# In the name of God

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# Preprocessing

- **Depressed subject 594 :**
  1. Re-reference the data (in comparison with M1 & M2)
  2. Removed Channels: CB1 CB2 HEOG VEOG EKG as they don't contain useful data
  3. High-pass Filtered the data
  4. Removed EKG channel
  5. Failed to innterpolate
  6. Referenced from average
  7. Performing ASR to remove artifacts
  8. ICA decomposition

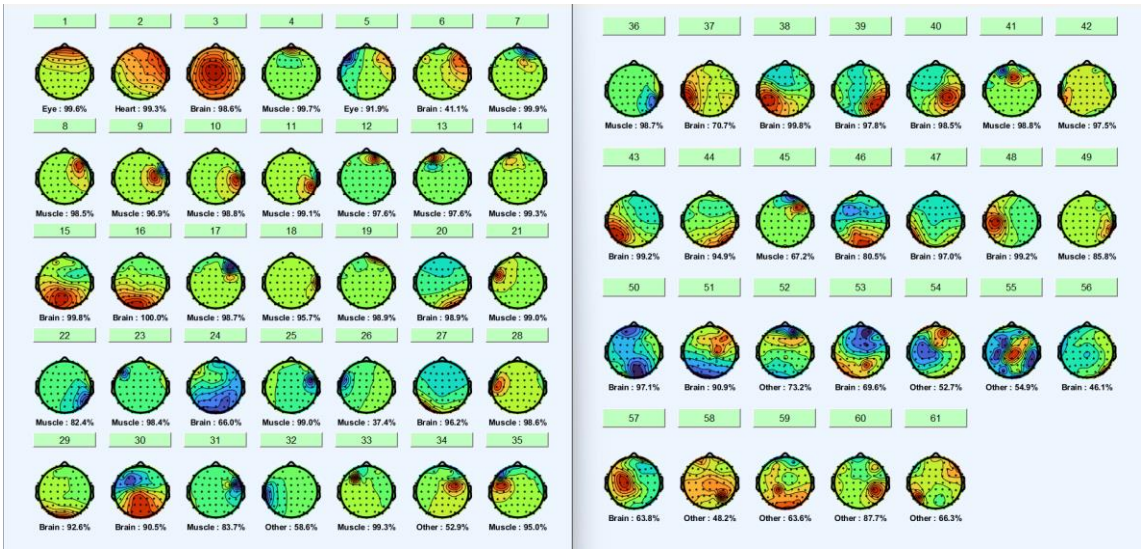


*Figure 1 classifing components using ICLable*

- Removed channels: 1, 2, 4, 5, 7, 8, 9, 10, 11, 12, 13, 14, 17, 18, 19, 21, 22, 23, 25, 28. Because they were muscle or eye signals and the formation of their Fourier transform was not alike brain signals.

  9. Normalization and rejecting noisy sections
  10. Epoching signals for stimulus and reward and punishment.

# 1. پتانسیل وابسته به رخداد ERP

پتانسیل وابسته به رخداد ERP یا Event-Related Potential به تغییرات الکتریکی مختص زمان و ناشی از یک رخداد خاص (مانند یک تحریک بصری، شنیداری یا حسی) در سیگنال‌های EEG اشاره دارد .ERPها نشان‌دهنده واکنش مغز به این تحریکات هستند

**محاسبهERP ها**

ERPها معمولاً با استفاده از سیگنال‌های EEG خام و طی چند مرحله محاسبه می‌شوند:

1. **ثبت سیگنال** :**EEG** ابتدا سیگنال EEG در طی زمان و در چندین نقطه (الکترودها) از روی سر فرد ثبت می‌شود. این ثبت‌ها به هنگام تحریکات مختلف انجام می‌گیرند.
2. **تقسیم به بازه‌های زمانی** :سیگنال EEG به بخش‌های زمانی یا "اپوک‌ها" تقسیم می‌شود که هرکدام شامل زمان قبل و بعد از رخداد تحریک است. این بازه‌ها معمولاً کوتاه (چند صد میلی‌ثانیه) و وابسته به زمان رخداد هستند.
3. **میانگین‌گیری اپوک‌ها**ERP ها با میانگین‌گیری از سیگنال‌های EEG در اپوک‌های مختلف (وابسته به رخدادهای مشابه) استخراج می‌شوند. این کار به کاهش نویز و برجسته‌سازی پاسخ‌های مرتبط با رخداد کمک می‌کند، چرا که سیگنال‌های غیرمرتبط با رخداد میانگین شده و محو می‌شوند، اما سیگنال‌های مرتبط با رخداد تقویت می‌شوند.
4. **فیلترگذاری** :معمولاً از فیلترهای فرکانسی خاصی برای حذف نویزها و بهبود سیگنال ERP استفاده می‌شود.

**کاربردهای ERP در سیگنال‌هایEEG**

ERPها به چند دلیل در مطالعات EEG مورد استفاده قرار می‌گیرند:

- ERPها کمک می‌کنند تا فرآیندهای شناختی مانند توجه، ادراک، حافظه و تصمیم‌گیری بررسی شوند. تغییرات خاصی در این پتانسیل‌ها به عنوان نشانگرهای فرآیندهای خاص مغزی شناخته می‌شوند.
- ERPها اطلاعات دقیق زمانی در مورد فعالیت عصبی نواحی مختلف مغز ارائه می‌دهند و به محققان کمک می‌کنند تا ساختارهای درگیر در پردازش‌های مختلف را شناسایی کنند.

- ERPها در تشخیص و بررسی اختلالات عصبی مانند افسردگی، اسکیزوفرنی و اوتیسم کاربرد دارند. تغییرات خاص درERP های بیماران می‌تواند به شناخت بهتر از این اختلالات کمک کند و همچنین امکان تشخیص زودهنگام را فراهم می‌کند.

ERPها به دلیل دارا بودن تفکیک زمانی بالا، به محققان امکان می‌دهند تا دقیقاً به زمان پاسخ‌های مغزی پی ببرند. این ویژگیERP ها را به ابزاری قدرتمند برای بررسی و تحلیل پاسخ‌های عصبی مغز در برابر تحریکات مختلف تبدیل کرده است، زیرا تغییرات میلی‌ثانیه‌ای در واکنش‌های مغز را به خوبی نمایش می‌دهند.

## 2. P300 & FRN

**P300**

مولفه **P300**یا **P3**به نوعی پتانسیل مثبت در حدود 300 میلی‌ثانیه بعد از رخداد یک محرک توجه‌برانگیز در سیگنال EEG اشاره دارد. این مولفه از مهم‌ترین مولفه‌های ERP است و معمولاً زمانی که فرد به محرک‌های نادر و مهم توجه می‌کند، ظاهر می‌شود P300 .معمولاً در آزمایش‌هایی مانند **آزمایش Oddball**مشاهده می‌شود؛ در این آزمایش به فرد دو نوع محرک نشان داده می‌شود، که یکی رایج و دیگری نادر است، و P300 پس از محرک نادر و توجه‌برانگیز ظاهر می‌شود.

این مولفه در نواحی خلفی و مرکزی مغز با فعالیت بالا مشاهده می‌شود و از طریق اندازه و تأخیر زمانی آن می‌توان به بررسی توجه و پردازش شناختی افراد پرداخت. تغییرات در P300 می‌تواند به عنوان نشانگری از برخی اختلالات شناختی و عصبی مانند آلزایمر و اختلالات نقص توجه مورد استفاده قرار گیرد.

**FRN**

مولفه **FRN**یا **Feedback-Related Negativity**یک پتانسیل منفی است که در حدود 200 تا 300 میلی‌ثانیه پس از دریافت بازخورد منفی ظاهر می‌شود. این مولفه نشان‌دهنده واکنش مغز به بازخوردهای غیرمنتظره یا نامطلوب است و در واقع، نمایانگر سیگنال‌های مرتبط با ارزیابی عملکرد و یادگیری مبتنی بر بازخورد است.

FRNبه عنوان یک شاخص از ارزیابی عملکرد و یادگیری از طریق بازخورد شناخته می‌شود. زمانی که فرد نتیجه‌ای نامطلوب یا خلاف انتظار دریافت می‌کند، FRNظاهر می‌شود و نشان می‌دهد که مغز این نتیجه را به عنوان یک سیگنال خطا یا نیاز به اصلاح تفسیر می‌کند.

