GX Dataset - Comparing F30 and M30 Stimulation

Overview

The goal of this analysis is to examine and compare behavioral and physiological outcomes from Experiment 2 of the GX dataset.

The GX dataset explored the use of various tES types on enhancing vigilance and attention.

The dataset included behavioral and neurophysiological outcomes quantifying stimulation related changes.

In these analyses we focus on outcomes from:

- Karolinska Sleepiness Scale (KSS)
- Compensatory Tracking Task (CTT deviation)
- Electrocardiographic monitoring (ECG - RMSSD and LF/HF ratio)
- Electroencephalographic (EEG – PSD Frequency bandpower ratios)

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Background Info

What is the GX dataset?

A dataset combining high-density electroencephalography (EEG) with physiological and continuous behavioral metrics during transcranial electrical stimulation (tES; including tDCS and tACS). Data includes within participant application of nine High-Definition tES (HD-tES) types targeted three brain regions (frontal, motor, parietal) with three waveforms (DC, 5Hz, 30Hz), with more than 783 total stimulation trials over 62 sessions with EEG, physiological (ECG or EKG, EOG), and continuous behavioral vigilance/alertness metrics.

The dataset data descriptor can be found here:

- Gebodh, N., Esmaeilpour, Z., Datta, A. et al. Dataset of concurrent EEG, ECG, and behavior with multiple doses of transcranial electrical stimulation. Nature Sci Data 8, 274 (2021). https://doi.org/10.1038/s41597-021-01046-y

Where can I find the GX dataset and Code?

You can access the GX dataset in multiple formats.

- Raw EEG, ECG, EOG data in `.cnt` formant
- Raw EEG, ECG, EOG data formated to comply with BIDS standard where data are in `.set` format (EEGlab)
- Raw downsampled EEG, ECG, EOG data (1k Hz) in `.mat` format for Experiment 1 and Experiment 2 (works with MATLAB and Python)
- Raw behavioral CTT data `.csv` format
- Questionnaire data in `.xlsx` format

The main code repository contains processing scripts and examples of how to use the GX dataset:

- https://github.com/ngebodh/GX_tES_EEG_Physio_Behavior

Data Used Here

The data used here were extracted from Experiment 2 of the GX dataset.

EEG and ECG data were minimally preprocessed and measures extracted using the YASA and Systole libraries in Python.

For the EEG we extract PSD bandpower ratios and for the ECG we extract time (RMSSD) and frequency (LF/HF ratio) heart rate variability metrics.

The following data files are used within this code:

- `GX_KKS_Exp2.xlsx` - This contains the KSS data for F30 and M30, pre and post intervention
- `HRV_Perf_mean.csv` - This contains the CTT deviation from during to pre stimulation
- `HRV_RMSSD.csv` - This contains the RMSSD data from during to pre stimulation
- `HRV_lf_hf_ratio.csv` - This contains the LF/HF ratio data from during to pre stimulation
- `EEG_stats_Allfeats.csv` - This contains channel-wise EEG data for PSD band power changes as well as CTT deviation data (Post-Pre)

Note:

- The data from the HRV analysis only computes DURING - PRE Stimulation
- The data from the EEG analysis only computes POST - PRE Stimulation.
- The CTT measure that comes from the HRV is DURING-PRE
- The CTT measure that comes from the EEG is POST- PRE

Required Files

To run this file you will need the following helper files:

- helper_importfile_GX_KSS_Exp2.p - imports KSS scores
- helper_GX_PlottingOutcomes_Fig_Stats.p - runs the stats and plots figures
- fdr_bh.m - computes the BH correction to the p-values. Can be downloaded here.

General Set-up

Clear residuals

```
%Set code parameters
SveAllpics=1; %Save figures 0-No, 1-Yes
closefigs =0; %Close figures after saving 0-No, 1-Yes
export_date = '04182024';%Folder name with date code was run
pathsave = 'Results\'; %Folder to hold plots and stats outputs
sub_folder_name = ['FigOutput_' export_date];
warning ('off','all');
```

Folder Set-up

```
%Create folders for results and figures
```

```
prefix = strcat(pathsave);

    if SveAllpics==1 %1-Save output pics, 0-Don'd save output pics

        existance=exist(strcat(pathsave,sub_folder_name));
        if existance==0
            [s,m,mm]=mkdir(pathsave,sub_folder_name);
            prefix = strcat(pathsave,sub_folder_name,'\');
        else
        %Delete existing files
        dat_type_delete = {'fig', 'png', 'pdf', 'eps','txt'};
        for item_in =1:numel(dat_type_delete)
            delete([pathsave sub_folder_name '\*.' dat_type_delete{item_in}]);
        end
            prefix = strcat(pathsave,sub_folder_name,'\');
        end
    end
```

Set Up Stats Holder

```
%Collect all stats outcomes
all_p_values={};
Table_p_val={};
stats_results ={};
```

Statistics

All data were tested for adherence to normality with the Anderson-Darling's test (`adtest` function).

A two-tailed paired t-test (`ttest` function) or Wilcoxon signed rank test (*`signrank`* function) was conducted under the null hypothesis that the difference between groups came from a normal distribution with unknown variances at a significance level or 5%. Data were gated between non/parametric tests based on the Anderson-Darling's test.

Corrections for multiple comparisons were performed using the Benjamini & Hochberg procedure (`fdr_bh` function).

Effect sizes were calculated using Robust Cohen's *d* (*`meanEffectSize`* function with *Effect = 'robustcohen'*) or matched-pairs rank biserial correlation coefficient for the Wilcoxon signed-rank test, *r*.

Looking at the KSS data

Here we import the KSS outcomes. Once imported we look at the changes from pre to post for both F30 and M30 and compare arms.

