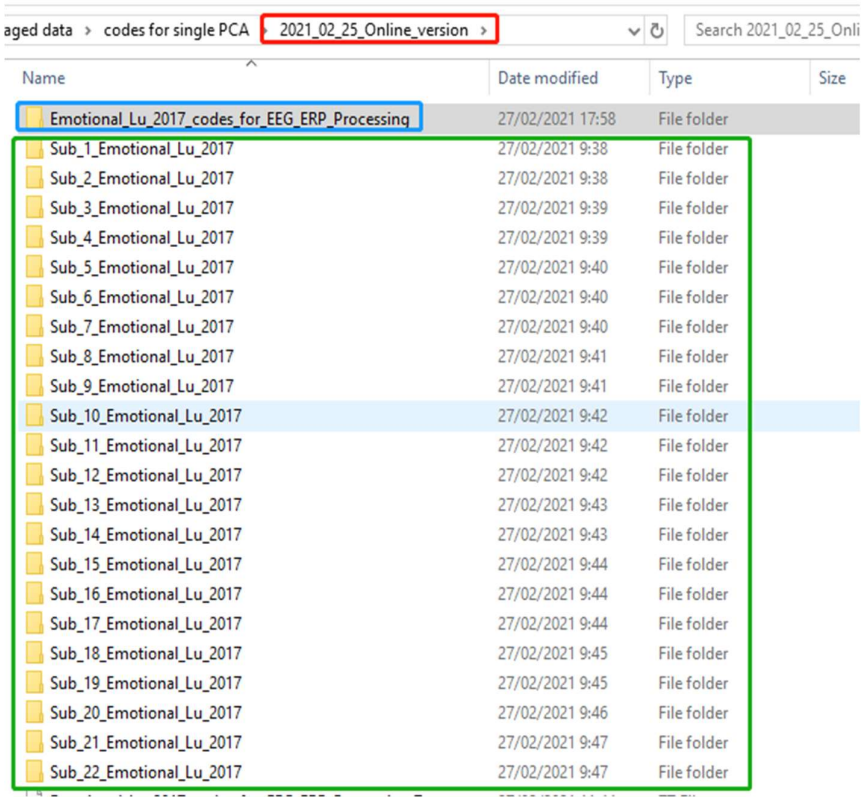
1. Tips before running the codes

(1). Citation:
When using this code, please cite the following articles:
(a). Guanghui Zhang, Xueyan Li, Yingzhi Lu, Timo Tiihonen, Zheng Chang, and Fengyu Cong. (2021). Single-trial-based Temporal Principal Component Analysis on Extracting Event-related Potentials of Interest for an Individual Subject. bioRxiv. DOI:10.1101/2021.03.10.434892
(b). Fengyu Cong, Yixiang Huang, Igor Kalyakin, Hong Li, Tiina Huttunen-Scott, Heikki Lyytinen, Tapani Ristaniemi, Frequency Response based Wavelet Decomposition to Extract Children's Mismatch Negativity Elicited by Uninterrupted Sound,Journal of Medical and Biological Engineering, 2012, 32(3): 205-214, DOI: 10.5405/jmbe.908
(c). Guanghui Zhang, Xueyan Li, and Fengyu Cong. Objective Extraction of Evoked Event-related Oscillation from Time-frequency Representation of Event-related Potentials. Neural Plasticity. DOI:10.1155/2020/8841354
(d). Lu, Y., Luo, Y., Lei, Y., Jaquess, K. J., Zhou, C., & Li, H. (2016). Decomposing valence intensity effects in disgusting and fearful stimuli: an event-related potential study. Social neuroscience, 11(6), 618-626. doi:https://doi.org/10.1080/17470919.2015.1120238

(2). Please install EEGLAB (http://sccn.ucsd.edu/eeglab/) and ERPLAB.
(3). If you want to successful run those codes (marked by blue color), please put the cods and the EEG datasets (marked by green color) in the same folder (marked by red color), as show in the following figure:



(4). The data for each condition and each subject should be saved separately and preprocessed (e.g., filtering, ICA, segmentation, baseline correction). Noted that the data of trials are not averaged.

(5) Information for demo data (http://zhangg.net/publications/): (a) Within-subject two-factor designed experiment (Valence and Negative-category: 3 [Moderate, Extreme, Neutral]* 2[Disgusting, Fear]; 20 datasets for 20 subjects are used). (b) N2 is the ERP of interest (190-290ms; FCz, FC3, FC4, Cz, C3, and C4 electrodes). (c) fs: 1000ms; Epoch: -200:900ms.

2 Fourth techniques are used to extract N2 of interest

Before using the first three techniques ('WF','aPCA', and 'sPCA') to extract N2, please firstly handle 'm_0_Filter_data_by_wavelet_filter.m' so that the preprocessed single-trial EEG data are filtered by wavelet filter.

2.1 'WF'

N2 is quantified using conventional time-domain analysis at group analysis for the filtered data; Please run 'm_Conventional_time_domain_analysis_for_filtered_data' to obtain grand waveforms at specific electrodes, topographies, and similarities of topographies across all subject, statistical analysis results, and mean/peak amplitudes of all subjects.

PS: The users need to modify the codes based on their datasets if the users want to use this demo codes to analyze their own datasets.

2.2 'aPCA'

N2 is measured from the averaged ERP data across single trials of all subject simultaneously by using temporal principal component analysis and Promax rotation. Please 'm_Averaged_Group_PCA_Rotation__Projection_filtered_data'.

PS: The users need to modify the codes based on their datasets if the users want to use this demo codes to analyze their own datasets.

2.3 'sPCA'

N2 is measured from the single-trial EEG data of all subject simultaneously by using temporal principal component analysis and Promax rotation.

Please run 'm_Single_trials_Group_PCA_Rotation_Projection_filtered_data'.

PS: The users need to modify the codes based on their datasets if the users want to use this demo codes to analyze their own datasets.

2.4 'iPCA'

ERPs of interest are extracted from the single-trial EEG of individual subject using temporal principal component analysis and Promax rotation.

2.4.1 Extracting ERPs of interest from single-trial EEG of individual subject

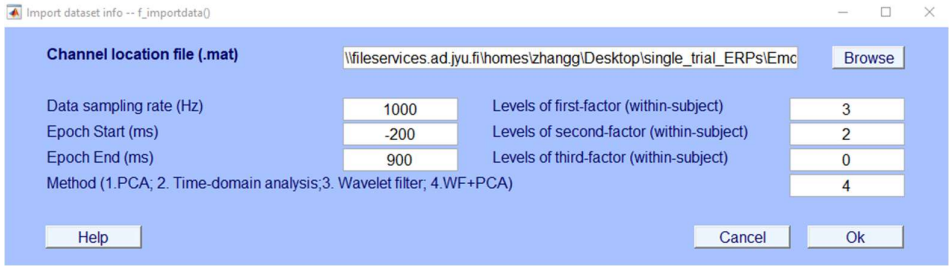
Please run 'm_1_0_Individual_PCA_Rotation_extract_component' to obtain the ERPs of interest from single-trial EEG data of an individual subject.

