

Train Features

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Live script used to train networks with feature data

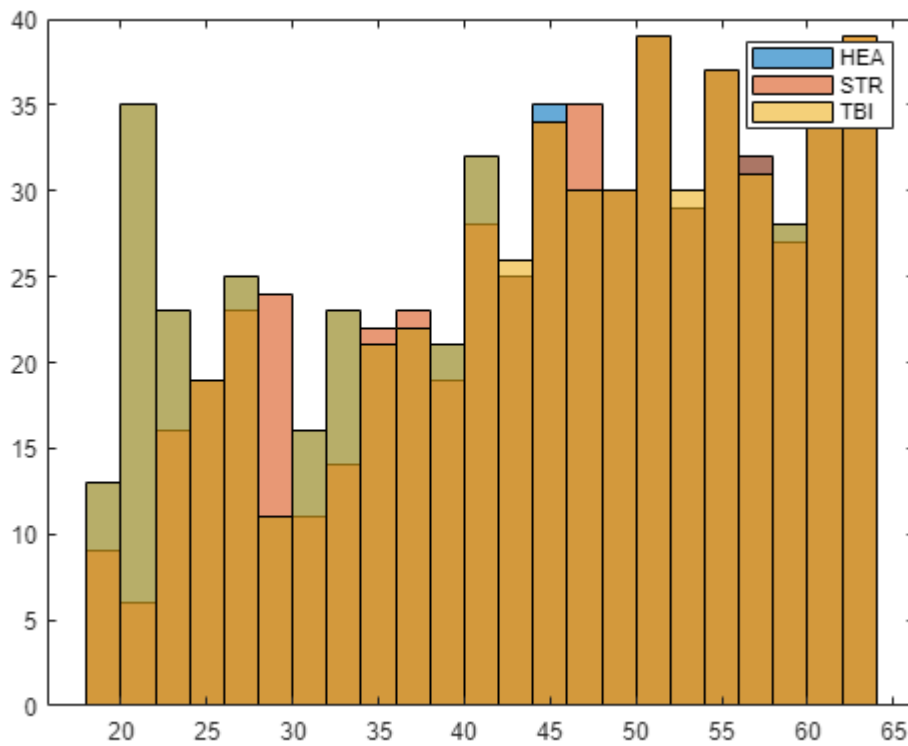
Using PreDREEG, PreDREEGplot, and DREEGd, one can generate *_3F.mat files used in commented code below. Although these files are not included, the generated result is saved in AllFeatures.mat. The commented code is provided for reproducibility.

```
% 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 use saved data after.

```
% AMdl = fitcdiscr(F.Features,F.Label,'DiscrimType','linear',...
%
% 'OptimizeHyperparameters','auto','HyperparameterOptimizationOptions',...
%
% struct('ShowPlots',false,'Verbose',1,'UseParallel',true,'Repartition',true,'SaveIntermediateResults',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 Features with LDA

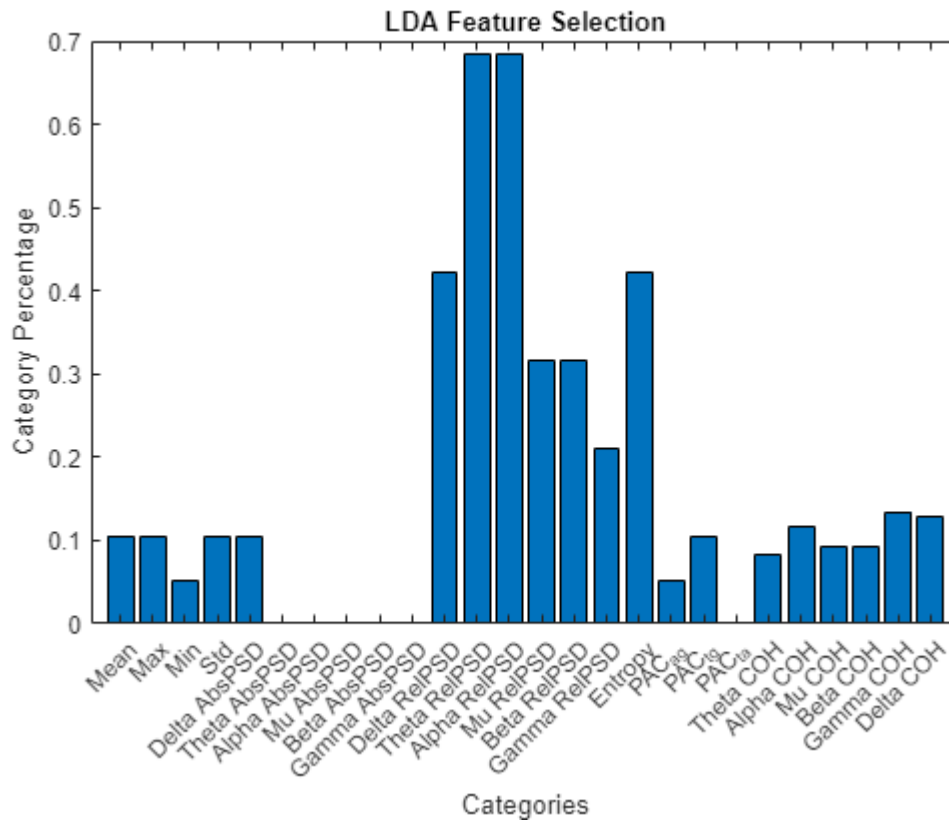
```
load("AllFeatures.mat");
```

```
[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