## 3. لود کردن داده ها در پایتون

لود کردن داده ها برای مثال داده ۵۹۸ در پایتون:

- نصب mne و خواندن داده ها از گوگل درایو.

```
# Install MNE if not already installed
!pip install mne

# Import necessary libraries
import mne
```

Show hidden output

```
# data depressed 598
eeglab_file_path = '/content/drive/MyDrive/Neuroscience/CHW1/Preprocessed_data/598/598_preprocessed.set'
depData_598_preprocessed = mne.io.read_raw_eeglab(eeglab_file_path, preload=True)
print(depData_598_preprocessed.info)


depData_598_epochs_positive_fb = mne.io.read_epochs_eeglab('/content/drive/MyDrive/Neuroscience/CHW1/Preprocessed_data/598/598_preprocessed_rewardEpochs.set')
depData_598_positive_fb_data = depData_598_epochs_positive_fb.get_data()

depData_598_epochs_negative_fb = mne.io.read_epochs_eeglab('/content/drive/MyDrive/Neuroscience/CHW1/Preprocessed_data/598/598_preprocessed_punishmentEpochs.set')
depData_598_negative_fb_data = depData_598_epochs_negative_fb.get_data()

depData_598_epochs_stimulus = mne.io.read_epochs_eeglab('/content/drive/MyDrive/Neuroscience/CHW1/Preprocessed_data/598/598_preprocessed_stimulusEpochs.set')
depData_598_stimulus_data = depData_598_epochs_stimulus.get_data()
```

*Figure 2 loading dataset 598*

## 4. حذف کردن کانال های خواسته شده

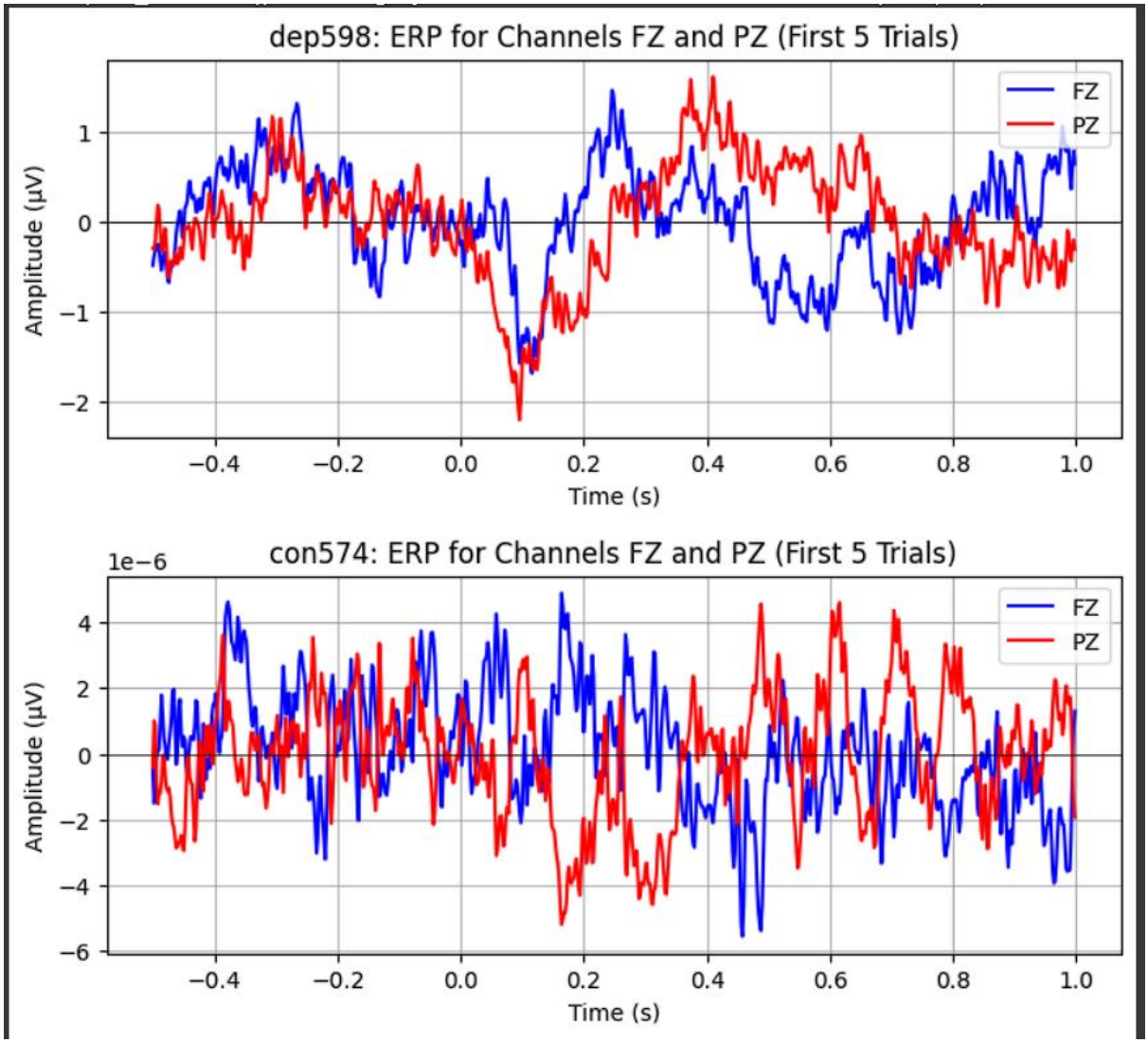
```
# Define the channels to keep
red_channels = ['FPZ', 'F7', 'F3', 'FZ', 'F4', 'F8', 'T7', 'C3', 'CZ', 'C4', 'T8', 'P7', 'P3', 'PZ', 'P4', 'P8', 'OZ']

# Select these channels in the raw data
depData_598_preprocessed = depData_598_preprocessed.copy().pick_channels(red_channels)

# for epochs
depData_598_epochs_positive_fb = depData_598_epochs_positive_fb.copy().pick_channels(red_channels)
depData_598_epochs_negative_fb = depData_598_epochs_negative_fb.copy().pick_channels(red_channels)
depData_598_epochs_stimulus = depData_598_epochs_stimulus.copy().pick_channels(red_channels)
```

*Figure3 removing unwanted channels*

## 5. نرمالیزه کردن با محاسبه z-score

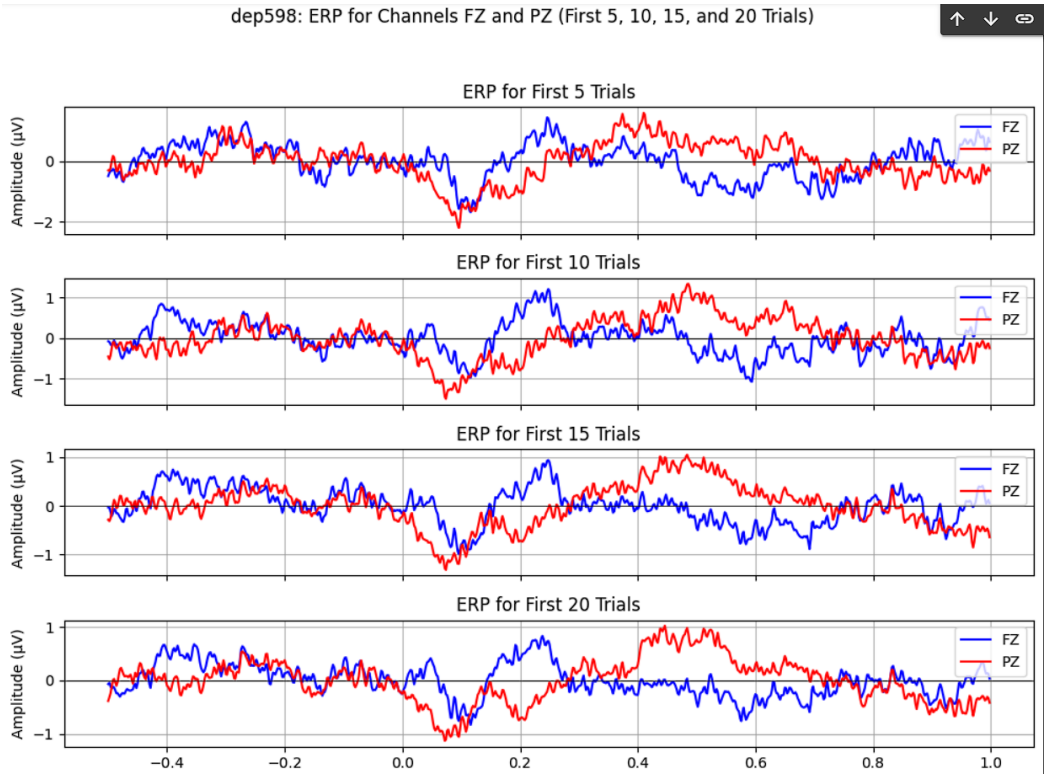
```
from scipy.stats import zscore
# Define a function that normalizes each epoch using z-score
def zscore_normalize(data):
    # Apply z-score normalization across epochs (axis 0 is epochs, axis 2 is time points)
    return zscore(data, axis=0)

# Apply z-score normalization to the selected channels in each epochs object
# dataset dep 598
depData_598_epochs_positive_fb.apply_function(zscore_normalize)
depData_598_epochs_negative_fb.apply_function(zscore_normalize)
depData_598_epochs_stimulus.apply_function(zscore_normalize)
# dataset dep 594
depData_594_epochs_positive_fb.apply_function(zscore_normalize)
depData_594_epochs_negative_fb.apply_function(zscore_normalize)
depData_594_epochs_stimulus.apply_function(zscore_normalize)
# dataset dep 571
depData_571_epochs_positive_fb.apply_function(zscore_normalize)
depData_571_epochs_negative_fb.apply_function(zscore_normalize)
depData_571_epochs_stimulus.apply_function(zscore_normalize)
# dataset dep 566
depData_566_epochs_positive_fb.apply_function(zscore_normalize)
depData_566_epochs_negative_fb.apply_function(zscore_normalize)
depData_566_epochs_stimulus.apply_function(zscore_normalize)
# dataset dep 564
depData_564_epochs_positive_fb.apply_function(zscore_normalize)
depData_564_epochs_negative_fb.apply_function(zscore_normalize)
depData_564_epochs_stimulus.apply_function(zscore_normalize)
```

