Train Features

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Live script used to train networks with feature data

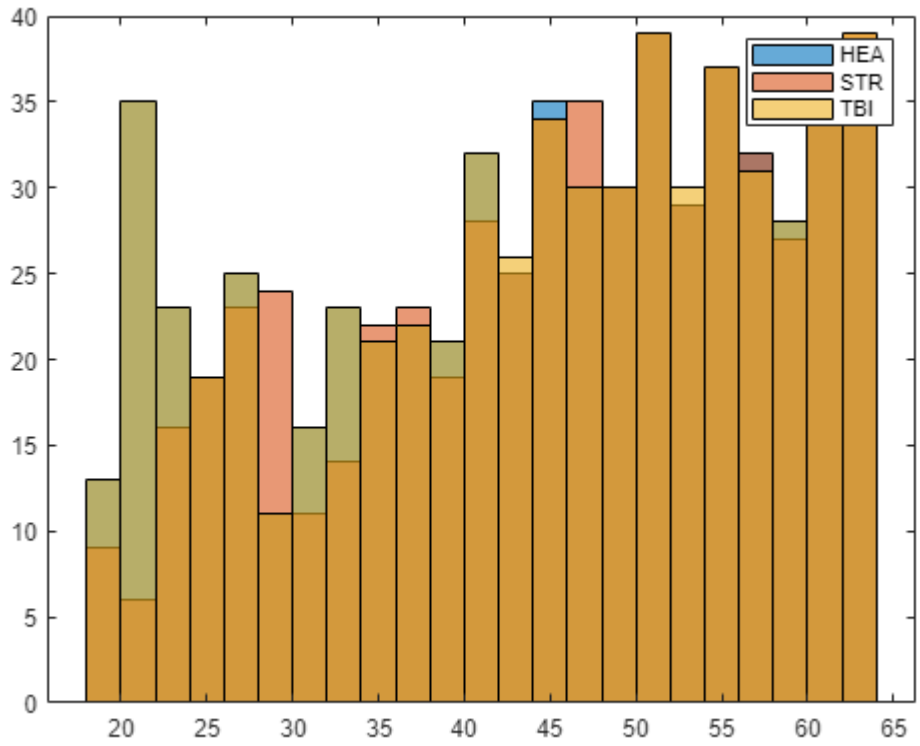
Using PreDREEG, PreDREEGplot, and DREEGd, one can generate *_3F.mat files used in commented code below. Although these files are not included, the generated result is saved in AllFeatures.mat. The commented code is provided for reproducability.

```
% load("Sep22.mat")
% T = split(string(files(:,1)),'.');
% T = split(T(:,1),"\");
% T = T(:,end);
% F = table();
% %load("HEA_3F.mat")
% s = split(HEA_3F.names(:,1),"\");
% s = join([s(:,end-1),s(:,end)],"_");
% s = join([s HEA_3F.names(:,2)],"-");
% in = ismember(s,T);
% f = table(s(in),categorical(repmat("HEA",
[sum(in),1])),HEA_3F.F(in,:),'VariableNames',["Filename","Label","Features"]);
% F = [F;f];
% %load("STR_3F.mat")
% s = split(STR_3F.names(:,1),"\");
% s = join([s(:,end-1),s(:,end)],"_");
% s = join([s STR_3F.names(:,2)],"-");
% in = ismember(s,T);
% f = table(s(in),categorical(repmat("STR",
[sum(in),1])),STR_3F.F(in,:),'VariableNames',["Filename","Label","Features"]);
% F = [F;f];
% %load("TBI_3F.mat")
% s = split(TBI_3F.names(:,1),"\");
% s = join([s(:,end-1),s(:,end)],"_");
% s = join([s TBI_3F.names(:,2)],"-");
% in = ismember(s,T);
% f = table(s(in),categorical(repmat("TBI",
[sum(in),1])),TBI_3F.F(in,:),'VariableNames',["Filename","Label","Features"]);
% F = [F;f];
```

Used Matched Age and Gender subjects/sessions of HEA and STR

```
% [HEA,STR,TBI] = MatchSubjects();
```

```
# HEA subjects/sessions: 599/629
# STR subjects/sessions: 529/586
# TBI subjects/sessions: 552/629
```




```
% s = split(HEA.Location,'\');
% s = string(s(:,9));
% s = split(s,'.');
% HEA = s(:,1);
% s = split(STR.Location,'\');
% s = string(s(:,9));
% s = split(s,'.');
% STR = s(:,1);
% s = split(TBI.Location,'\');
% s = string(s(:,9));
% s = split(s,'.');
% TBI = s(:,1);
% HEA_in = [];
% for i  = 1:length(HEA)
%     HEA_in = [HEA_in; find(contains(F.Filename,HEA(i)))];
% end
% STR_in = [];
% for i  = 1:length(STR)
%     STR_in = [STR_in; find(contains(F.Filename,STR(i)))];
% end
% TBI_in = [];
% for i  = 1:length(TBI)
%     TBI_in = [TBI_in; find(contains(F.Filename,TBI(i)))];
% end
% in = [HEA_in; STR_in; TBI_in];
% F = F(in,:);
```

```
% featNames = getFeatureNames();
% f = array2table(F.Features);
% f.Properties.VariableNames = featNames;
```

LDA Feature Selection

Only need to generate once, can used saved data after.

```
% AMdl = fitcdiscr(F.Features,F.Label,'DiscrimType','linear',...
%
'OptimizeHyperparameters','auto','HyperparameterOptimizationOptions',...
%
struct('ShowPlots',false,'Verbose',1,'UseParallel',true,'Repartition',true,'SaveInte
rmediateResults',true));
% r = AMdl.DeltaPredictor;
% r_logical = r > mean(r)+std(r);
% gf = F.Features(:,r_logical);
% G = F;
% G.Features = gf;
```