PS: Because ERPs of interest are extracted from individual subject, the data types are described as the following: one, two, and three factor (Similar to within-subject design). Data format: '.set','erp', and 'vhdr'.

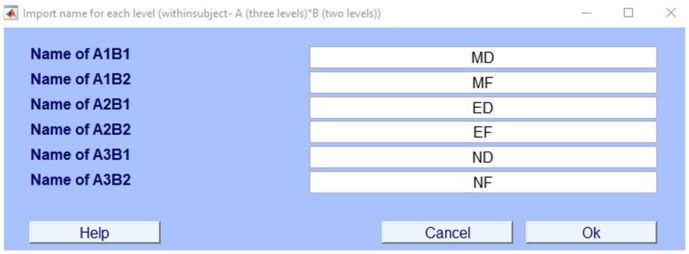
PS: This function can be used to plot the waveforms and topographies (the data of trials are averaged automatically) for different conditions by either using conventional time-domain analysis or wavelet filter.

Here, WF+ PCA is taken as an example to describe how to use this code.

Step 1: Adding the basic parameters for the analyzed individual subject's data. Two different PCA can be used to extract ERPs of interest (1. PCA (for the original data) and 4.WF +PCA (for the filter data by wavelet filter)). The second and third methods are used to plot waveforms and topographies for the original and wavelet filter filtered datasets.

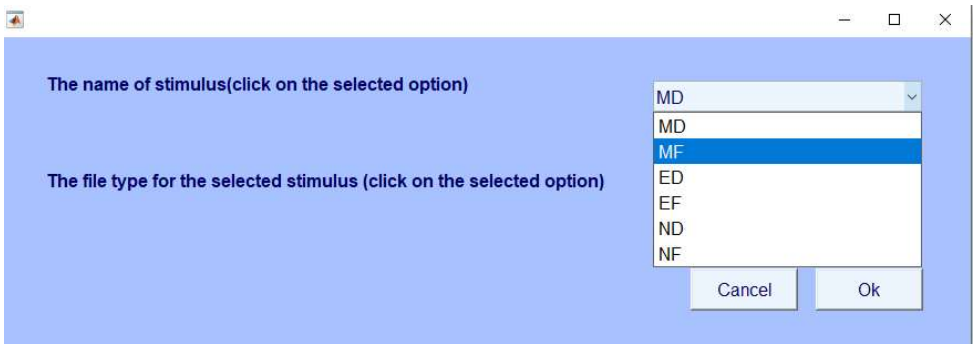


Step 2: Giving the names for different experimental condition.

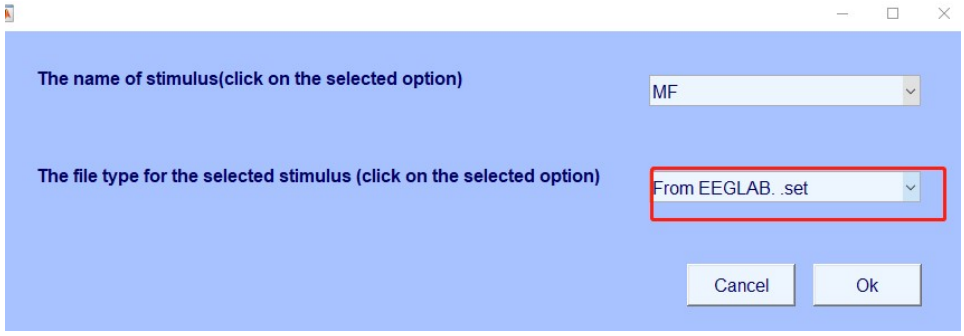


Step 3: Importing the data for different conditions, separately.

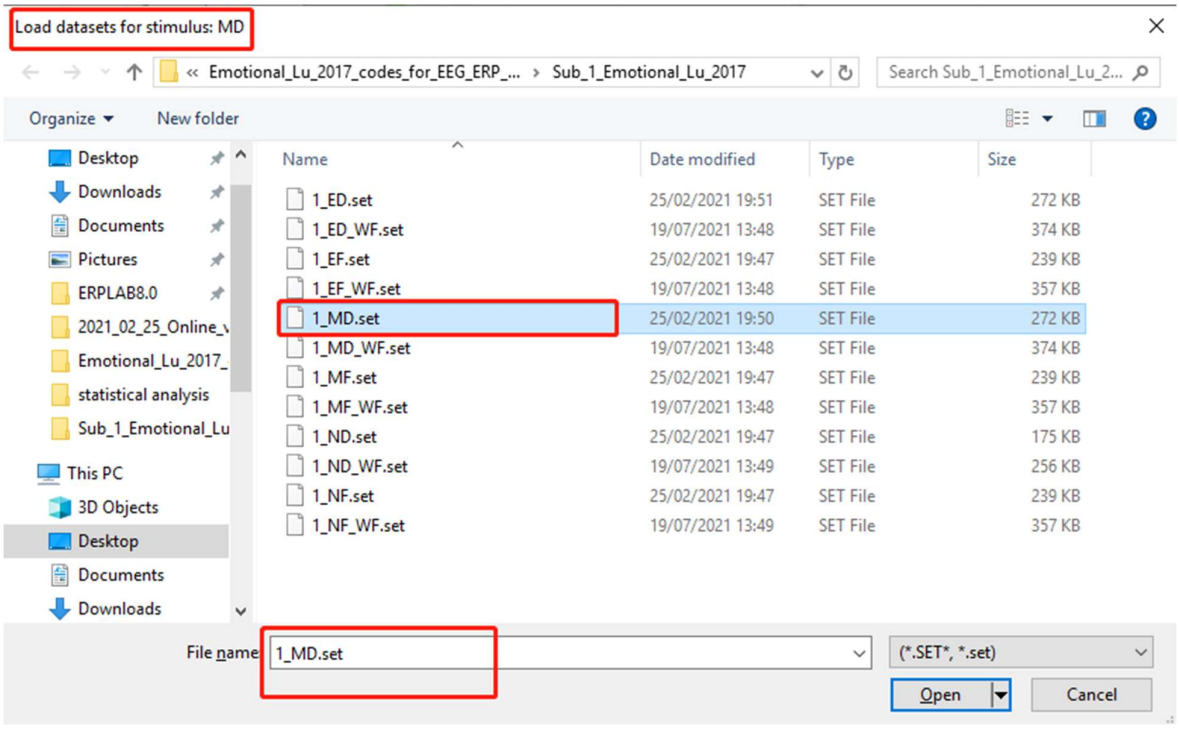
(a) Selecting the name for one condition (in order).