## 6. ERP یک نمونه سالم و یک نمونه افسرده برای ۵ ترایل اول

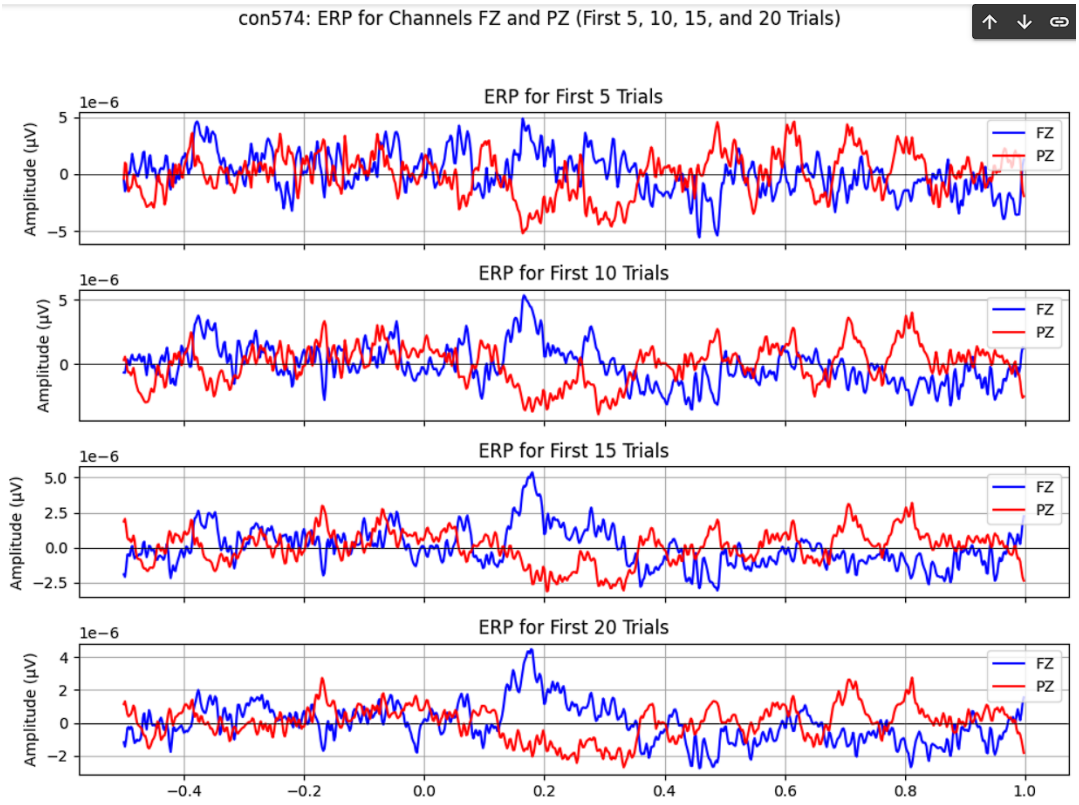


## 7. رسم و محاسبه ERP برای ترایل های بیشتر

برای سابجکت افسرده:

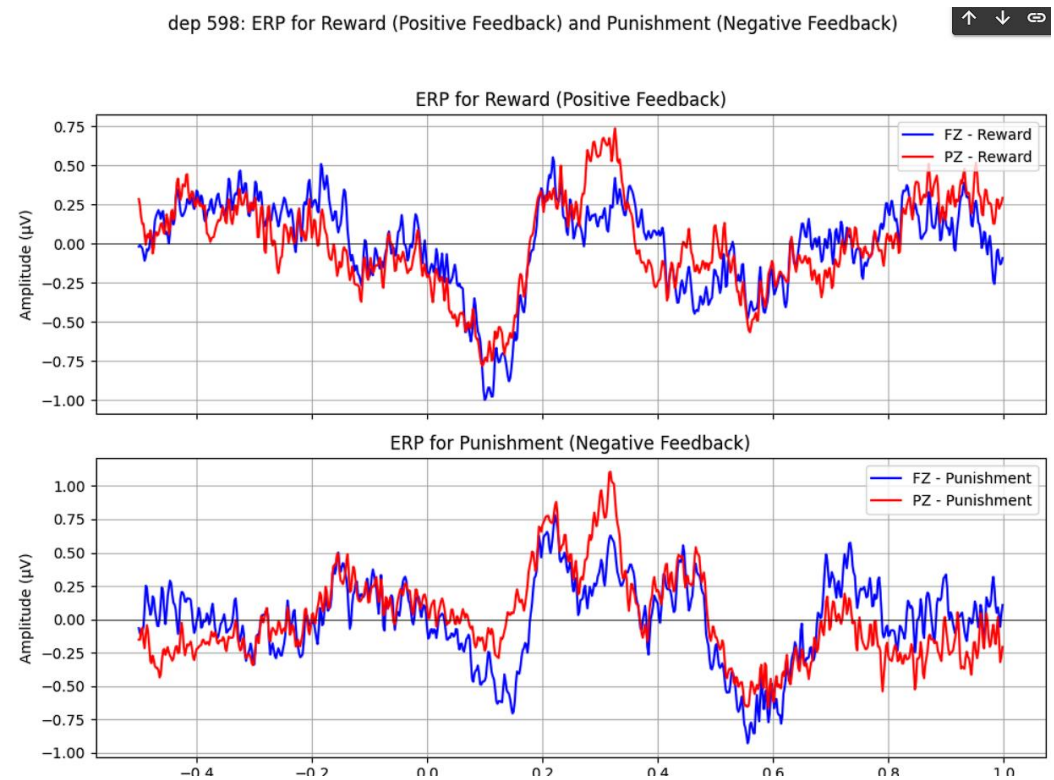


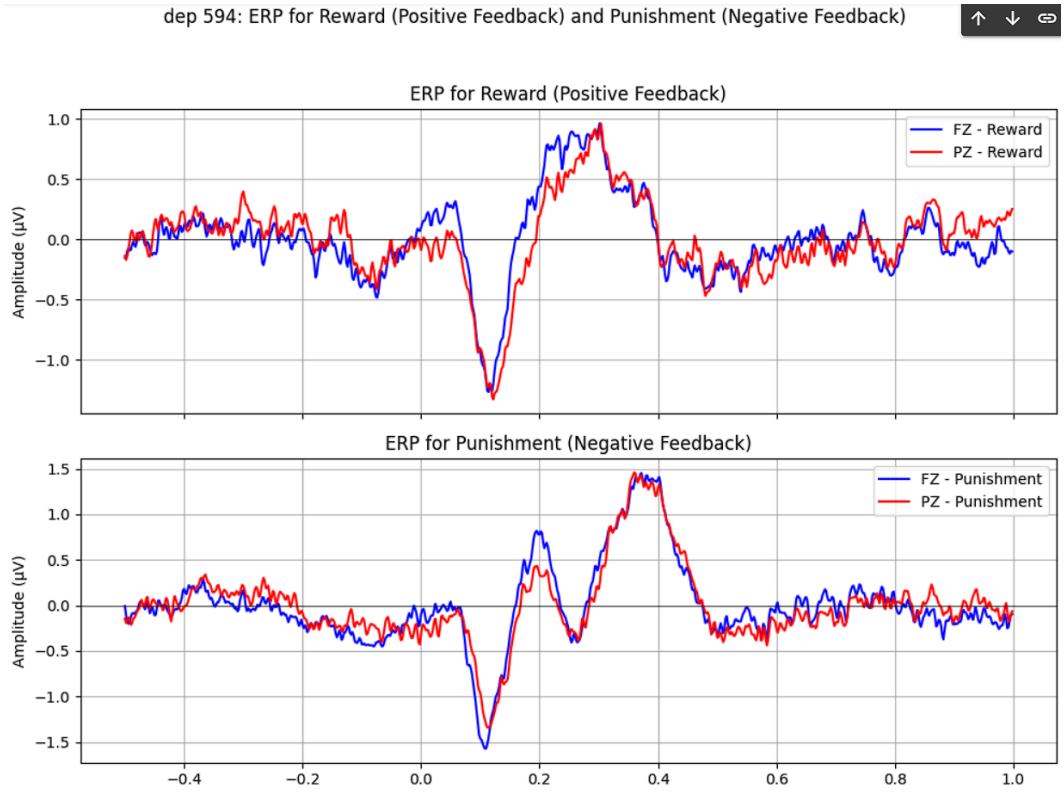

برای سابجکت سالم:



