ML_3Type

establish a 3 type classifier for SE/E/NE data, according to SZa, CLa, LAa and 3 '_Err'

'effc': 0=SE; 1=E; 2=NE

NE(>0.7), E(0.7~0.3), SE(<0.3)

In [10]:
```
import pandas as pd
import matplotlib.pyplot as plt
from sklearn import decomposition as skldec
import numpy as np
import seaborn as sns
import time
import os

from sklearn.linear_model import SGDClassifier
from sklearn.ensemble import RandomForestClassifier
from sklearn.svm import SVC

save_dir = 'input your file dir' #r'E:\Github'
```

Function

In [2]:
```
from sklearn.model_selection import GridSearchCV

def GridSearch_result(ML, X, y, param_grid, cv=3, score="accuracy"):
    start = time.time()
    grid_search = GridSearchCV(ML, param_grid, cv=cv, scoring=score, refit=True)
    grid_search.fit(X, y)
    end = time.time()
    print("Run Time:%s s" % (end-start))
    return [grid_search.best_params_, grid_search.best_estimator_]
```

In [126…

```
from sklearn.metrics import confusion_matrix
from sklearn.metrics import accuracy_score
from sklearn.metrics import roc_curve
from sklearn.model_selection import cross_val_predict
from sklearn.metrics import roc_auc_score  #AUC

def ML_result(ML, X, y, label, roc=0, feedback=0, save_dir=None,
              cmap=sns.color_palette('tab10'), cv=3, ifprint=False):
    "Input: ML classifier. "
    "fit, and Output confusion_matrix, accuracy_score / roc_curve"

    #ML.fit(X, y)
    y_pred = cross_val_predict(ML, X, y, cv=cv)

    conf_mat = confusion_matrix(y, y_pred)
    accu = accuracy_score(y, y_pred)
    if roc != 0:
        if roc == "rf":
            y_probas_forest = cross_val_predict(ML, X, y, cv=cv, method="predict_proba")
            y_scores = y_probas_forest[:, 1] # score = proba of positive class
        if roc == "sgd":
            y_scores = cross_val_predict(ML, X, y, cv=cv, method="decision_function")
        fpr, tpr, thresholds = roc_curve(y, y_scores)
        auc = roc_auc_score(y, y_scores)
        plot_roc_curve([fpr], [tpr], label=[label], auc=[auc], cmap=cmap, save_dir=save_dir)
        plt.show()
        if feedback == 1:
            return {"conf_mat":conf_mat, "accu":accu, "auc":auc, "fpr":fpr, "tpr":tpr}
        else:
            return {"conf_mat":conf_mat, "accu":accu, "auc":auc}
    if ifprint == True:
        print({"conf_mat":conf_mat, "accu":accu})
    return {"conf_mat":conf_mat, "accu":accu}
```

