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Evaluation of Cognitive Capacity of an Individual Using Biosignals-EOG and EEG with P300 Emphasis

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Abstract: The attention and cognitive capacity of an individual is an evaluating factor in assessment of cognitive impairment and for analyzing the rate of progression. The prevailing method of evaluation of cognition is questionnaire based followed by the analysis of Electro Encephalo Gram (EEG). The present research is based to bring a correlation between Eye Blink Rate (EBR) obtained from Electroculogram (EOG) and P300 which is an event related component of the EEG for evaluation of cognition. Frontal and parietal electrodes are used to pick the EOG and ERP respectively. The biopotential raw signals obtained are preprocessed and stored. The signals are then taken to MATLAB environment for analysis. For a designed stimulus presentation, EBR (index of attention) and the P300 component (measure of cognitive capacity) are acquired from 10 participant's data base set and the values are tabulated and analyzed using brain computer interface. The remarkable correlation and dependence exist between EBR and ERP through the statistical analysis.

Key words: Electro Enchepelo Gram (EEG), Electrooculogram (EOG), EBR , ERP, Brain Computer Interface (BCI)

INTRODUCTION

Cognition rely upon a lot of physiological processes which appears as summation of neuronal potential and for every individual is subject to an extensive research to understand how cognitive abilities of individual brain. Neuron potential data obtained from the surface electrode provide physical evidence to the investigation of cognition. The most complex thinking process requires many conceivable parameters and solutions to the problem of how cognitive operation could be predicted. The mental ability is affected by various conditions as fatigue, stress, brain damage, Lesions and Tumors.

Literature review: Biosignal acquisition-Nitish and Thakor has described the placement of electrodes on the specific points on the scalp for data acquisition and preprocessing of the signal with specific design requirements for biosignals.

Blinks as an index of cognitive activity (Orchard and Stern, 1991) indicated that changes of attention and changes in mental operation during reading or speaking is reflected in the eye blinking . As the people with mild cognitive impairment showed remarkably higher Eye Blink Rate (EBR) than the normal and healthy subjects, EBR can be used to measure the cognitive impairment based on attention. The typical duration of eye closure during blinks is 40-200 m sec. Nakano *et al*. (2009) conducted a study based on occurrence spontaneous eye blinks related to attention. To test this prognosis, they examined 14 subjects for the spontaneous eye blinks and concluded that eye blinks correlated with the visual stimulus showing the involvement of progress of cognitive process. The mean blink rate is 17 blinks/min. It can be as low as 4.5 while reading (Bentivoglio *et al*., 1997) (back and forth) or vertical (up and down) movements of the eye that occur when looking or when reading is called Saccades.

Fundamentals of EEG measurement (Teplan, 2002) described that potential of ERP components are often much smaller in magnitude than spontaneous EEG components which cannot be recognized from EEG trace without preprocessing. With the digital averaging technique ERP thus reflected with high temporal resolution reflecting the patterns of neuronal activity evoked by a response to a stimulus.

Stimulus for P300 acquisition (Sellers *et al*., 2012) described the electrode position for P300 position as in the proposed methodology and also the variability in its latency reflects the fact that the P300 is elicited by the decision based on latency. Polich (2007, 2010) reviewed through observation and theoretical outcome of the P300 by considering components that contribute to its magnitude, latency and various general characteristics.

P300 in current scenario (Fazel *et al*., 2012) indicates the current research in P300 and its potential future

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prediction of cognitive disorder by brain computer interface. Some of its importance is reected by several reasons. The P300 response is easy to measure and non-invasive and it requires less than 10 min of training and it works with the majority of subjects including those with the severe neurological disease.

Aleksandrov and Maksimova (1985) with experimental results suggested that P300 reflected the process of reorganization of the structure of the behavior which is responsible for the transition from ones normal stage to any other transition in cognition. The recorded ERP reflected with a high temporal resolution, the patterns of neuronal activity evoked by a stimulus (Taylor and Baldeweg, 2002).

