Task description

1. Investigation of the methods (what is the method doing, how can you use it, etc.).
2. Implementation of the methods to the data:
   (a) Using correlation and RMC/WB/ANN to estimate the connections between different EEG channels in α (8-12 Hz) and β (15-30 Hz) frequency regions for different values of brightness intensity $I \in (0.1 - 1.0)$, finding an optimal value of I for each subject characterized by maximal connectivity.
   (b) Estimating efficiency of Pearson correlation and RMC/WB/ANN.
   (c) Investigation of the time-dependence of the coupling strength, finding an optimal value of time window for calculation of the coupling strength.
   (d) Using a Nonparametric Test for checking a hypothesis of achieving maximal connectivity in the found range of the optimal brightness intensity.
3. Writing a report.

The methods for analysis are:

1. Pearson Correlation.
2. Artificial Neural Networks.
3. Statistical analysis - Nonparametric Test

The dataset is Mona Lisa portraits.

Participant	Optimal Intensity	Max Correlation	Maximal Connectivity Channels
1	0.8	0.8274	Fcz-A1 Fz-A1
2	0.9	0.9220	F3-A1 F7-A1
3	0.1	0.9177	Fz-A1 Fcz-A1
4	0.3	0.9243	F3-A1 Fc3-A1
5	0.4	0.8946	F3-A1 Fc3-A1

Table 1: Maximal Connectivity with Pearson Correlation method

Solution

Pearson Correlation

The equation for Pearson Correlation is

$$\rho = \frac{cov(X, Y)}{\sigma_X \sigma_Y} \tag{1}$$

where

- cov is a covariance;
- σ_X is a standard deviation of X;
- σ_Y is a standard deviation of Y;

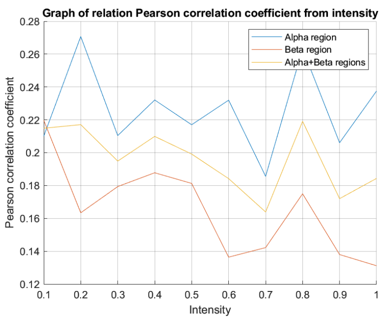
In our case, Pearson Correlation was used to identify the maximal connectivity among all channels of EEG by estimating coefficient values for every channel with each other in α and β regions. Due to the estimations the correlation matrix with coefficients can be considered as hidden channels dependency.

The next table 1 represents the results of estimating maximal connectivity with Pearson Correlation method.

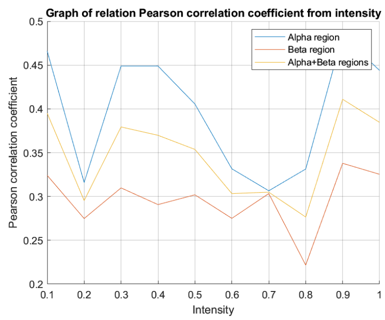
On the Fig. 1 the results of correlation estimation for each participants in dataset are presented. As you can see, the results in the alpha and beta region were not the same. Since in the frequency range the signals have different connectivity.

Artificial Neural Network

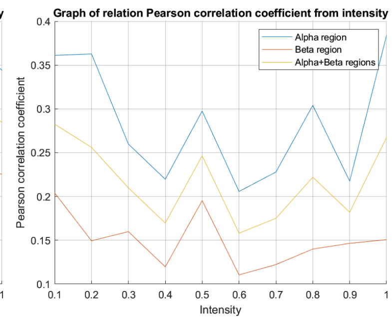
Feedforward neural networks are artificial neural networks where the connections between units do not form a cycle. Feedfoward neural networks are primarily used for supervised learning in cases where the data to be learned is neither sequential nor time-dependent. That is, feedforward neural networks compute a function f on fixed size input x such that