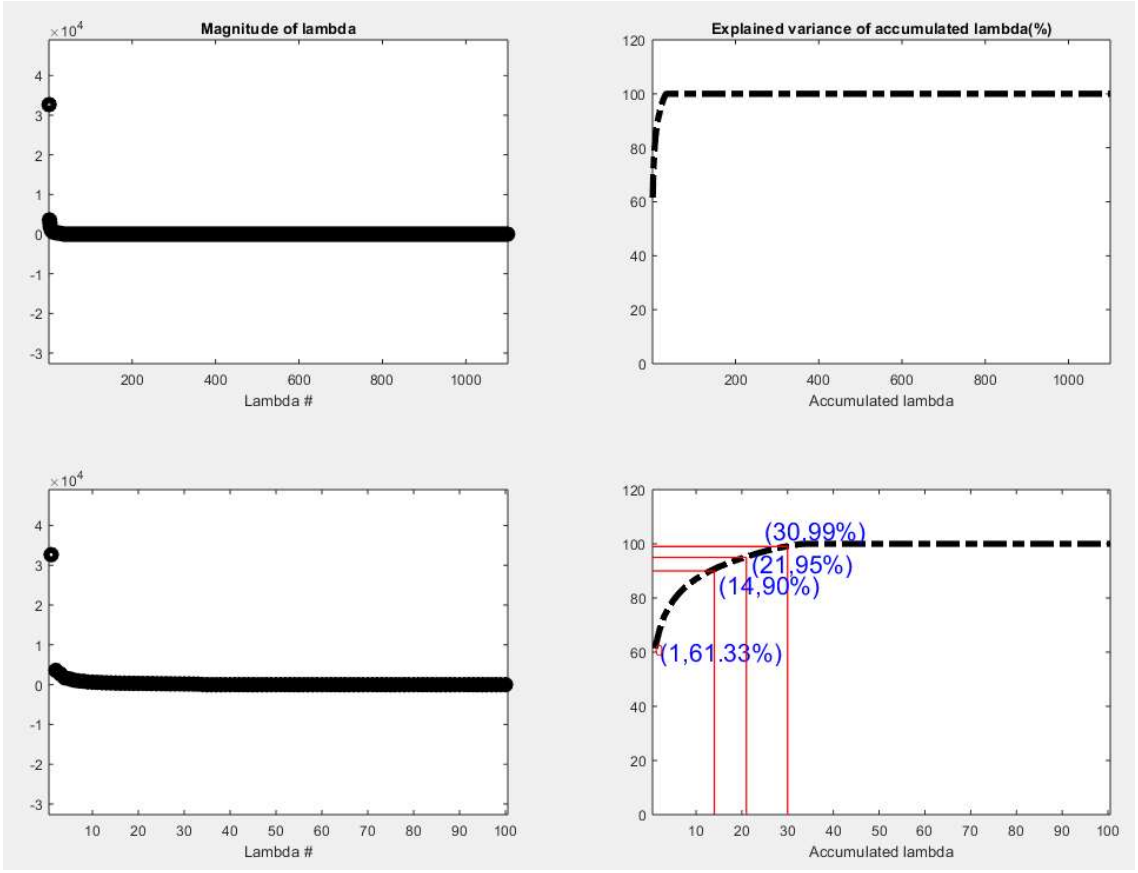
(b). Selecting data format (.set, .vhdr, or .erp).

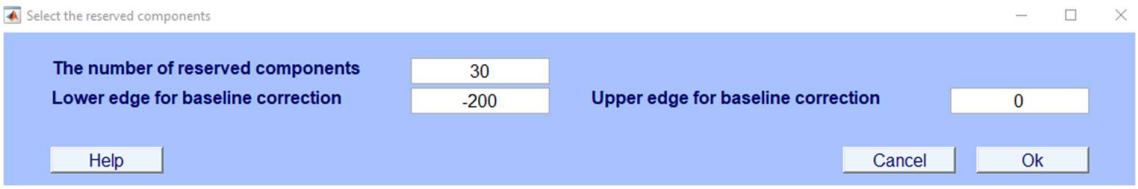


(c). Selecting data of one condition for one subject.

