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Brain neuro
Language
Processing

Comparing Programming Language Comprehension between Novice and Expert Programmers using EEG Analysis

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Motivation

- **Research Question**

- What differences exist in the information processing between novices and experts when they try to understand programming?

- **In traditional study of program understanding**

- Checking validity or via self-assessment scores
- Subjective (cannot examine what is happening inside the brain)

- **Brain imaging to study information for programming comprehension**

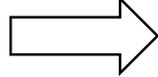
- EEG (electroencephalogram)
-

Experimental Design



16channels

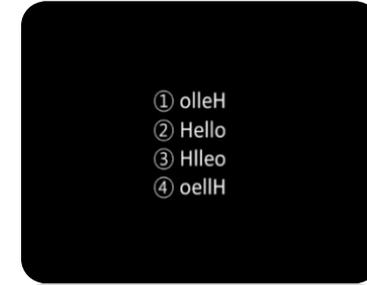
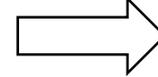
watch



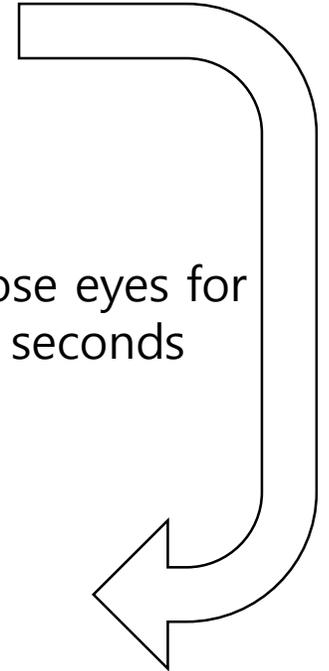
```
public static void main(String[] args) {  
    String word = "Hello";  
    String result = new String();  
    for ( int j = word.length() - 1; j >= 0; j-- )  
        result += word.charAt(j);  
    System.out.println(result);  
}
```

Code snippet
Randomly showing

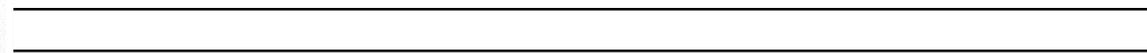
Click on multiple
choice number



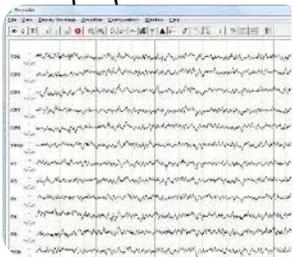
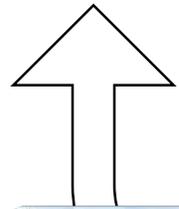
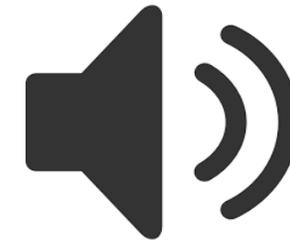
Close eyes for
30 seconds



Open eyes



Recording brain waves & input information

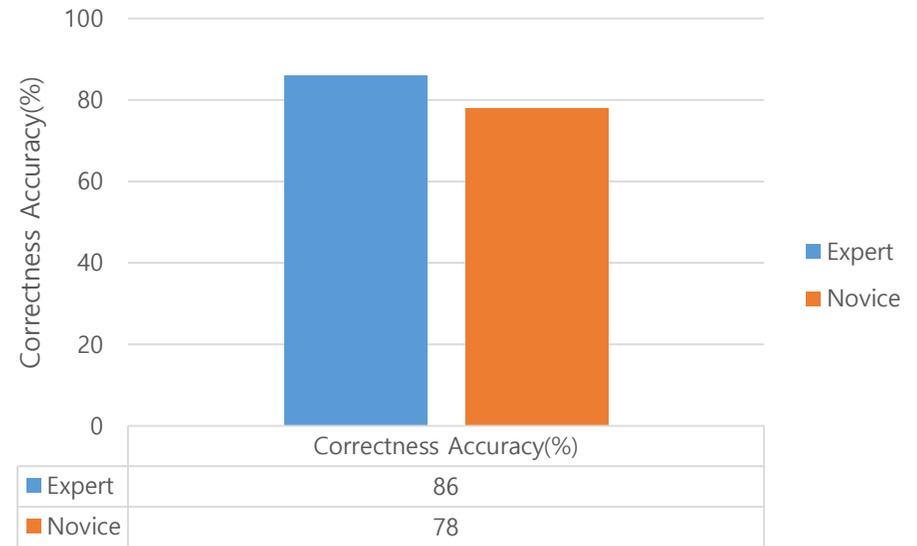
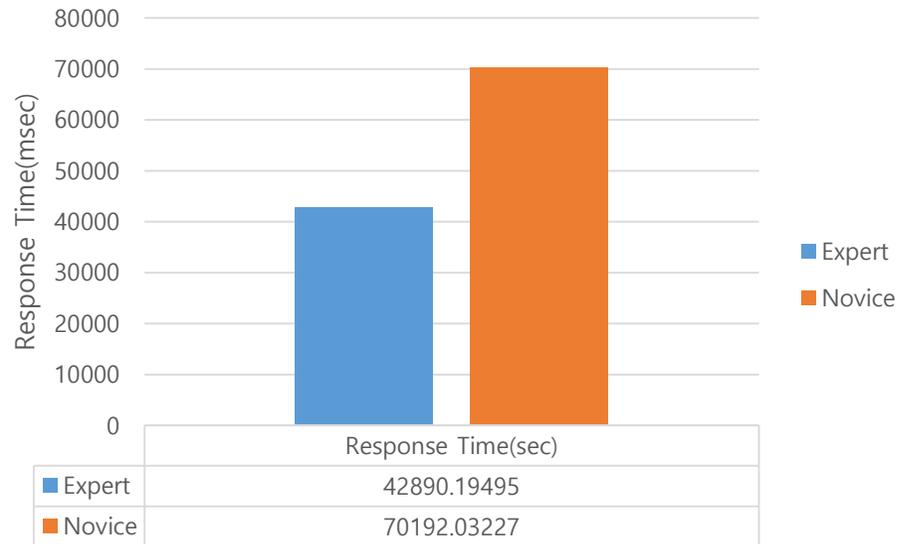