Existing system: With the increasing demand, psycho cognitive assessment depends upon various neurophysiologic parameters. The complexity involved in making an optimum decision based on EEG analysis still hangs on the balance. To overcome these hardships with the EEG system with much reduced complexity and efficient analysis has been proposed, P300 is evoked in response to odd and meaningful stimuli known as "Oddball Stimuli" (Picton *et al*., 1995).

Proposed system: The proposed system utilizes an instrumentation amplifier with high CMRR as a part of acquisition module which is precise, a necessity for acquisition of P300and EOG since it is of µV-mV range. Also, the instrumentation amplifier utilized is cheap compared to the EEG module commercially available. The frequency band of the signal is obtained through filters designed at cut off frequency of desired interest. Acquisition of EOG and P300 signal and for analysis of acquired signals, MATLAB is chosen. Hence, the complexity for analysis and also the cost is deducted enormously.

MATERIALS AND METHODS

Role of EOG and P300 in Psycho-cognitive analysis: Ladas *et al*.(2014) recorded the EBR by placing two EOG surface electrodes above and below the left eye. They investigated the correlation between EBR as an indicator of Dopamine Activity (DA) and cognitive function.EOG has its usage in psycho-cognitive analysis in the form of blink rate. The relationship between EBR and attention is shown in Fig. 1. The more attention required by a task, the fewer endogenous blinks occur. Therefore, people with mild cognitive impairment showed significantly higher Eye Blink Rate (EBR) than the healthy subjects. Hence, it can be used to measure the cognitive impairment.

Various studies have used the P300 to investigate information processing in a variety of neuropsychiatric disorders such as alcoholism, schizophrenia, depression and multiple sclerosis and also in normal elderly the latency is increased. In general, a prolonged latency and/or amplitude decrement was seen for the patient groups. Thus, the P300 appears to be a very general measure to characterize information processing deficits in neuropsychiatric diseases. It lacks diagnostic specificity which limits its use for differential diagnosis. Figure 2 shows the spatial amplitude potential around frontal, central and parietal region of brain and found to be symmetric around C_z:

- F_z-Electrode position in the frontal region along the central axis
- C_z-Electrode position in the central region along the central axis
- P_z-Electrode position in the parietal region along the central axis

The decision to select P300 BCI paradigms is re ected by several reasons:

- The P300 response is easy to measure and non-invasive
- It requires <10 min of training
- It research with the majority of subjects including those with the severe neurological disease

The general block diagram of P300 and EOG acquisition module is shown in Fig. 3.