```

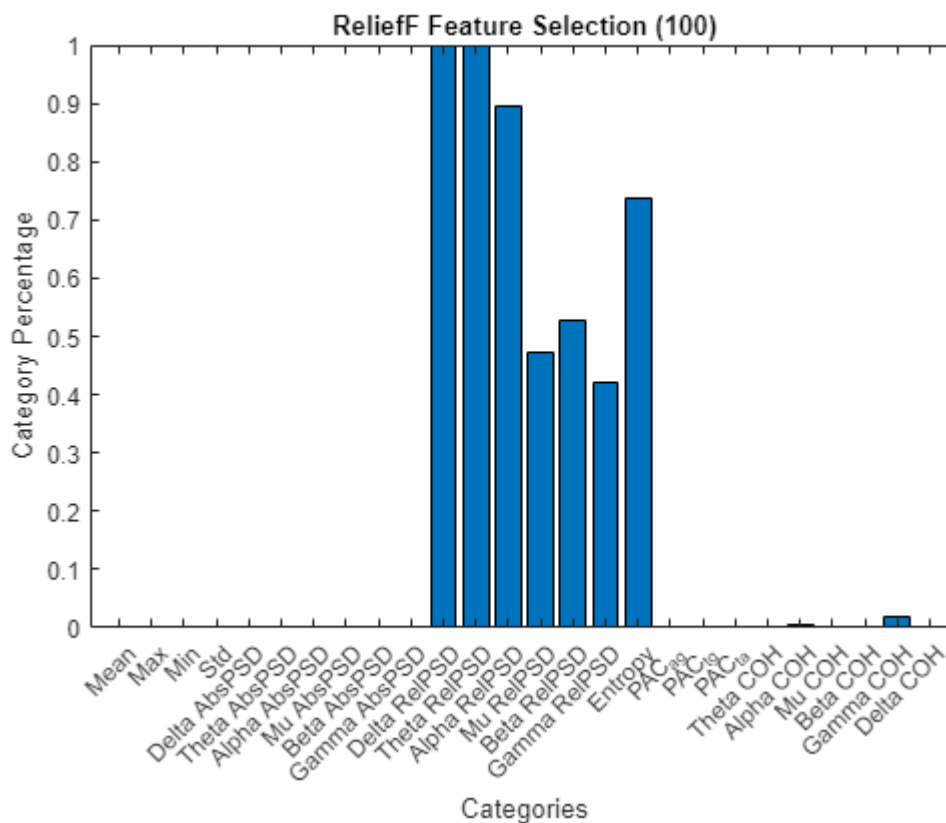
% [featureIndex,score] = reliefF(...
%     F.Features, ...
%     F.Label, ...
%     10);
% save("RelieffScores.mat","featureIndex","score");

```

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')
```