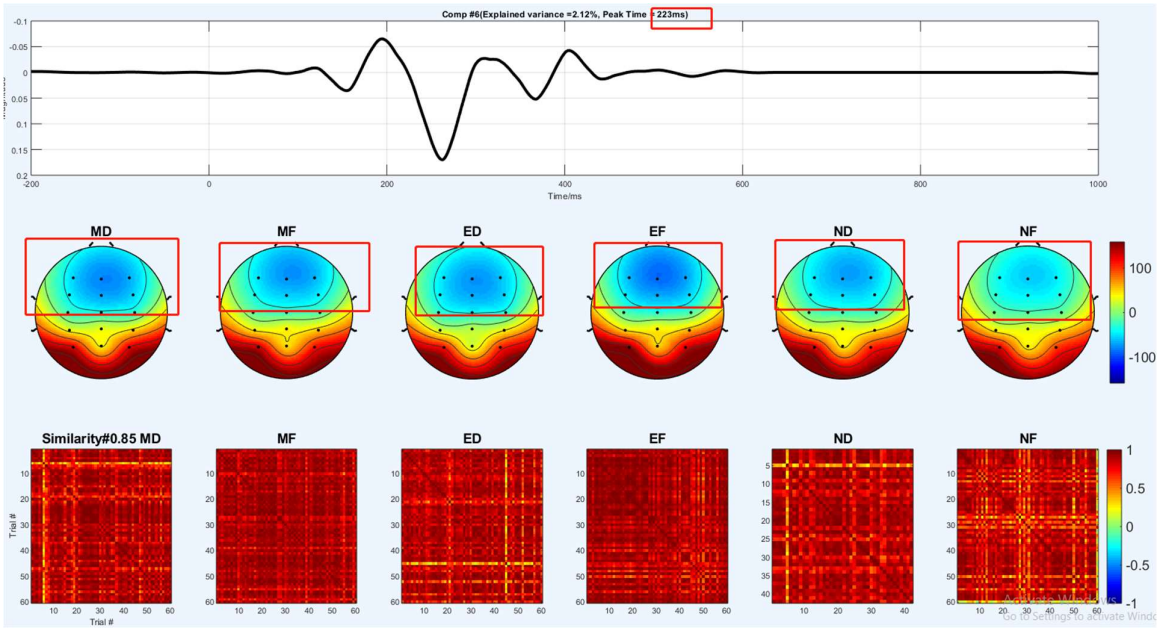


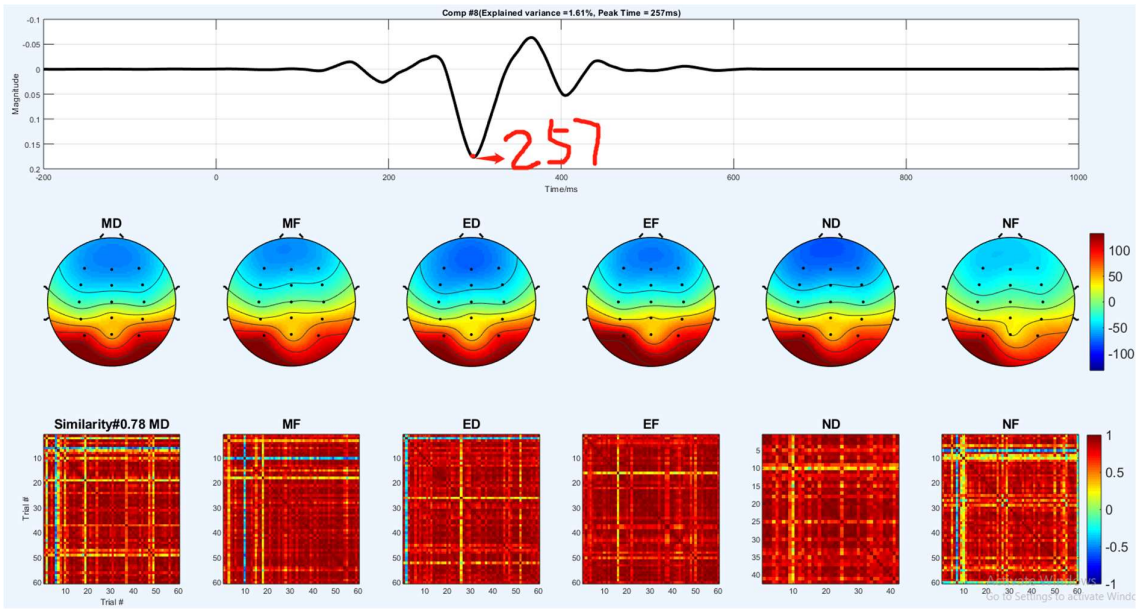
Step 4: Selecting the number of reserved components based on the cumulative explained variance method and adding the parameters for baseline correction.





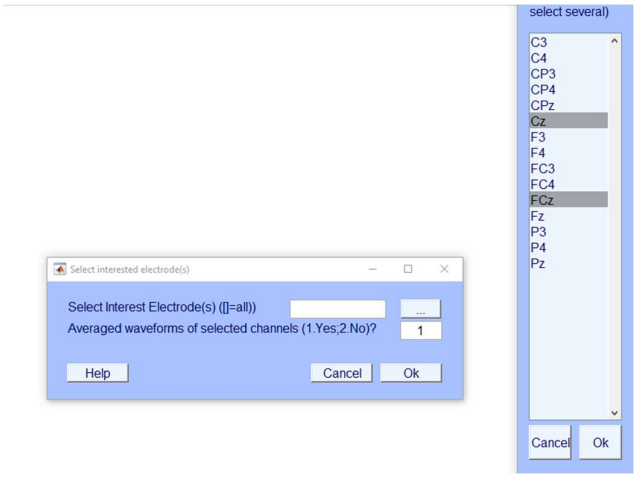
Step 5: Selecting components of interest (rotated PCs) based on the properties of analyzed ERP in temporal (i.e., waveform, latency) and spatial (i.e., topography) domains. Here, 6th and 8th are selected because their temporal and spatial properties conform to those of N2.

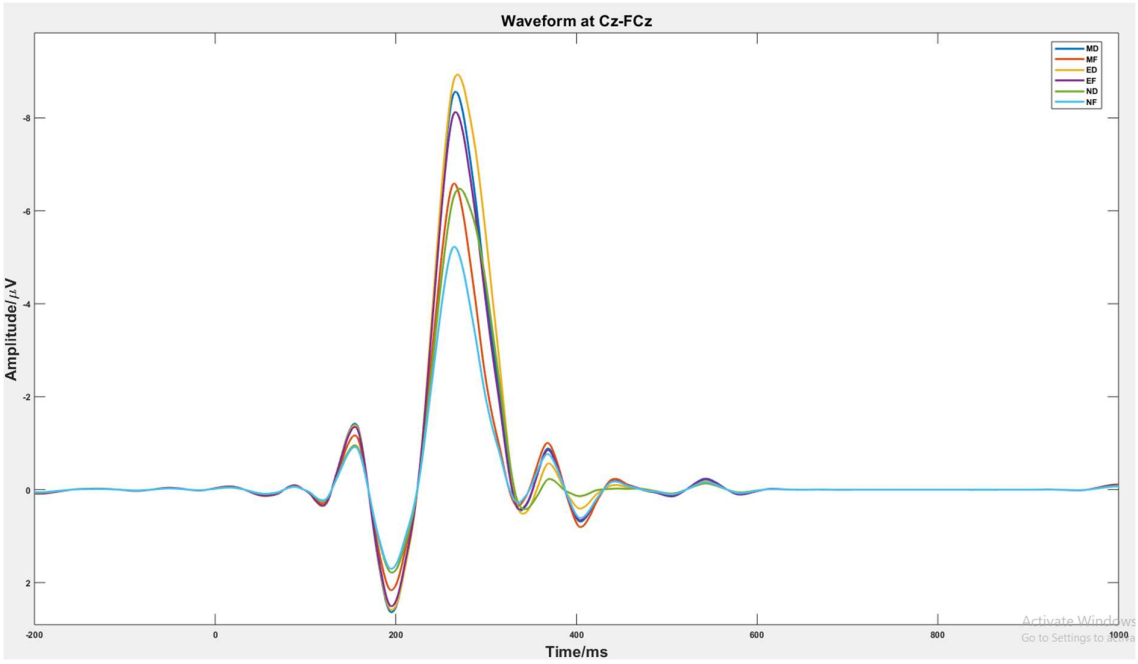




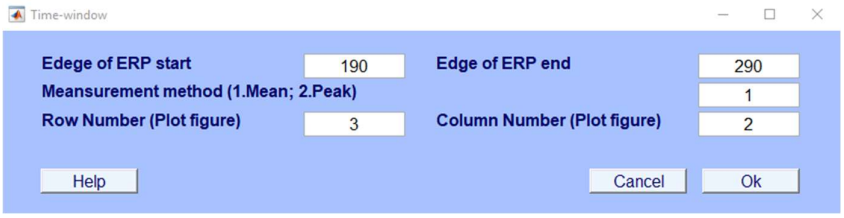
Step 6: Plotting the averaged waveforms at the selected electrodes. Note: (a). Single trial data are averaged under each condition. (b). The waveforms for different channels

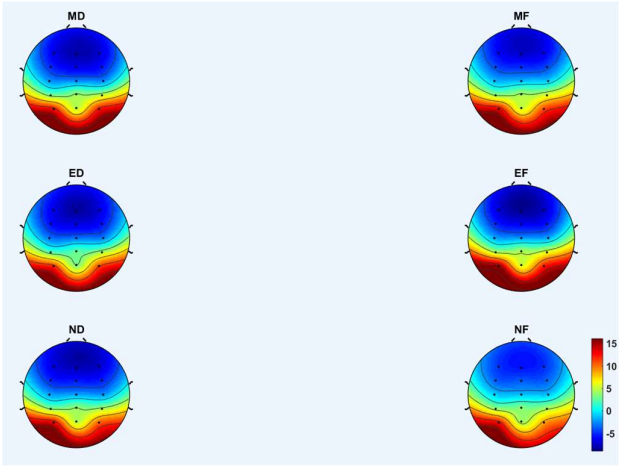
can be averaged (Option '1. Yes') or they are allowed to plot one by one (Option '2. No').