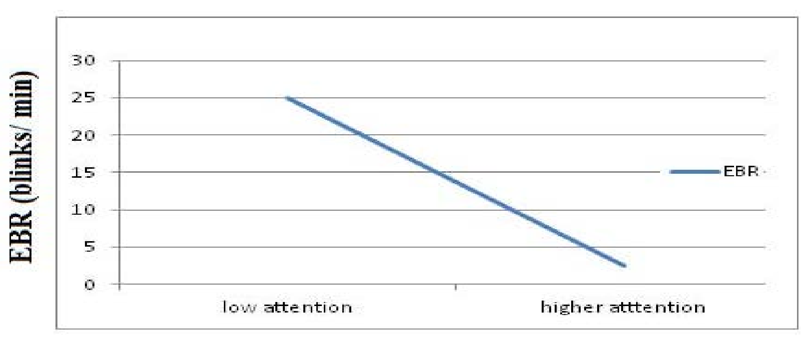

Fig. 1: Relation between EBR and attention exhibited

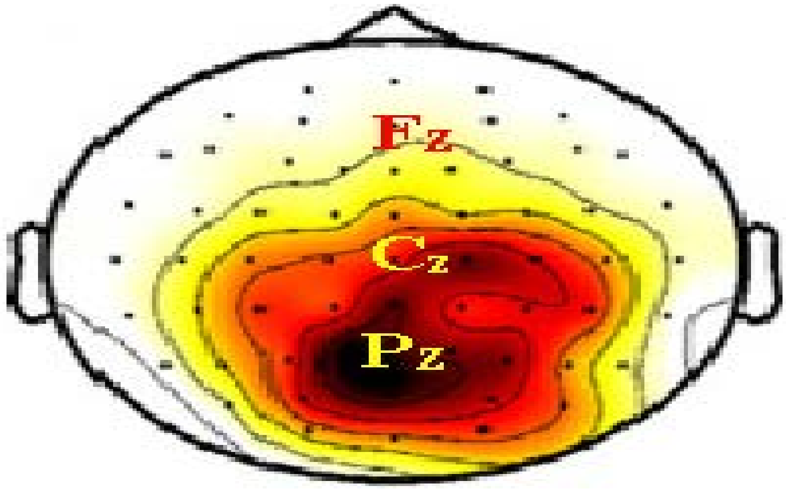

Fig. 2: Amplitude distribution of P300 over scalp

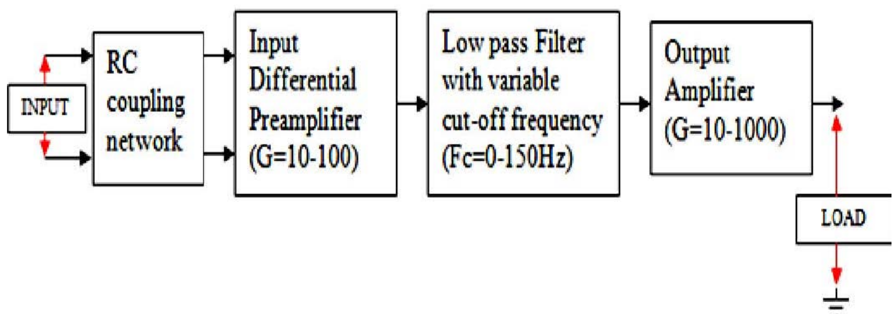

Fig. 3: General block diagram of P300 and EOG acquisition circuit

Analysis of EOG and P300: In case of Mild Cognitive Impairment (MCI) occurring as in case of degenerative disorders and brain trauma, there is a marked decline in the ability to exhibit attention and hence leads to impaired cognition. In this experiment Eye Blink Rate (EBR) calculated from EOG is used as the index for attention exhibited during an activity. This is correlated with the amplitude of the P300 signal elicited during an oddball task to show the relation between attention and cognition, thus providing a tool to measure the extent of cognitive capacity of the subject. The overall architecture is shown in Fig. 4.

Stimulus design for EBR Estimation and P300: The participants were presented for a period of one minute. The acquired EOG was logged for feature extraction using MATLAB and the EBR is estimated using vertical EOG.
P300 signals are acquired by using speller presentation that consisted of a series of alphabets randomly appearing on the screen. They are given a letter to be identified and counted from the speller. To provide the reference for the potential occurrence the event triggers are also logged along with the EEG containing the P300 data and features of the peaks are identified using MATLAB. The Front panel of stimulus presentation shown in Fig. 5.

EOG and EEG signal preprocessing: The EOG and EEG signals were preprocessed as both the signals involved DC level shifting in case of baseline shift low pass filtering Butterworth infinite impulse response digital filters, using amplification of the signal to increase the magnitude for easier mathematical approach of data point's analysis. The signal preprocessing is shown in Fig. 6.