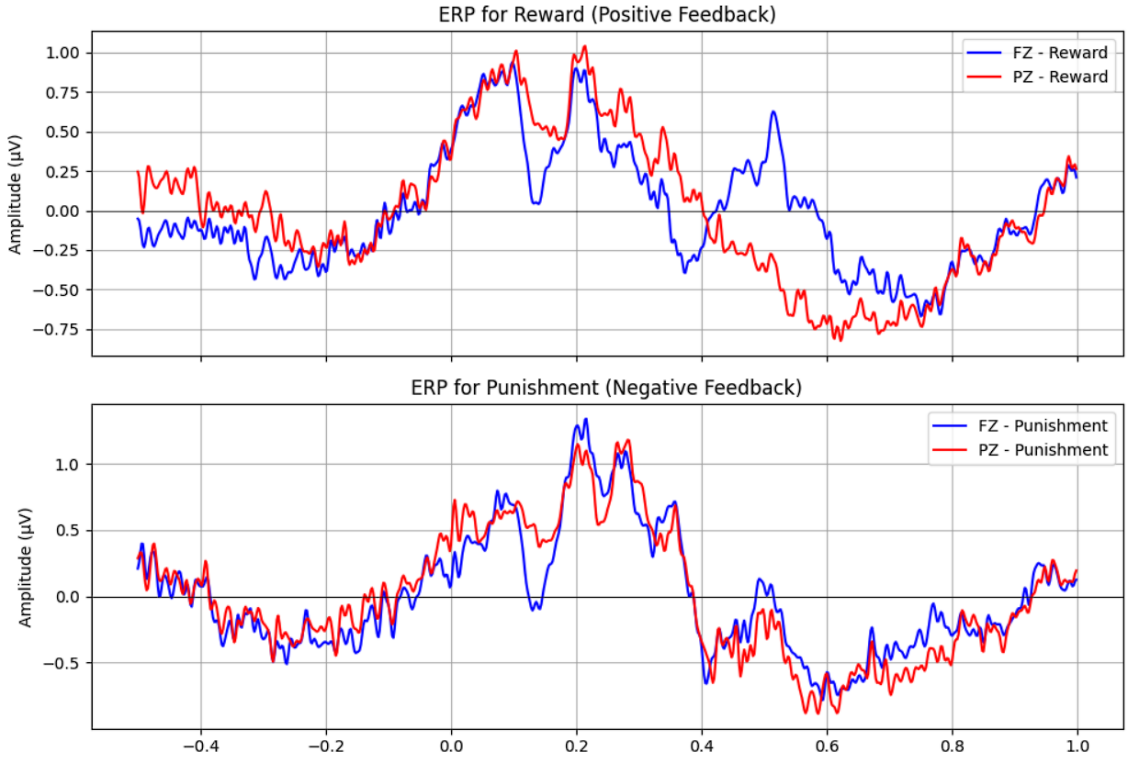
## 8. رسم ERP برای کانالهای FZ , PZ برای تمامی سابجکت ها