We use the Wilcoxon signed rank test for between group comparisons.

```
%Import the KSS values
GXKKSExp2 = helper_GX_ImportKSS_Exp2('GX_KKS_Exp2.xlsx', "Sheet1", [2, 16]);

for ii=1 %Added to keep code block together
    t1=[];
    t1 = stack(GXKKSExp2, {["KSSpre1" "KSSpre2"] ...
                           ["KSSpost1" "KSSpost2"]...
                           ["Arm1" "Arm2"]},...
                    "NewDataVariableName",...
                           ["KSSPre" "KSSPost" "Arm"],...
                    "IndexVariableName","Treatment");

    t1(:,{'Sub','AgeYears','GenderMF',...
          'Heightcm','Weightkg',...
          'KSSPre','KSSPost','Arm'})


    t1_F30=t1( t1.Arm=='F30',:) ;
    ii = (t1_F30.KSSPost - t1_F30.KSSPre);

    [~,~,idx] = unique(t1_F30.StartingID,'stable');
    t1_F30_merged=accumarray(idx,ii,[],@median) ;

    t1_M30=t1( t1.Arm=='M30',:) ;
    ii = (t1_M30.KSSPost - t1_M30.KSSPre);

    [~,~,idx] = unique(t1_M30.StartingID,'stable');
    t1_M30_merged=accumarray(idx,ii,[],@median);
    y_var='KSS';
    var_in= y_var;
    diff_period ='Po-Pr';

    figure;
    [stats_out,p] = helper_GX_PlottingOutcomes_Fig_Stats(var_in,...
                    t1_F30_merged,t1_M30_merged, diff_period);

    fprintf ('\n%s\n',stats_out)
```

```
    stats_results{end+1}=stats_out;
    Table_p_val{end+1,1}=var_in;
    Table_p_val{end,2}=p;


    fname=[strcat('GX_F30vM30_Behavior_', var_in)];

     if SveAllpics==1
           h = gcf;
           saveas(h,strcat(prefix,fname,'.fig'),'fig');
           print(h,'-dpng', strcat(prefix,fname,'.png'), '-r600');
           print(h,'-dpdf', [prefix,fname], '-r600');

     end
     if closefigs==1, close all,  end


end
```

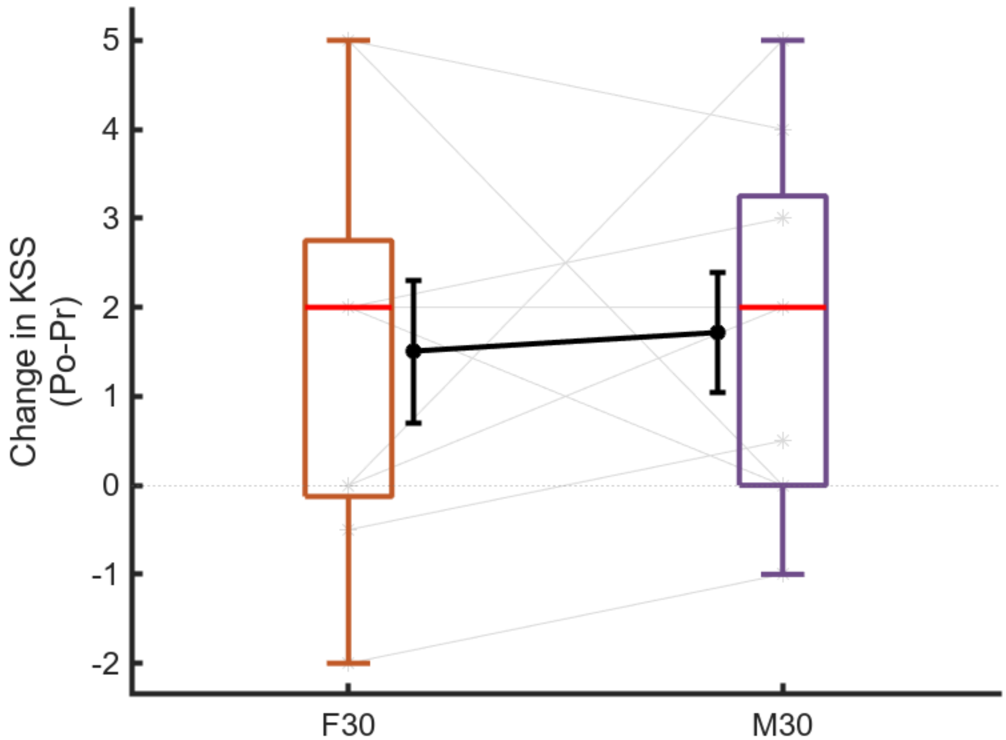
```
ans = 30×8 table
```

	Sub	AgeYears	GenderMF	Heightcm	Weightkg	KSSPre	KSSPost
1	'11'	21	F	167.64	61.235	3	8
2	'11'	21	F	167.64	61.235	4	4
3	'12'	20	F	157.48	68.946	1	2
4	'12'	20	F	157.48	68.946	3	3
5	'13'	28	F	162.56	56.7	3	8
6	'13'	28	F	162.56	56.7	4	8
7	'14'	36	M	172.72	91.63	2	7
8	'14'	36	M	172.72	91.63	4	4
9	'15'	30	M	175.2599999...	58.967	6	8
10	'15'	30	M	175.2599999...	58.967	7	9
11	'16'	29	F	167.64	58.967	3	5
12	'16'	29	F	167.64	58.967	4	4
13	'18'	30	M	175.2599999...	58.967	6	8
14	'18'	30	M	175.2599999...	58.967	6	8

⋮

```
F30 Median = 2 ± 2.875
M30 Median = 2 ± 3.25
z = -0.355, p = 0.72234 n=(F30:9,M30:9)
```

```
MPRB Cor Coef r = 0.156±0.311
There was no significant difference (at an alpha =0.05)in the change in KSS (Po-Pr) ratings betweenF30 (Median:2,IQR
The effect size measured by MPRB Cor Coef r = 0.156 ± 0.311, indicating a small effect size
```



Cardiac HRV Outcomes

Here we look at the cardiac outcomes for time (RMSSD) and frequency (LF/HF ratio).

```
files_in_folder=ls('*.csv');
diff_period ='During minus Pre';

HRV_stats_results={};
for file_num=1:size(files_in_folder,1)

file_in = files_in_folder(file_num,:);
if ~contains(file_in,'HRV_All_') && ~contains(file_in,'EEG')

    file_in = strrep(file_in,' ','');
    var_in=string(file_in(5:end-4));
```

