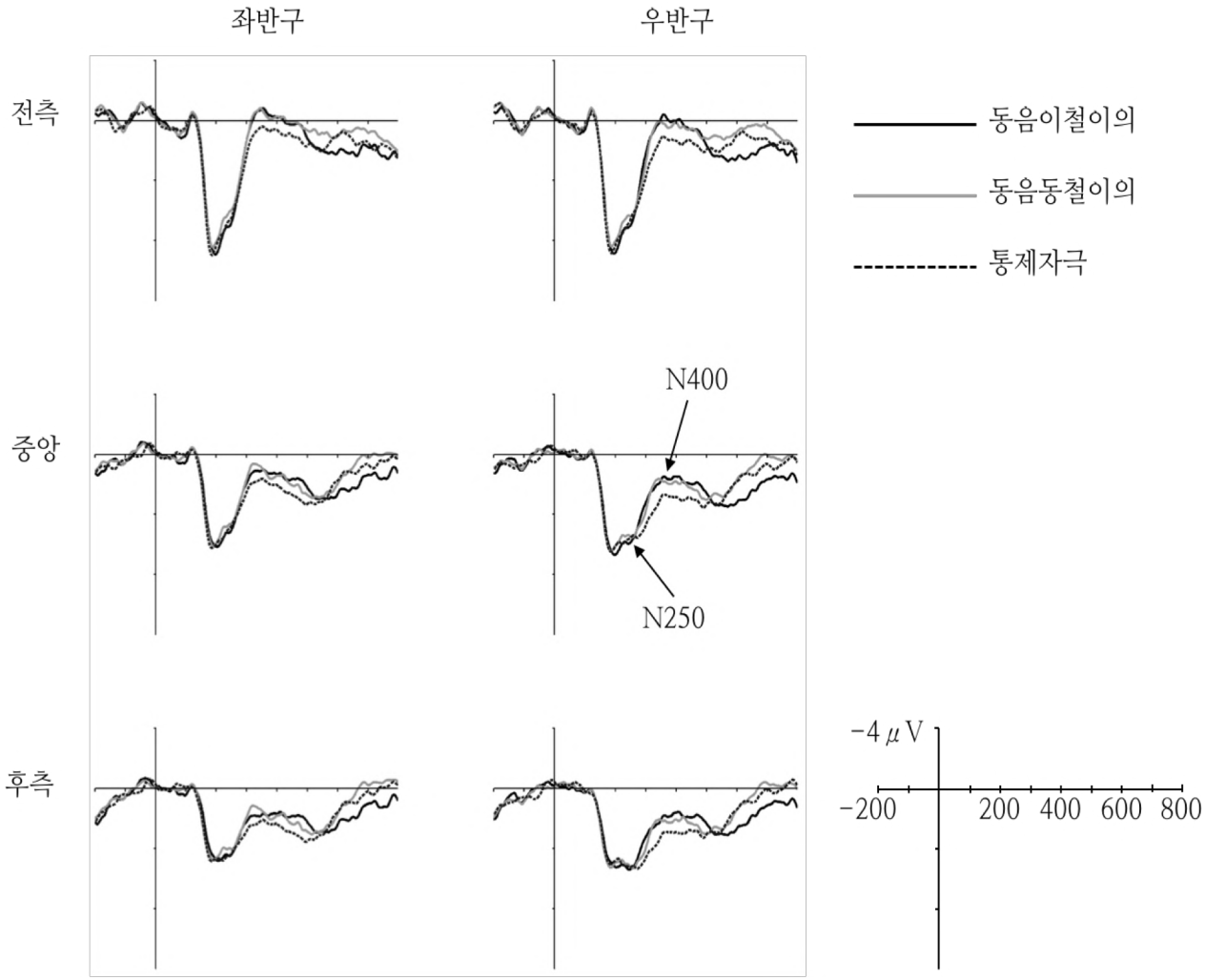
- 표기 부호가 음운 부호로 전환되어 의미에 접속하지 않는다면 동음이철어와 동음동철어 간의 뇌파 차이가 발생하지 않을 것임.
  - 동음이철어: 세끼-새끼
  - 동음동철어: 지각 (perception; lateness; earth's curst)
  - 통제자극: 탄알
- 방법
  - 참가자: 21명
  - 과제: go/no-go lexical decision task