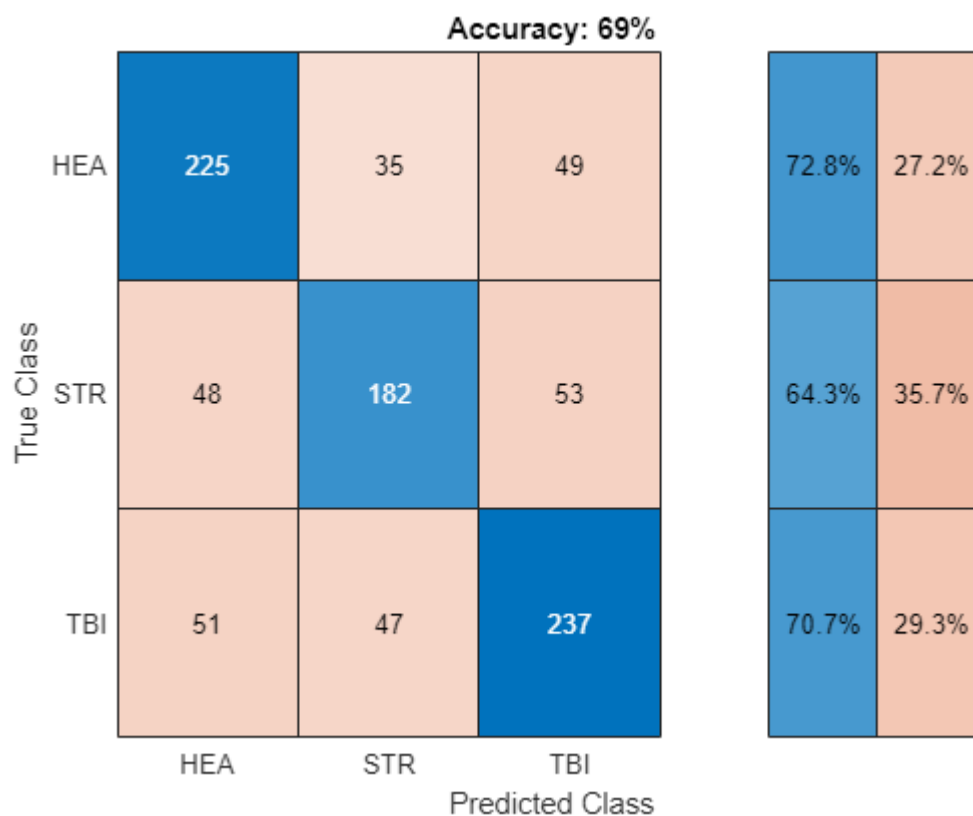
All Data

Using the Classification Learner, several SVM models were developed:

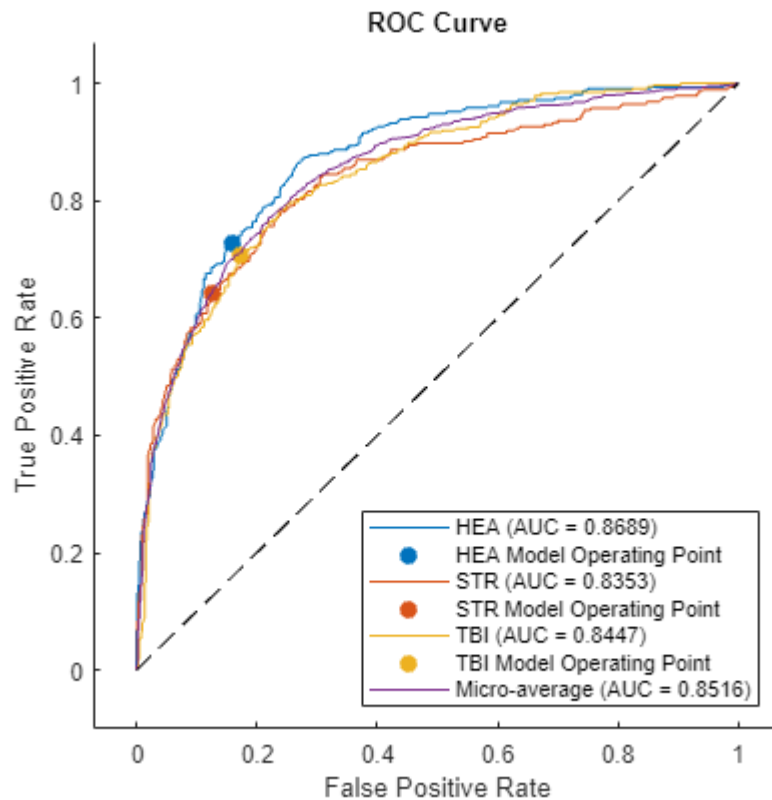
ReliefF - Cubic SVM

```
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);
```