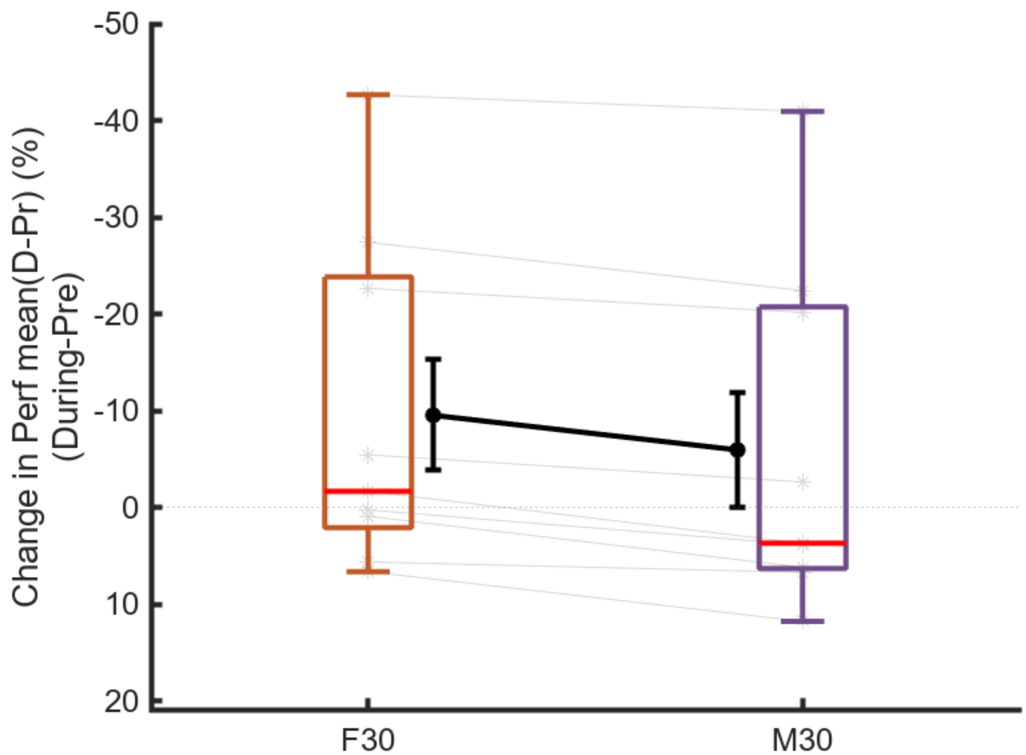
```
    disp(strcat('Running: ', var_in));


    T= readtable([file_in]);
    t1=T



    t1_F30=t1( t1.StimType=="F30" &  t1.Participant>10,:) ;
    t1_F30_merged=t1_F30.(var_in).*100 ;

    t1_M30=t1( t1.StimType=="M30" &  t1.Participant>10,:);
    t1_M30_merged=t1_M30.(var_in).*100;

    var_in= strrep(var_in,'_',' ');
    var_in=char(var_in);


    var_in = [var_in,'(D-Pr)'];


    figure;
    [stats_out,p] = helper_GX_PlottingOutcomes_Fig_Stats(var_in,...
                        t1_F30_merged,t1_M30_merged, diff_period);

    fprintf ('\n%s\n',stats_out);
    stats_results{end+1}=stats_out;
    Table_p_val{end+1,1}=var_in;
    Table_p_val{end,2}=p;


    fname=char([strcat('GX_F30vM30_HRV_', var_in)]);

    if SveAllpics==1
           h = gcf;
           saveas(h,strcat(prefix,fname,'.fig'),'fig');
           saveas(h,strcat(prefix,fname,'.png'),'png');
           print(h,'-dpng', strcat(prefix,fname,'.png'), '-r600');
           print(h,'-depsc', strcat(prefix,fname,'.eps'), '-r600');
           print(h,'-dpdf', [prefix,fname], '-r600');
       end
     if closefigs==1, close all,  end



end
end
```

```
Running:Perf_mean
t1 = 18×5 table
```

	Var1	Perf_mean	Participant	StimType	Period
1	0	-0.01690851465...	11	'F30'	'PercentChange'
2	1	0.002508658855...	13	'F30'	'PercentChange'
3	2	0.066153561405...	14	'F30'	'PercentChange'
4	3	0.008986822931...	16	'F30'	'PercentChange'
5	4	-0.05451296452...	20	'F30'	'PercentChange'
6	5	-0.22649343781...	1219	'F30'	'PercentChange'
7	6	0.056215359779...	1518	'F30'	'PercentChange'
8	7	-0.42659283478...	212526	'F30'	'PercentChange'
9	8	-0.27414562776...	222324	'F30'	'PercentChange'
10	0	0.036844414679...	11	'M30'	'PercentChange'
11	1	0.038281631184...	13	'M30'	'PercentChange'
12	2	0.117549250053...	14	'M30'	'PercentChange'
13	3	0.061660300352...	16	'M30'	'PercentChange'
14	4	-0.02653065658...	20	'M30'	'PercentChange'

⋮

```
F30 Mean = -9.60877 ± 17.1836
M30 Mean = -6.00818 ± 17.7388
t(8) = -6.4991, p = 0.00018828 n=(F30:9,M30:9)
Cohen's d = -0.163(-0.827,-0.079)
There was a significant difference (at an alpha =0.05)in the change in Perf mean(D-Pr) (During minus Pre) ratings be
The effect size measured by Cohen's d = -0.163 ± 0.084, indicating a small effect size
```