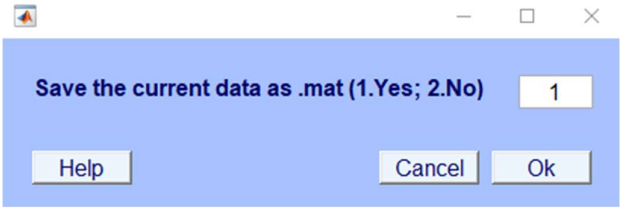


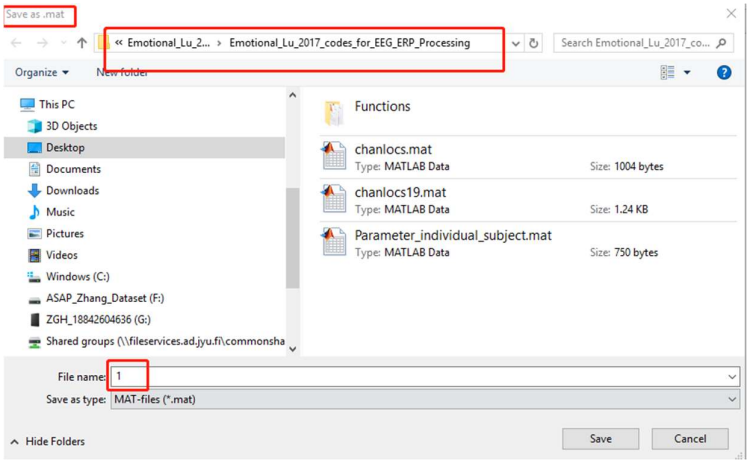
Step 7: Plotting topographies for different conditions. (a). Defining the time-window for ERP of interest. (b). Choosing the measurement method to calculate the amplitudes of ERP for different conditions. (c) . Defining the numbers of row and column to define the plotted format of topographies.





Step 8: Saving the current data (the projected data for extraction of ERP by using PCA from individual subject's data) to a specific folder as '.mat' format and giving a name to this data (<u>the size is channels × samples × stimuli</u>).





Tab.1 The number of reserved components ('R'), selected components ('K'), and the explained variance ('EV', %) of each selected component for different subjects (demo datasets).

	Sub.1	Sub.2	Sub.3	Sub.4	Sub.5	Sub.6	Sub.7
R	30	31	32	29	30	29	32
K	6,8	6,11,12	7,8,10	1,10,16	3,9,11	11,12	10,12,14,32
EV	2.12,1.61	2.8,1.58,1.52	3.02,2.74,2.24	54.6,1.43,0.76	7.12,2.39,1.88	1.16,1.03	1.76,1.59,1.26,0.52
	Sub.8	Sub.9	Sub.10	Sub.11	Sub.12	Sub.13	Sub.14
R	30	31	30	30	28	29	28
K	4,7,9	10,12,31	12,27	1,12,14	3,9,11	9,12	12,14,15
EV	4.36,3.06,2.05	1.6,1.48,0.61	1.68,0.37	37.88,1.45,1.01	5.61,1.43,1.21	2.4,1.68	1.21,0.96,0.9
	Sub.15	Sub.16	Sub.17	Sub.18	Sub.19	Sub.20	
R	31	29	32	33	30	31	
K	5,14,17	2,13,18	6,15	7,19	2,8,11	1,22,25,31	
EV	3.44,1.18,0.95	10.8,0.88,0.54	3.23,1.81	3.31,0.97	9.13,1.98,1.64	47.02,0.8,0.72,0.56	

2.4.2 Group analysis for the data obtained from m_1_0

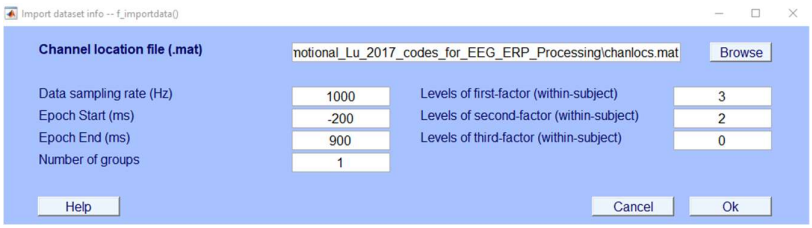
Running 'm_1_1_Individual_PCA_Grand_waveform analysis_All_subjects' to plot the grand averaged waveforms, topographies, and similarities of topographies over all subjects, respectively. The statistical analysis results obtained by ANOVA are also given.

(1) Data type: Within-subject [one, two, and three factors] and between-subject analysis [two and three factors] designed experiments.

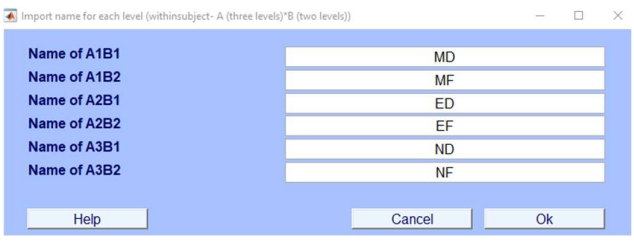
(2) Functions: (a). Plot waveforms at the typical electrodes; (b). Plot grand averaged topographies within predefined time window; (c). Statistical analysis results by using ANOVA; (d). Export the data within the predefined time window at the selected electrodes to excel files.

PS: The users do not need to modify the codes.