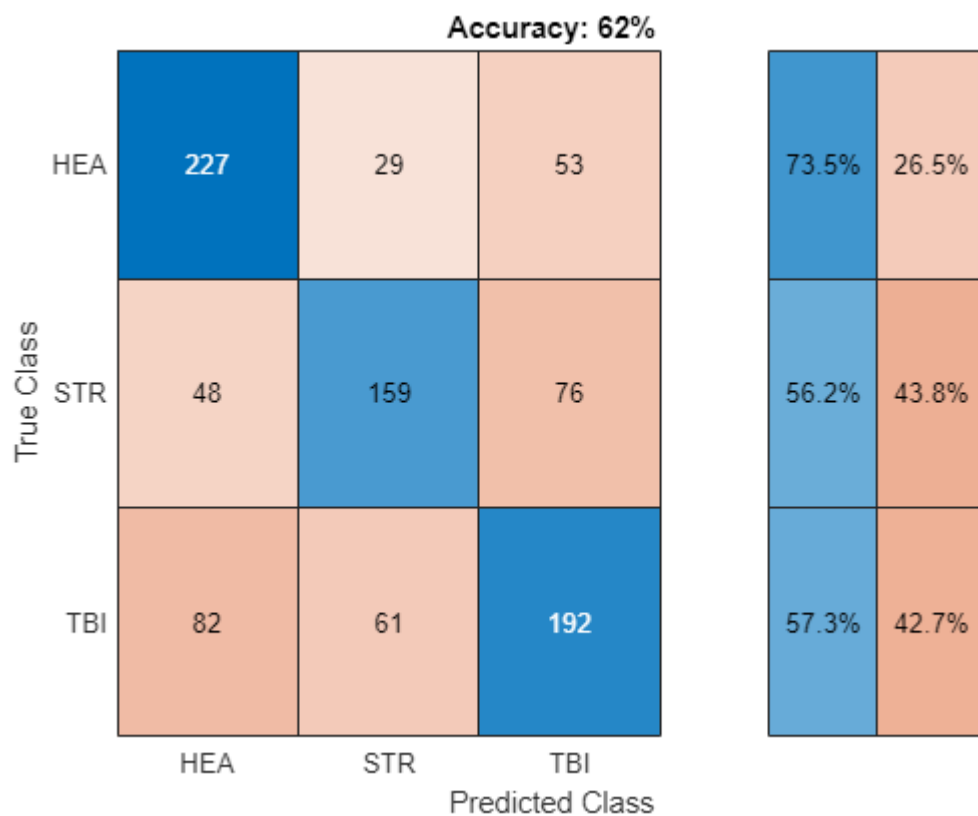
```
metrics(SVM);
```



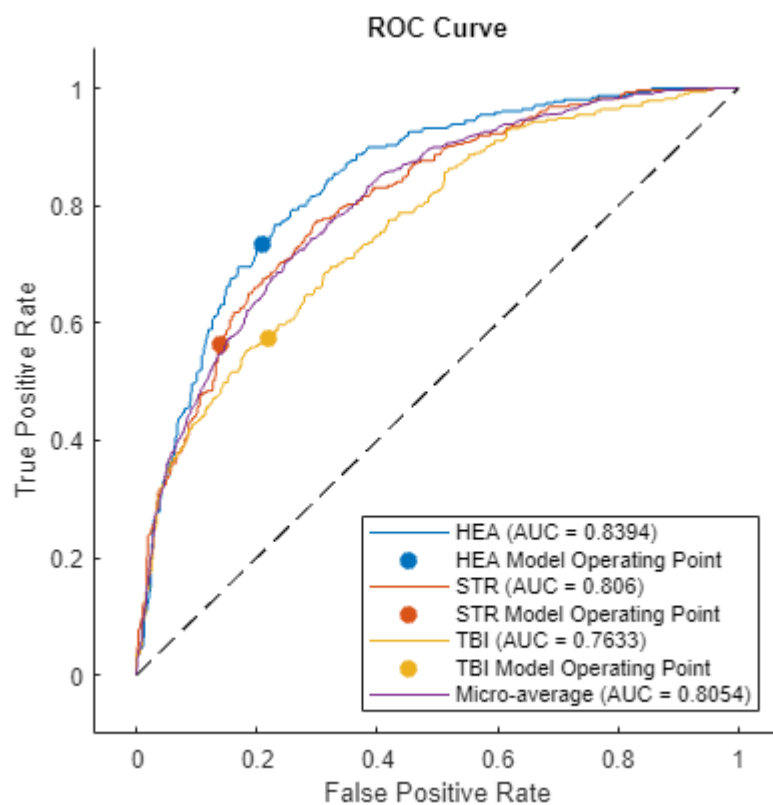
LDA - Medium Gaussian SVM

```
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);
```