Feature extraction: The EOG and P300 data logged in the form of text file is imported into the workspace of the MATLAB Environment. This file is then used to extract the features from the stored signal data. The eye blink rate is estimated with parameters individual peak height and the average peak height is developed as an m-file. The m-file "find peaks" with the feature time period, input signal, slope threshold, amplitude threshold and

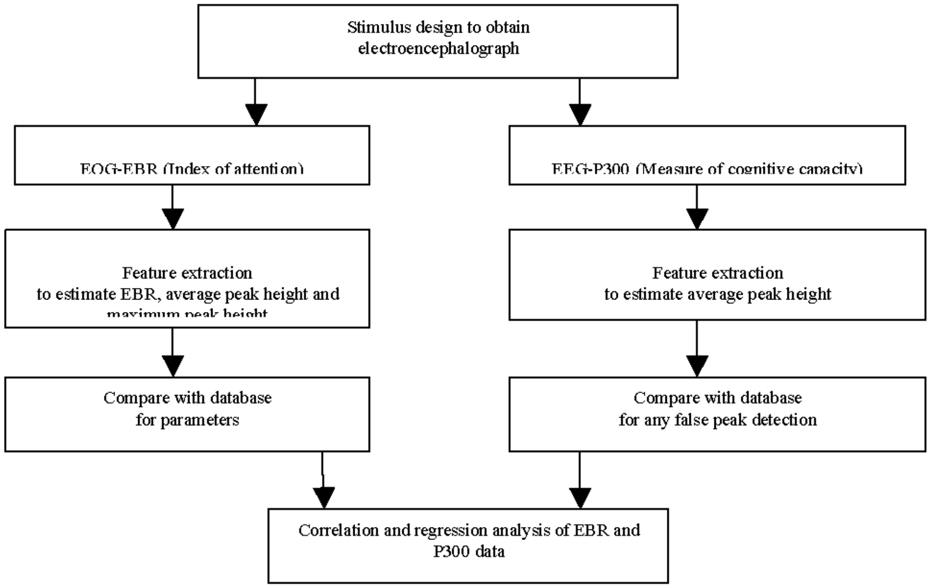

Fig. 4: EBR and P300 cognition prediction brain computer interface system

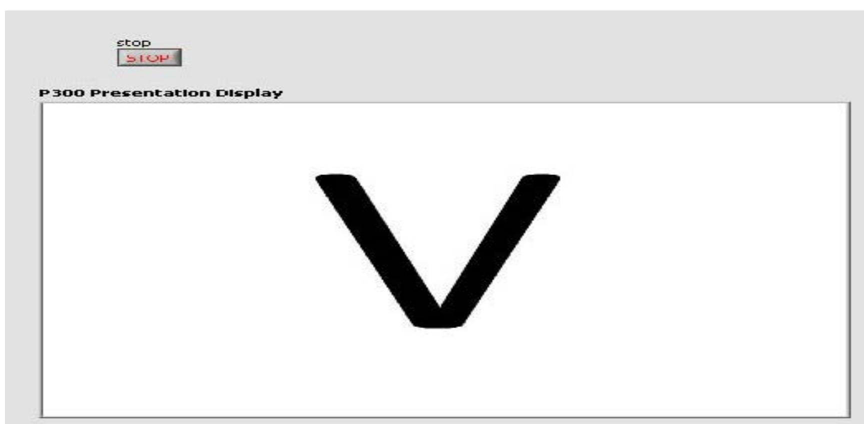

Fig. 5: Stimulus for EBR

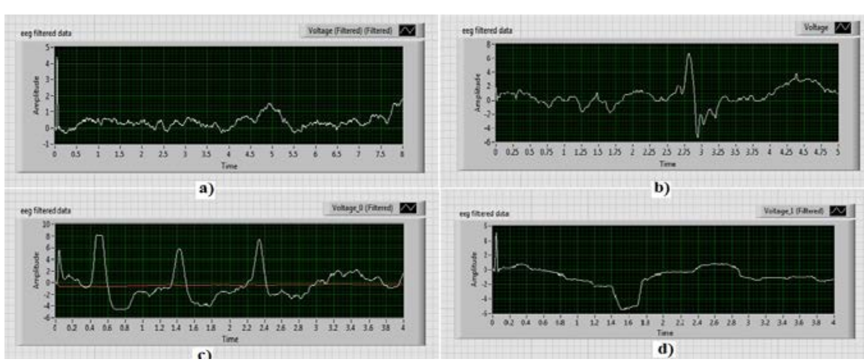

Fig. 6: Preprocessing of signal

Table 1: Experimental values of the EBR and P300 amplitude

Participants	Eye blink rate (Blinks/min) At rest	During reading	P300 Amplitude (µV)
1	16.00	3.00	65.00
2	14.00	0.00	85.00
3	10.00	0.00	80.00
4	13.00	5.00	60.00
5	15.00	2.00	75.00
6	12.00	4.00	70.00
7	14.00	1.50	78.00
8	10.00	1.00	75.00
9	12.50	3.50	65.00
10	17.00	6.00	55.00
Mean	13.35	2.60	70.80
SD	2.39	2.05	9.47
Min.	10.00	0.00	55.00
Max.	17.00	6.00	85.00

Table 2: Calculation of correlation coefficient, 'r'

n	EBR (x) During reading (blinks/min)	P300 amplitude (y)	x^2	y^2	xy
1	3.0	65	9	4225	195
2	0.0	85	0	7225	0
3	0.0	80	0	6400	0
4	5.0	60	25	3600	300
5	2.0	75	4	5625	150
6	4.0	70	16	4900	280
7	1.5	78	2.25	6084	117
8	1.0	75	1	5625	75
9	3.5	65	12.25	4225	227.5
10	6.0	55	36	3025	300

Total $\Sigma x=26$; $\Sigma y=708$; $\Sigma x^2=105.5$; $\Sigma y^2=50934$; $\Sigma xy=1674.5$

compared with the training set physionet database. The amplitude of the P300 components are estimated using the same m-file and the peak locations are correlated with the logged event data to eliminate the false peaks and to obtain the average peak height of the P300 signal.