First Minute Selection

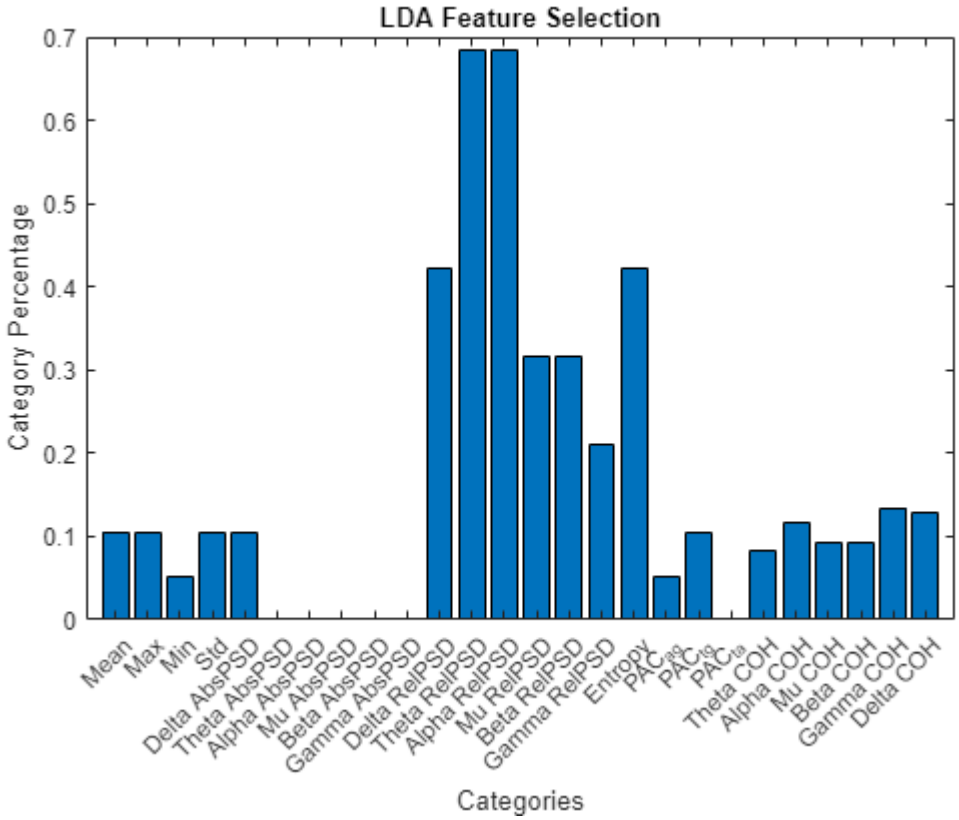
```
% O = F(or(endsWith(F.Filename,"-1"),endsWith(F.Filename,"-2")),:);
% countcats(O.Label)
% OMdl = fitcdiscr(O.Features,O.Label,'DiscrimType','linear',...
%
'OptimizeHyperparameters','auto','HyperparameterOptimizationOptions',...
%
struct('ShowPlots',false,'Verbose',1,'UseParallel',true,'Repartition',true));
% o = OMdl.DeltaPredictor;
% o_logical = o > mean(o)+std(o);
% h = O.Features(:,o_logical);
% H = O;
% H.Features = h;
% save("AllFeatures.mat","F","f","G","r_logical","r","O","o","o_logical","H");
```

Load Feaures with LDA

```
load("AllFeatures.mat");
```

```
[varnames,varcats,ind] = MakeFeatureTableNames();
f = F.Features';
g = G.Features';
in = ismember(f,g,'rows');
LDAfeatures = varnames(in);
c = zeros(1,length(varcats));
for i = 1:length(c)
    c(i) = sum(contains(LDAfeatures,varcats(i)));
end
```

```
c = c./[repmat(19,[1,length(c)-6]), repmat(length(ind),[1,6])];
varcats(18) = "PAC_{ag}";
varcats(19) = "PAC_{tg}";
varcats(20) = "PAC_{ta}";
varcats = reordercats(categorical(varcats),varcats);
figure;
bar(varcats,c);
title("LDA Feature Selection")
ylabel("Percentage")
ylabel("Category Percentage")
xlabel("Categories")
```




```
%set(gca,'TickLabelInterpreter','none')
```

Calculate ReliefF to rank top 100

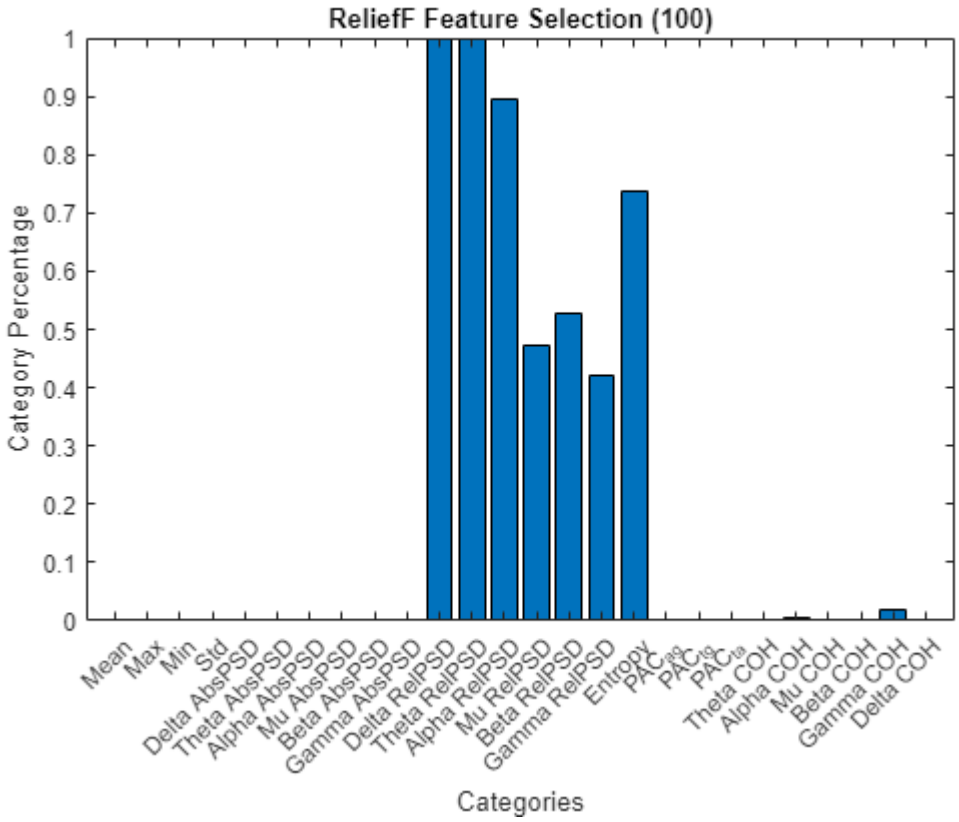
Only need to run once

```
% [featureIndex,score] = relieff(...
%     F.Features, ...
%     F.Label, ...
%     10);
% save("RelieffScores.mat","featureIndex","score");
```