Experimental Results

- Performance
 - EEG Power
 - Correlations between performance and EEG Power
-

Experimental Results

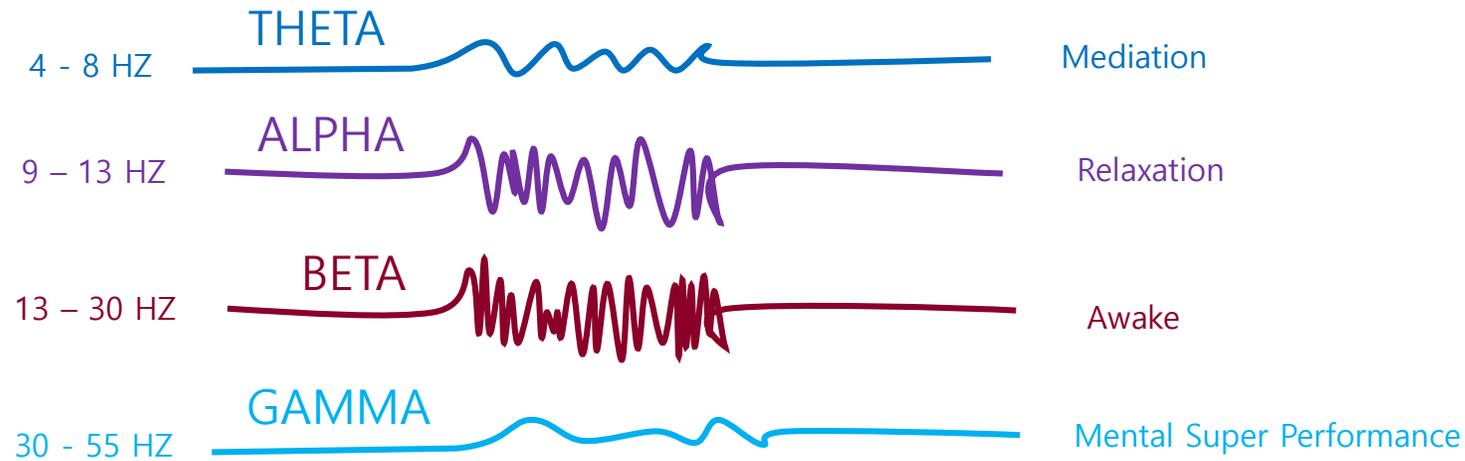
PERFORMANCE



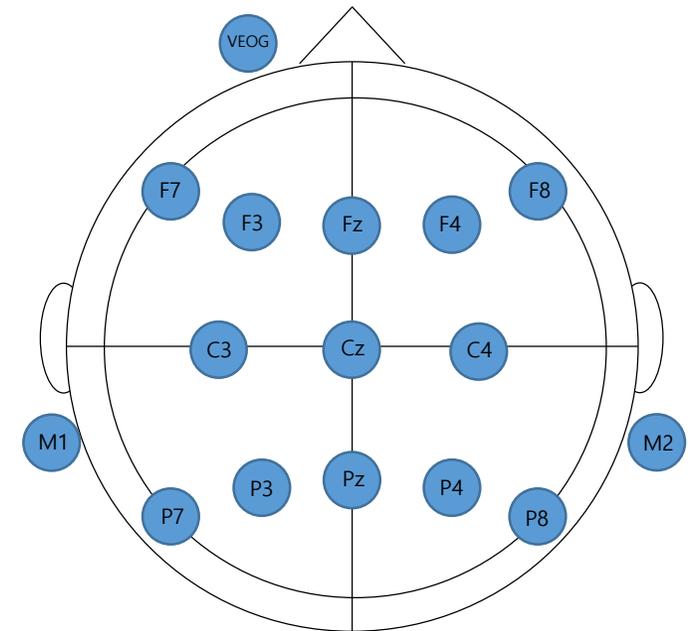
Experimental Results

EEG POWER

BAND

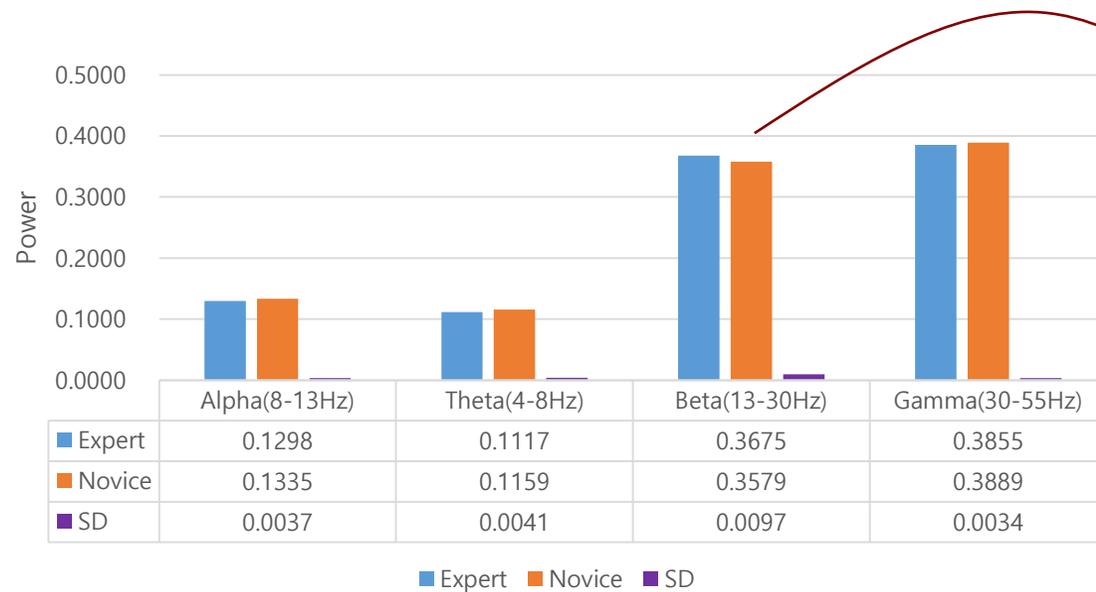


16 - CHANNEL



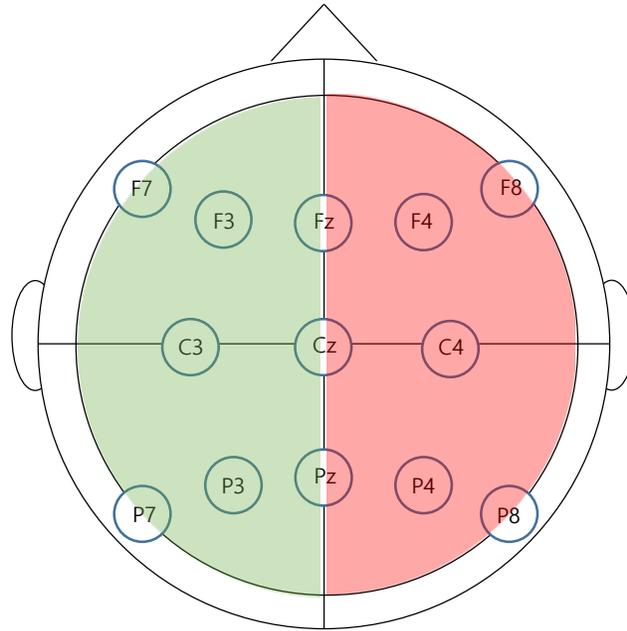
Experimental Results

EEG POWER



- Beta, Gamma are very high in all band
- The high results of Gamma and Beta frequencies are reasonable since program comprehension cognitive skills
- The **expert group** sees higher activation in **Beta** frequencies than the novice group
- Beta frequencies occur in conscious thought and **logical thinking**
- Gamma frequencies occur in attention, memory, linguistic processing, information processing