시각적 단어재인에서 음운부호의 활성화 시점: 동음이의어의 사건관련 뇌전위 연구 (언어과학연구. 76, 1-21)

- 결과

자극 유형	어휘 판단 시간	오류율
동음이철이의(예, 가치/같이)	640(104.4)	10(11.6)
동음동철이의(예, 경비)	569(90.8)	1.6(2.2)
통제자극(예, 온탕)	566(89.5)	2.0(3.4)

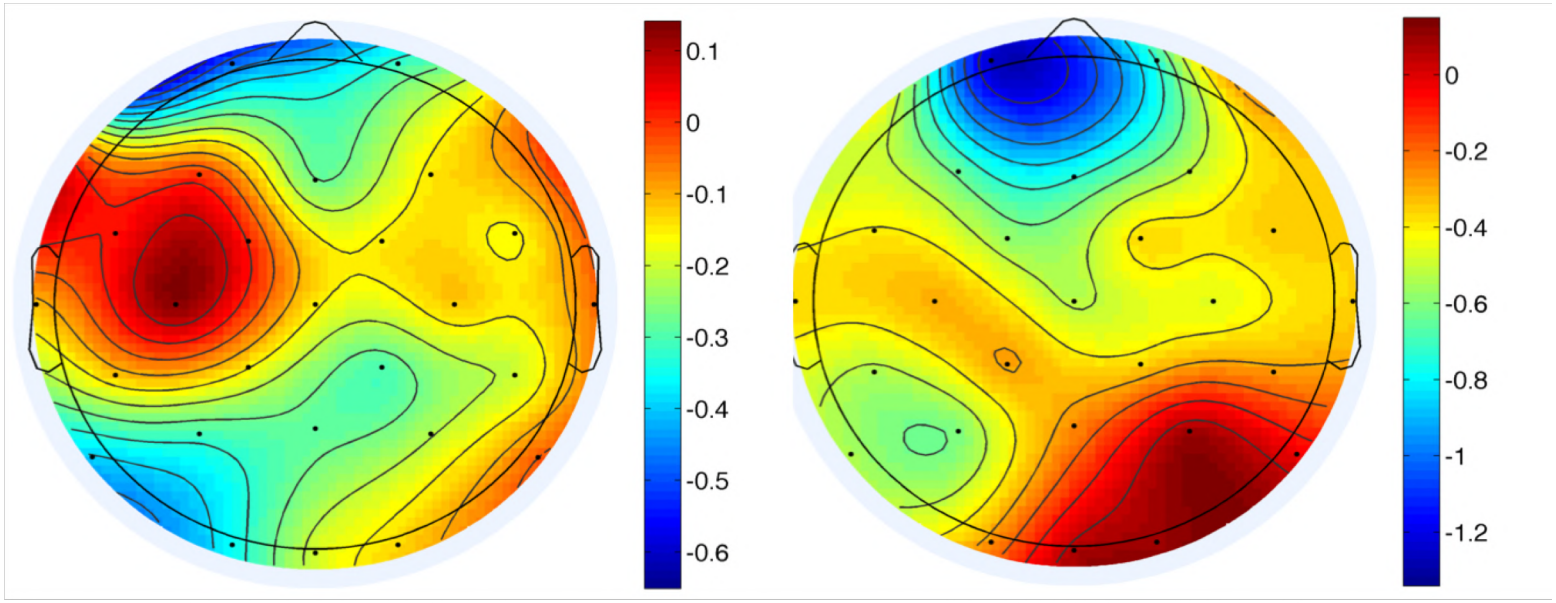
시각적 단어재인에서 음운부호의 활성화 시점: 동음이의어의 사건관련 뇌전위 연구 (언어과학연구. 76, 1-21)



시각적 단어재인에서 음운부호의 활성화 시점: 동음이의어의 사건관련 뇌전위 연구 (언어과학연구. 76, 1-21)