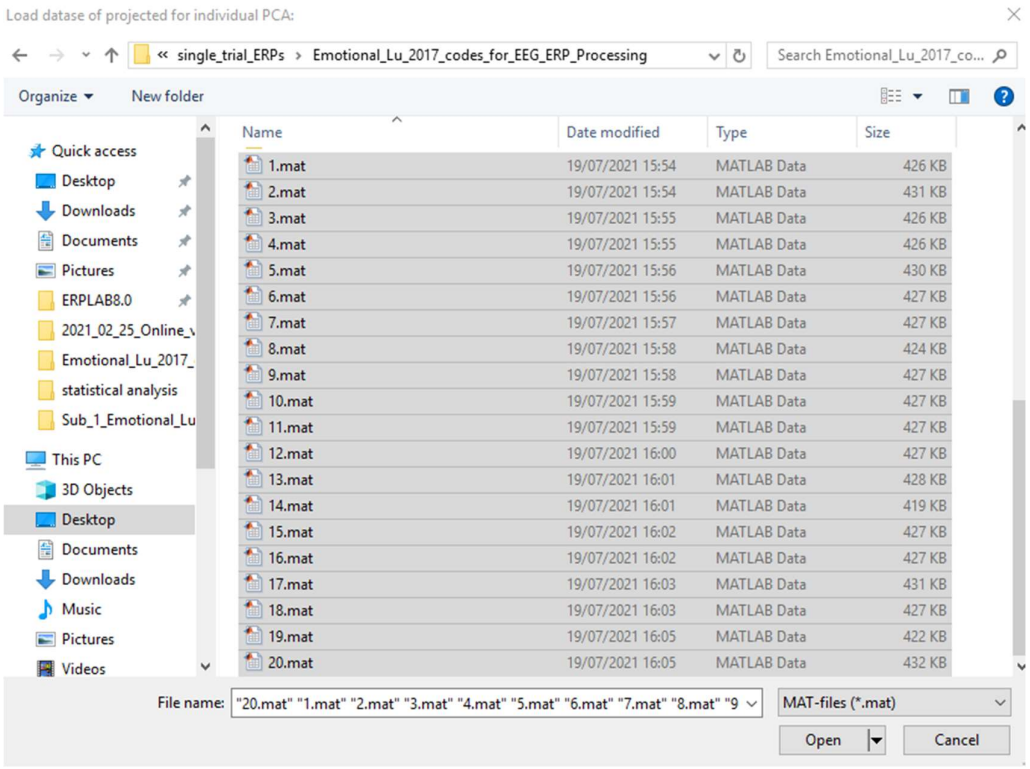
Step 1: Adding the basic parameters for the analyzed individual subject's data.



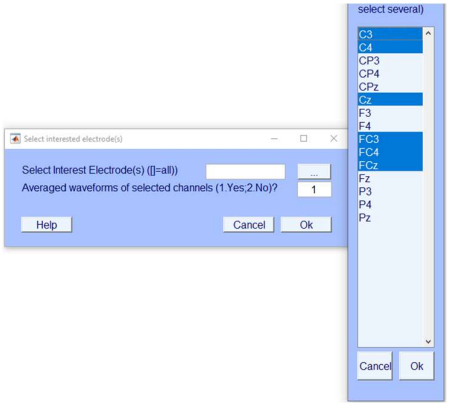
Step 2: Giving the names for different experimental conditions.

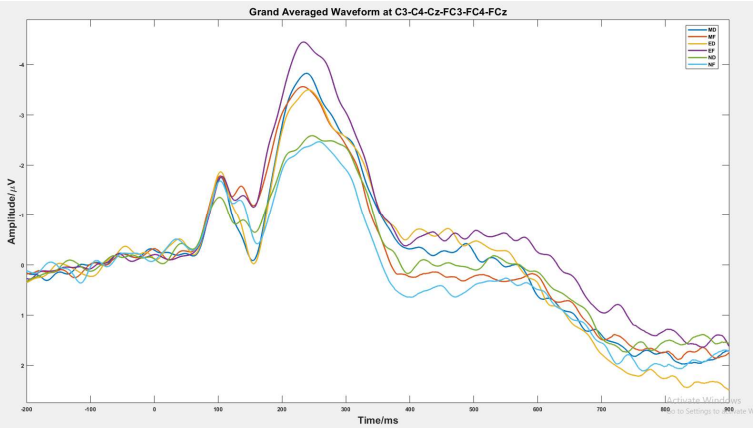


Step 3: Importing the datasets for all subjects obtained from 'm_1_0' (the back-projection of the selected components of interest when using temporal PCA plus Promax rotation to extract ERPs from single-trial EEG data of individual subject).

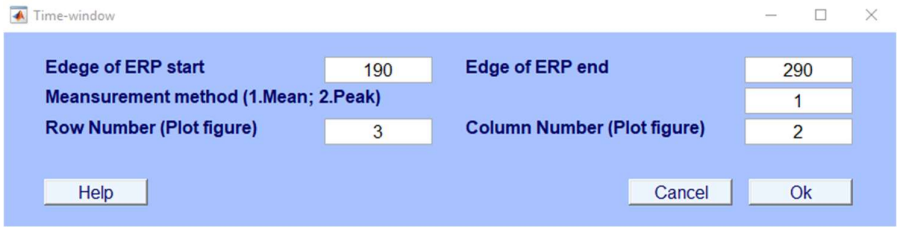


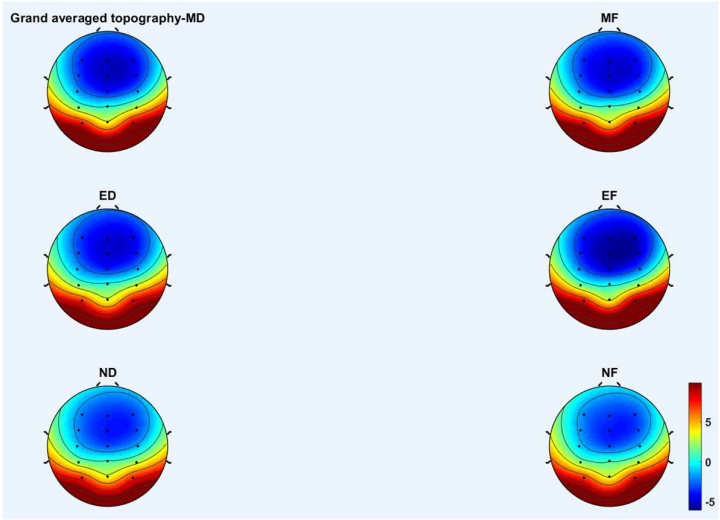
Step 4: Plotting the grand averaged waveforms at the selected electrodes. Note: (a). The data are averaged over all subjects under each condition. (b). The waveforms for different channels can be averaged (Option '1. Yes') or they are allowed to plot one by one (Option '2. No').