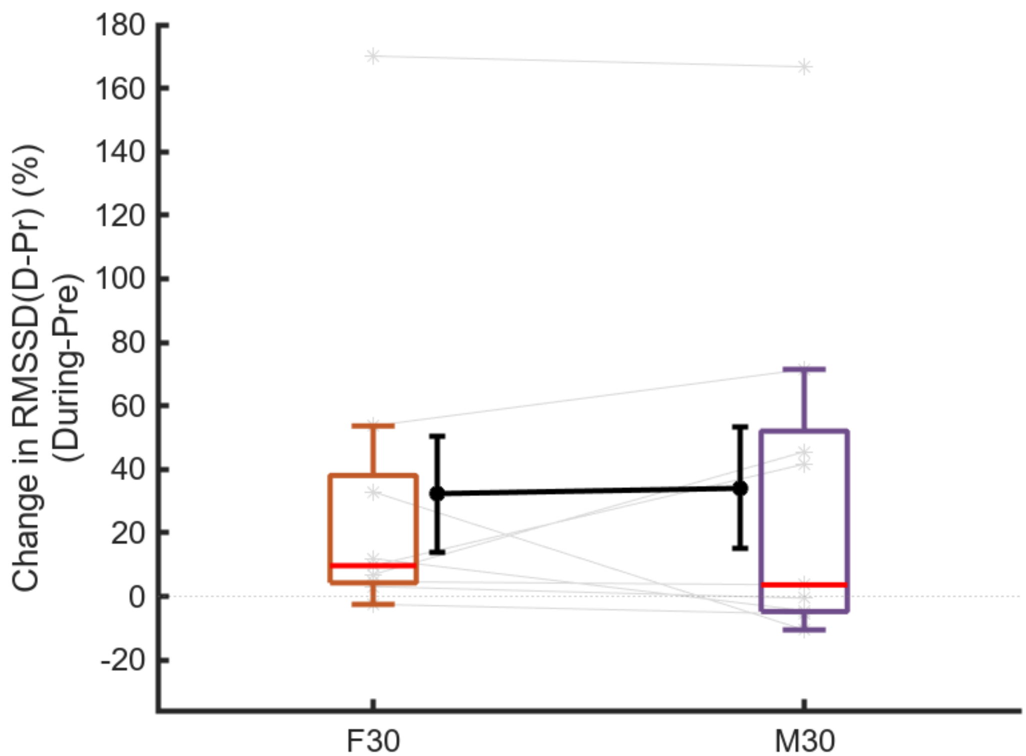



```
Running:RMSSD
t1 = 18×5 table
```

	Var1	RMSSD	Participant	StimType	Period
1	0	0.096823116346...	11	'F30'	'PercentChange'
2	1	0.53679218233035	13	'F30'	'PercentChange'
3	2	1.70098205900038	14	'F30'	'PercentChange'
4	3	-0.02493750747...	16	'F30'	'PercentChange'
5	4	0.046488315264...	20	'F30'	'PercentChange'
6	5	0.119107676142...	1219	'F30'	'PercentChange'
7	6	0.328962130952...	1518	'F30'	'PercentChange'
8	7	0.068994460019...	212526	'F30'	'PercentChange'
9	8	0.030806478680...	222324	'F30'	'PercentChange'
10	0	0.416399789653...	11	'M30'	'PercentChange'
11	1	0.714688312024...	13	'M30'	'PercentChange'
12	2	1.66750387382848	14	'M30'	'PercentChange'
13	3	-0.05563703996...	16	'M30'	'PercentChange'
14	4	0.036118335084...	20	'M30'	'PercentChange'

⋮

```
F30 Median = 9.68231 ± 33.8352
M30 Median = 3.61183 ± 56.785
z = 0.178, p = 0.85895 n=(F30:9,M30:9)
MPRB Cor Coef r = 0.067±0.4
There was no significant difference (at an alpha =0.05)in the change in RMSSD(D-Pr) (During minus Pre) ratings betwe
The effect size measured by MPRB Cor Coef r = 0.067 ± 0.4, indicating a small effect size
```



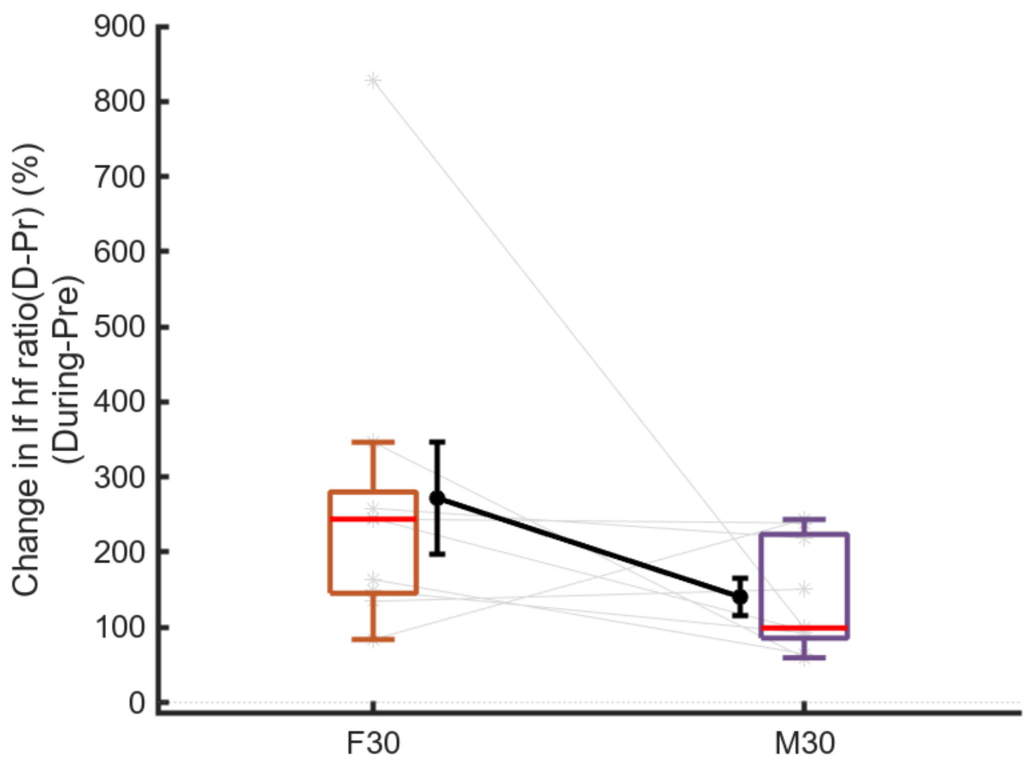

```
Running:lf_hf_ratio
t1 = 18×5 table
```