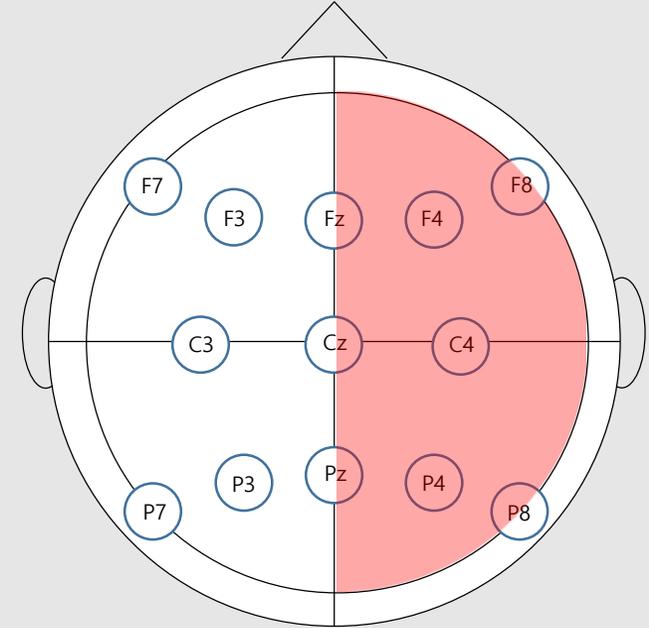
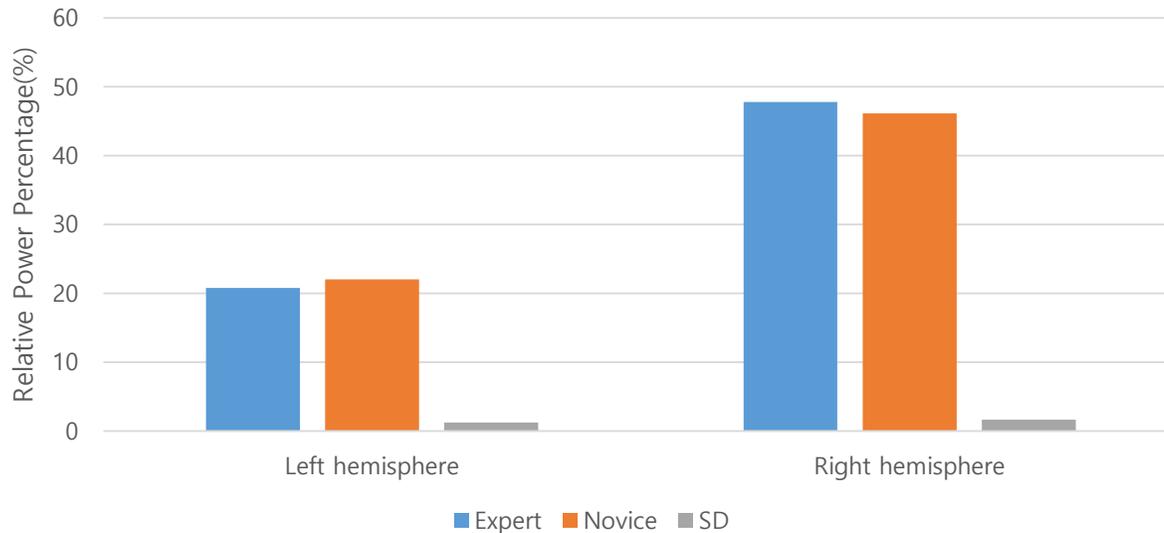
Experimental Results



Comparing Left – Right hemisphere (좌반구 – 우반구) Balance

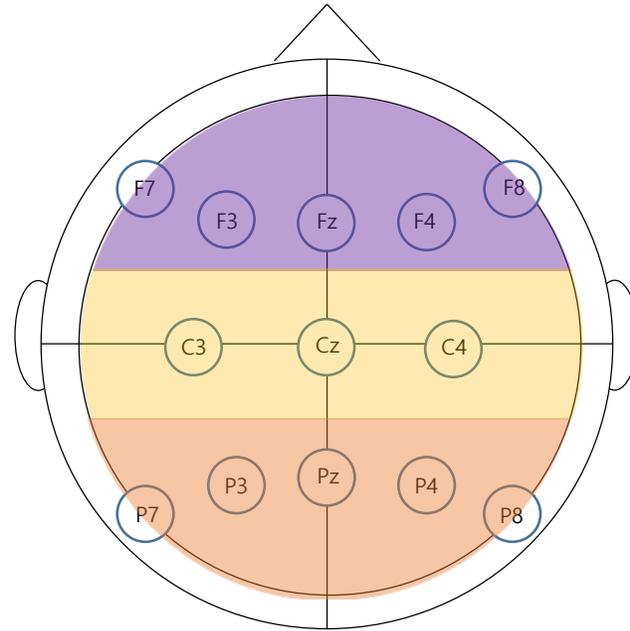
Experimental Results

EEG POWER



- The **Expert group** higher than the novice group
- Right hemisphere is related to coarse coding
 - Coarse coding : encoding given information
 - 기억하기 쉽도록 주어진 정보를 부호화

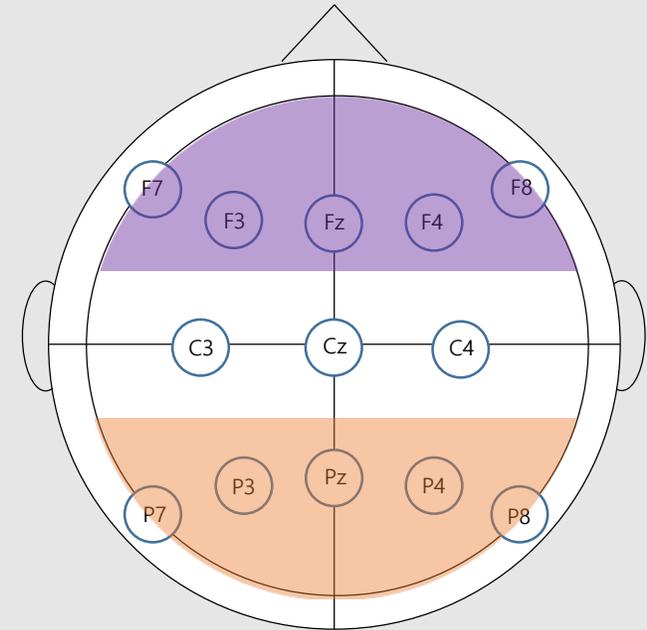
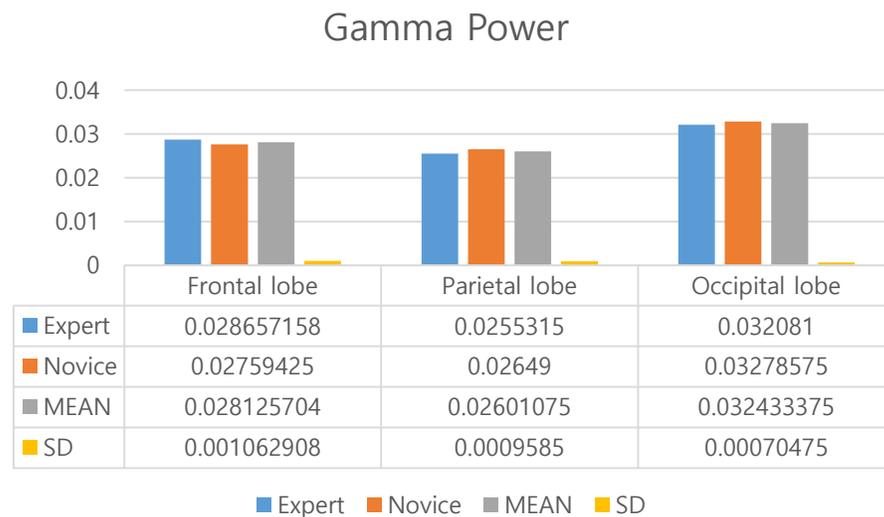
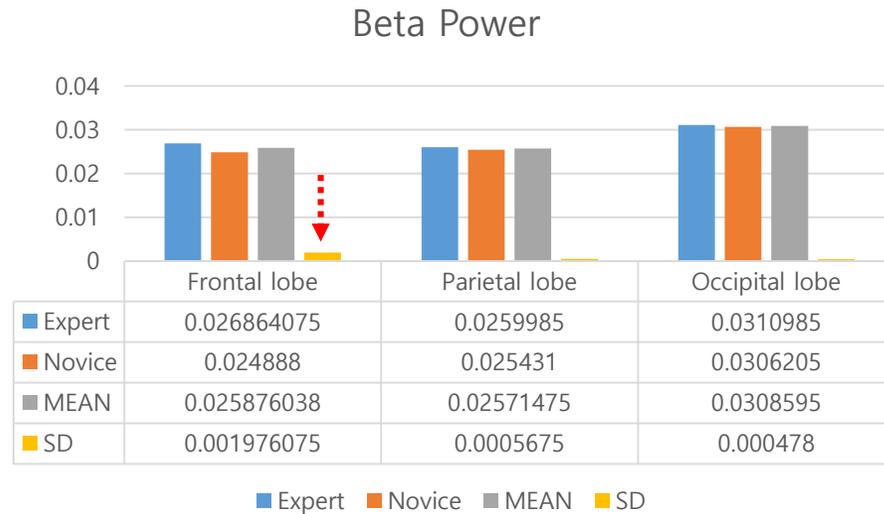
Experimental Results