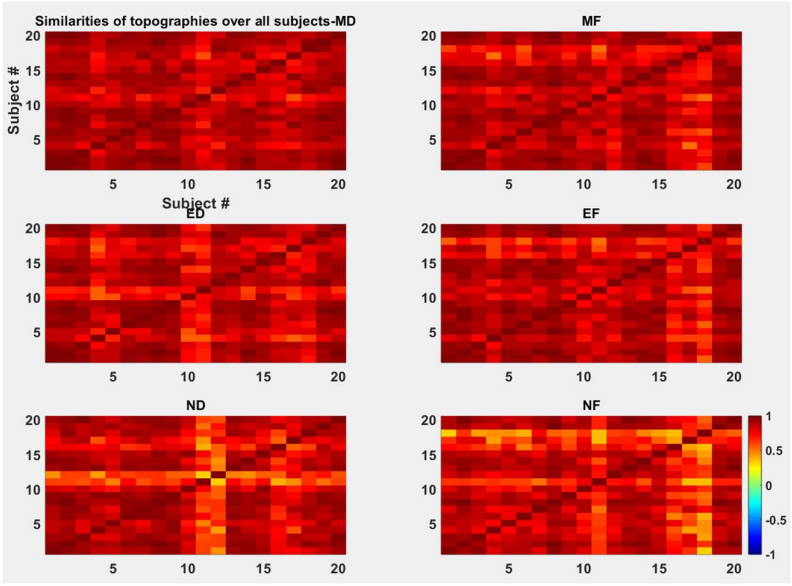




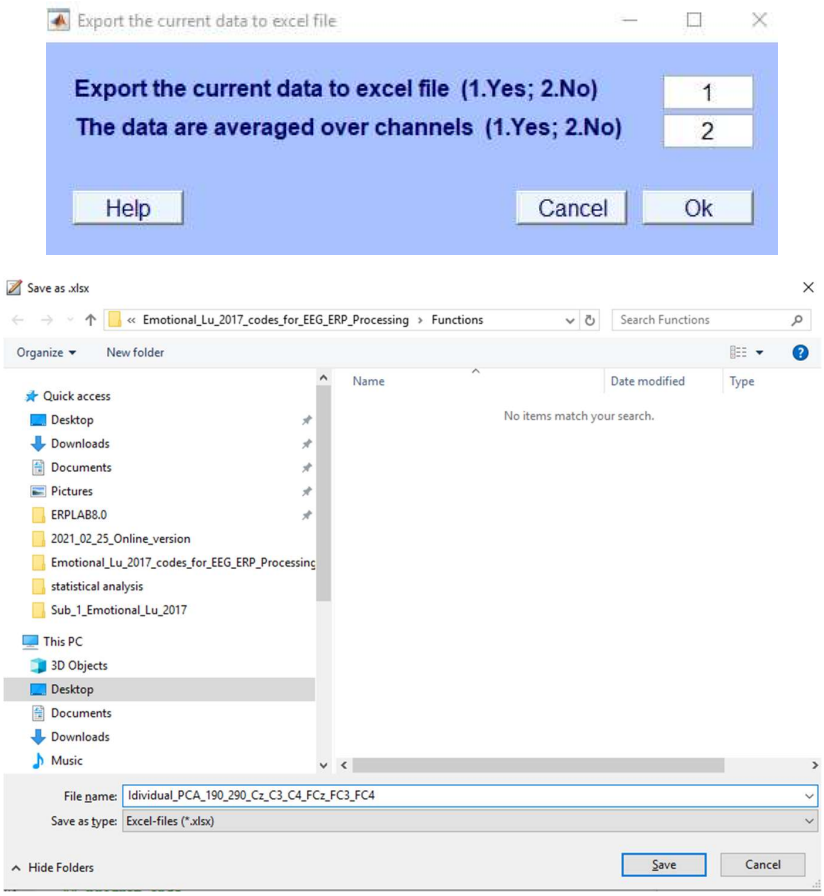
Step 5: Plotting topographies and similarities of topographies among all subjects for different conditions. (a). Defining a time window for ERP of interest. (b). Choosing the measurement method to calculate the amplitudes of ERP for different conditions. (c). Giving the numbers of row and column to define the plotted format of topographies.







Step 6: Exporting the current data to excel file for further analysis (e.g., using SPSS). Noted that the data for different channels can be averaged (Option '1. Yes') or they are allowed to export (Option '1. No').



