Human Attention and Electroencephalograms

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Research Article

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Abstract

MATLAB is an advanced numerical calculation tool that is widely used by engineers and scientists. MATLAB is popular in such fields as image processing, signal processing, communications, and automation systems. MATLAB efficiently reflects changes in research results. The use of the electroencephalogram (EEG) is an important method for exploring human brain activity. It provides useful evaluation data about the changeability of the EEG frequency band. By simplifying the programming environment and improving the EEG results, EEG-MATLAB coding was developed in this study. Ten recordings of subjects were performed using EEGs. The EEG features were compared under two conditions: relax and un-relax. For statistical analysis, a correlation coefficient was used to correlate the two sessions with EEG-extracted features. The objective of this study was to help researchers in EEG analysis to run the code and compare the EEG bands: delta (up to 4-Hz), theta (4–8-Hz), alpha (8–15-Hz), beta (15–32-Hz), and gamma (≥ 32 -Hz) waves. The results of this study can also be used for any analysis that employs EEGs in mental status research.

I. Introduction

A mathematical program is used to simulate, analyze, or calculate numerical data [1]. Mathematical software improves geometric calculations. The four major mathematical software packages are Mathematica, MATLAB, R, and Python [2].

Mathematica is the standard for symbolic computation. Part of its strength is its ability to create and calculate expressions [3]. It is a trust in symbolic computation. Moreover, its ultimate disadvantages are its programming language, portability, and speed [3]. MATLAB is the norm for numerical computations under a broad classification of numerical analyses. It is less suitable for symbolic estimation, but its numerical analysis tools are familiar in the industry [4]. In addition to numerous additional packages, it can effectively incorporate data from everything from webcams to particle physics experiments [5]. Its usefulness as a pure mathematics tool might not be as evident as that of Mathematica, but if one intends to collaborate with applied mathematicians, physicists, or engineers, a working understanding of MATLAB is vital [6].

Python should be combined with Scipy and NumPy. By combining the free programming/scripting language with strong (C-based) packages for scientific computation, this suite can rival the numerical analysis tools of MATLAB [7]. MATLAB validates the simulation of functions and data in advanced applications and calculations, leading to clear results [6]. Hence, MATLAB is generally applied in many research fields, such as signal processing in biomedical engineering calculations [1]. Moreover, it is a required course at many universities. Therefore, MATLAB programming textbooks have been written [8]. The memory problem is one of the drawbacks of MATLAB while downloading and installing it, which is time consuming [9]. MATLAB is difficult to use on mobile phones and tablets.

MATLAB programming based on electroencephalogram (EEG) analysis was established and calculated in this project according to the real state of the installed programming environment [10].

The human brain is an extensive and complex organ. It contains 100 billion nerves or more that connect to synapses [11]. The brain is a control organ that functions together with other organs. The brain includes the cortex, which is the outermost coating of the brain cells [11].

EEGs are useful for analyzing the brain's feedback to attention because of its cost savings and practicality. It also provides useful information for exploring irregularities in human behavior [12]. In addition, EEGs provide a useful source of neurofeedback, and researchers have discovered many brain disorders using EEGs. The 10–20 system is the standard electrode location on the scalp, and it is traditionally used for recording EEG data [13]. Based on the 10–20 system, the electrode is characterized by a letter to denote the lobe or part of the brain it is reading [14]. Even-numbered electrodes are used for the right part of the brain, while odd-numbered ones are used for the left part of the brain. For example, the Fp2 electrode refers to an electrode in the right frontal plane, and F3 refers to an electrode in the left frontal lobe.

The EEG signal appears in the small microvolt range. The raw EEG time series are usually converted into a frequency series and categorized into five EEG frequency power bands: delta (up to 4-Hz), theta (4–8-Hz), alpha (8–15-Hz), beta (15–32-Hz), and gamma (≥ 32 -Hz) waves [16].

In this study, EEG features were extracted from the raw EEG data for all subjects. Then, the signals were evaluated for two different situations using MATLAB, and the results show the trends. It was confirmed that MATLAB provides logical and accurate results for the five EEG frequency bands.