Load Relief F scores

```
load("ReliefFScores.mat")
```

```
RFnames = varnames(featureIndex(1:100));
c = zeros(1,length(varcats));
for i = 1:length(c)
    c(i) = sum(contains(RFnames,string(varcats(i))));
end
c = c./[repmat(19,[1,length(c)-6]), repmat(length(ind),[1,6])];
varcats(18) = "PAC_{ag}";
varcats(19) = "PAC_{tg}";
varcats(20) = "PAC_{ta}";
varcats = reordercats(categorical(varcats),string(varcats));
figure;
bar(varcats,c);
title("ReliefF Feature Selection (100)")%+
num2str(find(score(featureIndex)<.01,1)-1) +")")
ylabel("Category Percentage")
xlabel("Categories")
```




```
%set(gca,'TickLabelInterpreter','none')
```

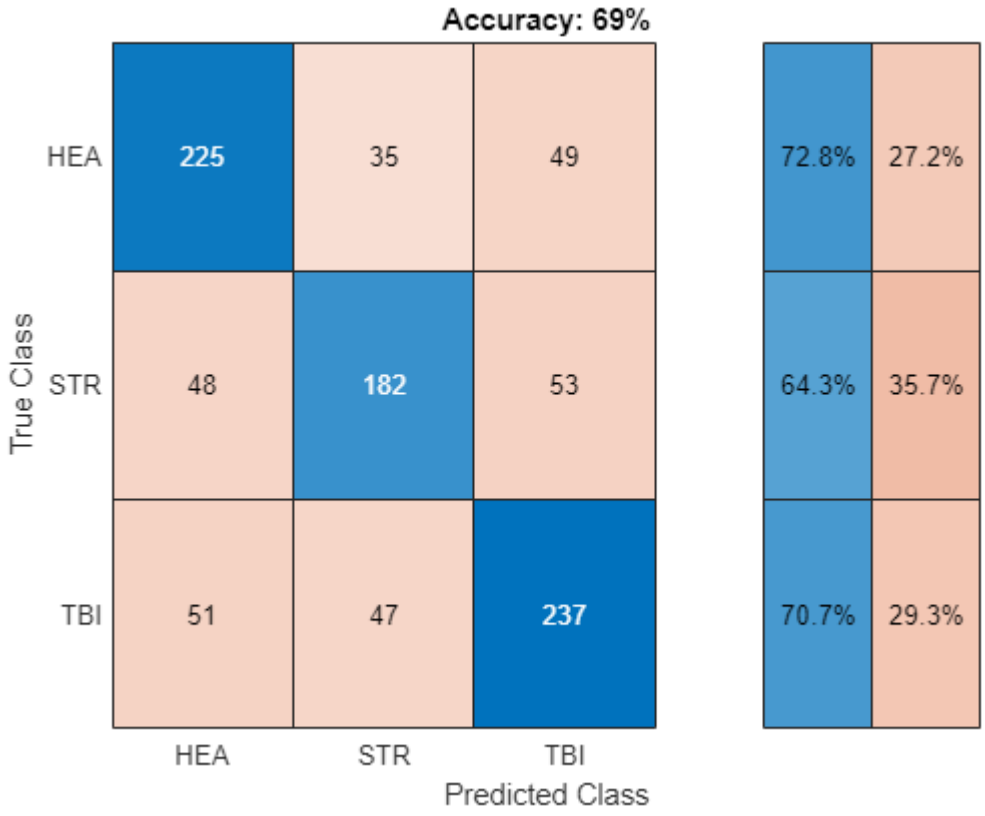
All Data

Using the Classification Learner, several SVM models were developed:

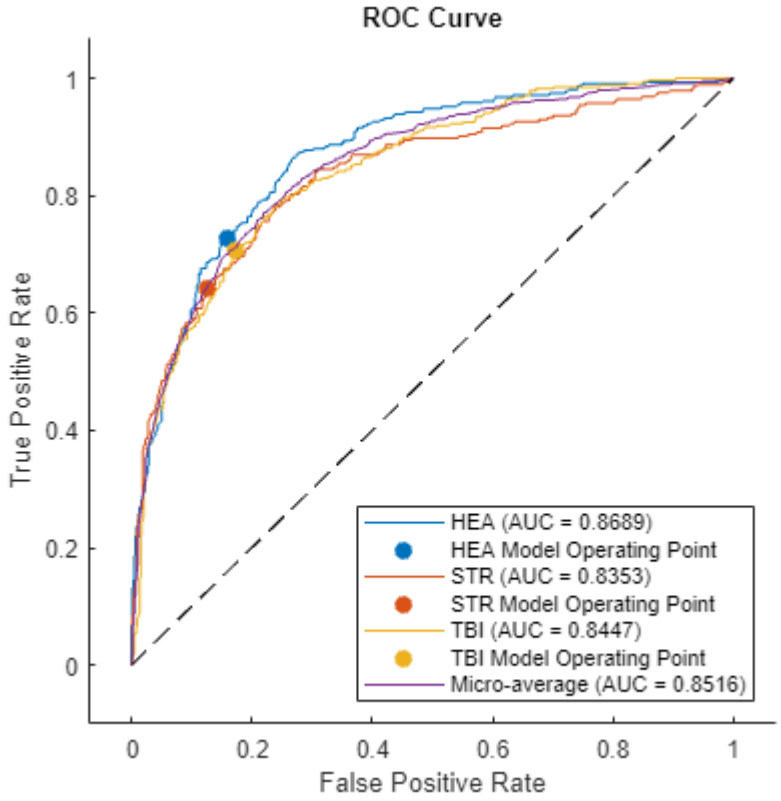
ReliefF - Cubic SVM

```
load('ReliefF_SVM.mat')
s = split(string(trainedModel1.ClassificationSVM.PredictorNames),'_');
s = s(:,:,2);
q = array2table(F.Features);
q = q(:,str2double(s));
q.Properties.VariableNames =
trainedModel1.ClassificationSVM.X.Properties.VariableNames;
in = ismember(q,trainedModel1.ClassificationSVM.X,"rows");
testData = F(~in,:);
testLabels = F.Label(~in);

SVM = MdlResults(trainedModel1,testData,testLabels);
classify(SVM);
```