	Var1	lf_hf_ratio	Participant	StimType	Period
1	0	1.34527690825...	11	'F30'	'PercentChange'
2	1	2.43943159013...	13	'F30'	'PercentChange'
3	2	1.63532790312...	14	'F30'	'PercentChange'
4	3	2.44654830252...	16	'F30'	'PercentChange'
5	4	8.27503645458...	20	'F30'	'PercentChange'
6	5	0.83683230671...	1219	'F30'	'PercentChange'
7	6	3.46218431503...	1518	'F30'	'PercentChange'
8	7	2.5814325050694	212526	'F30'	'PercentChange'
9	8	1.48887198640...	222324	'F30'	'PercentChange'

	Var1	lf_hf_ratio	Participant	StimType	Period
10	0	1.50695600838...	11	'M30'	'PercentChange'
11	1	2.38765146011...	13	'M30'	'PercentChange'
12	2	0.64461586626...	14	'M30'	'PercentChange'
13	3	0.95673571821...	16	'M30'	'PercentChange'
14	4	0.99109784889...	20	'M30'	'PercentChange'

⋮

```
F30 Median = 243.943 ± 134.865
M30 Median = 99.1098 ± 138.322
z = 1.599, p = 0.10974 n=(F30:9,M30:9)
MPRB Cor Coef r = 0.6±0.267
There was no significant difference (at an alpha =0.05)in the change in lf hf ratio(D-Pr) (During minus Pre) ratings
The effect size measured by MPRB Cor Coef r = 0.6 ± 0.267, indicating a large effect size
```



EEG Outcomes

Here we look at the EEG outcomes. We also look at the CTT deviation ('Perf_mean') for post-pre.

```
files_in_folder=ls('*.csv');
file_in= 'EEG_stats_Allfeats.csv';
diff_period ='Post minus Pre';
select_feats = ["Perf_mean", "at", "dt"];
EEG_stats_results={};


T= readtable([file_in]);

t1=T;
t1.Feature=string(t1.Feature);

Features = string(unique(t1.Feature));
Features = Features(contains(Features,  select_feats ));


for ii_feat=1:length(Features)

    var_in=Features(ii_feat);

    disp(strcat('Running: ', var_in));

    chan_mean =["P8","P4","O2","P7","P3","O1"];

    t1_F30=t1( t1.StimType=="F30" &  t1.Participant>10 &  t1.Feature==var_in,:);
    t1_F30_merged=mean(t1_F30{:,[chan_mean]}.*100, 2);


    t1_M30=t1( t1.StimType=="M30" &  t1.Participant>10 &  t1.Feature==var_in,:);
    t1_M30_merged=mean(t1_M30{:,[chan_mean]}.*100, 2);

    if contains(var_in, "Perf_mean")
        t1_F30.CTT = t1_F30{:,'Fp1'}.*100;%The CTT are just repeated across channels.
        t1_M30.CTT = t1_M30{:,'Fp1'}.*100;
        t1_F30(:,{'Participant','CTT','StimType','Period','Feature'})
        t1_M30(:,{'Participant','CTT','StimType','Period','Feature'})
    else
        t1_F30(:,2:end)
        t1_M30(:,2:end)

    end

    var_in= strrep(var_in,'_',' ');
    var_in=char(var_in);
```

```
    if var_in=="at";
        var_in="Alpha Theta Ratio";
    elseif  var_in=="dt";
        var_in="Delta Theta Ratio";
    elseif var_in=="Perf mean"
        var_in = 'Perf mean(Po-Pr)';
    end



    figure;
    [stats_out,p] = helper_GX_PlottingOutcomes_Fig_Stats(var_in,...
                    t1_F30_merged,t1_M30_merged, diff_period);


        fprintf ('\n%s\n',stats_out);
        stats_results{end+1}=stats_out;

        Table_p_val{end+1,1}=var_in;
        Table_p_val{end,2}=p;

        fname=char([strcat('GX_F30vM30_EEG_', var_in)]);


         if SveAllpics==1
               h = gcf;
               saveas(h,strcat(prefix,fname,'.fig'),'fig');
               saveas(h,strcat(prefix,fname,'.png'),'png');
               print(h,'-dpng', strcat(prefix,fname,'.png'), '-r600');
               print(h,'-depsc', strcat(prefix,fname,'.eps'), '-r600');
               print(h,'-dpdf', [prefix,fname], '-r600');
           end
         if closefigs==1, close all,  end



end
```

```
Running:Perf_mean
ans = 9×5 table
```

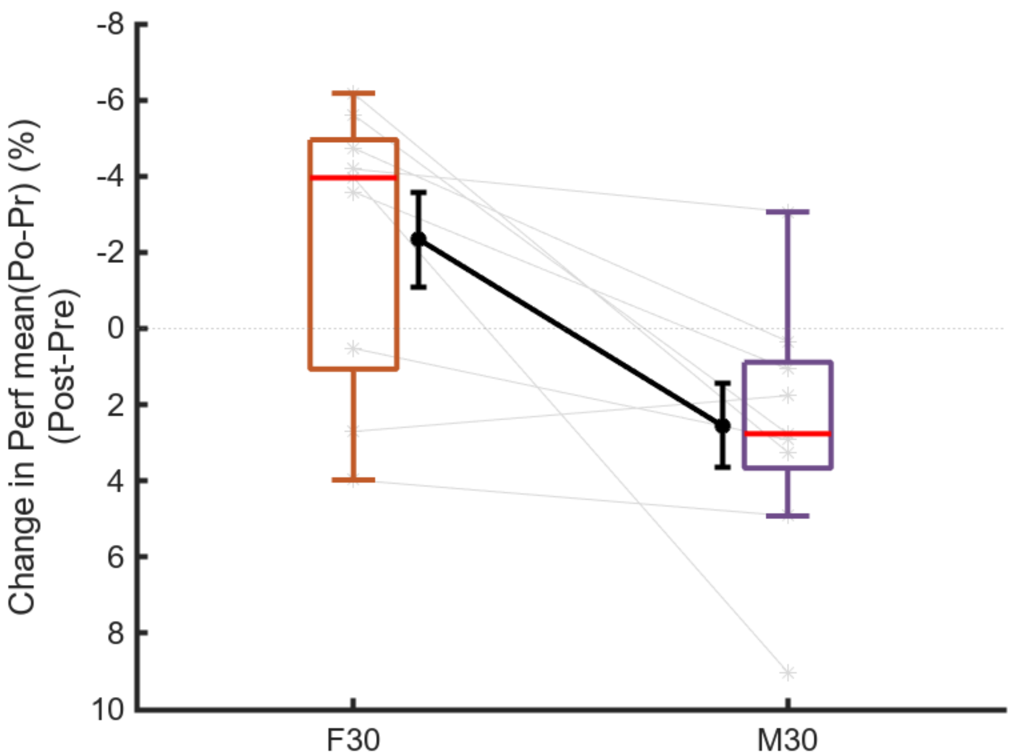
	Participant	CTT	StimType	Period	Feature
1	11	-4.7347786	'F30'	'PercentChange'	"Perf_mean"
2	13	-3.9573892	'F30'	'PercentChange'	"Perf_mean"
3	14	-3.5847967	'F30'	'PercentChange'	"Perf_mean"
4	16	-4.1841026	'F30'	'PercentChange'	"Perf_mean"