Comparing Frontal (전두엽) – Parietal (두정엽) – Occipital (후두엽) lobe Balance

Experimental Results

EEG POWER



- **Significant activation** in the **occipital lobe**
- But, per-group **difference** was highest in **frontal lobe**
 - Occipital lobe is usually responsible for visual processing

Experimental Results

SIGNIFICANT TEST BETWEEN CHANNELS AND BANDS

Table 1. Cross correlation between channels and bands

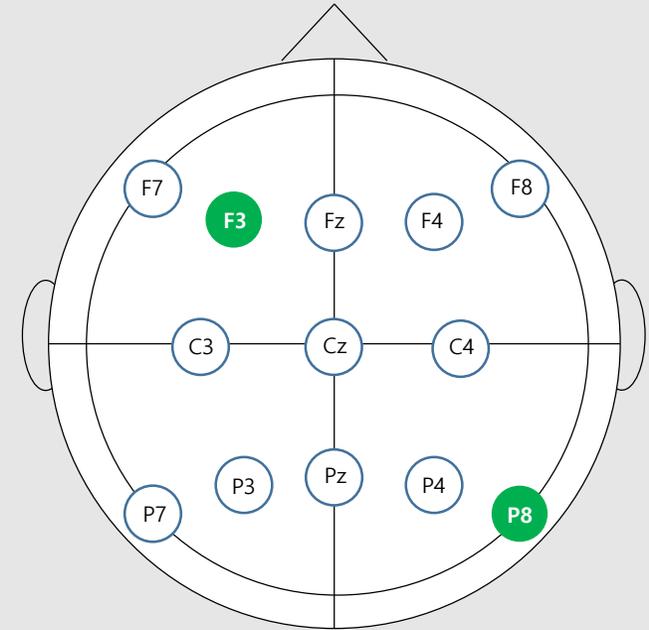
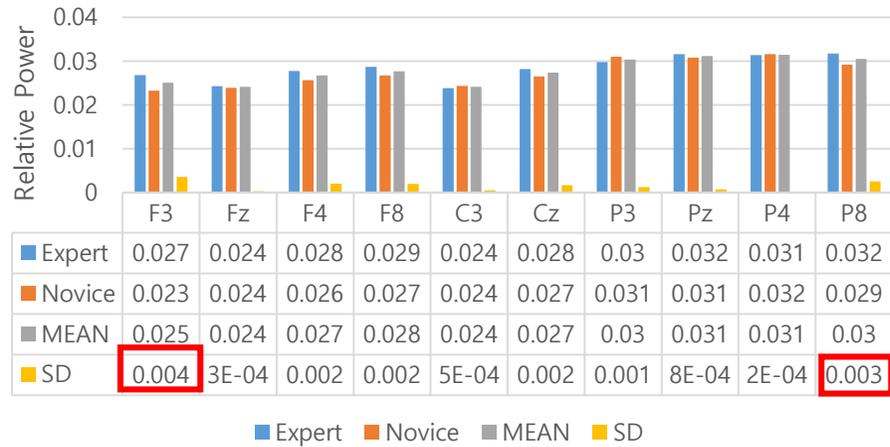
Band		F7	F3	Fz	F4	F8	C3	Cz	C4	P7	P3	Pz	P4	P8
Theta	Low frequency	0.046 *	0.352	2.40E-07 ***	0.134	0.008 **	2.31E-05 ***	0.342	8.73E-06 ***	0.0013 **	1.72E-06 ***	0.753	4.01E-06 ***	0.550
Alpha		0.206	0.087	6.61E-08 ***	0.459	0.004 **	4.57E-05 ***	0.449	0.010 *	1.99E-05 ***	1.10E-10 ***	0.176	1.02E-05 ***	0.480
Beta	High frequency	0.760	3.92E-10 ***	0.518	9.81E-06 ***	0.0005 **	0.264	3.71E-06 ***	0.543	0.354	0.0006 **	0.024 *	0.545	1.09E-06 ***
Gamma		0.145	0.154E-05 ***	3.65E-07 ***	0.086	0.132	0.003 **	0.0007 **	0.772	0.060	4.14E-06 ***	0.008 **	0.004 **	0.001 **

- ANOVA
- P-value < .05
- 두 집단간 통계적으로 유의미한 차이가 있다는 것을 확인하기 위하여 수행

Experimental Results

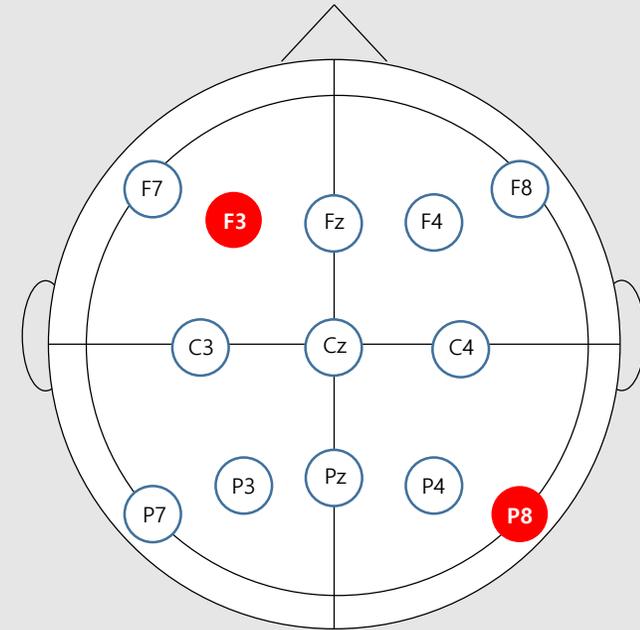
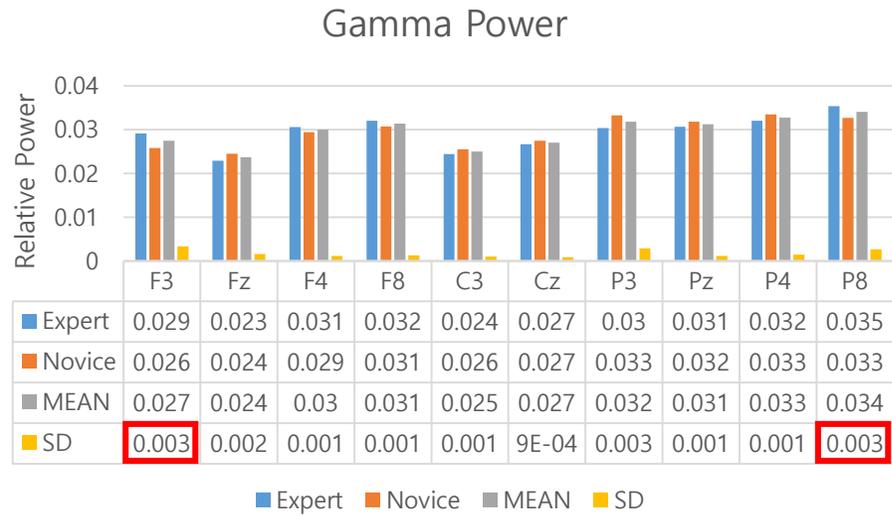
EEG POWER