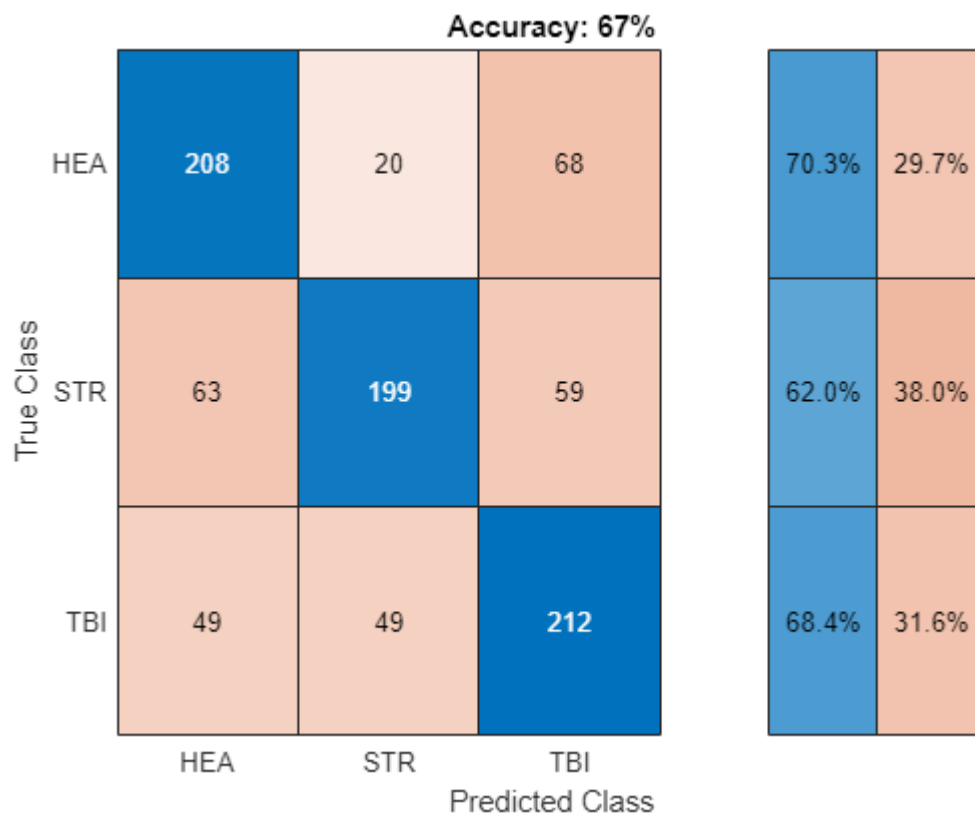


```
metrics(SVM);
```