- N400에서만 조건 간 유의한 차이($F(1, 19) = 5.97$, $p < .05$, $\eta 2 = .23$)
- N250 진폭의 차이가 유발되지 않은 이유가 자소-음소 전환을 더 적극적으로 사용하지 않아서이지 음운부호를 활성화시키지 않아서가 아니라면 N250을 유발한 뇌영역이 음운부호 처리를 담당하는 뇌영역인 좌측 하전두회(left inferior frontal gyrus)와 좌측 상측두이랑(left superior temporal gyrus)에 기반해야 함

시각적 단어재인에서 음운부호의 활성화 시점: 동음이의어의 사건관련 뇌전위 연구 (언어과학연구. 76, 1-21)

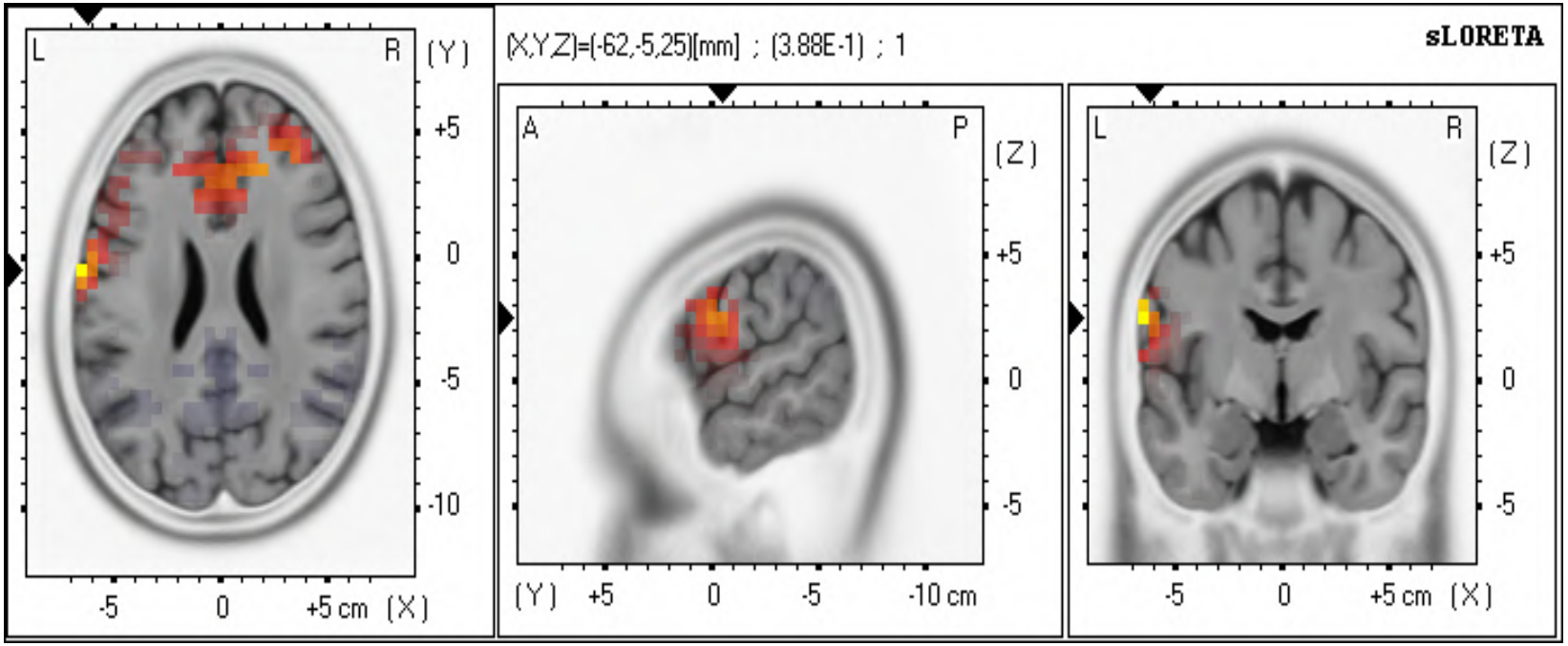


A. 동음이철이의-통제조건

B. 동음동철이의-통제조건

동음이철어와 동음동철어의 N250 유발 영역 차이
(200ms-300ms 간의 평균 전압)