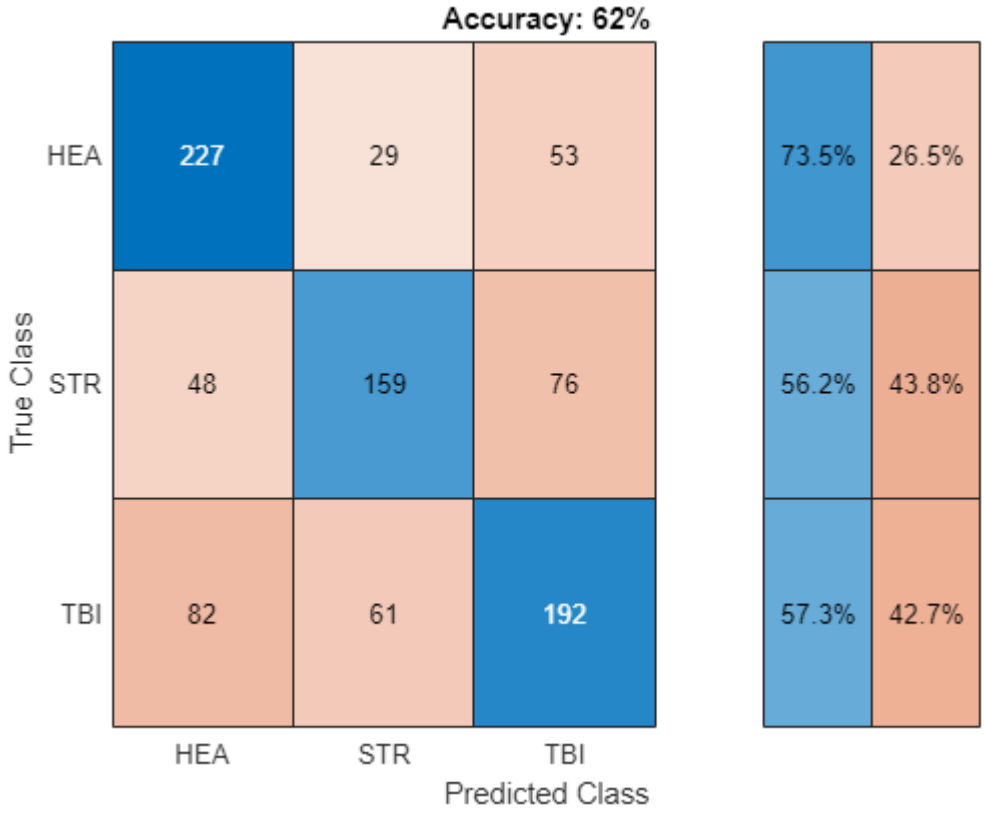

```
metrics(SVM);
```



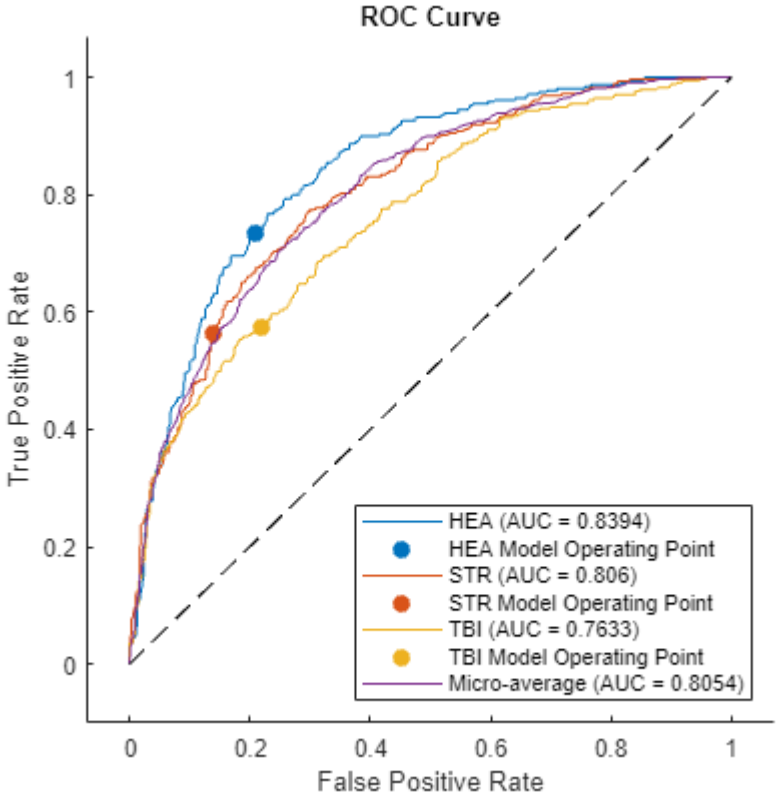
LDA - Medium Gaussian SVM

```
load('LDA_SVM.mat')
s = split(string(trainedModel.ClassificationSVM.PredictorNames),'_');
s = s(:,:,2);
q = array2table(G.Features);
q = q(:,str2double(s));
q.Properties.VariableNames =
trainedModel.ClassificationSVM.X.Properties.VariableNames;
in = ismember(q,trainedModel.ClassificationSVM.X,"rows");
testData = G(~in,:);
testLabels = G.Label(~in);

SVM = MdlResults(trainedModel,testData,testLabels);
classify(SVM);
```