**برای سابجکت های افسرده:**

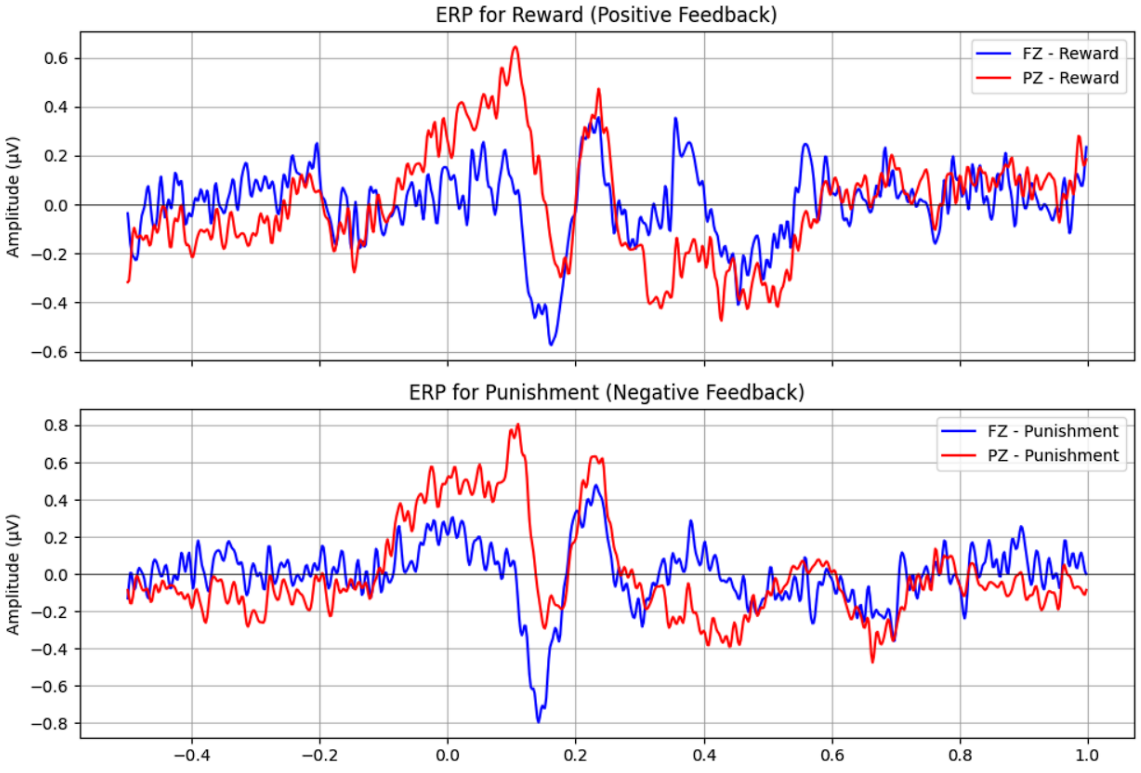


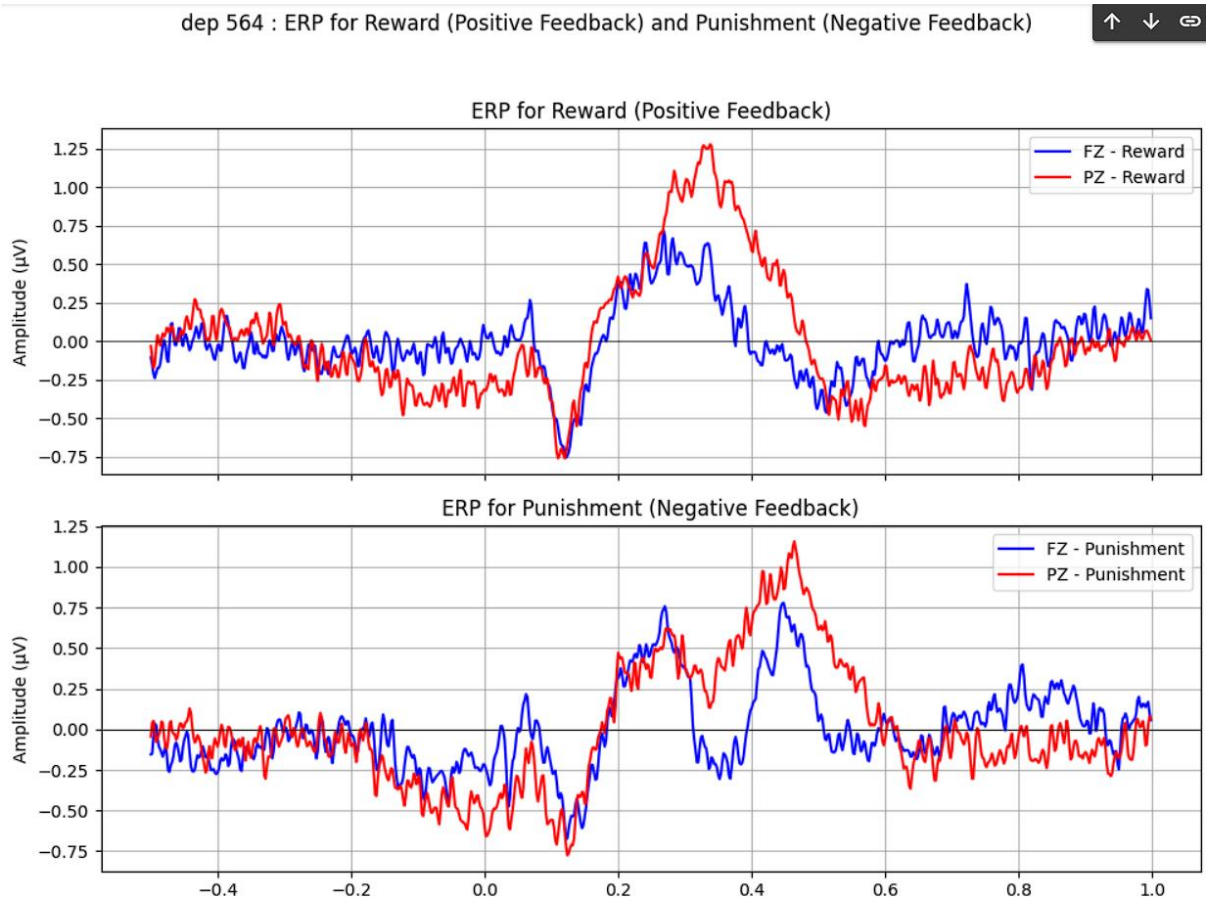



# dep 571: ERP for Reward (Positive Feedback) and Punishment (Negative Feedback)

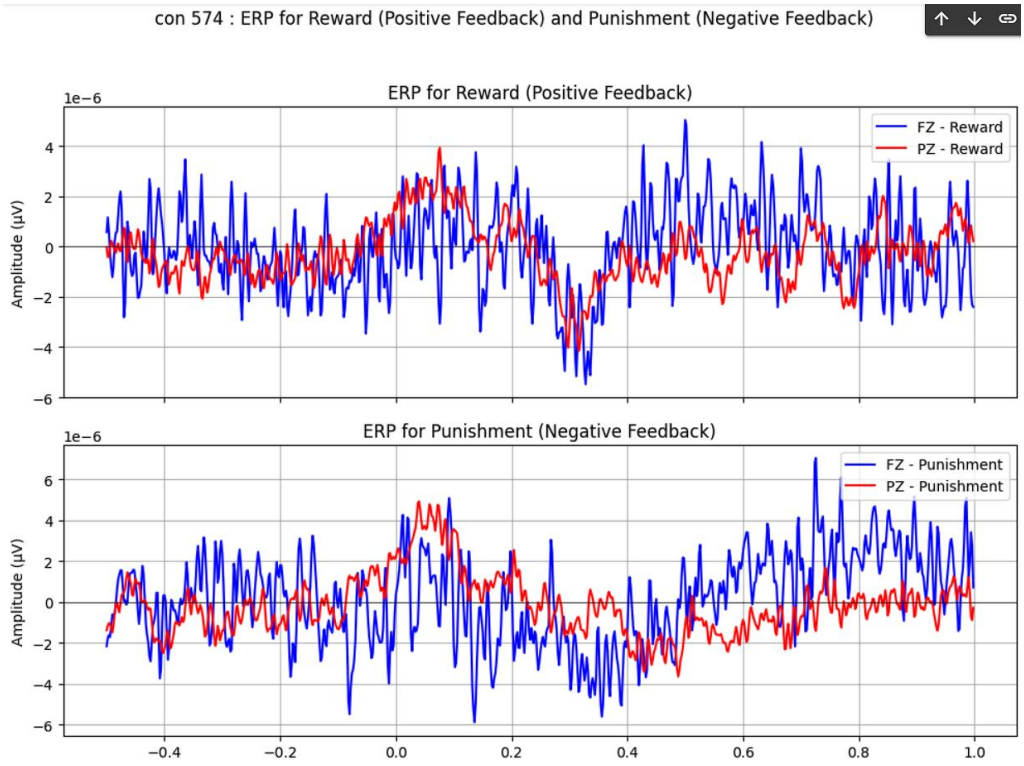


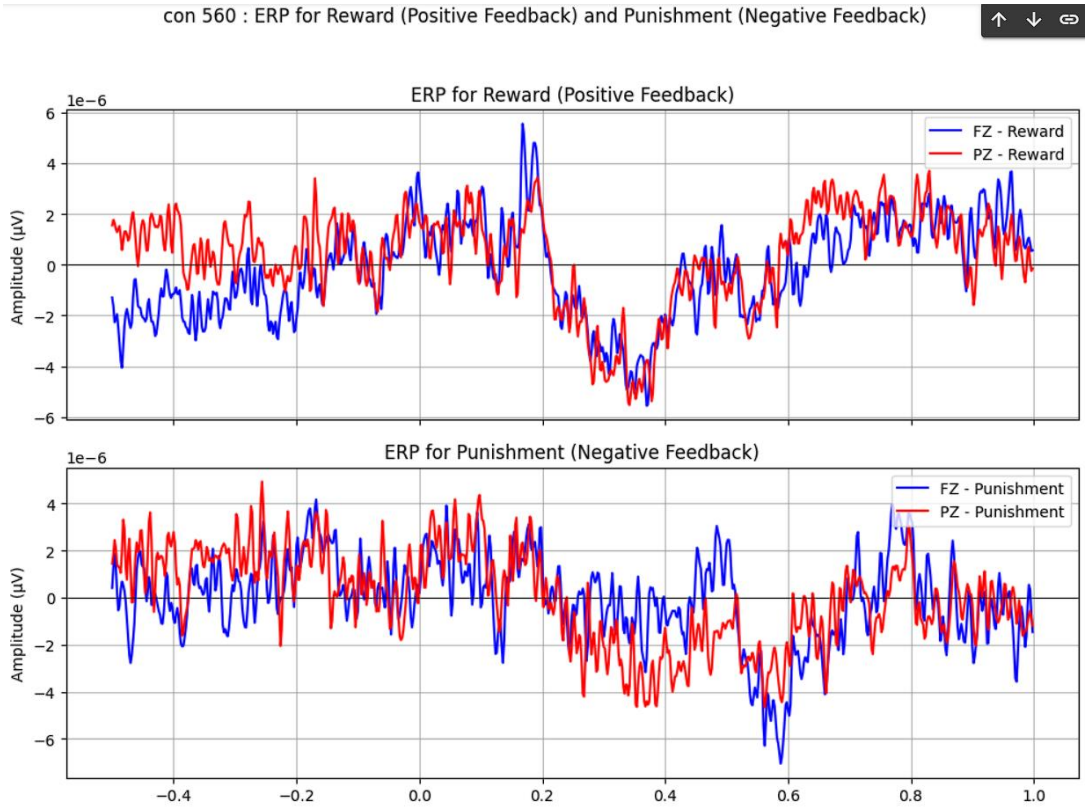

dep 566: ERP for Reward (Positive Feedback) and Punishment (Negative Feedback)