II. Eeg Calculation

Normalized left or right hemisphere delta band power:

$$(nLDP \text{ or } nRDP) = \frac{\text{Summation of Delta power}}{\text{Total Power}} * 100(1)$$

Normalized left or right hemisphere theta band power:

$$(nLTP \text{ or } nTP) = \frac{\text{Summation of theta power}}{\text{Total Power}} * 100(2)$$

Normalized left or right hemisphere alpha band power:

$$(nLAP \text{ or } nRAP) = \frac{\text{Summation of alpha power}}{\text{Total Power}} * 100(3)$$

Normalized left or right hemisphere Beta band power:

$$(nLBP \text{ or } nRBP) = \frac{\text{Summation of Beta power}}{\text{Total Power}} * 100(4)$$

Normalized left or right hemisphere gamma band power:

$$(nLGP \text{ or } nRGP) = \frac{\text{Summation of gamma power}}{\text{Total Power}} * 100 \quad (5)$$

Bands power asymmetry for all delta, theta, alpha, and beta (DPA or TPA or APA or BPA):

$$\text{Band power asymmetry} = \frac{EEG_{band}(\text{Right}) - EEG_{band}(\text{Left})}{EEG_{band}(\text{Right}) + EEG_{band}(\text{Left})} \quad (6)$$

iii. System Design

The development of this MATLAB code system is primarily for the convenience of MATLAB programmers. Programmers can write down the code by launching the MATLAB coding area and following the mentioned steps:

Step 1: The user begins MATLAB, writes and enters the code, inputs the parameters, assumes the sampling frequency is 300 Hz, and uses Welch's power spectral density estimation for four EEG electrodes: F3, F4, Fp1, and Fp2.

```
%  
  
clear;  
  
clc;  
  
len = length(F3);  
  
len2 = abs(len/8);  
  
fs = 300;  
  
[f3Data,f] = pwelch(F3, len2,[],len,fs);  
  
[f4Data,f] = pwelch(F4, len2,[],len,fs);  
  
[fp1Data,f] = pwelch(Fp1, len2,[],len,fs);  
  
[fp2Data,f] = pwelch(Fp2, len2,[],len,fs);  
  
%
```

Step 2: Plotting the results:

```
figure  
  
maxFreq = 20;
```

```

plot(f(f < maxFreq), 10*log(f3Data(f < maxFreq)));

hold on;

plot(f(f < maxFreq), 10*log(f4Data(f < maxFreq)));

hold on;

plot(f(f < maxFreq), 10*log(fp1Data(f < maxFreq)));

hold on;

plot(f(f < maxFreq), 10*log(fp2Data(f < maxFreq)));

hold off;

legend('F3','F4','Fp1','Fp2')

title('Un-Relax - Power Spectral Density ')

xlabel('Frequency (Hz)')

ylabel('Power/Frequeancy (dB/Hz)')

```

```
%_____
```

Step 3: Estimating the normalized (left, right) hemisphere delta band powers :

```
%_____
```

```

delta1 = 0;

delta2 = 4;

fdelta = f;

for i = 1 : length(f)

if ((i > delta1) && (i < delta2))

fdelta(i) = 1;

else

fdelta(i) = 0;

end

```

end

nLdpF3 = 100*sum(f3Data(fdelta == 1))/sum(f3Data)

nRdpF4 = 100*sum(f4Data(fdelta == 1))/sum(f4Data)

nLdpFp1 = 100*sum(fp1Data(fdelta == 1))/sum(fp1Data)

nRdpFp2 = 100*sum(fp2Data(fdelta == 1))/sum(fp2Data)

%_____

Step 4: Estimating the normalized (left, right) hemisphere theta band powers:

%_____

theta1 = 4;

theta2 = 8;

ftheta = f;

for i = 1 : length(f)

if ((i > theta1) && (i < theta2))

ftheta(i) = 1;

else

ftheta(i) = 0;

end

end

nLtpF3 = 100*sum(f3Data(ftheta == 1))/sum(f3Data)

nRtpF4 = 100*sum(f4Data(ftheta == 1))/sum(f4Data)

nLtpFp1 = 100*sum(fp1Data(ftheta == 1))/sum(fp1Data)

nRtpFp2 = 100*sum(fp2Data(ftheta == 1))/sum(fp2Data)