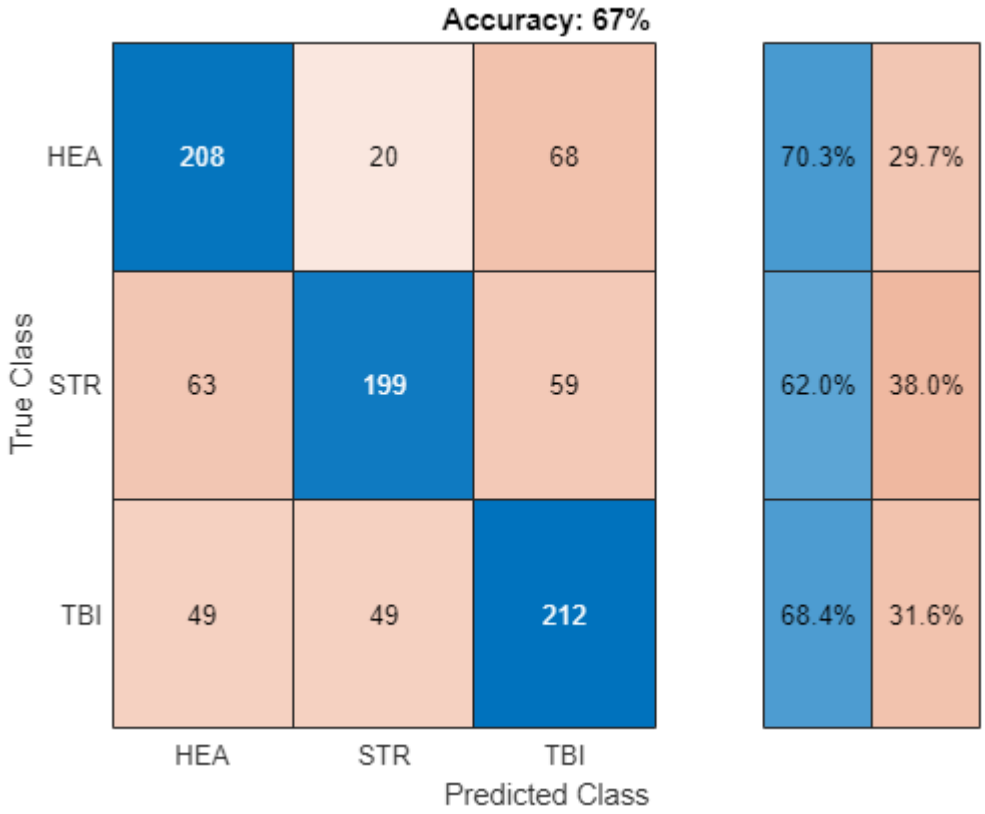

Accuracy: 62%
HEA
STR
TBI
True Class
227
29
53
48
159
76
82
61
192
73.5%
26.5%
56.2%
43.8%
57.3%
42.7%
HEA
STR
TBI
Predicted Class

```
metrics(SVM);
```

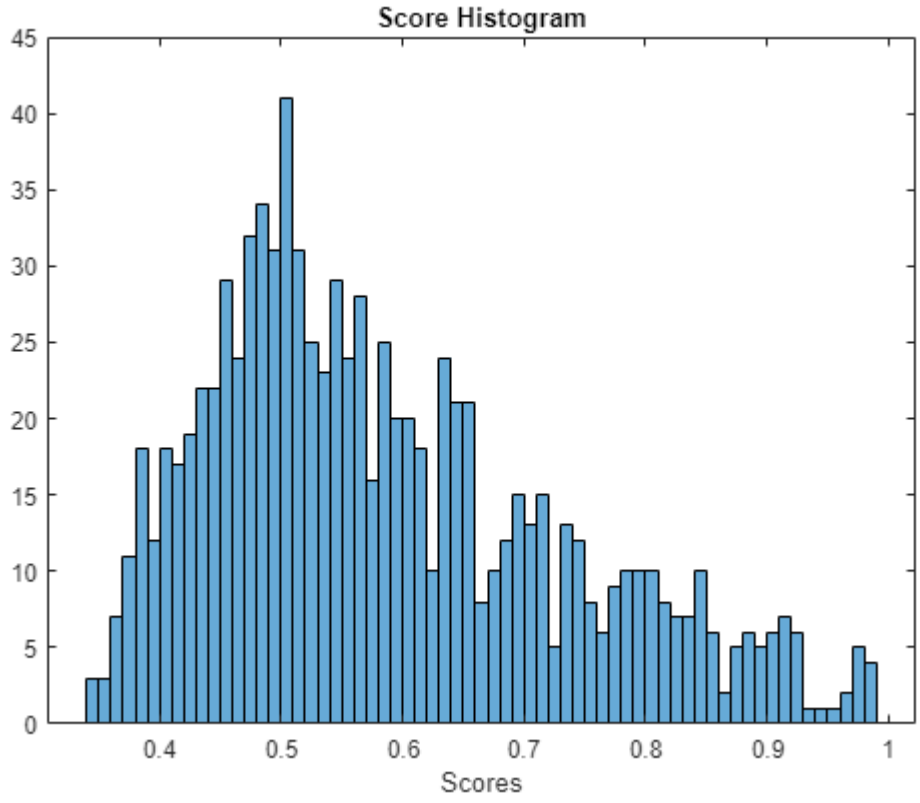

ROC Curve
True Positive Rate
False Positive Rate
0
0.2
0.4
0.6
0.8
1
HEA (AUC = 0.8394)
HEA Model Operating Point
STR (AUC = 0.806)
STR Model Operating Point
TBI (AUC = 0.7633)
TBI Model Operating Point
Micro-average (AUC = 0.8054)

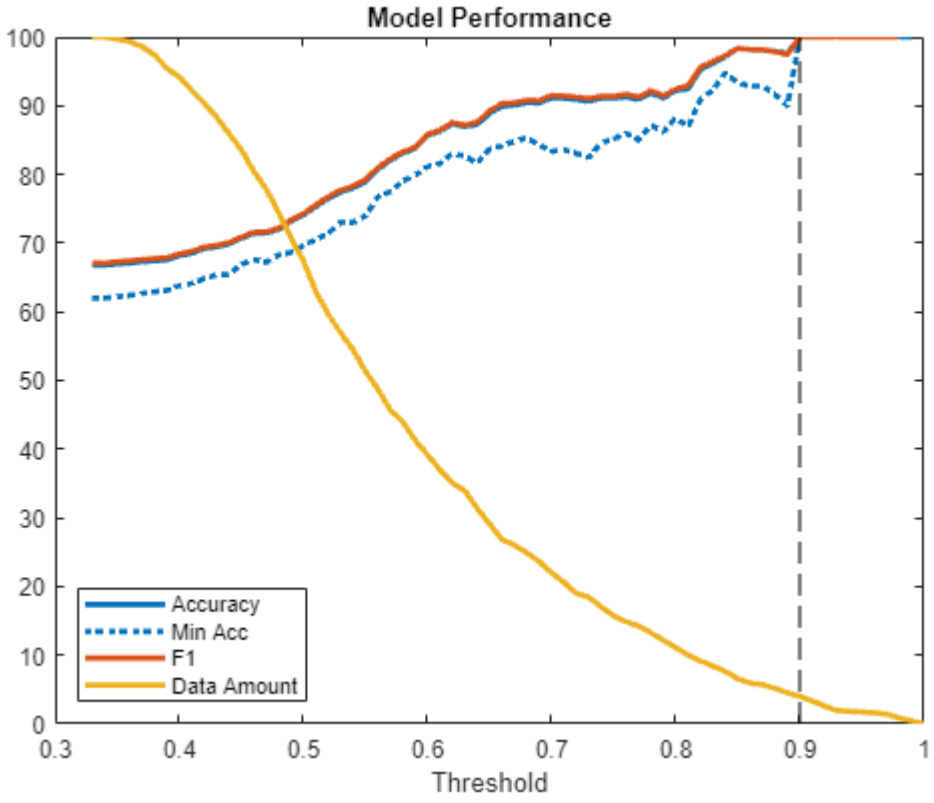
Deep Learning

```
load("F_DL.mat","f_test","f_testL");
load("F_DL.mat","net5b")
load("ReliefFScores.mat")
Fnet5b = MdlResults(net5b,f_test(:,featureIndex(1:100)),f_testL);
classify(Fnet5b);
```