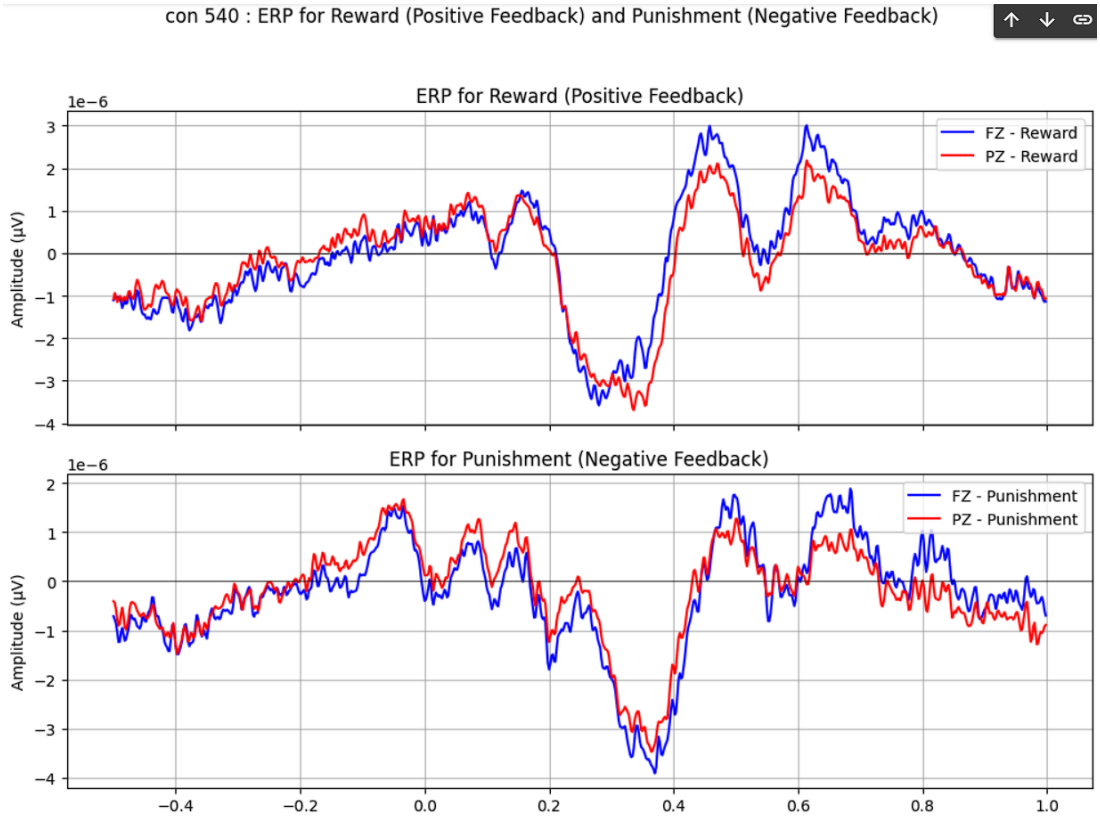




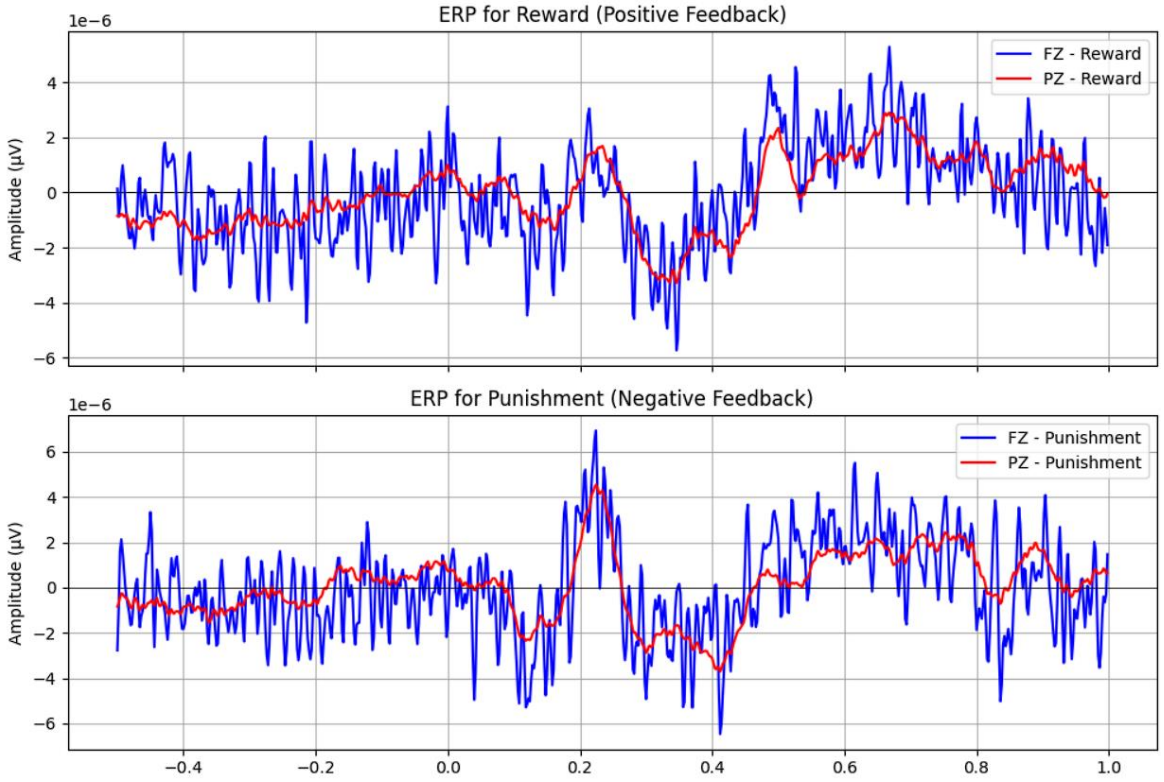

**برای سابجکت های سالم:**



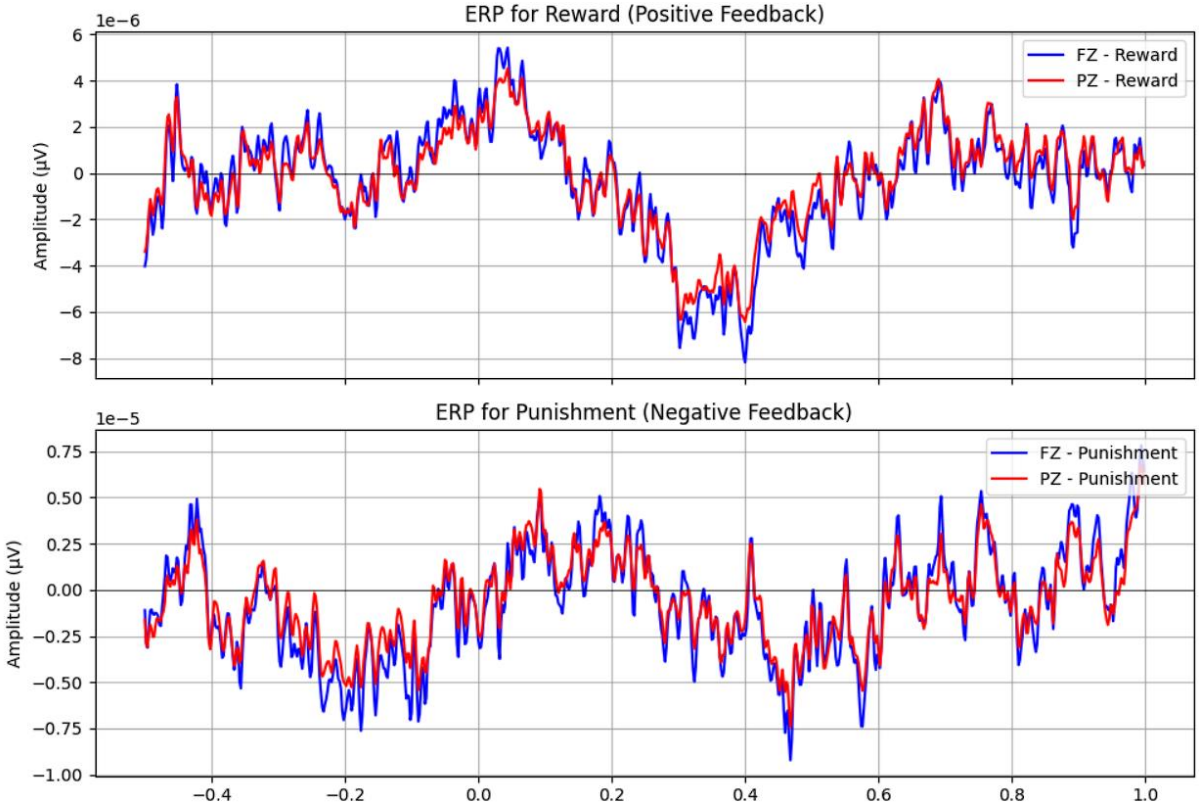

con 560 : ERP for Reward (Positive Feedback) and Punishment (Negative Feedback)
ERP for Reward (Positive Feedback)
1e−6
Amplitude (μV)
FZ - Reward
PZ - Reward
ERP for Punishment (Negative Feedback)
1e−6
Amplitude (μV)
FZ - Punishment
PZ - Punishment
−0.4
−0.2
0.0
0.2
0.4
0.6
0.8
1.0


con 540 : ERP for Reward (Positive Feedback) and Punishment (Negative Feedback)
ERP for Reward (Positive Feedback)
1e−6
Amplitude (μV)
FZ - Reward
PZ - Reward
ERP for Punishment (Negative Feedback)
1e−6
Amplitude (μV)
FZ - Punishment
PZ - Punishment
−0.4
−0.2
0.0
0.2
0.4
0.6
0.8
1.0

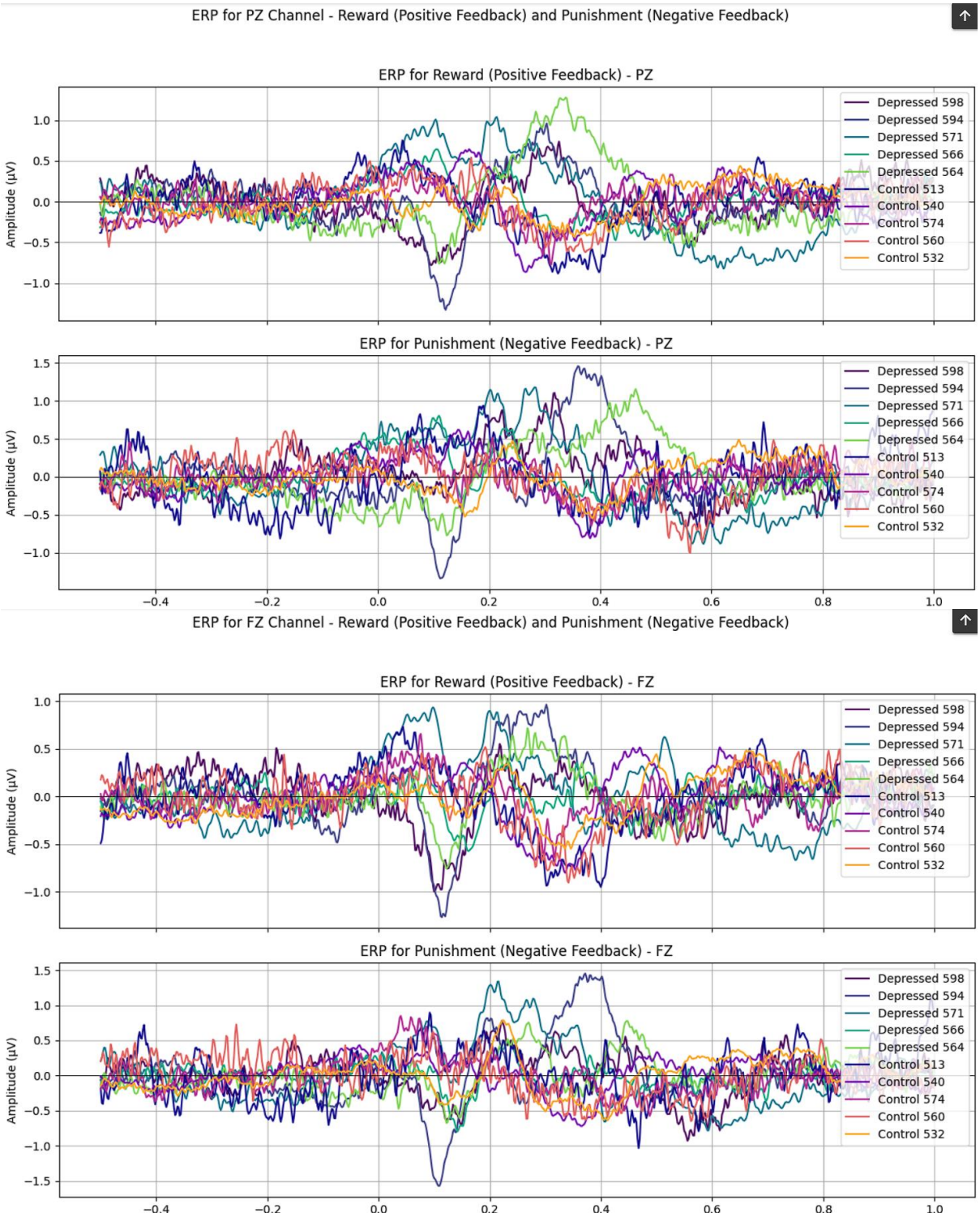
con 532 : ERP for Reward (Positive Feedback) and Punishment (Negative Feedback)




con 513 : ERP for Reward (Positive Feedback) and Punishment (Negative Feedback)



## 9. رسم سیگنال های ERP همه‌ی سابجکت ها روی یک نمودار



Based on the ERP plots for the FZ and PZ channels, we can make some observations that might help in drawing conclusions about the differences between depressed and control subjects in response to positive and negative feedback:

**1. Amplitude Variability:**

- Depressed subjects seem to show greater variability in ERP amplitude across the epochs, especially in response to negative feedback. This could reflect inconsistent neural responses to punishment, potentially linked to emotional or cognitive processing differences in depression.
- Control subjects tend to have a more stable, less variable amplitude pattern across time, suggesting a more consistent response to feedback.