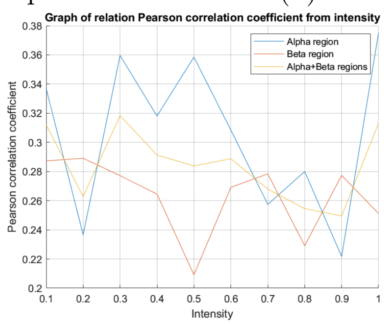
(a) Participant 1



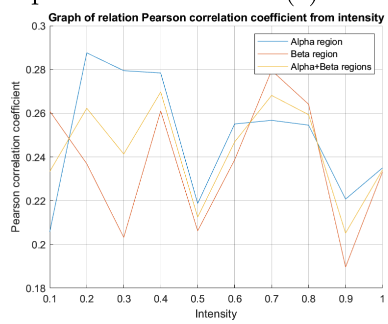
(b) Participant 2



(c) Participant 3



(d) Participant 4



(e) Participant 5

Figure 1: Pearson Correlation results

$f(x) \approx y$ for training pairs (x, y). In our case, we used the feedforward neural networks for the estimation of the nonlinear connectivity between EEG channels. We split in half the data into train and test sets. We train a neural network on training data and measure the accuracy score by formula:

$$Score = 1 - \frac{1}{n}\sum_{i=1}^{n}(Y_i - \hat{Y}_i)^2. \tag{2}$$

where

- n is a length of test set
- Y_i is a observed value from test set
- $\hat{Y}_i$ is a predicted value, based on input X_i

The next table 2 represents the results of estimating maximal connectivity with Artificial Neural Network method.

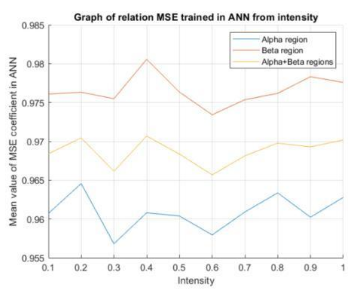
On the Fig. 2 you can see the results of estimation ANN for each participants in dataset. As you can see, the results in the alpha and beta region were not the same. Since in the frequency range the signals have different connectivity.

Efficiency of Pearson Correlation and Artificial Neural Network

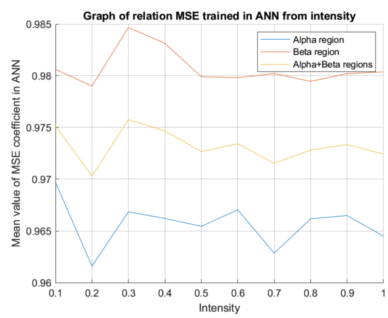
Both methods are the usable methods for estimating maximal connectivity of isolated channels, finding the hidden channels dependency. Pearson Correlation method allows to initialize

Participant	Optimal Intensity	Max Correlation	Maximal Connectivity Channels
1	0.4	0.9909	Fcz-A1 Fz-A1
2	0.3	0.9960	Cz-A2 C4-A4
3	1	0.9946	Fz-A1 Fcz-A1
4	0.4	0.9943	Fz-A1 F3-A1
5	0.6	0.9952	FC3-A1 F3-A1

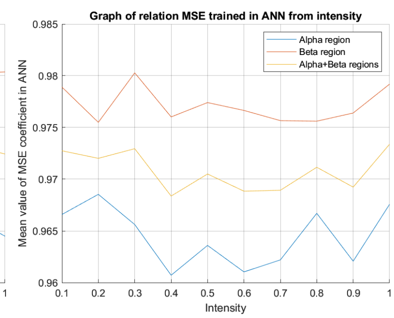
Table 2: Maximal Connectivity with Artificial Neural Network method