The EBR and P300 data analysis: The values obtained from 10 participants for EBR during rest and during reading and the P300 amplitude are tabulated in Table 1 and respective mean, standard deviation, min and max values are calculated. Some data's were discarded due to high amount of motion artefact reducing the readability of data.

Correlation and regression analysis of ebr and p300 data: Using Statistical analysis toolbox in MATLAB is used to verify the relation between the values of EBR and P300 for the measurement cognitive capacity .The correlation coefficient 'r' is established to resolve the interdependence of the data variables. To determine the value of 'r', Eq. 1 is used to find the value of 'r' in Table 2 where EBR value is denoted by 'x' and P300 amplitude is denoted by 'y'.

$$r = \frac{\sum dxdy}{\sqrt{(\sum dx2 \sum dy^2)}} \quad (1)$$

Where:

$$\sum dx^2 = \sum x^2 - \frac{(\sum x)^2}{n}$$

$$\sum dy^2 = \sum y^2 - \frac{(\sum y)^2}{n}$$

$$\sum dxdy = \sum xy - \frac{\sum x \sum y}{n}$$

and n is number of data values by applying Eq. 1 to the values obtained from Table 2, we get:

$$\sum dx^2 = \sum x^2 - \frac{(\sum x)^2}{n} = 37.9$$

$$\sum dy^2 = \sum y^2 - \frac{(\sum y)^2}{n} = 807.6$$

$$\sum dxdy = \sum xy - \frac{\sum x \sum y}{n} = -166.3$$

$$r = \frac{\sum dxdy}{\sqrt{(\sum dx^2 \sum dy^2)}} = -0.9505$$

In order to describe the dependence of amplitude of P300 on EBR which gives the measure of cognitive capacity regression analysis of the data set is done. To perform linear regression analysis curve fitting is done on the data. The EBR during reading is taken to be the independent variable and takes up the x axis. The equation of the linear curve and the parameters (RMSE, r^2, adjusted r) for evaluating goodness of fit are done in MATLAB environment using the curve fitting tool. The analysis is further extended to determine the range about which the dependent variable can vary given a value of EBR. The data prediction is done using the fit analysis option in the MATLAB environment