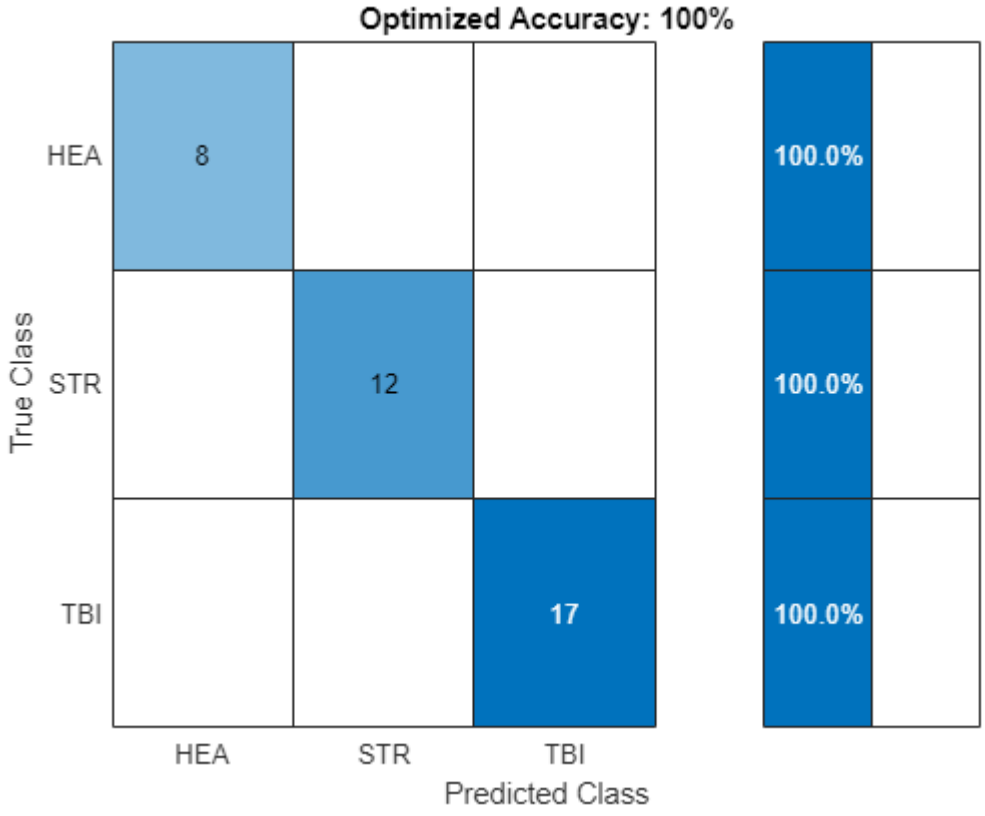


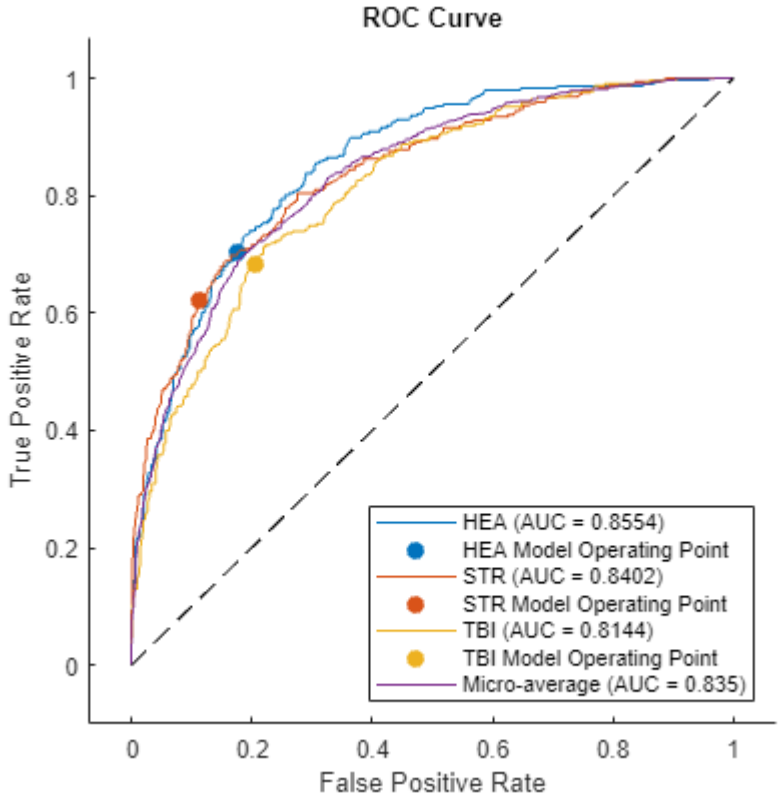

```
metrics(Fnet5b);
```



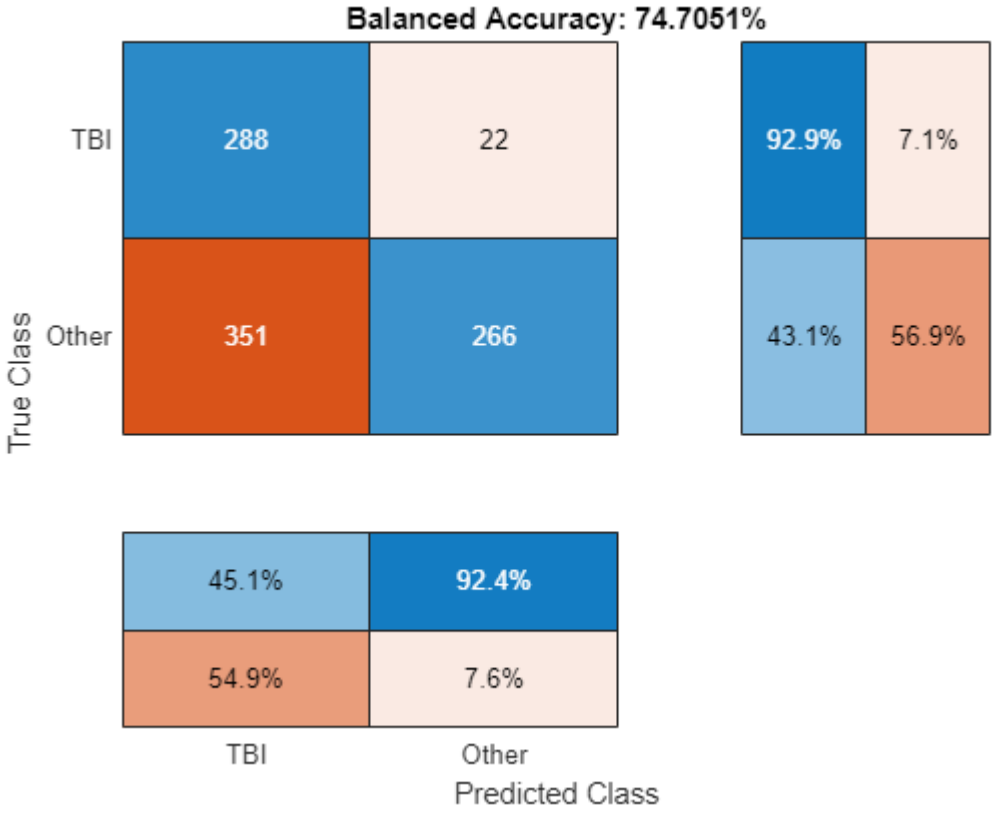



```
Data Remaining: 0.039914
```






```
BinaryPlot(Fnet5b)
```




```
ans = single

    0.7471
```