Beta Power

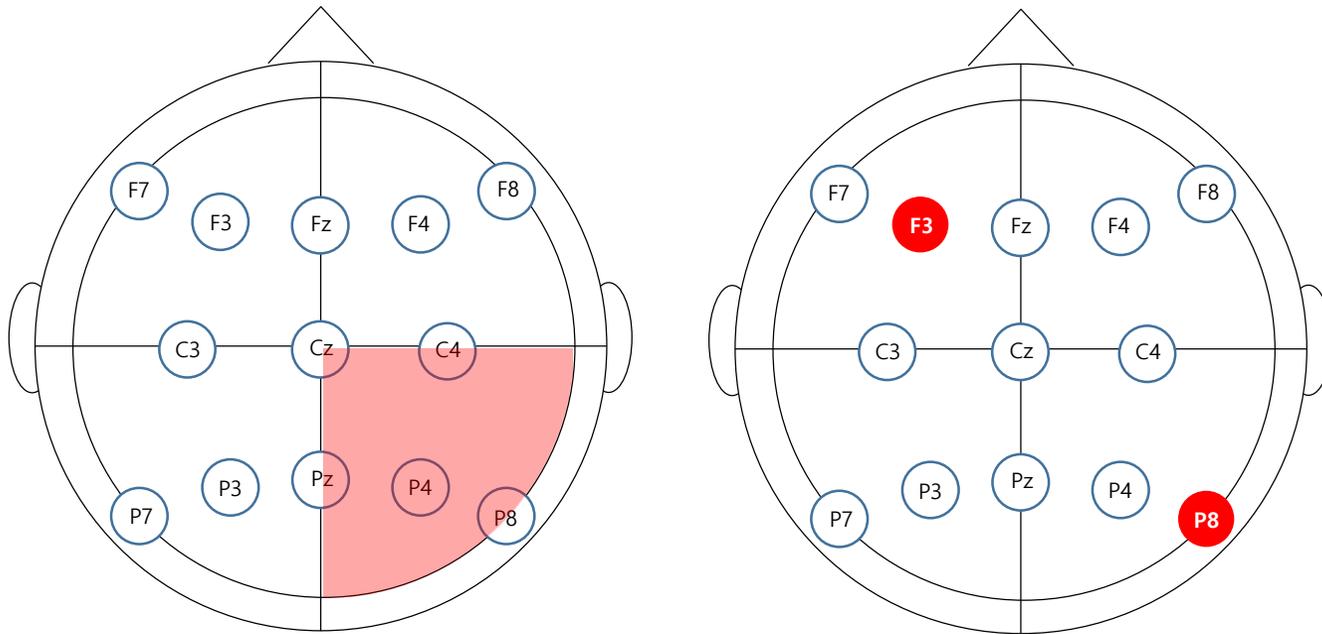


Experimental Results

EEG POWER

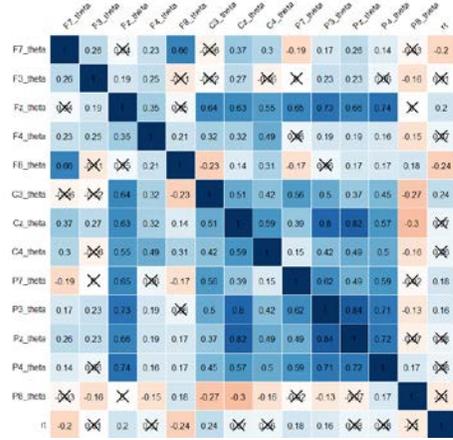


Experimental Results



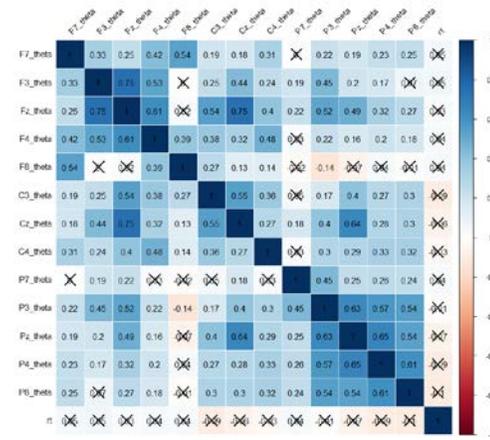
- 프로그램을 이해하는 것은 우반구 후두엽에서 베타파와 감마파가 많이 활성화됨
 - 기억하기 쉽도록 정보를 부호화
 - 프로그램을 보는 시각 정보에 영향을 받음
- F3와, P8에서 베타파와 감마파에 차이가 있고 능숙자 그룹이 더 높았음
 - **F3** is relate short term-memory(**memorizing number words**) in Gamma frequency (Schack et al. 2002)
 - Memorization of numbers and characters in program code
 - **P8** is relate language processing and reading, visual processing
 - Also, relate to **long term-memory recall** (Fries et al. 2013)
 - Retrieval java function
 - (e.g.. indexOf(), length(), charAt())