RESULTS AND DISCUSSION

With the cost effective system with an an overall gain of 10000-15000 and band limited the signal within the desired range (0.16-40Hz), the acquired signals were digitized at 200 Hz using NI USB6009 DAQ and the signals were analyzed using MATLAB Environments. The EOG and EEG data were collected from 10 participants using the system and analyzed to extract the EBR and the P300 amplitude. The scatter plot of the EBR during reading and P300 amplitude is done to get the overview of the relation and it was found to be linear and inverse. Figure 7 shows the scatter plot of the data points. The regression

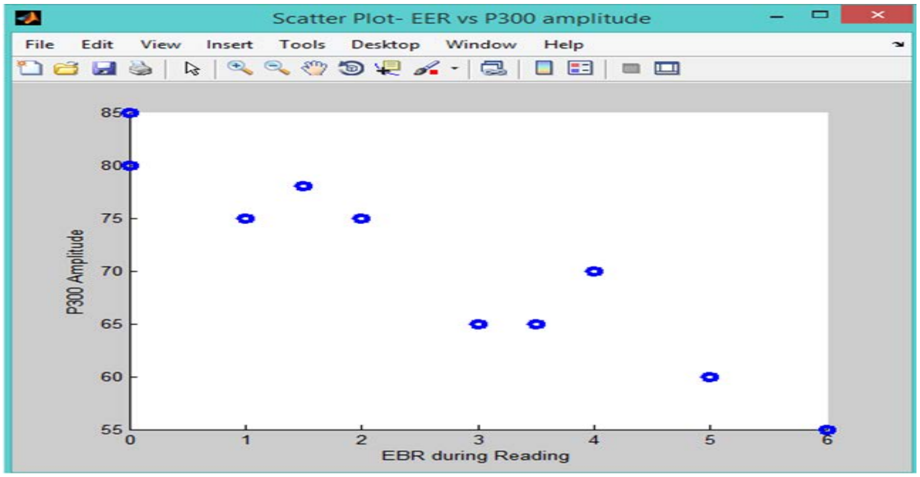

Fig. 7: Scatter plot for P300 and EBR

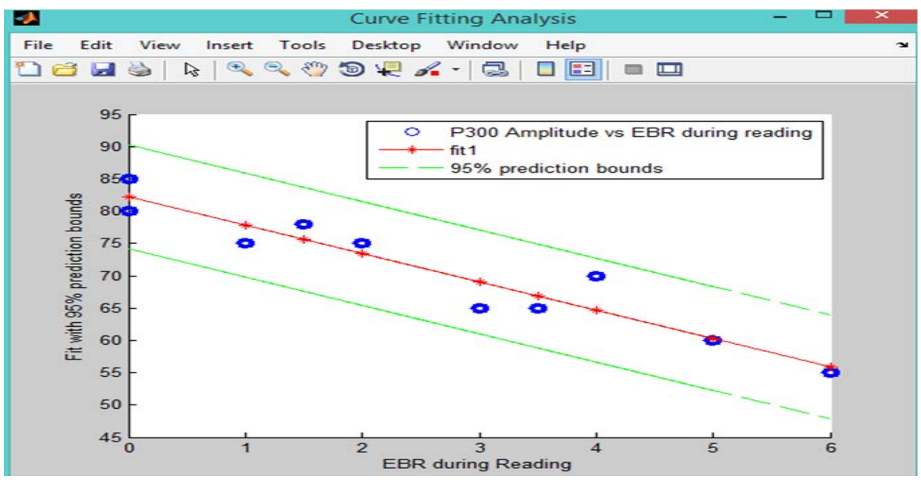

Fig. 8: Prediction bounds obtained from the curve fit analysis

analysis of the EBR and P300 data is used to describe the relation between them. From the correlation and regression analysis of the EBR and P300 data the value of 'r' was found to be -0.9505. The Degree Of Freedom (DOF) for the data set is 8 (since, DOF = n-2). On comparing the value of r and DF with the look up Table of Pearson's correlation coefficients as in Appendix 1 it was found that the value of 'r' exceeds the tabulated value(0.872) for $p = 0.001$ and hence the correlation is significant and the data points are negatively correlated. Figure 8 shows the results of fit analysis. The correlation-regression analysis of the data shows that there is inverse-linear relation between the attention provided and the cognition (i.e., the amplitude of P300 (measure of cognitive capacity) decreases with increase EBR (index of attention) and vice versa. The results show that the level of attention provoked to a stimulus provides a tool for measuring the underlying cognition process. Thus it also shows that this method of combining EBR and P300 amplitude can be used to predict with certainty the cognitive capacity of an individual in case of mild cognitive impairments which is difficult to be evaluated with conventional methods of prediction.