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Supporting Functions

```
function names = getFeatureNames()
```

```
names = [];
chAppend = string();
for i = 1:19
    chAppend(i) = "_Ch" + i;
end
cats = ["Mean","Max","Min","Std","AbsPSD_Delta","AbsPSD_Theta","AbsPSD_Alpha",...
    "AbsPSD_Mu","AbsPSD_Beta","AbsPSD_Gamma","RelPSD_Delta","RelPSD_Theta",...
    "RelPSD_Alpha","RelPSD_Mu","RelPSD_Beta","RelPSD_Gamma","Entropy",...
    "PACag","PACtg","PACta",];
for i = 1:length(cats)
    for j = 1:19
        names = [names cats(i) + chAppend(j)];
    end
end
ind = [ 0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,...
        0,  0,  0,  1,  1,  1,  1,  1,  1,  1,  1,  1,  1,  1,  1,  1,...
        1,  1,  1,  2,  2,  2,  2,  2,  2,  2,  2,  2,  2,  2,  2,  2,...
        2,  2,  2,  3,  3,  3,  3,  3,  3,  3,  3,  3,  3,  3,  3,  3,...
        3,  3,  4,  4,  4,  4,  4,  4,  4,  4,  4,  4,  4,  4,  4,  4,...
        5,  5,  5,  5,  5,  5,  5,  5,  5,  5,  5,  5,  5,  6,  6,  6,...
        6,  6,  6,  6,  6,  6,  6,  6,  6,  7,  7,  7,  7,  7,  7,  7,...
        7,  7,  7,  7,  8,  8,  8,  8,  8,  8,  8,  8,  8,  8,  9,  9,...
        9,  9,  9,  9,  9,  9,  9, 10, 10, 10, 10, 10, 10, 10, 10, 11,...
       11, 11, 11, 11, 11, 11, 12, 12, 12, 12, 12, 12, 13, 13, 13, 13,...
       13, 14, 14, 14, 14, 15, 15, 15, 16, 16, 17; 1,  2,  3,  4,  5,...
        6,  7,  8,  9, 10, 11, 12, 13, 14, 15, 16,...
       17, 18,  2,  3,  4,  5,  6,  7,  8,  9, 10, 11, 12, 13, 14, 15,...
       16, 17, 18,  3,  4,  5,  6,  7,  8,  9, 10, 11, 12, 13, 14, 15,...
       16, 17, 18,  4,  5,  6,  7,  8,  9, 10, 11, 12, 13, 14, 15, 16,...
       17, 18,  5,  6,  7,  8,  9, 10, 11, 12, 13, 14, 15, 16, 17, 18,...
        6,  7,  8,  9, 10, 11, 12, 13, 14, 15, 16, 17, 18,  7,  8,  9,...
       10, 11, 12, 13, 14, 15, 16, 17, 18,  8,  9, 10, 11, 12, 13, 14,...
       15, 16, 17, 18,  9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 10, 11,...
       12, 13, 14, 15, 16, 17, 18, 11, 12, 13, 14, 15, 16, 17, 18, 12,...
       13, 14, 15, 16, 17, 18, 13, 14, 15, 16, 17, 18, 14, 15, 16, 17,...
       18, 15, 16, 17, 18, 16, 17, 18, 17, 18, 18]+1;
bands = ["Theta","Alpha","Mu","Beta","Gamma","Delta"];
for i = 1:6
    for c = 1:length(ind)
        names = [names num2str(bands(i)) + "_Coherence_Ch" + ind(1,c) + "-Ch" +
ind(2,c)'];
    end
end
end

function [varnames,varcats,ind] = MakeFeatureTableNames()
ind = [ 0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,  0,...
        0,  0,  0,  1,  1,  1,  1,  1,  1,  1,  1,  1,  1,  1,  1,  1,...
        1,  1,  1,  2,  2,  2,  2,  2,  2,  2,  2,  2,  2,  2,  2,  2,...
        2,  2,  2,  3,  3,  3,  3,  3,  3,  3,  3,  3,  3,  3,  3,  3,...
```

```
         3,  3,  4,  4,  4,  4,  4,  4,  4,  4,  4,  4,  4,  4,  4,  4,...
         5,  5,  5,  5,  5,  5,  5,  5,  5,  5,  5,  5,  5,  6,  6,  6,...
         6,  6,  6,  6,  6,  6,  6,  6,  6,  7,  7,  7,  7,  7,  7,  7,...
         7,  7,  7,  7,  8,  8,  8,  8,  8,  8,  8,  8,  8,  8,  9,  9,...
         9,  9,  9,  9,  9,  9,  9, 10, 10, 10, 10, 10, 10, 10, 10, 11,...
        11, 11, 11, 11, 11, 11, 12, 12, 12, 12, 12, 12, 13, 13, 13, 13,...
        13, 14, 14, 14, 14, 15, 15, 15, 16, 16, 17; 1,  2,  3,  4,  5,...
         6,  7,  8,  9, 10, 11, 12, 13, 14, 15, 16,...
        17, 18,  2,  3,  4,  5,  6,  7,  8,  9, 10, 11, 12, 13, 14, 15,...