	Participant	CTT	StimType	Period	Feature
5	20	3.9765492	'F30'	'PercentChange'	"Perf_mean"
6	1219	-5.6071924	'F30'	'PercentChange'	"Perf_mean"
7	1518	0.5219996	'F30'	'PercentChange'	"Perf_mean"
8	212526	-6.1725393	'F30'	'PercentChange'	"Perf_mean"
9	222324	2.7046032	'F30'	'PercentChange'	"Perf_mean"

```
ans = 9×5 table
```

	Participant	CTT	StimType	Period	Feature
1	11	0.3412398	'M30'	'PercentChange'	"Perf_mean"
2	13	9.0218821	'M30'	'PercentChange'	"Perf_mean"
3	14	1.0662477	'M30'	'PercentChange'	"Perf_mean"
4	16	-3.0597716	'M30'	'PercentChange'	"Perf_mean"
5	20	4.920055	'M30'	'PercentChange'	"Perf_mean"
6	1219	2.7655294	'M30'	'PercentChange'	"Perf_mean"
7	1518	2.9239482	'M30'	'PercentChange'	"Perf_mean"
8	212526	3.2471711	'M30'	'PercentChange'	"Perf_mean"
9	222324	1.7645155	'M30'	'PercentChange'	"Perf_mean"

```
F30 Mean = -2.33752 ± 3.74503
M30 Mean = 2.55454 ± 3.30419
t(8) = -3.2015, p = 0.012583 n=(F30:9,M30:9)
Cohen's d = -1.212(-3.676,-0.482)
There was a significant difference (at an alpha =0.05)in the change in Perf mean(Po-Pr) (Post minus Pre) ratings bet
The effect size measured by Cohen's d = -1.212 ± 0.73, indicating a large effect size
```




```
Running:at
ans = 9×36 table
```

...

	Fp1	Fpz	Fp2	F7	F3	Fz	F4	F8
1	-0.11965...	-0.16330...	0.117731...	0.01625862	0.030039...	-0.07143...	-0.18205...	-0.28547...
2	-0.00166...	-0.04672...	-0.03165...	0.032563...	0.015783...	0.219414...	-0.14573...	-0.19076...
3	0.104601...	-0.03676...	0.006694...	0.15019525	-0.1190569	0.042349...	0.161079...	0.070267...
4	0.221842...	0.066350...	0.051553...	0.082584...	-0.05084...	0.119641...	0.167083...	0.058602...
5	-0.19192...	-0.14009...	-0.17654...	-0.00816...	0.035546...	-0.16307...	-0.15553...	-0.09432...
6	0.230178...	0.108072...	0.052342...	0.091550...	0.073502...	0.12238692	0.398156...	0.284269...
7	-0.03842...	0.025116...	0.208509...	0.040300...	-0.01371...	0.130667...	-0.03999...	-0.13453...
8	0.048655...	0.23834826	-0.03612...	0.077446...	0.059761...	0.25775533	0.143999...	0.053658...
9	-0.12369...	-0.07016...	-0.09839...	-0.06283...	-0.12904...	-0.06246...	-0.06094...	-0.05968...

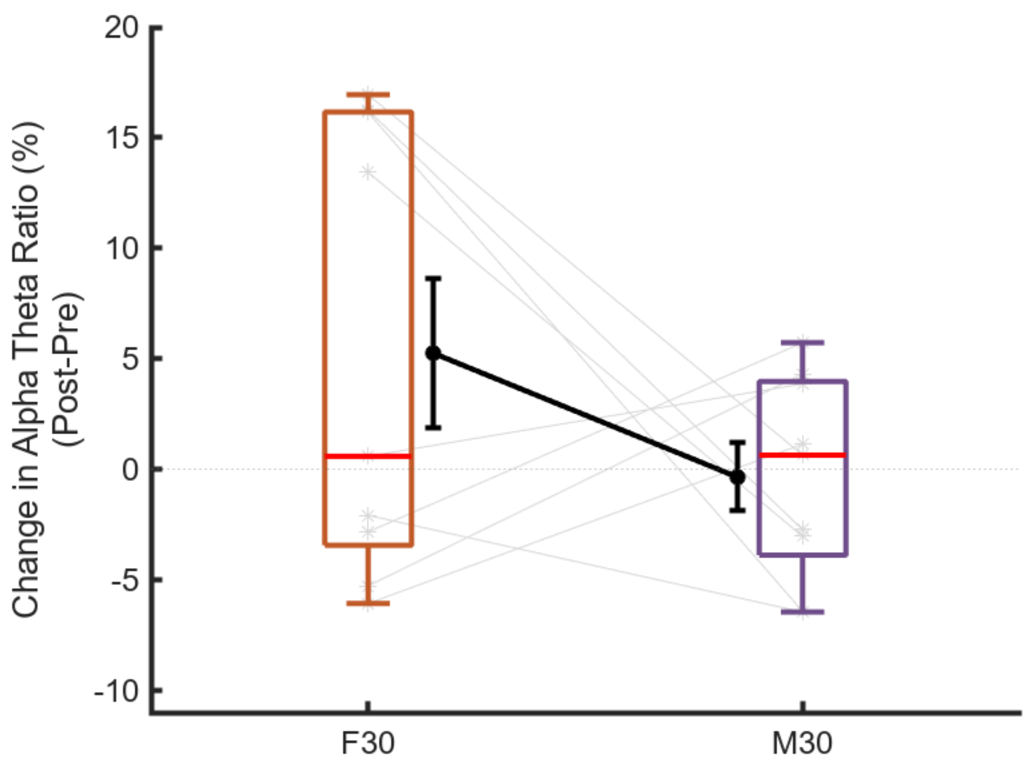
```
ans = 9×36 table
```

...