CONCLUSION

With the results obtained, correlation method can be used as new tool for the evaluation of cognitive impairment correlating the attention provided and the cognitive capacity.

APPENDIX

Appendix 1: Pearson's correlation coefficient chart

	2-tailed testing			1-tailed testing		
n	α = 0.01	α = 0.05	α = 0.1	α = 0.01	α = 0.05	α = 0.1
5	0.805	0.878	0.959	0.687	0.805	0.934
6	0.729	0.811	0.917	0.608	0.729	0.882
7	0.669	0.754	0.875	0.551	0.669	0.833
8	0.621	0.707	0.834	0.507	0.621	0.789
9	0.582	0.666	0.798	0.472	0.582	0.750
10	0.549	0.632	0.765	0.443	0.549	0.715
11	0.521	0.602	0.735	0.419	0.521	0.685
12	0.497	0.576	0.708	0.398	0.497	0.658
13	0.476	0.553	0.684	0.380	0.476	0.634
14	0.458	0.532	0.661	0.365	0.458	0.612
15	0.441	0.514	0.641	0.351	0.441	0.592
16	0.426	0.497	0.623	0.338	0.426	0.574
17	0.412	0.482	0.606	0.327	0.412	0.558
18	0.400	0.468	0.590	0.317	0.400	0.543
19	0.389	0.456	0.575	0.308	0.389	0.529
20	0.378	0.444	0.561	0.299	0.378	0.516
21	0.369	0.433	0.549	0.291	0.369	0.503
22	0.360	0.423	0.537	0.284	0.360	0.492
23	0.352	0.413	0.526	0.277	0.352	0.482
24	0.344	0.404	0.515	0.271	0.344	0.472
25	0.337	0.396	0.505	0.265	0.337	0.462
26	0.330	0.388	0.496	0.260	0.330	0.453
27	0.323	0.381	0.487	0.255	0.323	0.445
28	0.317	0.374	0.479	0.250	0.317	0.437
29	0.311	0.367	0.471	0.245	0.311	0.430
30	0.306	0.361	0.463	0.241	0.306	0.423
40	0.264	0.312	0.403	0.207	0.264	0.367
50	0.235	0.279	0.361	0.184	0.235	0.328
60	0.214	0.254	0.330	0.168	0.214	0.300
80	0.185	0.220	0.286	0.145	0.185	0.260
100	0.165	0.197	0.256	0.129	0.165	0.232
120	0.151	0.179	0.234	0.118	0.151	0.212
140	0.140	0.166	0.217	0.109	0.140	0.196
160	0.130	0.155	0.203	0.102	0.130	0.184
180	0.123	0.146	0.192	0.096	0.123	0.173
200	0.117	0.139	0.182	0.091	0.117	0.164
300	0.095	0.113	0.149	0.074	0.095	0.134
400	0.082	0.098	0.129	0.064	0.082	0.116
500	0.074	0.088	0.115	0.057	0.074	0.104

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