시각적 단어재인에서 음운부호의 활성화 시점: 동음이의어의 사건관련 뇌전위 연구 (언어과학연구. 76, 1-21)



sLORETA 결과: 동음이철이의와 동철자극과의 차이

시각적 단어재인에서 음운부호의 활성화 시점: 동음이의어의 사건관련 뇌전위 연구 (언어과학연구. 76, 1-21)

- 동음이철이의 조건과 동철 조건(동음동철이의 + 통제) 간을 비교하였다(Nichols, & Holmes, 2001). N250 영역에서 진폭의 정점을 보이는 245ms-265ms를 기준으로 동음이철이의 조건과 동철 조건 간에 **좌측 하전두회(left inferior frontal gyrus)를 포함한 좌측 전두엽 영역(최적 대응 10ms 기준)**에서 유의한 차이가 발견되었다($p < .01$).

Early use of orthographic information in spoken word recognition: Event-related potential evidence from the Korean language (2016, Psychophysiology, 53, 544-552)

- 말소리를 지각할때 단어의 표기 정보를 어떤 시점에서 사용하는가?
- 표기와 발음이 다른 단어를 사용하고 이때 표적 단어의 표기 음절 이웃(같은 표기 음절로 시작하는 단어들의 집합)을 조작함
- 표기와 발음이 다르면 우선 말소리를 지각할때 표기 정보를 더 쓸 것이고 또한 표기 음절 이웃이 많으면 많을 수록 표기 정보를 사용하는 정도가 더 증가할 것임

Table 1. *Examples of Conditional Stimuli*

Base word	Consistent version	Inconsistent version	Pseudoword	Illegal word
국모 (wife of king)	/kuk-mo/	/kung-mo/	/mung-mo/ /muk-mo/	/lumgnoj/

Early use of orthographic information in spoken word recognition: Event-related potential evidence from the Korean language (2016, Psychophysiology, 53, 544-552)