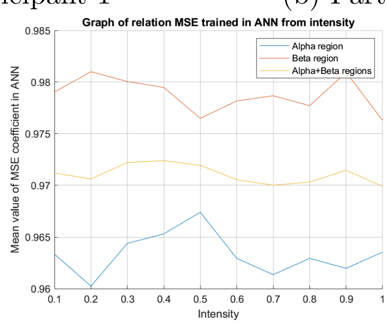
(a) Participant 1



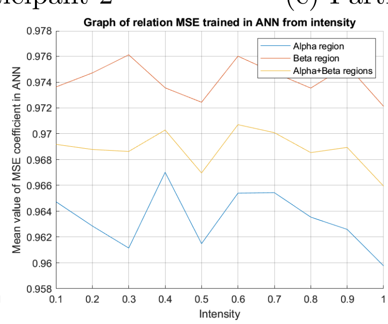
(b) Participant 2



(c) Participant 3



(d) Participant 4



(e) Participant 5

Figure 2: ANN results

the linear dependency. While Artificial Neural Network method allows to find the nonlinear dependency. However, the methods are not suitable for finding complex hidden channels dependencies.

From the proposed tables 1 and 2 for every participant the values of intensity on maximal connectivity is different. On the table 2 correlation for intensity is higher than in table 1. However, almost for every participant the channels for maximal connectivity stay the same. As you can see when comparing Fig. 1 and 2, different patients have different coincidences in the graphs for the alpha and beta region. Most likely this is due to the fact that different people have different sensitivity thresholds in different regions. Using matching patterns, you

Participant	The most sensitive region	I with max Corr and Ann	I with min Corr and Ann
1	Alpha	0.2	0.7
2	Alpha	0.1	0.2
3	Beta	0.3	0.8
4	Beta	0.9	0.6
5	Alpha	0.4	1

Table 3: Maximal Connectivity with Artificial Neural Network method

can calculate the most accurate intensity values at which maximum connectivity is observed. The results you can see in Table 3.

Time-Dependence of the Coupling Strength

In the time dependency task we calculate the best time window with the maximum coupling strength. We use the Pearson correlation as parameter of coupling strength because in our implementation this function need the more less time that ANN performance. On the Fig. 3 you can see the results of measure time dependence of the coupling strength for Participant 2 with intensity 0.9. As you can see the optimal time window for this case is equal 40 sec.

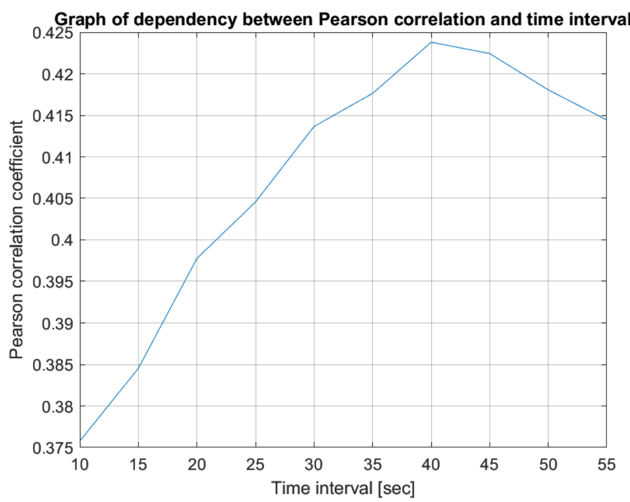


Figure 3: Time dependence of the Coupling Strength

Nonparametric Test

As a nonparametric test a Friedman's Test is used for checking a hypothesis of achieving maximal connectivity in the range of the optimal brightness intensity. The p-value estimates the ability to accept the hypothesis H_0 that columns in the range does not effect or to decline it in favor of an alternative hypothesis H_1. The hypothesis of achieving maximal connectivity represents as the alternative hypothesis.

As found range, the next range of optimal intensities is taken from estimation correlation $[0.1, 0.3, 0.4, 0.8, 0.9]$. The p-value is equal to $p = 4.3305e - 07$ that is less than 0.05. Then the hypothesis H_0 cannot be accepted. It means that the alternative hypothesis H_1 can be considered, which is a task hypothesis, that should be checked.

The range of optimal intensities is $[0.3, 0.4, 0.4, 0.6, 1]$ from ANN method. The p-value is equal to $p = 5.6641e - 07$ that is less than 0.05. H_1 can be considered, which is a task hypothesis, that should be checked.