**2. ERP Patterns and Peaks:**

- In the FZ channel (frontal area), which is often associated with attention and executive function, control subjects show a more defined pattern in response to positive feedback. Depressed subjects, however, show a more blunted or scattered response, indicating that they might process positive feedback differently, perhaps with less engagement or emotional response.
- In the PZ channel (parietal area), which is related to sensory processing and integration, there seems to be a more marked peak in response to negative feedback for control subjects than for depressed subjects. This might suggest that control individuals are more sensitive to punishment feedback, whereas depressed subjects show a flatter or more dispersed response, possibly reflecting reduced sensitivity or altered processing of negative stimuli.

**3. Latency Differences:**

- If there are shifts in peak latency between groups (e.g., a delay in the ERP peaks for depressed subjects), this might indicate slower processing or a delayed cognitive-emotional response in depression. A delayed response in the FZ or PZ channels for either feedback condition could reflect difficulties in quickly interpreting and reacting to feedback, a characteristic sometimes noted in depressive disorders.

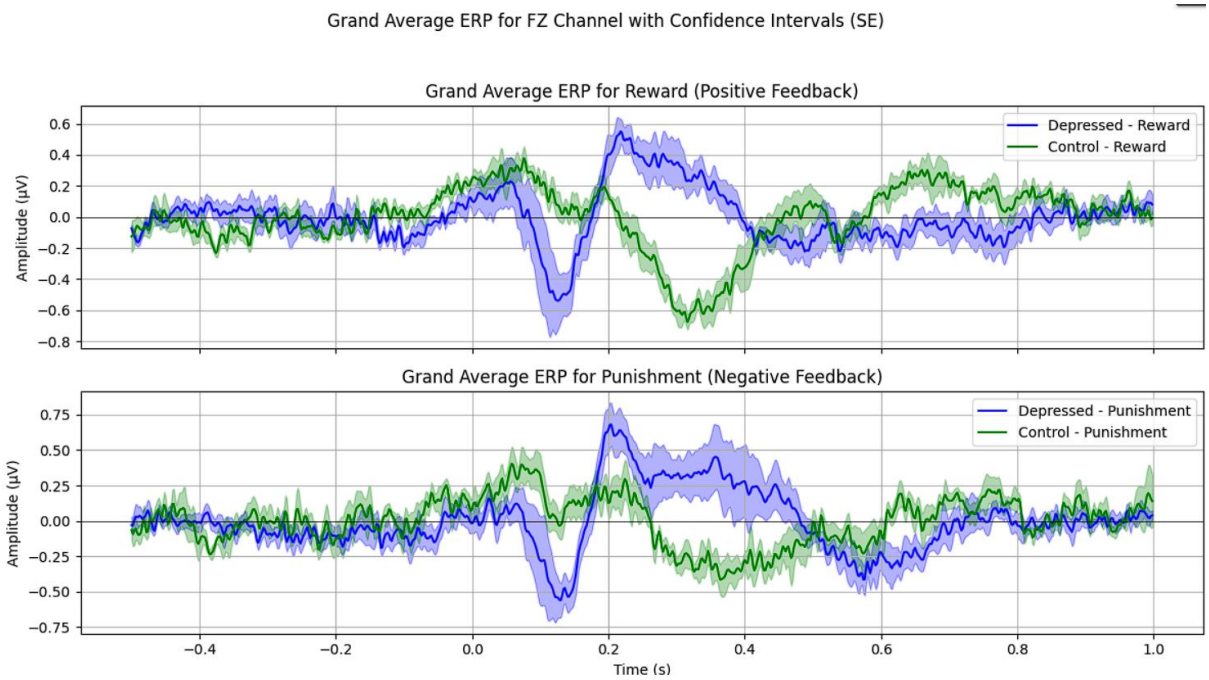
**4. Blunted Responses in Depressed Subjects:**

- A key feature in these plots could be the general reduction in ERP amplitude for the depressed group, especially in response to positive feedback. This blunted response might be consistent with the theory that individuals with depression have anhedonia, a reduced ability to experience pleasure or positive reinforcement, which can manifest as a weaker neural response to rewards.

**Potential Implications:**

- **Reward Sensitivity**: The reduced response to positive feedback in depressed individuals could indicate lower reward sensitivity, aligning with symptoms like anhedonia.
- **Punishment Processing**: A less distinct or inconsistent response to negative feedback might indicate altered punishment sensitivity, which can contribute to feelings of hopelessness or rumination in depression.
- **Cognitive Processing**: Differences in the FZ channel responses, especially in the control group, could suggest healthier cognitive control and emotional regulation, while depressed individuals may struggle with these processes.

## 10.رسم سیگنال ERP میانگین برای هر گروه از افراد سالم و افسرده




**Reward (Positive Feedback):**

1. **Amplitude Response**: Control subjects (green line) tend to exhibit a higher peak in response to positive feedback, especially around 0.2-0.5 seconds after the stimulus. This indicates a stronger neural response to reward, which might reflect a healthy sensitivity to positive reinforcement.
2. **Blunted Response in Depressed Subjects**: Depressed subjects (blue line) show a more blunted response to reward, with lower amplitude peaks across the same time frame. This reduced response may suggest anhedonia—a common symptom of depression where individuals have a diminished ability to experience pleasure or respond to positive stimuli.

3. **Consistency**: The standard error (shaded area) is relatively narrow for both groups, suggesting consistent responses among subjects in each group. However, the control group's response remains distinctively stronger, showing a clear difference in reward processing.

**Punishment (Negative Feedback):**

1. **Higher Amplitude in Depressed Subjects**: Interestingly, for punishment (negative feedback), depressed subjects show a relatively higher amplitude response, especially around 0.5 seconds post-stimulus. This could imply that depressed individuals have a heightened sensitivity to negative stimuli, which is consistent with findings that individuals with depression may focus more on negative experiences or feedback.
2. **Control Group's Reduced Response**: The control group shows a somewhat weaker response to punishment feedback, suggesting a more balanced or resilient reaction to negative feedback. This might reflect better emotional regulation or less tendency to dwell on negative stimuli.
3. **Variability**: The standard error in the punishment condition is slightly wider, especially for depressed subjects, which could indicate greater variability in how depressed individuals respond to negative feedback. This variability might reflect differences in symptom severity or individual differences in how punishment affects mood and cognition in depression.

**Summary:**

- **Reward Sensitivity**: Control subjects show a stronger and more consistent response to rewards, suggesting healthy reward processing. Depressed subjects, with a blunted response, may have reduced sensitivity to positive stimuli, which aligns with anhedonic symptoms.
- **Punishment Sensitivity**: Depressed individuals show a stronger response to punishment than control subjects, suggesting heightened sensitivity to negative feedback. This might contribute to the negative focus and rumination often observed in depression.

باندهای فرکانسی سیگنال‌های EEG به طور کلی به فعالیت‌های مختلف مغزی و حالت‌های رفتاری مرتبط هستند. این باندها و ویژگی‌های معمول آنها به شرح زیر است:

**Delta (0.5 – 4 Hz)**:

- **Characteristics**: Delta waves are the slowest brain waves, with low frequency and high amplitude.
- **Associations**: They are dominant during deep, restorative sleep (particularly stages 3 and 4 of NREM sleep). High delta activity can indicate deep relaxation or drowsiness, but abnormal delta patterns may signal brain injuries or neurological issues.

**Theta (4 – 8 Hz)**:

- **Characteristics**: Theta waves are slower than alpha waves but faster than delta.
- **Associations**: Theta waves are often seen in light sleep or deep relaxation (e.g., meditation). In waking states, they are associated with creativity, intuition, and emotional processing. High theta activity can be linked to inattention or distraction, particularly in children with ADHD.

**Alpha (8 – 12 Hz)**:

- **Characteristics**: Alpha waves are moderate in frequency and are typically dominant in relaxed, wakeful states.
- **Associations**: Alpha waves are prominent when a person is awake but calm and not actively processing information (e.g., eyes closed and relaxed). They are often linked to relaxation, focus, and a lack of sensory input. Reduced alpha activity can indicate stress or anxiety.