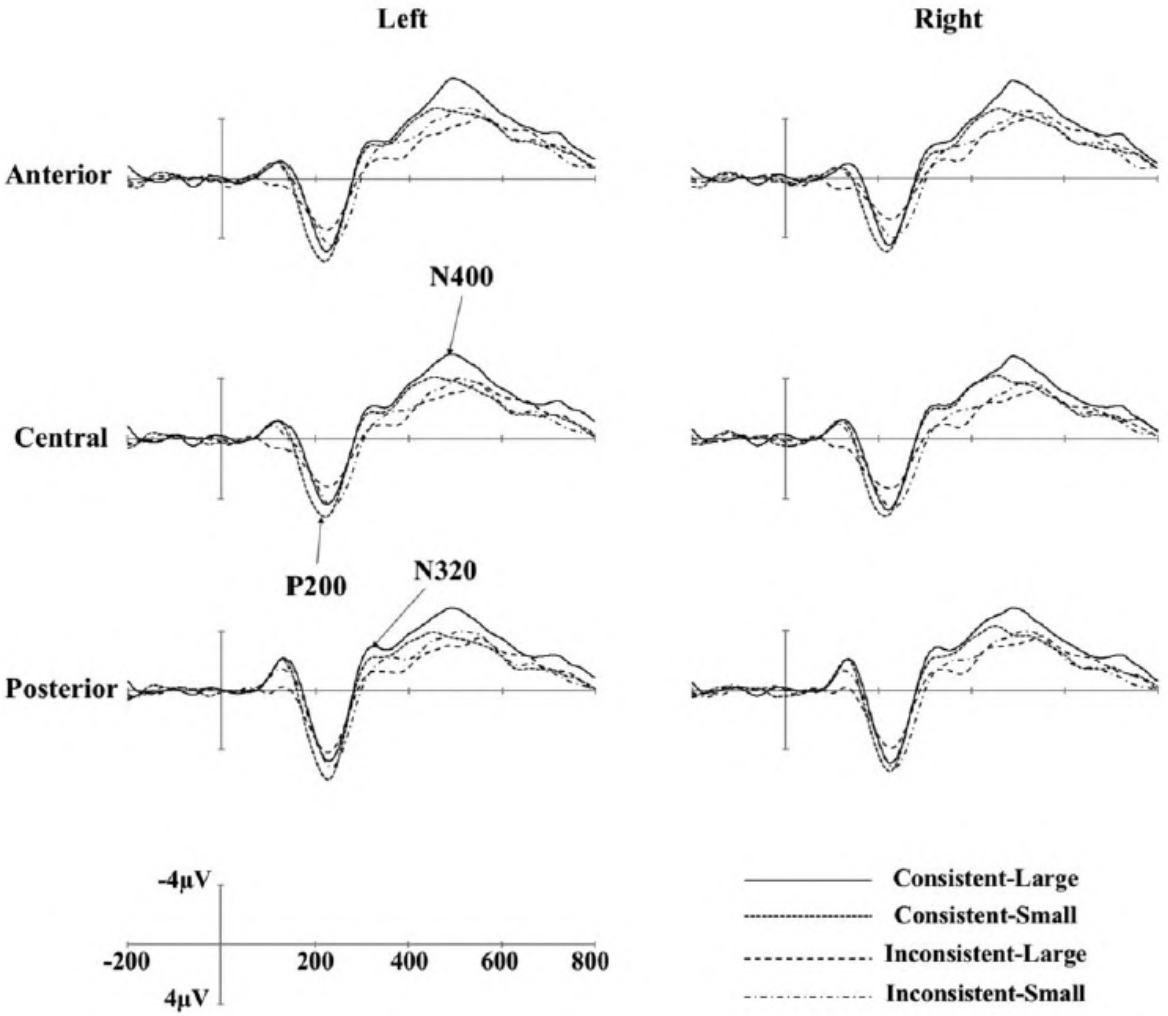
- Characteristics of materials

Table 2. *Means (Standard Deviations) of Conditional Stimuli*

	Large OSN	Small OSN
Word frequency of the base word	16.3(10.7)	16(10.3)
Consistent version		
Number of orthographic syllable neighbors	85(12.4)	12.3(10.9)
Bigram frequency (log)	3.4(0.1)	3.3(0.1)
Number of orthographic and phonological neighbors	3.0(1.9)	2.7(1.3)
Number of more frequent orthographic and phonological neighbors	2.5(1.9)	1.9(1.0)
Mean duration (ms)	668.9(44.2)	668.4(67.2)
Inconsistent version		
Number of phonological syllable neighbors	65.9(53.9)	74(68.4)
Bigram frequency (log)	3.4(0.1)	3.4(0.1)
Number of phonological neighbors	2.4(2.1)	2.7(2.1)
Number of more frequent phonological syllable neighbors	1.7(1.7)	1.9(1.8)
Mean duration (ms)	661.3(45.9)	672.3(58.1)

Note. OSN = large orthographic syllable neighborhood size.

Early use of orthographic information in spoken word recognition: Event-related potential evidence from the Korean language (2016, Psychophysiology, 53, 544-552)



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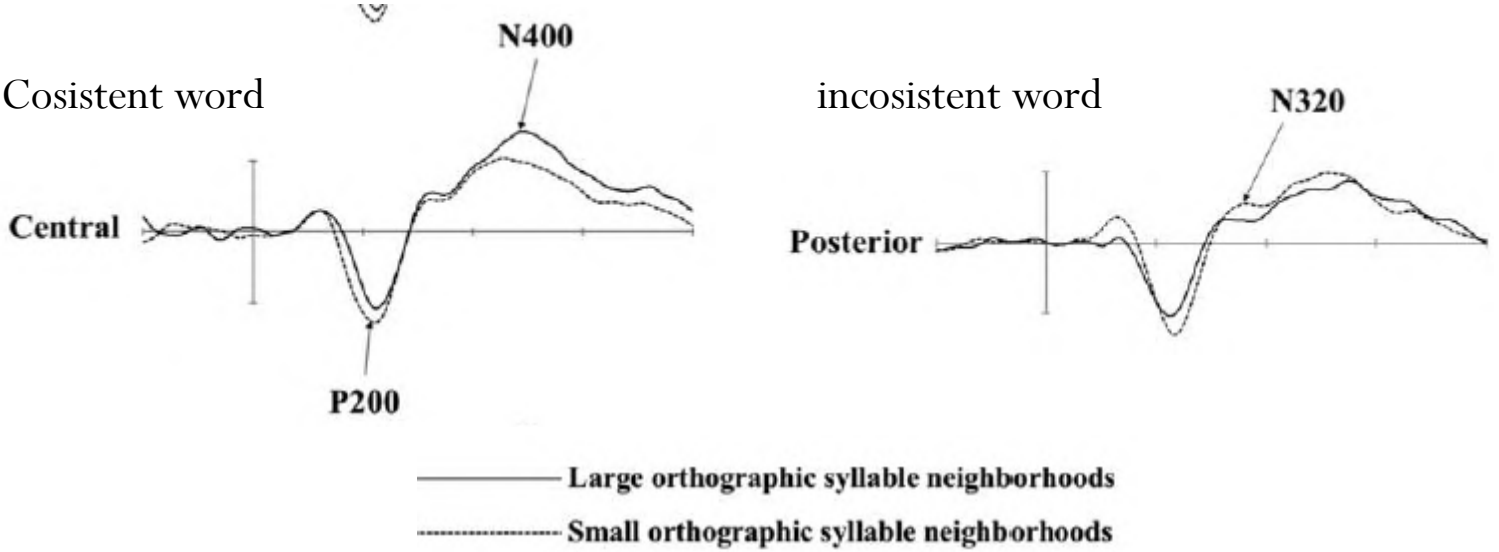