%_____

Step 5: Estimating the normalized (left, right) hemisphere alpha band powers:

%_____

alpha1 = 8;

alpha2 = 13;

fAlpha = f;

for i = 1 : length(f)

if ((i > alpha1) && (i < alpha2))

fAlpha(i) = 1;

else

fAlpha(i) = 0;

end

end

nLapF3 = 100*sum(f3Data(fAlpha == 1))/sum(f3Data)

nRapF4 = 100*sum(f4Data(fAlpha == 1))/sum(f4Data)

nLapFp1 = 100*sum(fp1Data(fAlpha == 1))/sum(fp1Data)

nRapFp2 = 100*sum(fp2Data(fAlpha == 1))/sum(fp2Data)

%_____

Step 6: Estimating the normalized (left, right) hemisphere beta band powers:

%_____

beta1 = 13;

beta2 = 30;

fBeta = f;

for i = 1 : length(f)

if ((i > beta1) && (i < beta2))

fBeta(i) = 1;

```

else

fBeta(i) = 0;

end

end

nLbpF3 = 100*sum(f3Data(fBeta == 1))/sum(f3Data)

nRbpF4 = 100*sum(f4Data(fBeta == 1))/sum(f4Data)

nLbpFp1 = 100*sum(fp1Data(fBeta == 1))/sum(fp1Data)

nRbpFp2 = 100*sum(fp2Data(fBeta == 1))/sum(fp2Data)

```

```
%_____
```

Step 7: Estimating the normalized (left, right) hemisphere gamma band powers:

```
%_____
```

```

gamma1 = 30;

gamma2 = 60;

fgamma = f;

for i = 1 : length(f)

if ((i > gamma1) && (i < gamma2))

fgamma(i) = 1;

else

fgamma(i) = 0;

end

end

nLgpF3 = 100*sum(f3Data(fgamma == 1))/sum(f3Data)

nRgpF4 = 100*sum(f4Data(fgamma == 1))/sum(f4Data)

nLgpFp1 = 100*sum(fp1Data(fgamma == 1))/sum(fp1Data)

```


$$nRgpFp2 = 100 * \text{sum}(fp2Data(fgamma = 1)) / \text{sum}(fp2Data)$$

%_____

Step 8: Estimating delta power band asymmetry, theta band power asymmetry, alpha band power asymmetry, beta band power asymmetry, and gamma-band power asymmetry:

%_____

$$fDPA = (nRdpF4 - nLdpF3) / (nRdpF4 + nLdpF3)$$

$$fDBPA = (nRdpFp2 - nLdpFp1) / (nRdpFp2 + nLdpFp1)$$

$$fTPA = (nRapF4 - nLapF3) / (nRapF4 + nLapF3)$$

$$fpTPA = (nRapFp2 - nLapFp1) / (nRapFp2 + nLapFp1)$$

$$fAPA = (nRapF4 - nLapF3) / (nRapF4 + nLapF3)$$

$$fpAPA = (nRapFp2 - nLapFp1) / (nRapFp2 + nLapFp1)$$

$$fBPA = (nRbpF4 - nLbpF3) / (nRbpF4 + nLbpF3)$$

$$fpBPA = (nRbpFp2 - nLbpFp1) / (nRbpFp2 + nLbpFp1)$$

$$fGPA = (nRapF4 - nLapF3) / (nRapF4 + nLapF3)$$

$$fpGPA = (nRapFp2 - nLapFp1) / (nRapFp2 + nLapFp1)$$

%_____

IV. Methods

Simultaneously calculating EEG features using MATLAB, including the power spectral density, for two EEG sessions (relax and un-relax) is proposed. The relax session is a closed eye session for the subject, while the un-relax session involves performing the Stroop color word test [17]. Ten subjects (nine right-handed and one left-handed) participated. There were five female and five male subjects, with a mean age of 21 ± 0.9 years. A consent form was obtained from all participants. The noise from physiological and nonphysiological artifacts during recording was reduced using band-pass filtering (1–35 Hz). The DSI-24 dry electrode EEG headset was used for EEG recording. It includes 21 sensors at positions according to the 10–20 international standard. EEG signals were obtained using a DSI-Streamer at a sampling rate of 300 Hz [18]. F3, F4, Fp1, and Fp2 were selected for the EEG signal analysis. MATLAB R2017a software was used for statistical analysis. The Institutional Review Board approved this study.

V. Results

Figures 1 and 2 show the power spectral densities for the F3, F4, Fp1, and Fp2 electrodes. Tables 1–5 show the estimations for the delta, theta, alpha, beta, and gamma frequency bands in two recording sessions, relax and un-relax. Table 6 shows the asymmetry calculations for all the frequency bands.

TABLE 1

EEG Features CALCULATION DELTA

Feature	Relax	Un-Relax	Trend
<i>nLdpF3</i>	31	28	↓
<i>nRdpF4</i>	34	33	↓
<i>nLdpFp1</i>	37	33	↓
<i>nRdpFp2</i>	35	32	↓

TABLE 2

EEG Features CALCULATION theta

Feature	Relax	Un-Relax	Trend
<i>nLtpF3</i>	21	20	↓
<i>nRtpF4</i>	24	23	↓
<i>nLtpFp1</i>	25	24	↓
<i>nRtpFp2</i>	23	22	↓

TABLE 3

EEG Features CALCULATION alpha

Feature	Relax	Un-Relax	Trend
<i>nLapF3</i>	5.5	7	↑
<i>nRapF4</i>	6.2	6.7	↑
<i>nLapFp1</i>	7.5	8	↑
<i>nRapFp2</i>	6	8	↑

TABLE 4

EEG Features CALCULATION beta

Feature	Relax	Un-Relax	Trend
<i>nLbpF3</i>	0.5	4	↑
<i>nRbpF4</i>	0.5	1.4	↑
<i>nLbpFp1</i>	1.9	4.3	↑
<i>nRbpFp2</i>	1	4.3	↑

TABLE 5

EEG Features CALCULATION gamma

Feature	Relax	Un-Relax	Trend
<i>nLgpF3</i>	0.2	1.8	↑
<i>nRgpF4</i>	0.3	0.5	↑
<i>nLgpFp1</i>	0.87	1.9	↑
<i>nRgpFp2</i>	0.5	2	↑

TABLE 6

frequency bands and asymmetry

Feature	Relax	Un-Relax	Trend
<i>fDPA</i>	0.3	0.3	↓↑
<i>fDBPA</i>	0.1	0.1	↓↑
<i>fTPA</i>	0.3	0.3	↓↑
<i>fpTPA</i>	0.1	0.1	↓↑
<i>fAPA</i>	0.36	0.32	↓
<i>fpAPA</i>	0.1	0.1	↓↑
<i>fBPA</i>	0.4	0.55	↑
<i>fpBPA</i>	0.4	0.2	↓
<i>fGPA</i>	0.3	0.3	↓↑
<i>fpGPA</i>	0.1	0.1	↓↑

Vi. Discussion

Advanced code implants were used to compare the performances of EEG signals for the five frequency bands. In addition, the asymmetry of the frequency bands was calculated. The significant benefit of this code is that it can be used to assess the effect of any comparison between two sessions in such EEG research areas as mental status.

Usually, EEG analysis is performed using commercial software. EEG LAB is a well-known free software for professional EEG researchers. The coding used in this study is beneficial for beginners in EEG analysis. However, the code clearly shows the power of the spectral density behavior. The delta (up to 4-Hz), theta (4–8-Hz), alpha (8–15-Hz), beta (15–32-Hz), and gamma (≥ 32 -Hz) waves clearly appear in Figs. 1 and 2.

In Figs. 1 and 2, the alpha band appears in a relax session (8–15 Hz), while the alpha band disappears in the un-relax session.