능숙자



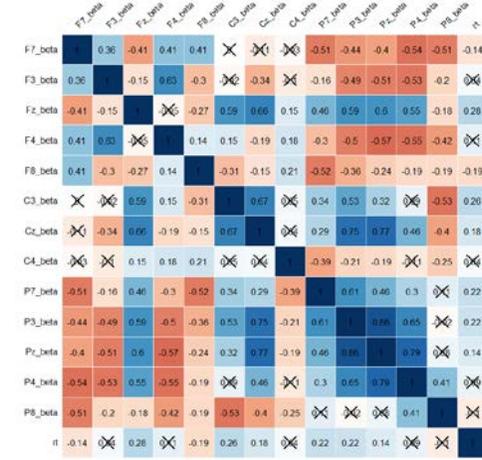
theta

비능숙자



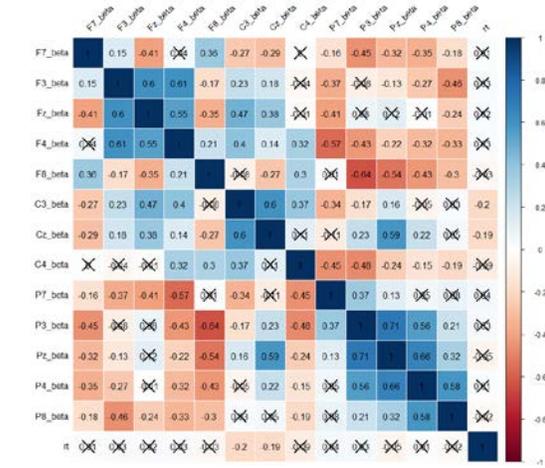
beta

능숙자

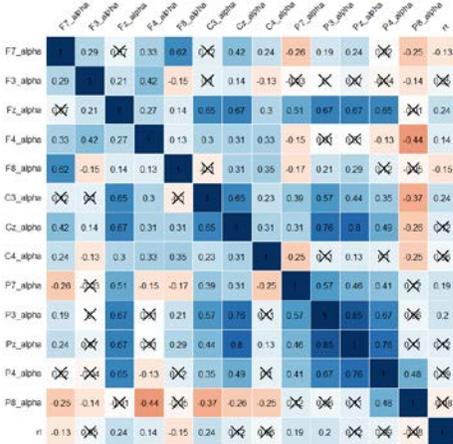


gamma

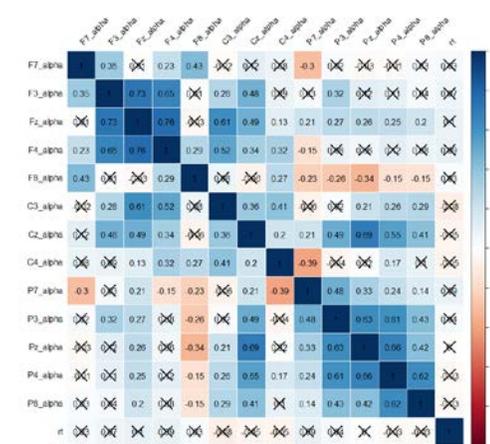
비능숙자



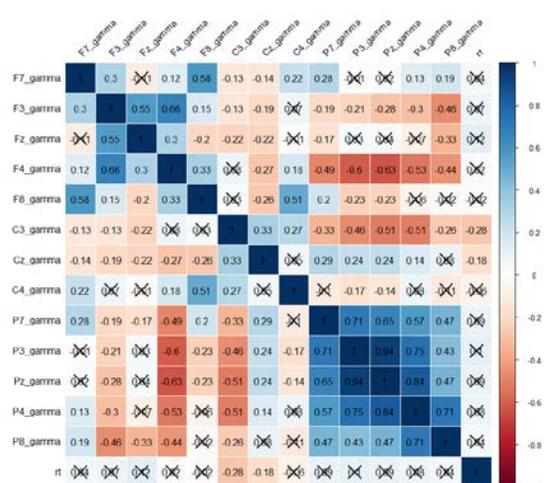
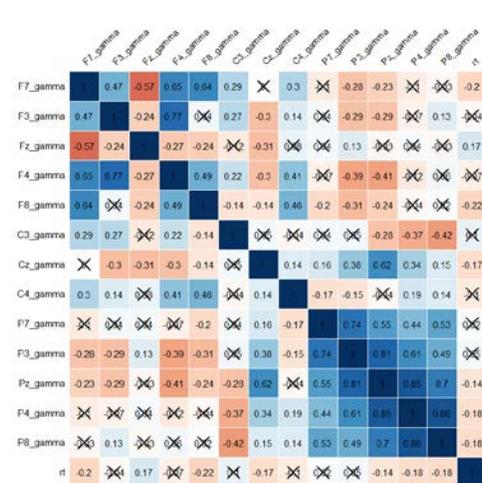
alpha