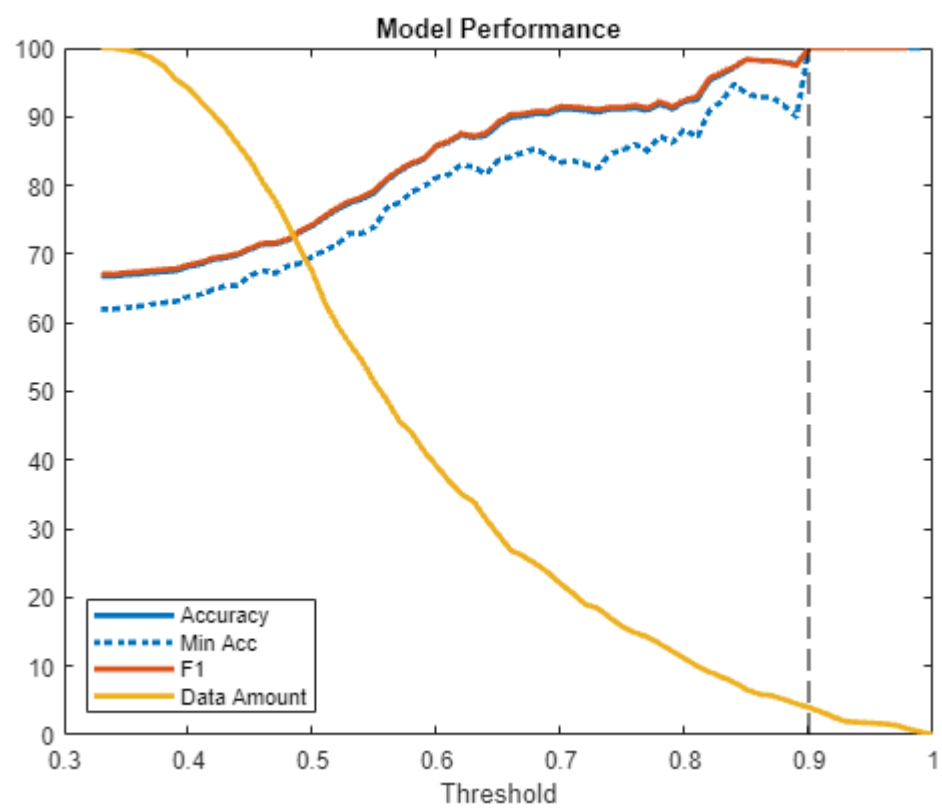
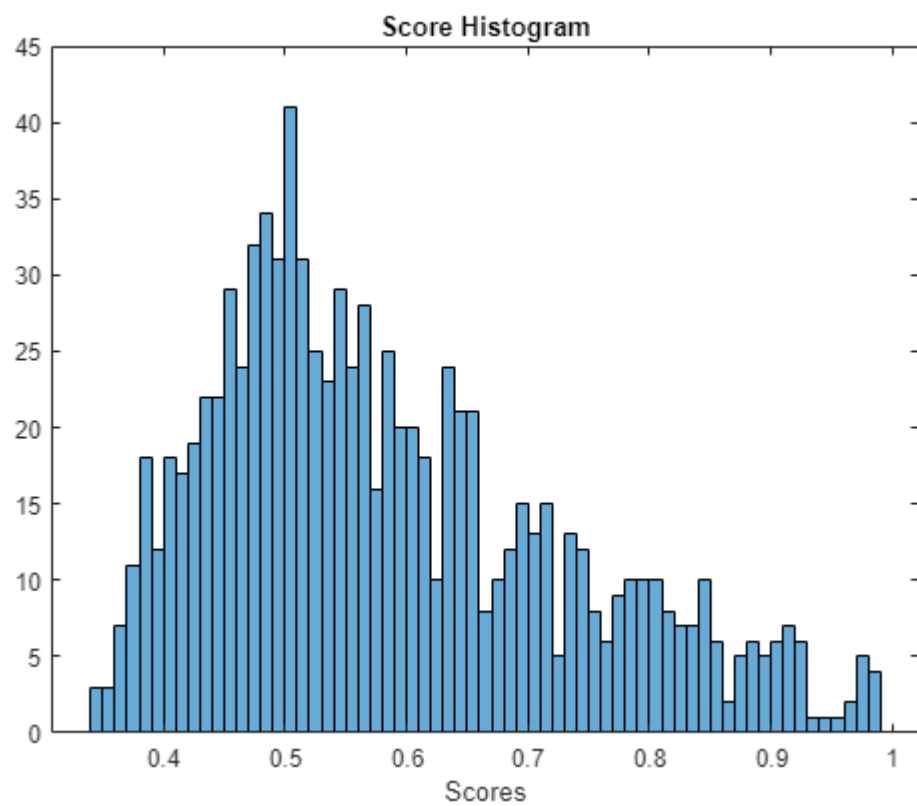