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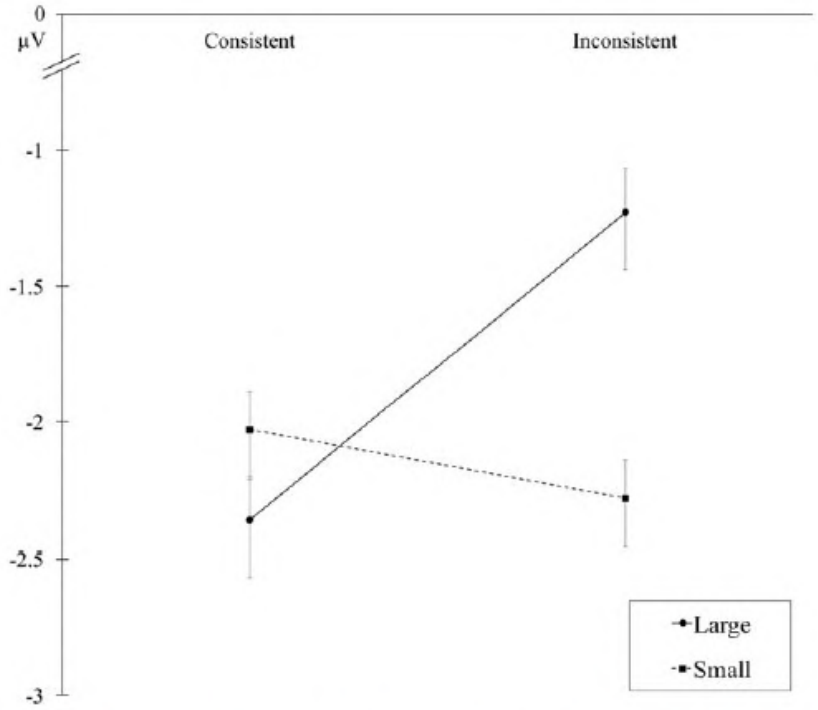

Figure 4. The difference of N320 mean amplitudes between large and small orthographic syllable neighbors in consistent and inconsistent words

The main effects of consistency and orthographic syllable neighborhood were not significant (consistency: $F(1,41)=51.13$, $MSE=523.78$, $p=5.29$; orthographic syllable neighborhood size: $F(1,41)=52.07$, $MSE=528.48$, $p=5.15$). By contrast, the interaction between consistency and orthographic neighborhood size was significant, $F(1,41)=54.41$, $MSE=527.48$, $p<.05$.

Early use of orthographic information in spoken word recognition: Event-related potential evidence from the Korean language (2016, Psychophysiology, 53, 544-552)

- It seems that P200 in this study reflects bottom-up processing of structuring a syllable unit from input, whereas N320 reflects matching or mismatching of orthography and phonology during the prelexical spoken word recognition process.