저주파



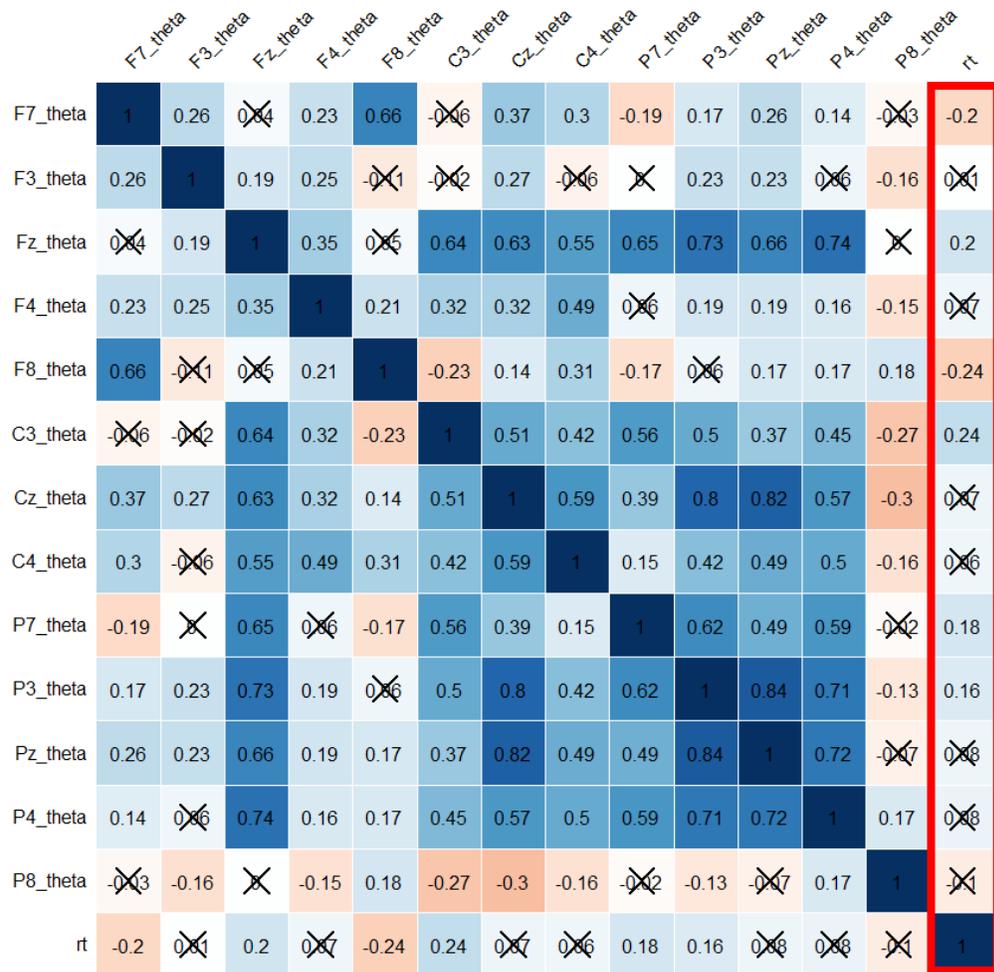
고주파



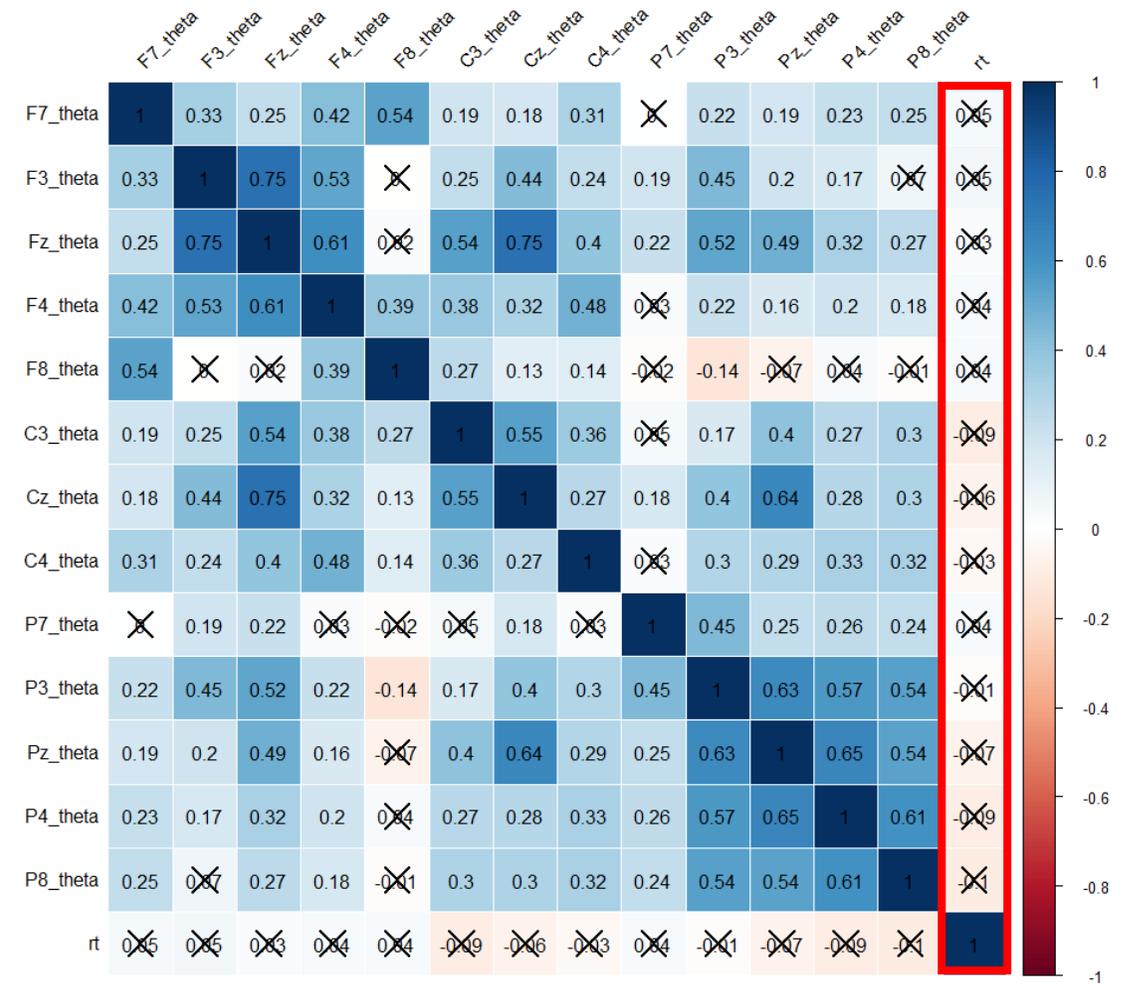
Experimental Results

CORRELATION(PEARSON) BETWEEN PERFORMANCE AND EEG Power

능숙자



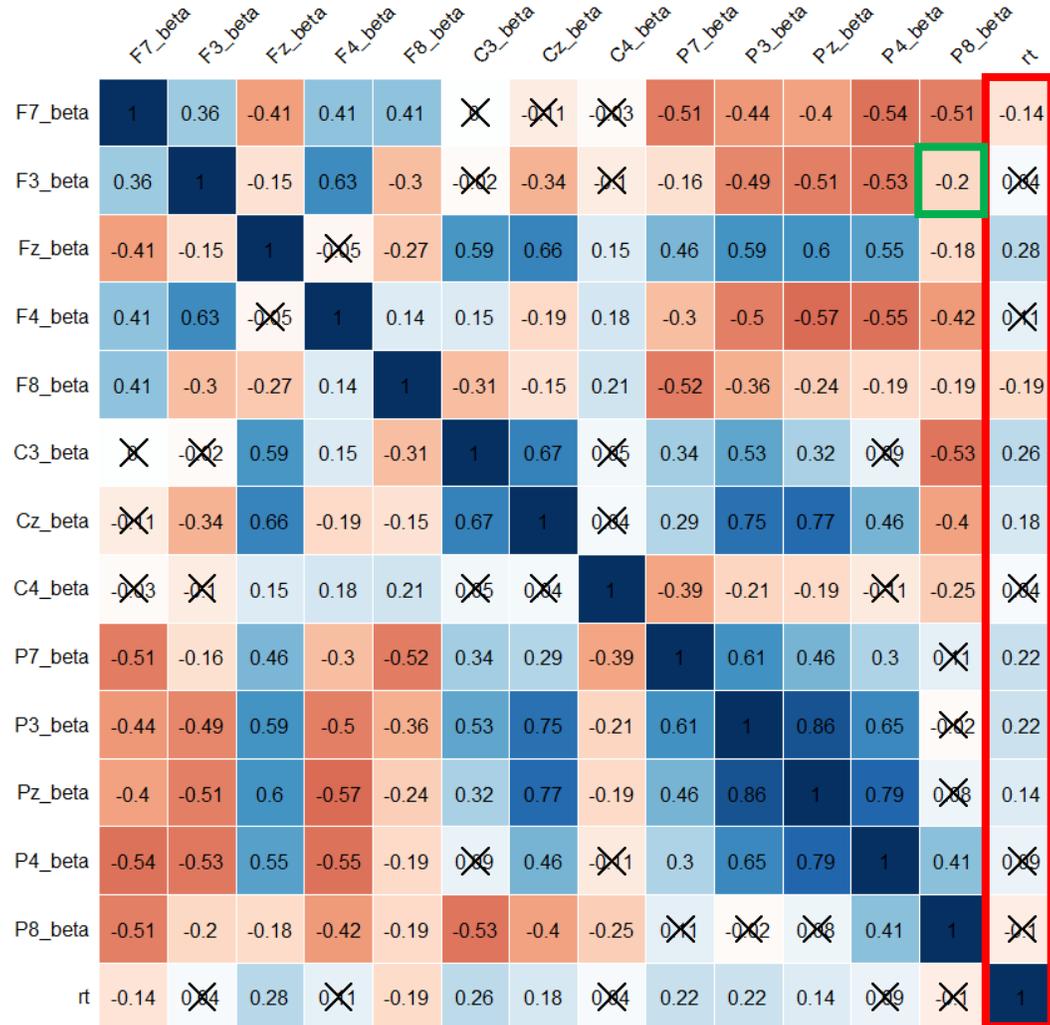
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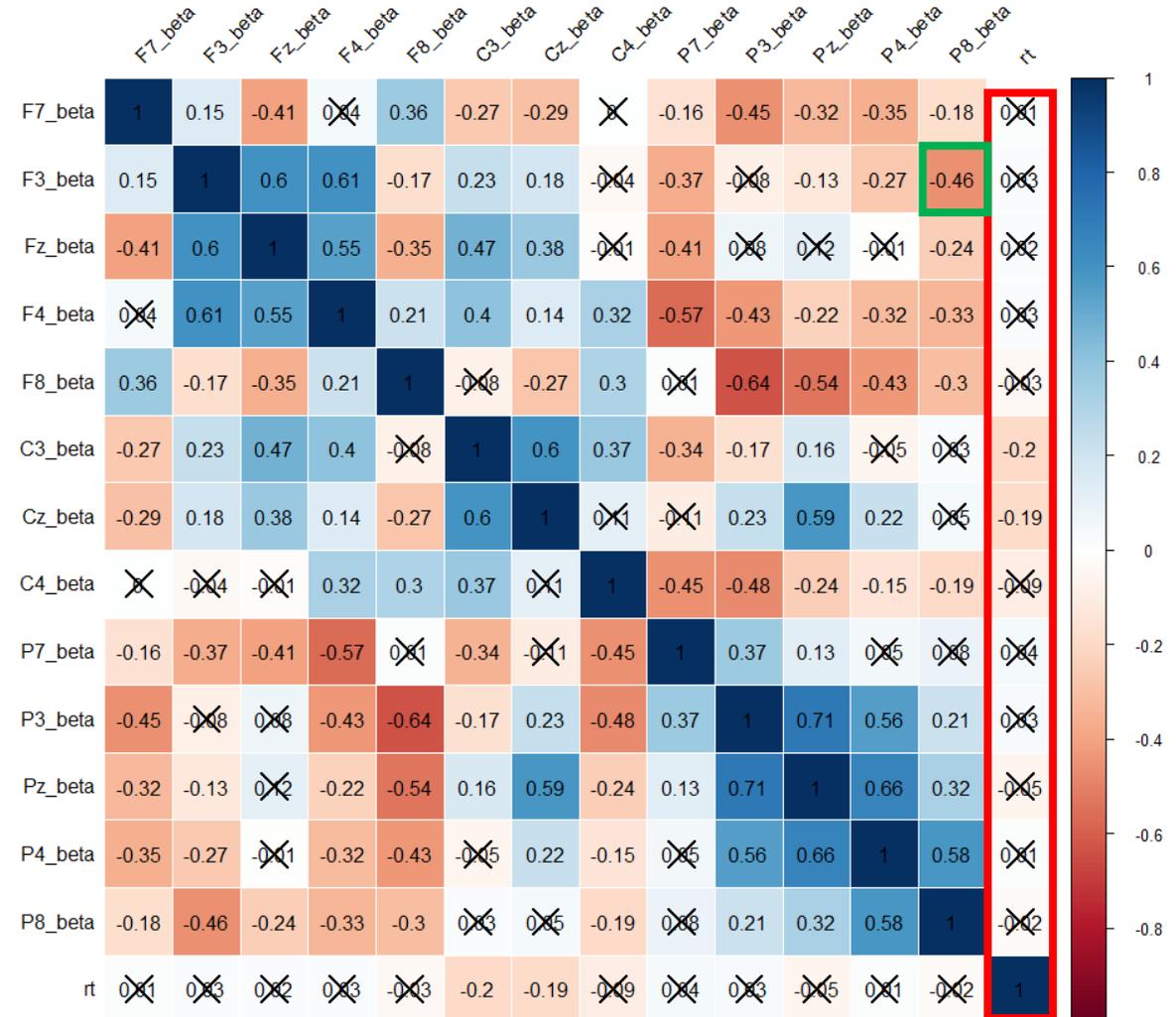
Experimental Results