Deep Learning

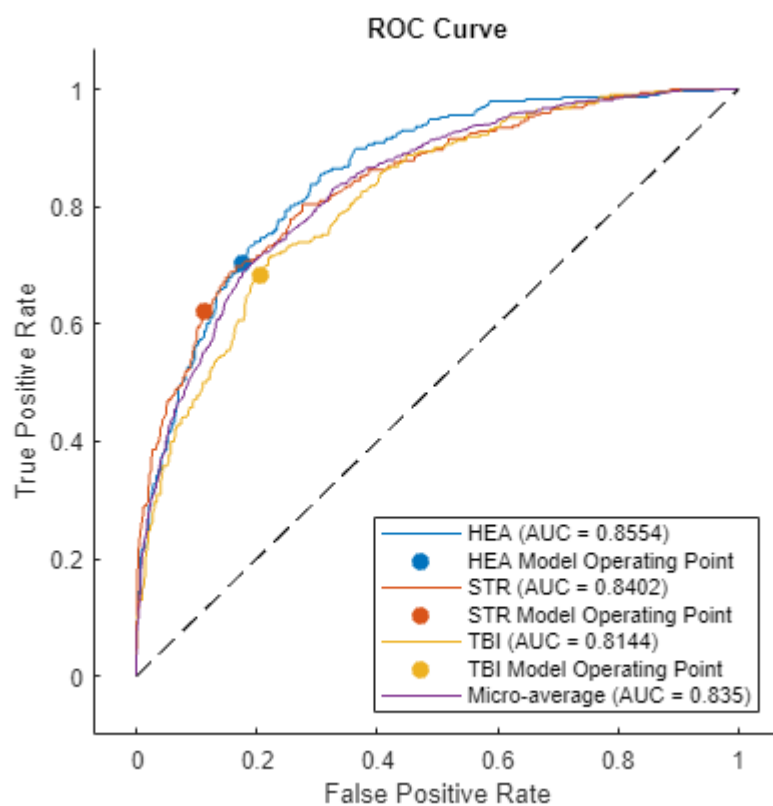
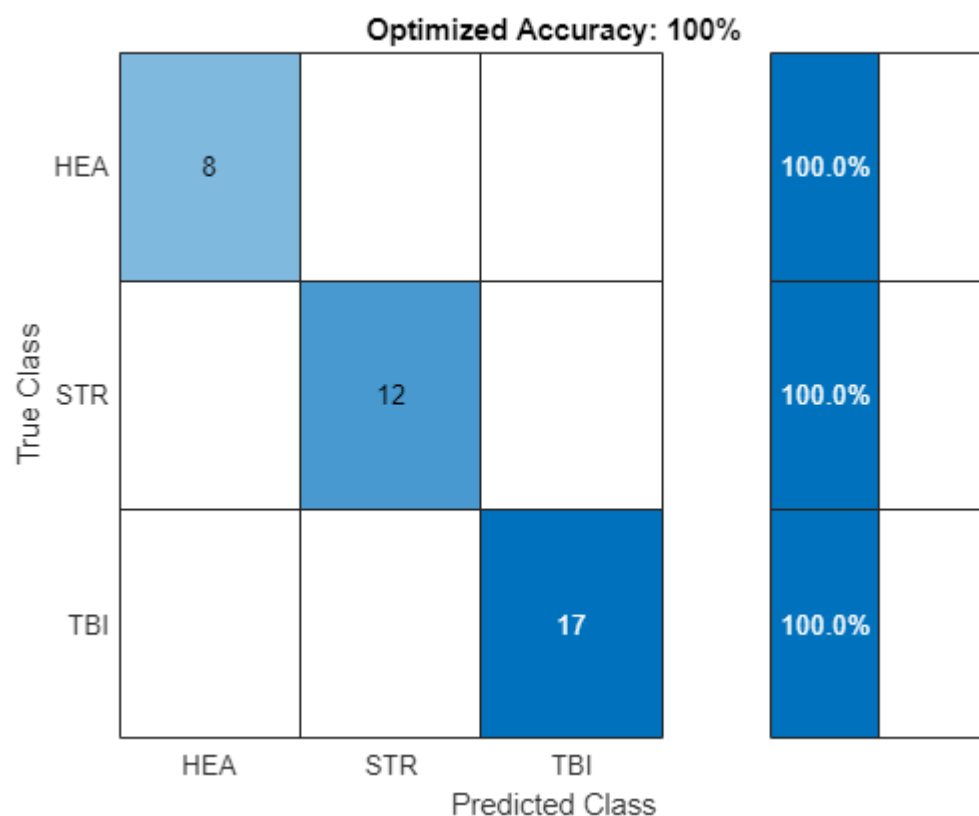
```
load("F_DL.mat","f_test","f_testL");  
load("F_DL.mat","net5b")  
load("RelieffScores.mat")  
Fnet5b = MdlResults(net5b,f_test(:,featureIndex(1:100)),f_testL);  
classify(Fnet5b);
```