        16, 17, 18,  3,  4,  5,  6,  7,  8,  9, 10, 11, 12, 13, 14, 15,...
        16, 17, 18,  4,  5,  6,  7,  8,  9, 10, 11, 12, 13, 14, 15, 16,...
        17, 18,  5,  6,  7,  8,  9, 10, 11, 12, 13, 14, 15, 16, 17, 18,...
         6,  7,  8,  9, 10, 11, 12, 13, 14, 15, 16, 17, 18,  7,  8,  9,...
        10, 11, 12, 13, 14, 15, 16, 17, 18,  8,  9, 10, 11, 12, 13, 14,...
        15, 16, 17, 18,  9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 10, 11,...
        12, 13, 14, 15, 16, 17, 18, 11, 12, 13, 14, 15, 16, 17, 18, 12,...
        13, 14, 15, 16, 17, 18, 13, 14, 15, 16, 17, 18, 14, 15, 16, 17,...
        18, 15, 16, 17, 18, 16, 17, 18, 17, 18, 18]+1;

varnames = [];
varcats = [];
for i = 1:19
    varnames = [varnames, "Mean Ch"+i];
end
varcats = [varcats, "Mean"];
for i = 1:19
    varnames = [varnames, "Max Ch"+i];
end
varcats = [varcats, "Max"];
for i = 1:19
    varnames = [varnames, "Min Ch"+i];
end
varcats = [varcats, "Min"];
for i = 1:19
    varnames = [varnames, "Std Ch"+i];
end
varcats = [varcats, "Std"];
for i = 1:19
    varnames = [varnames, "Delta AbsPSD Ch"+i];
end
varcats = [varcats, "Delta AbsPSD"];
for i = 1:19
    varnames = [varnames, "Theta AbsPSD Ch"+i];
end
varcats = [varcats, "Theta AbsPSD"];
for i = 1:19
    varnames = [varnames, "Alpha AbsPSD Ch"+i];
end
varcats = [varcats, "Alpha AbsPSD"];
for i = 1:19
```

```
    varnames = [varnames, "Mu AbsPSD Ch"+i];
end
varcats = [varcats, "Mu AbsPSD"];
for i = 1:19
    varnames = [varnames, "Beta AbsPSD Ch"+i];
end
varcats = [varcats, "Beta AbsPSD"];
for i = 1:19
    varnames = [varnames, "Gamma AbsPSD Ch"+i];
end
varcats = [varcats, "Gamma AbsPSD"];
for i = 1:19
    varnames = [varnames, "Delta RelPSD Ch"+i];
end
varcats = [varcats, "Delta RelPSD"];
for i = 1:19
    varnames = [varnames, "Theta RelPSD Ch"+i];
end
varcats = [varcats, "Theta RelPSD"];
for i = 1:19
    varnames = [varnames, "Alpha RelPSD Ch"+i];
end
varcats = [varcats, "Alpha RelPSD"];
for i = 1:19
    varnames = [varnames, "Mu RelPSD Ch"+i];
end
varcats = [varcats, "Mu RelPSD"];
for i = 1:19
    varnames = [varnames, "Beta RelPSD Ch"+i];
end
varcats = [varcats, "Beta RelPSD"];
for i = 1:19
    varnames = [varnames, "Gamma RelPSD Ch"+i];
end
varcats = [varcats, "Gamma RelPSD"];
for i = 1:19
    varnames = [varnames, "Entropy Ch"+i];
end
varcats = [varcats, "Entropy"];
for i = 1:19
    varnames = [varnames, "PAC_ag Ch"+i];
end
varcats = [varcats, "PAC_ag"];
for i = 1:19
    varnames = [varnames, "PAC_tg Ch"+i];
end
varcats = [varcats, "PAC_tg"];
for i = 1:19
    varnames = [varnames, "PAC_ta Ch"+i];
end
```

```
varcats = [varcats, "PAC_ta"];
for i = 1:length(ind)
    varnames = [varnames, "Theta COH ch"+ind(1,i)+"-ch"+ind(2,i)];
end
varcats = [varcats, "Theta COH"];
for i = 1:length(ind)
    varnames = [varnames, "Alpha COH ch"+ind(1,i)+"-ch"+ind(2,i)];
end
varcats = [varcats, "Alpha COH"];
for i = 1:length(ind)
    varnames = [varnames, "Mu COH ch"+ind(1,i)+"-ch"+ind(2,i)];
end
varcats = [varcats, "Mu COH"];
for i = 1:length(ind)
    varnames = [varnames, "Beta COH ch"+ind(1,i)+"-ch"+ind(2,i)];
end
varcats = [varcats, "Beta COH"];
for i = 1:length(ind)
    varnames = [varnames, "Gamma COH ch"+ind(1,i)+"-ch"+ind(2,i)];
end
varcats = [varcats, "Gamma COH"];
for i = 1:length(ind)
    varnames = [varnames, "Delta COH ch"+ind(1,i)+"-ch"+ind(2,i)];
end
varcats = [varcats, "Delta COH"];
end
```