Tables 1–5 justify the estimation of the five power frequency bands for the two situations. Alpha, beta, and gamma increased, as shown in the trend, whereas delta decreased. Theta has a different direction, which increases in the left theta power (F3) and right theta power (F4). Moreover, the left theta power (Fp1) and right theta power (Fp2) decreased in the un-relax session.

All EEG features were tested using the correlation coefficient, and then r was calculated. Six negative correlations were found in the EEG features between the relax and un-relax sessions: left delta power (Fp1), left theta power (Fp1), left beta power (F3), left beta power (Fp1), left gamma power (F3), and left gamma power (Fp1). A strong positive correlation was found in delta power asymmetry between F3 and F4, delta power asymmetry between Fp1 and Fp2, theta power asymmetry between F3 and F4, theta power asymmetry between Fp1 and Fp2, alpha power asymmetry between F3 and F4, alpha power asymmetry between Fp1 and Fp2, gamma power asymmetry between F3 and F4, and gamma power asymmetry between Fp1 and Fp2. However, beta power asymmetry showed a positive correlation.

A moderate positive correlation was found in the left delta power (F3), right delta power (F4), right delta power (Fp1), left theta power (F3), right theta power (F4), left alpha power (F3), right alpha power (F4), right beta power (F4), and right gamma power (F4). A positive correlation was found in right theta power (Fp2), left alpha power (Fp1), right alpha power (Fp2), right beta power (Fp2), right gamma power (Fp2), and beta band power asymmetry in F3 and F4 and in Fp1 and Fp2.

Delta waves are less than 4 Hz and appear during deep sleep and abnormal situations. Peak activities decrease delta waves when a high focus is required [18]. As shown in Table 1, the delta waves dropped in electrodes F3, F4, Fp1, and Fp2.

Theta activity is related to memories and emotions and increases in meditation and prayer [18]. The theta wave decreased in electrodes F3, F4, Fp1, and Fp2, as shown in Table 2. It is reduced during focusing and that can be seen in the results of the un-relax session.

Alpha waves are found during relaxation, during meditation, and when the eyes are closed [19]. In Table 3, the alpha waves have stable results for all electrodes because of the un-relax session. Figures 2 and 3

clearly show a decrease in the alpha waves [20]. Beta waves appear when the eye is open and during listening, thinking, and solving a problem [19]. In this study, beta waves increased considerably in all electrodes during the un-relax session, as shown in Table 4. Gamma waves appear in critical thinking or high-level information processing [19]. In Table 5, the gamma waves increase for all electrodes in the un-relax session.

Delta power asymmetry, theta power asymmetry, and gamma power asymmetry had stable results. Alpha power asymmetry showed a decrease in the F3 and F4 electrodes, which is consistent with the finding that alpha fell in the un-relax session [21]. Beta power asymmetry increased in the F3 and F4 electrodes in the un-relax session, indicating that beta waves appeared in the un-relax sessions [21]. The number of subjects is a challenge because of the subject preparation and the time required for EEG recording.

Vii. Conclusion

The brain is the most complex organ, and EEGs can be used to investigate the processing by the brain. The outcomes of the EEG analysis in this study make it possible to observe and understand the behavior of the brain in many situations, such as focusing or learning. The results of this study can be used for the education of beginners in EEG analysis.

Declarations

Consent for Publication:

The author gives consent for publication in the above Journal. Therefore, anyone can read material published in the Journal.

Conflict of interests:

The author declares no conflict of interest concerning this study.

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This study received no grant from any funding agency in the public or industrial.

Authors' Contributions:

Eyad Attar: collection, organizing, review of the literature, preparing the manuscript, manuscript review, modification, editing, and revision.

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Patient Permission:

All participants permit the author to collect the data and sign the consent form.

Data Availability:

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Study Approval:

This is an observational study. The KAU electrical and computer department has confirmed that no ethical approval is required.

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Figures

Figure 1

PSD for relax session: four electrodes

Figure 2

PSD for Un-relax session: four electrodes