	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ
1	C3-ED	C3-EF	C3-ND	C3-NF	C4-MD	C4-MF	C4-ED	C4-EF	C4-ND	C4-NF	Cz-MD	Cz-MF	Cz-ED	Cz-EF	Cz-ND	Cz-NF	FC3-MD	FC3-MF	FC3-ED	FC3-EF	FC3-ND	FC3-NF	FC4-MD	FC4-MF	FC4-ED	FC4-EF	FC4-ND	FC4-NF	FCz-MD	FCz-MF	FCz-ED	FCz-EF	FCz-ND	FCz-NF
2	-4.44286	-4.22256	-3.76731	-2.93809	-2.99912	-1.39883	-2.50192	-2.57936	-2.37532	-1.54313	-3.50189	-2.98878	-3.60737	-4.48342	-2.73944	-2.49055	-7.24768	-6.78184	-8.10503	-8.86504	-7.92853	-6.9132	-6.87983	-5.87299	-6.40777	-7.63135	-6.22673	-4.9111	-8.63014	-7.60203	-8.70556	-9.86984	-7.56825	-6.43612
3	-3.40224	-5.37803	-0.38844	-2.79539	-0.7041	-0.7535	-0.12039	-3.83705	0.915998	-1.18642	-4.70929	-5.53226	-4.09525	-7.89507	-2.47825	-5.08274	-5.52003	-5.90009	-5.77277	-6.80143	-1.47626	-3.58762	-5.42341	-5.33425	-4.6737	-8.04669	-2.33235	-4.71383	-7.44723	-7.36931	-7.16003	-9.3482	-6.41252	-6.48105
4	-5.26661	-6.08253	-7.08571	-6.39212	-5.2582	-4.65094	-5.66807	-5.15771	-6.21332	-4.20281	-5.67365	-4.75474	-6.01681	-5.1948	-6.02436	-4.66483	-6.22548	-6.32859	-6.09682	-6.43068	-6.80325	-6.41081	-6.44906	-6.08995	-7.43826	-7.14756	-7.21839	-5.86487	-6.2991	-5.81972	-6.84384	-6.09696	-6.55922	-5.58624
5	-1.29246	-1.51749	1.993544	-1.06896	-0.58976	-1.0621	-0.41408	-2.42789	-0.89054	-1.52356	-5.46448	-5.24333	-5.10575	-7.13774	-5.00538	-4.91752	-1.29921	-0.34601	-3.53403	-2.83006	-0.0709	-2.50812	-3.89167	-4.57142	-4.03428	-6.70028	-5.15797	-5.12353	-5.9258	-5.72779	-5.84887	-7.64411	-5.75825	-5.44771
6	0.437738	-0.7839	1.638773	1.659371	-1.10102	0.064611	0.689898	0.393356	1.033088	1.385986	-4.86927	-3.76858	-2.17053	-3.91645	-1.16416	-0.64765	-3.56715	-1.46048	-0.61361	-2.73897	0.510144	0.462741	-3.69978	-2.59257	-1.04715	-2.96736	-0.12527	0.05324	-7.94635	-7.04511	-4.94654	-6.93787	-3.20562	-2.91425
7	0.661063	-1.87566	-0.72525	0.529658	0.631749	1.522117	1.217793	-0.64053	0.275835	2.65534	-4.09787	-2.19468	-2.25251	-3.9147	-3.63417	-1.89873	-2.52341	-5.69037	-1.8115	-6.71177	-2.53622	-2.69852	-2.15949	-1.51126	-1.08167	-3.85325	-1.60543	0.153312	-5.92443	-6.16402	-3.33981	-6.00728	-6.34711	-3.24907
8	-2.22733	-2.35742	-1.51939	-1.00569	-0.28447	-1.05545	-0.45517	-0.21515	-0.08002	-0.85066	-4.18015	-4.55711	-3.65546	-4.63993	-3.2434	-4.17289	-2.36055	-1.08776	-3.04432	-1.81619	-1.3556	0.840382	-2.39184	-3.6472	-3.21296	-3.17901	-2.70104	-2.43166	-4.31063	-5.18236	-5.19835	-5.60932	-3.68404	-3.42038
9	-3.87436	-4.78334	-2.36514	-2.52893	-4.21321	-4.89246	-3.83939	-6.08081	-3.39477	-4.11793	-6.21019	-7.45742	-6.28963	-8.48465	-5.00409	-5.99619	-4.99579	-6.66296	-5.72809	-7.43021	-4.34059	-4.99649	-6.2387	-7.59876	-6.14699	-9.19488	-5.02706	-6.13103	-7.51943	-9.37396	-8.02666	-10.758	-6.18511	-7.63025
10	1.111684	3.408629	2.659156	3.672461	3.323328	3.47599	2.955059	3.965897	2.312717	4.552541	-1.67235	-2.16658	-2.67105	-1.14383	-1.1784	-0.67947	-0.45184	0.701562	-0.25879	1.387801	0.641118	1.979766	-0.21461	0.612422	-0.38309	0.613422	-0.67041	2.401224	-2.22155	-2.43915	-3.37903	-1.35414	-1.85262	-0.90644
11	-1.77585	-1.39411	-1.95138	-2.39477	-5.41431	-4.4235	-6.65994	-5.51293	-6.12466	-4.44569	-3.7368	-2.49575	-2.88571	-2.92877	-1.56389	-3.46064	-3.83308	-2.85632	-2.6122	-1.5752	-4.57321	-2.05491	-7.1879	-5.93981	-6.75828	-5.991	-6.903	-5.32684	-3.48104	-2.26253	-2.3755	-2.74629	-3.44754	-3.05224
12	-0.71665	-1.92348	-2.57238	-0.40904	-2.0565	-1.39792	-1.44848	-2.66237	-2.0158	-1.09103	-3.38205	-2.74864	-3.5805	-3.56906	-4.11232	-1.32704	-2.06477	-4.2395	-1.08679	-3.17442	-2.5135	-0.0882	-2.23613	-2.78931	-0.9873	-3.76144	-1.11352	-0.87021	-2.53412	-3.40971	-3.00683	-3.70744	-2.5794	-0.85719
13	2.987431	1.870042	1.906797	2.208542	1.731424	-1.73223	1.766545	-1.01677	0.236344	-0.50763	-1.31072	-5.24606	-0.68564	-5.8985	-1.79603	-3.09648	1.77648	-0.44796	2.193249	-0.51283	1.48714	0.005036	0.364971	-1.78388	-0.74283	-3.16386	0.682891	-1.35198	-1.47185	-1.66743	-1.32481	-1.36625	-1.69238	-0.97797
14	-0.47585	-2.92261	-0.98245	-1.71807	-2.20699	-3.64391	-1.53017	-3.14506	-0.19697	-1.72128	-4.71748	-7.38438	-4.33155	-7.02988	-3.16122	-5.09875	-1.38916	-3.04461	-0.17176	-2.64548	-1.56837	-1.73252	-4.18711	-6.01777	-3.44603	-5.92504	-2.81394	-4.53748	-4.12162	-7.60115	-3.43553	-7.30722	-3.81567	-5.7377
15	-8.08217	-9.10192	-6.25806	-7.42433	-4.80631	-4.05538	-4.41994	-4.44078	-2.53205	-3.34653	-11.8168	-11.0427	-11.1191	-11.9199	-8.27013	-10.0823	-12.7096	-12.7926	-11.8634	-13.4468	-9.31987	-10.9082	-9.69455	-9.95801	-9.07687	-10.5087	-6.84825	-9.11035	-13.1345	-12.5464	-12.4133	-13.2102	-9.21471	-11.3779
16	1.009757	1.629627	1.310381	2.619632	-0.9426	1.857795	-0.96369	0.967163	-0.07414	1.489656	-0.52974	1.19711	-0.64107	-0.65367	0.485543	1.018444	-0.90571	0.503354	-1.6256	-0.76732	-0.52241	2.008268	-0.85051	0.33768	-2.0304	-0.28831	-1.13948	0.592987	-1.11864	0.424866	-1.59727	-1.17683	-0.25676	0.481403
17	-0.63951	-0.4385	0.924719	1.002722	-4.47588	-3.86189	-5.85246	-5.9632	-4.48661	-4.64325	-1.27285	-1.41877	-2.33919	-3.19438	-1.22385	-0.71108	-1.54461	-1.3969	-2.88831	-1.30558	-0.89391	-0.52131	-6.71539	-5.63321	-8.06601	-7.42985	-6.06695	-6.31794	-3.734	-3.4546	-4.47056	-4.23549	-3.08804	-2.57716
18	-2.08714	-2.35745	-1.14348	-2.14194	0.260857	-2.42486	-0.48207	-1.04449	0.347172	-0.19594	-1.42205	-1.93589	-2.07366	-2.50026	-0.87257	-1.55994	-2.44016	-1.45925	-1.68326	-1.6235	-0.36555	-1.00644	-1.1775	-2.17203	-0.87319	-1.40035	-0.13032	-0.20788	-2.82636	-2.16351	-2.66269	-2.85455	-1.3249	-1.54102
19	0.620588	0.730602	1.472738	1.554815	-0.46945	-0.54797	-1.35746	-1.29194	1.528926	1.440344	-3.11442	-3.18951	-2.73854	-4.48378	-1.09602	-2.66398	-0.1973	0.920496	0.394746	0.887635	0.798445	2.116338	-2.13943	-1.93429	-2.77571	-2.61887	-0.10401	-0.61311	-3.84696	-3.40437	-3.43315	-4.59488	-1.77139	-2.69481
20	2.002072	0.703827	2.314334	2.533493	-2.54728	-2.86073	-2.44561	-4.13703	-2.11953	-1.53916	-4.7687	-3.39971	-4.32137	-5.40812	-3.02693	-3.01798	-1.56881	-1.2253	-1.1678	-2.49077	-0.15834	-0.06509	-4.62236	-4.29373	-4.6673	-5.86246	-3.55816	-2.85159	-5.70632	-4.30593	-5.18947	-5.97408	-3.64138	-3.51246
21	-2.97666	-3.29638	-1.92385	-0.44255	-1.6865	-0.57808	-0.59272	-1.65857	-0.74595	0.427383	-3.7541	-2.0767	-3.14669	-3.68575	-2.08081	-0.94083	-3.59502	-1.73201	-2.81806	-3.5979	-0.86623	0.25861	-5.7756	-3.97681	-4.63683	-5.50825	-3.77534	-2.27501	-4.05661	-2.26686	-3.40664	-3.93679	-2.22404	-1.05867
22																																		