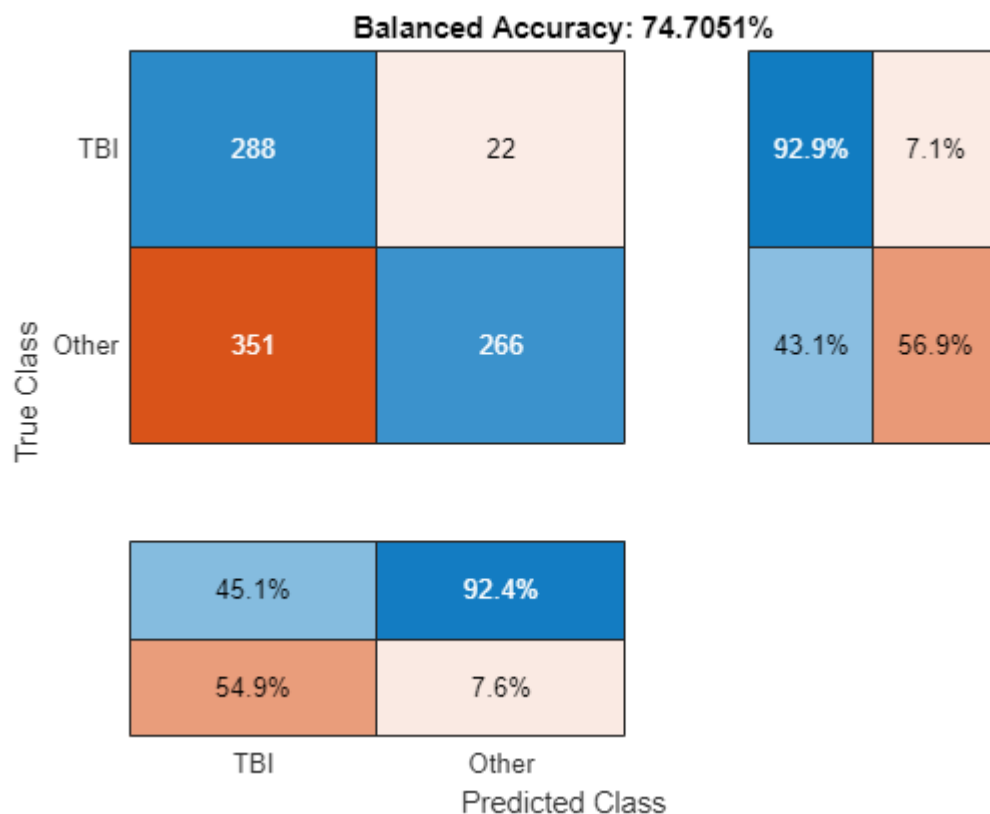
```
metrics(Fnet5b);
```



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, ...
        0,  0,  0,  1,  1,  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,  2,  2,  3,  3,  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,  4,  4, ...
        5,  5,  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,  6,  7,  7,  7,  7,  7,  7,  7,  7, ...
        7,  7,  7,  7,  8,  8,  8,  8,  8,  8,  8,  8,  8,  8,  8,  8,  9,  9, ...
        9,  9,  9,  9,  9,  9,  9,  9, 10, 10, 10, 10, 10, 10, 10, 10, 10, 11, ...
        11, 11, 11, 11, 11, 11, 12, 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
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, ...
        0,  0,  0,  1,  1,  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,  2,  2,  3,  3,  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,  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, 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, 9, 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

```

```

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

```