CORRELATION BETWEEN PERFORMANCE AND EEG Power

능숙자



비능숙자



Experimental Results

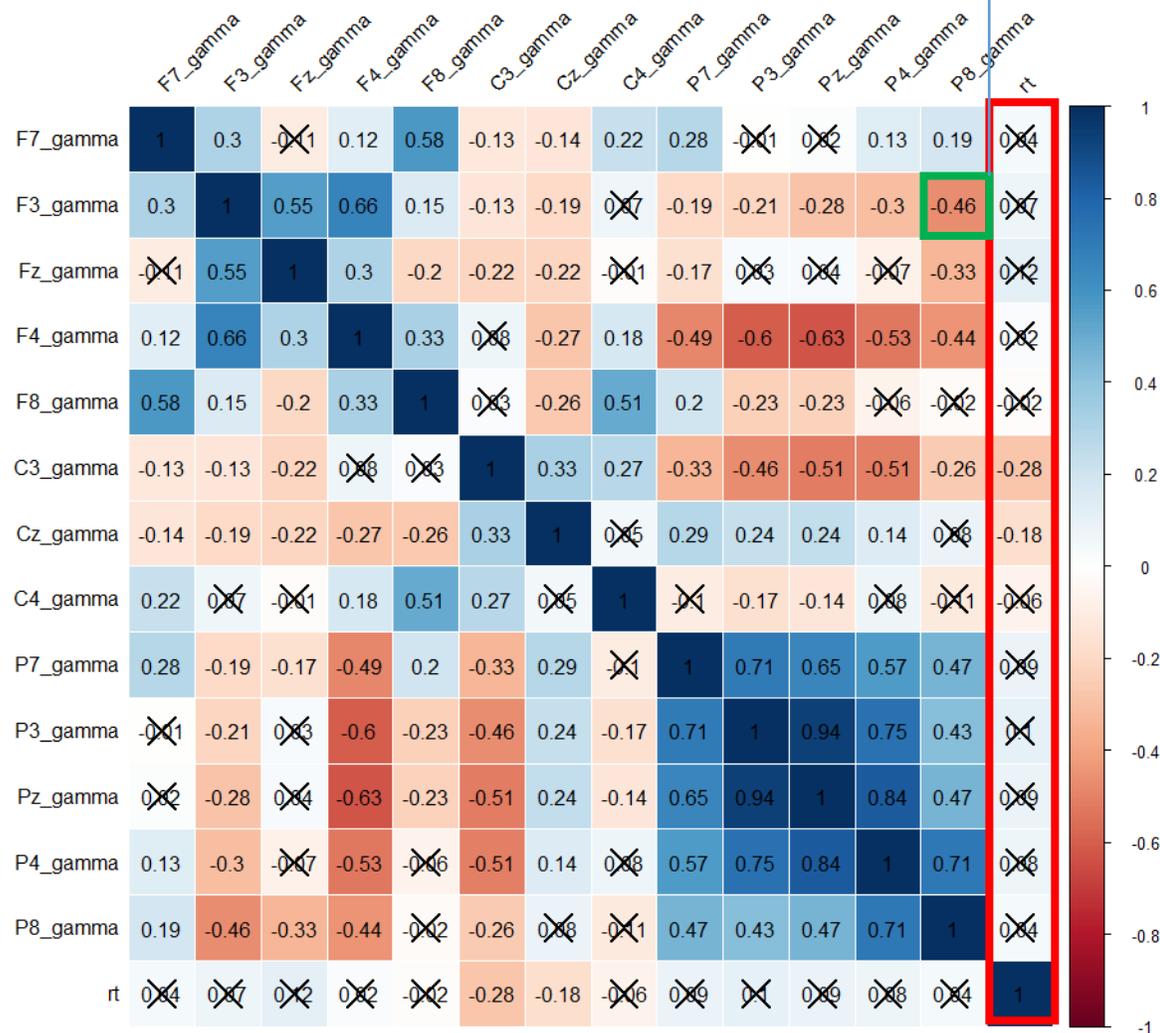
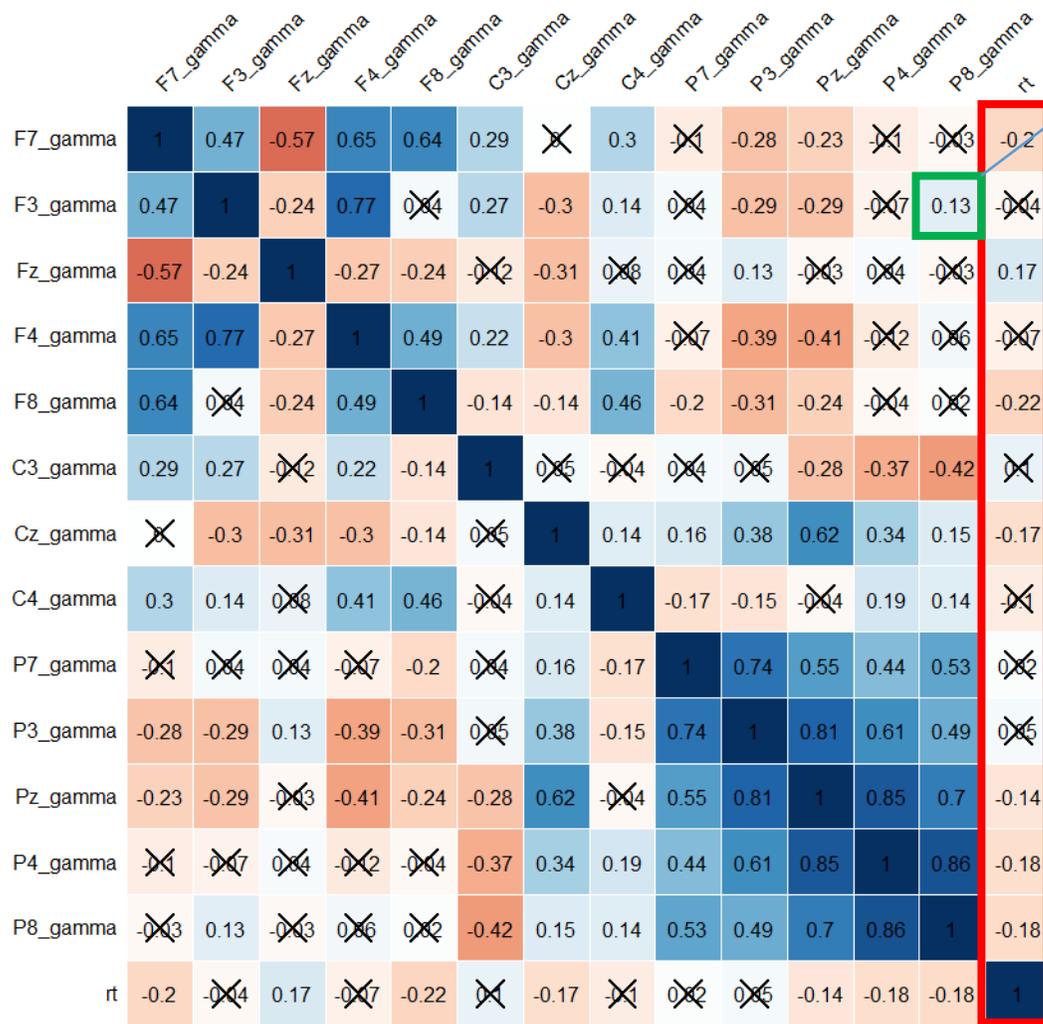
CORRELATION BETWEEN PERFORMANCE AND EEG Power

동기화

비동기화

능숙자

비능숙자



Future work

- SVM classifier
- Cognitive measurement data
- Eye tracker