	Fp1	Fpz	Fp2	F7	F3	Fz	F4	F8
1	0.050896...	0.129160...	0.075431...	0.064078...	-0.13110...	0.081114...	-0.10217...	-0.16582...
2	-0.23414...	-0.03305...	-0.25875...	-0.07645...	-0.24933...	0.028385...	-0.11926...	-0.01589...

	Fp1	Fpz	Fp2	F7	F3	Fz	F4	F8
3	0.34401165	0.230286...	0.223528...	0.127930...	0.075599...	0.071174...	0.165588...	0.248697...
4	0.034460...	0.101528...	-0.05040...	-0.13810...	0.032966...	0.017701...	0.181738...	-0.11192...
5	-0.22466...	-0.25966...	-0.03829...	-0.14351...	-0.14534...	-0.15937...	-0.00775...	0.019491...
6	-0.06759...	-0.02996...	-0.08632...	0.036708...	-0.13482...	-0.05272...	0.026338...	0.042080...
7	-0.09531...	-0.11231...	-0.12642...	-0.15354...	-0.04653...	0.005392...	-0.14882...	-0.16334...
8	-0.00335...	-0.04351...	-0.08336	-0.05691...	-0.05614...	-0.01467...	0.057058...	0.002510...
9	0.147765...	0.034783...	0.027805...	0.044836...	0.067610...	0.090013...	0.000695...	0.146327...

```
F30 Median = 0.604077 ± 19.5926
M30 Median = 0.654815 ± 7.85086
z = 1.125, p = 0.26039 n=(F30:9,M30:9)
MPRB Cor Coef r = 0.422±0.222
There was no significant difference (at an alpha =0.05)in the change in Alpha Theta Ratio (Post minus Pre) ratings b
The effect size measured by MPRB Cor Coef r = 0.422 ± 0.222, indicating a medium effect size
```




```
Running:dt
ans = 9×36 table
```

...

	Fp1	Fpz	Fp2	F7	F3	Fz	F4	F8
1	-0.17473...	-0.20965...	0.237305...	-0.11945...	0.14767139	-0.14015...	0.089272...	0.107722...
2	-0.08630...	-0.04876...	0.07227547	-0.06745...	-0.03606...	0.098430...	-0.07152...	0.066675...

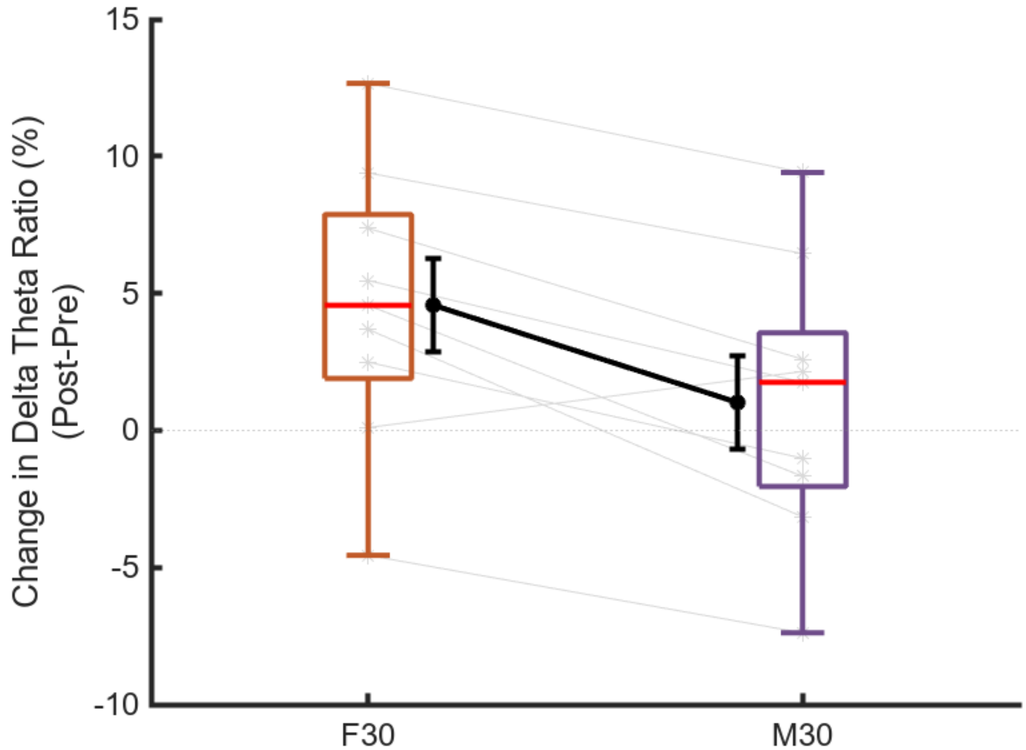
	Fp1	Fpz	Fp2	F7	F3	Fz	F4	F8
3	0.012032...	0.100072...	0.0049043	-0.05544...	-0.12327...	5.05e-06	0.001920...	-0.00506...
4	0.027344...	0.159549...	0.032497...	0.220902...	0.00571192	0.116222...	0.348856...	0.277891...
5	0.08081087	0.012960...	0.052031...	-0.08327...	0.132593...	-0.06415...	0.013373...	-0.06938...
6	0.222757...	0.028032...	0.095344...	-0.09663...	0.031676...	0.016998...	0.118684...	0.135270...
7	0.004809...	-0.10842...	-0.05274...	-0.11951...	0.048406...	0.05147883	-0.11147...	-0.18547...
8	-0.02753...	0.081964...	0.096975...	0.182761...	0.07576553	-0.00584...	0.005705...	-0.05325...
9	-0.01588...	0.009419...	-0.10540...	0.078678...	-0.07760...	0.012307...	-0.07420...	-0.07498...

```
ans = 9×36 table
```

...