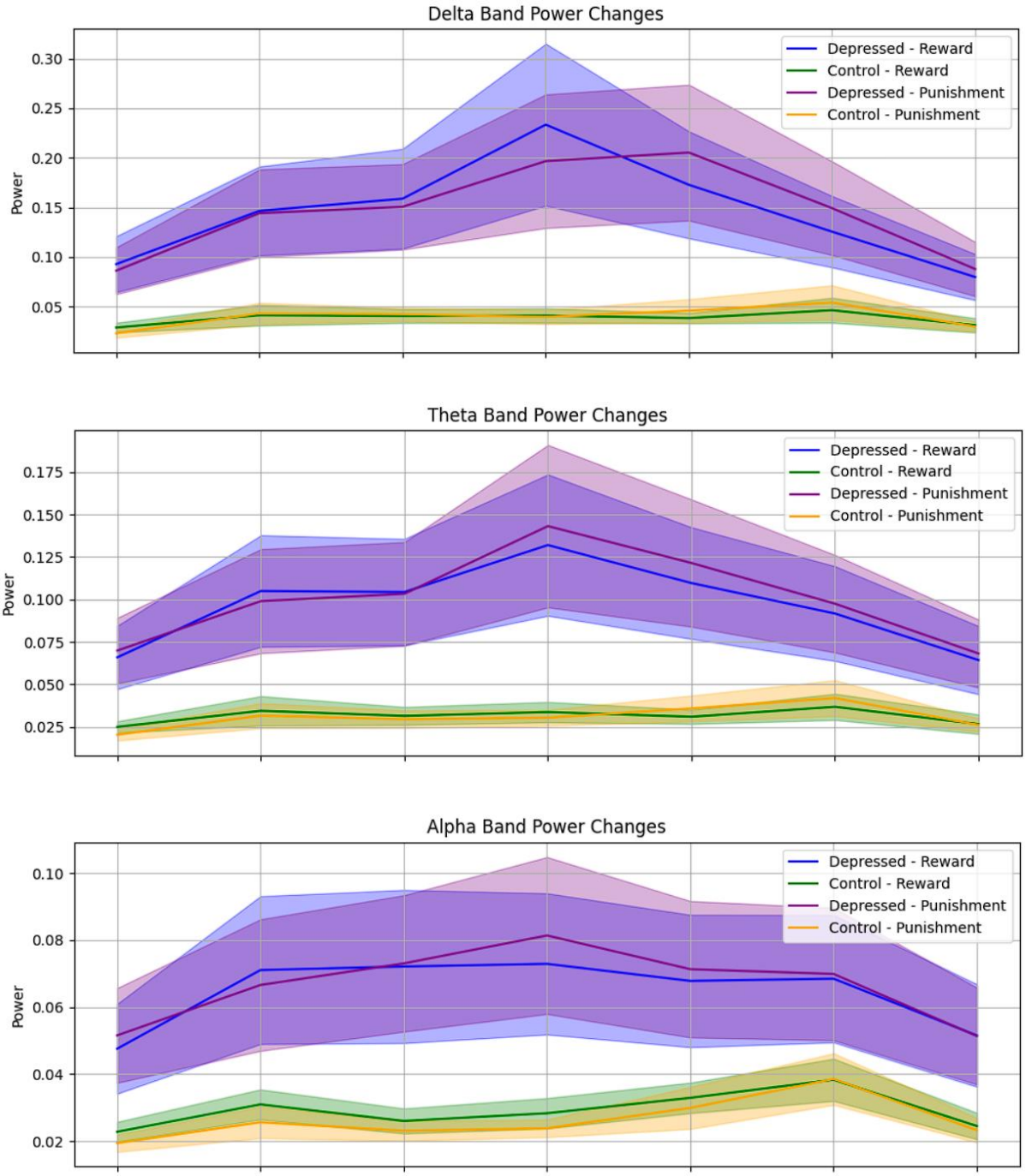
**Beta (12 – 30 Hz)**:

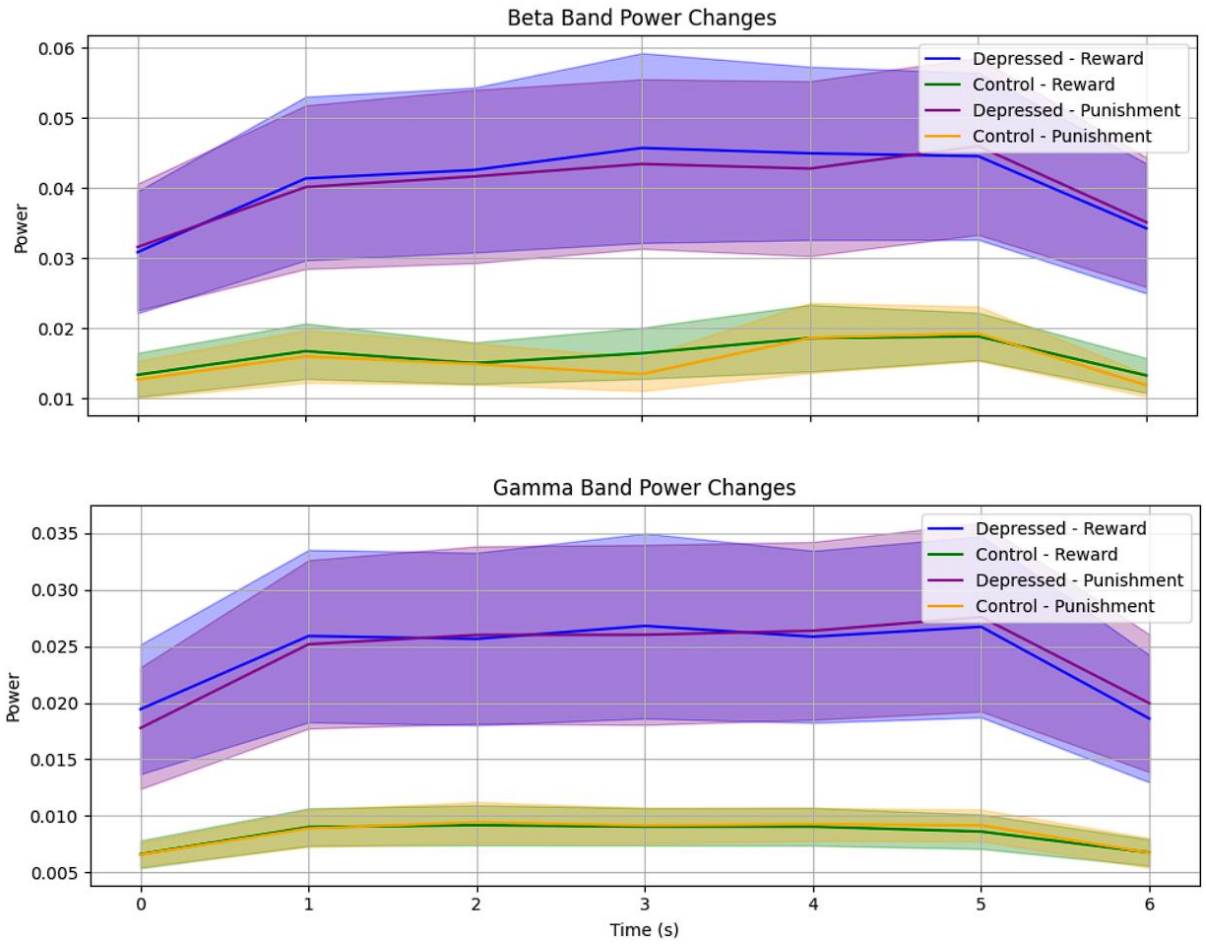
- **Characteristics**: Beta waves are faster and are associated with active, alert mental states.
- **Associations**: They are linked to concentration, problem-solving, and active thinking. High beta activity is associated with active alertness, anxiety, or stress, whereas low beta can be seen in drowsiness or relaxed states.

**Gamma (30 – 80 Hz)**:

- **Characteristics**: Gamma waves have the highest frequency and are associated with cognitive processing and high-level information integration.
- **Associations**: They are often linked to cognitive functions such as memory, attention, and sensory perception. Increased gamma activity can indicate heightened focus, and it is sometimes associated with learning and problem-solving.

Power Changes Across Frequency Bands with Confidence Intervals (Control vs. Depressed)






**Summary of Results**

1. **Delta Band**:
    - **Reward**: The difference between depressed and control subjects is substantial. Depressed individuals show much higher power levels in response to reward stimuli compared to controls.
    - **Punishment**: Similar to reward, the delta band power is higher in the depressed group than in the control group, indicating a pronounced response in low-frequency activity for both conditions.
2. **Theta Band**:
    - **Reward**: The theta power is also elevated in the depressed group compared to the control group, but with a slightly reduced difference compared to the delta band.
    - **Punishment**: There's a clear separation between the groups, with depressed subjects again showing higher theta power. This band shows notable differences between conditions as well.
3. **Alpha Band**:

- **Reward**: Depressed individuals exhibit higher alpha power than control subjects, although the difference is less pronounced than in the delta and theta bands.
- **Punishment**: Similar patterns are observed, with the depressed group having higher alpha power.

4. **Beta Band**:
   - **Reward**: The difference between control and depressed groups is present but smaller. The power levels are relatively similar for both conditions, suggesting that beta activity may not vary as much between the groups in response to reward or punishment.
   - **Punishment**: Differences are visible but not as pronounced as in lower frequencies.
5. **Gamma Band**:
   - **Reward and Punishment**: The differences between groups are minimal in the gamma band. Both control and depressed subjects have similar power levels, indicating that high-frequency activity might not vary significantly across the two conditions.

**Conclusion**

- **Overall**, depressed subjects show significantly higher power in the **delta** and **theta** bands compared to controls, especially in response to reward stimuli. This pattern suggests that depressed individuals might have heightened low-frequency activity, potentially linked to altered cognitive and emotional processing.
- The **alpha band** also shows some differences, though they are less prominent than in delta and theta.

**Answers to Questions**

1. **In which frequency band is the difference between control and depressed subjects more pronounced in the reward test?**
   - **Delta Band**: The difference in power is largest in the delta band for the reward condition, with depressed subjects showing much higher power than controls.
2. **In which frequency band is the difference between control and depressed subjects more pronounced in the punishment test?**
   - **Theta Band**: The theta band shows a prominent difference between control and depressed groups in the punishment test, with depressed subjects exhibiting higher power.