	Fp1	Fpz	Fp2	F7	F3	Fz	F4	F8
1	-0.19661...	-0.01893...	0.026974...	-0.28017...	0.018044...	0.039542...	0.107883...	-0.07523...
2	0.200651...	0.179469...	0.163225...	0.137766...	0.05029887	0.124623...	0.350715...	0.15090546
3	0.190385...	0.080024...	0.128968...	-0.12178...	0.081389...	-0.09429...	0.100674...	0.047246...
4	-0.03598...	-0.15379...	-0.17039...	-0.08462...	-0.08823...	-0.05394...	-0.00496...	0.014339...
5	-0.16009...	-0.07156...	-0.06416...	0.020702...	-0.13329...	-0.01989...	0.056806...	-0.05315...
6	0.205886...	0.116892...	0.055609...	0.085557...	0.055502...	-0.01180...	0.061326...	0.039226...
7	-0.01928...	-0.01799...	0.00083403	0.003485...	-0.13438...	-0.06974...	-0.03063...	-0.03379...
8	0.006595...	-0.03813...	0.077764...	-0.00599...	0.018570...	-0.00576...	-0.03061...	-0.03556...
9	-0.01031...	0.01086743	0.013191	-0.02493...	-0.00763...	0.027722...	0.098849...	0.036512...

```
F30 Mean = 4.57382 ± 5.07161
M30 Mean = 1.01349 ± 5.04552
t(8) = 4.1947, p = 0.0030183 n=(F30:9,M30:9)
Cohen's d = 0.686(0.269,1.892)
There was a significant difference (at an alpha =0.05)in the change in Delta Theta Ratio (Post minus Pre) ratings be
The effect size measured by Cohen's d = 0.686 ± -1.207, indicating a large effect size
```



Organize All Statistics

Here we gather all the p-values from the statistical tests run above and perform the BH correction.

```
%Get all our collected stats
All_stats_results=reshape(stats_results,size(stats_results,2),1);


TT=cell2table(Table_p_val,'Variable',{'Var','pval'})
```

TT = 7×2 table

	Var	pval
1	"KSS"	0.722338991965049
2	"Perf mean(D-Pr)"	0.0001882822248...
3	"RMSSD(D-Pr)"	0.858954922737482
4	"lf hf ratio(D-Pr)"	0.109744638747013

	Var	pval
5	"Perf mean(Po-Pr)"	0.0125831584162...
6	"Alpha Theta Ratio"	0.260392943610483
7	"Delta Theta Ratio"	0.0030182749632...

BH Correct p-values

We adjust the p-values using the Benjamini & Hochberg procedure.

The `fdr_bh` function can be found here.

```
%These are the variables to correct p-vals
vars_to_test= {'KSS','Perf mean(D-Pr)',...
                'Perf mean(Po-Pr)',...
                'RMSSD(D-Pr)',...
                'lf hf ratio(D-Pr)',...
                'Alpha Theta Ratio',...
                'Delta Theta Ratio'};

TT2= TT(ismember(TT.Var,vars_to_test),:);

%Note that Perf_mean is seen twice. The 1st one if Perf_mean from pre to
%during and the 2nd is Perf_mean from pre to post.

[h, crit_p, adj_ci_cvrg, adj_p]=fdr_bh(TT2.pval,0.05,'pdep','yes');
```

```
Out of 7 tests, 3 are significant using a false discovery rate of 0.050000.
FDR/FCR procedure used is guaranteed valid for independent or positively dependent tests.
```

```
TT2.BH_adjusted_pval=adj_p;
TT2.rounded_pval=round(adj_p,3)
```

TT2 = 7×4 table

	Var	pval	BH_adjusted_pval	rounded_pval
1	"KSS"	0.722338991965049	0.842728823959224	0.843
2	"Perf mean(D-Pr)"	0.0001882822248...	0.00131797557418656	0.001
3	"RMSSD(D-Pr)"	0.858954922737482	0.858954922737482	0.859
4	"lf hf ratio(D-Pr)"	0.109744638747013	0.192053117807273	0.192
5	"Perf mean(Po-Pr)"	0.0125831584162...	0.0293607029712846	0.029
6	"Alpha Theta Ratio"	0.260392943610483	0.364550121054677	0.365

	Var	pval	BH_adjusted_pval	rounded_pval
7	"Delta Theta Ratio"	0.0030182749632...	0.0105639623714256	0.011

These are the p-values for all the otucome measures.

Show Significant Outcomes

Once we have the corrected values we can print our significant outcomes.

```
TT3=table(TT2.Var(h), TT2.pval(h), ...
        adj_p(h),...
        'VariableNames',...
        ["VarName","OriginalP","AdjustedP"]);

TT3.RoundedAdjustedP = round(adj_p(h),3)
```

TT3 = 3×4 table

	VarName	OriginalP	AdjustedP	RoundedAdjustedP
1	"Perf mean(D-Pr)"	0.0001882822248...	0.001317975574...	0.001
2	"Perf mean(Po-Pr)"	0.0125831584162...	0.029360702971...	0.029
3	"Delta Theta Ratio"	0.0030182749632...	0.010563962371...	0.011

Save Stats Outcomes

Once we have all out stats outcomes we save them to a text file for easy viewing.

```
%Write results to table
fname='All_stats_results.txt';
writecell(All_stats_results,[prefix,fname])

fname='All_stats_results_p_vals.txt';
writetable(TT,[prefix,fname],'Delimiter','|')

fname='All_stats_results_sig_corrected_p_vals.txt';
writetable(TT3,[prefix,fname],'Delimiter','|')
```

```
%Export file to HTML
export('GX_F30vM30_Analysis.mlx', format='html');
export('GX_F30vM30_Analysis.mlx', format='pdf', Margins=[25 84 84 25]);
```