In [318…

```
def conf_mat_heatmap(conf_mat, rect_set, title, ticklabel=['SE','E','NE'],
                     cmap=None, density=True, save_dir=None,):
    'draw conf_matrix heatmap'
    fig = plt.figure(dpi=130, figsize=(2.5, 2.5))
    ax1 = fig.add_subplot(111)
    density_mat = conf_mat / np.sum(conf_mat, axis=1).reshape(conf_mat.shape[0], -1)
```

```
    if cmap == None:  #return matplotlib colormap
        cmap = sns.cubehelix_palette(rot=0.2, gamma=0.5, dark=0.3, light=1, as_cmap=True)#violet
    if density == False: #annotation show raw number
        h = sns.heatmap(data=density_mat, xticklabels=ticklabel, yticklabels=ticklabel,
                        vmin=0, vmax=1, annot=conf_mat, mask=density_mat==0,
                        linewidths=1, linecolor="0.7", cbar=False, #turn off color bar
                        annot_kws={'size':12,'color':"k",'family':"Arial"}, #'weight':600,
                        square=True, cmap=cmap, ax=ax1)
    elif density == True:
        h = sns.heatmap(data=density_mat, xticklabels=ticklabel, yticklabels=ticklabel,
                        vmin=0, vmax=1, annot=True, fmt=".1%", mask=density_mat==0,
                        linewidths=1, linecolor="0.7", cbar=False,
                        annot_kws={'size':11,'color':"k",'family':"Arial",},
                        square=True, cmap=cmap, ax=ax1)
    ax1.tick_params(width=2, length=4, colors="k")
    rect = plt.Rectangle(xy=rect_set["xy1"], width=rect_set["width1"], height=rect_set["height1"],
                         fill=False, edgecolor="k", linewidth=rect_set["linewidth1"])
    ax1.add_patch(rect)

    rect_cb = [1, 0.13, 0.11, 0.74] # color bar
    cbar_ax = fig.add_axes(rect_cb)
    cb = h.figure.colorbar(h.collections[0], cax=cbar_ax) #show colorbar
    cb.ax.tick_params(direction='out', labelsize=9, length=4, width=1, colors="k",
                      right=True)#left=True,
    rect2 = plt.Rectangle(xy=rect_set["xy2"], width=rect_set["width2"], height=rect_set["height2"],
                         fill=False, edgecolor="k", linewidth=rect_set["linewidth2"] )
    cbar_ax.add_patch(rect2)
    font1 = {'family':'Arial', 'color':'k', 'weight':'bold', 'size': 12}
    accu = conf_mat.trace()/conf_mat.sum()
    ax1.set_xlabel('Accuracy Score:{:.1%}'.format(accu), font1);
    ax1.set_ylabel("Actual", font1);
    ax1.set_title(str(title)+'\n Predicted', font1);
    if save_dir != None:
        plt.savefig(os.path.join(save_dir, title+'.png'), bbox_inches='tight', dpi=150)

rect_set={"xy1":(0.015,0.017), "width1":1.96, "height1":1.96,"linewidth1":2.2,
                    "xy2":(0.03,0.004), "width2":0.97, "height2":0.99,"linewidth2":1.1}
rect_set2={"xy1":(0.023,0.017), "width1":2.94, "height1":2.96,"linewidth1":2.2,
                    "xy2":(0.03,0.004), "width2":0.97, "height2":0.99,"linewidth2":1.1}
```

```
cmap2=sns.cubehelix_palette(start=2.75, rot=0, gamma=1, hue=2, dark=0.5, light=1, as_cmap=True)#blue
cmap3=sns.cubehelix_palette(start=0.8, rot=0, gamma=0.9, hue=1.2, dark=0.5, light=1, as_cmap=True)#bricks
```

import data

In [343…

```
file_path = os.path.join(save_dir,'ML_dataset.xlsx')
df = pd.read_excel(file_path, sheet_name='adj_effc_3t', index_col=0)
df.dropna(inplace=True)
df.head()
```

Out[343]:

id	cancer	sample_id	LAa	LAErr	SZa	SZErr	CLa	CLErr	effc	kill
81	CCom	A3	1.51085	0.13405	1.34627	0.02986	1.83637	0.22148	2	0.30000
16	GC	5	1.03143	0.22530	1.20558	0.06233	0.82232	0.09236	2	0.07000
60	KC	A6	0.11333	0.01206	1.15431	0.10533	0.02664	0.00668	0	0.97336
37	PaC	6	0.81366	0.01794	1.14430	0.09914	0.97903	0.07454	2	0.00000
90	GC	A2	1.71732	0.40495	1.12907	0.01176	1.44957	0.08896	2	0.04000

In [4]:

```
#split data
df3 = df.loc[:, ["LAa","LAErr","SZa","SZErr","CLa","CLErr"]]
df3.head()
```

Out[4]:

id	LAa	LAErr	SZa	SZErr	CLa	CLErr
81	1.51085	0.13405	1.34627	0.02986	1.83637	0.22148
16	1.03143	0.22530	1.20558	0.06233	0.82232	0.09236
60	0.11333	0.01206	1.15431	0.10533	0.02664	0.00668
37	0.81366	0.01794	1.14430	0.09914	0.97903	0.07454
90	1.71732	0.40495	1.12907	0.01176	1.44957	0.08896

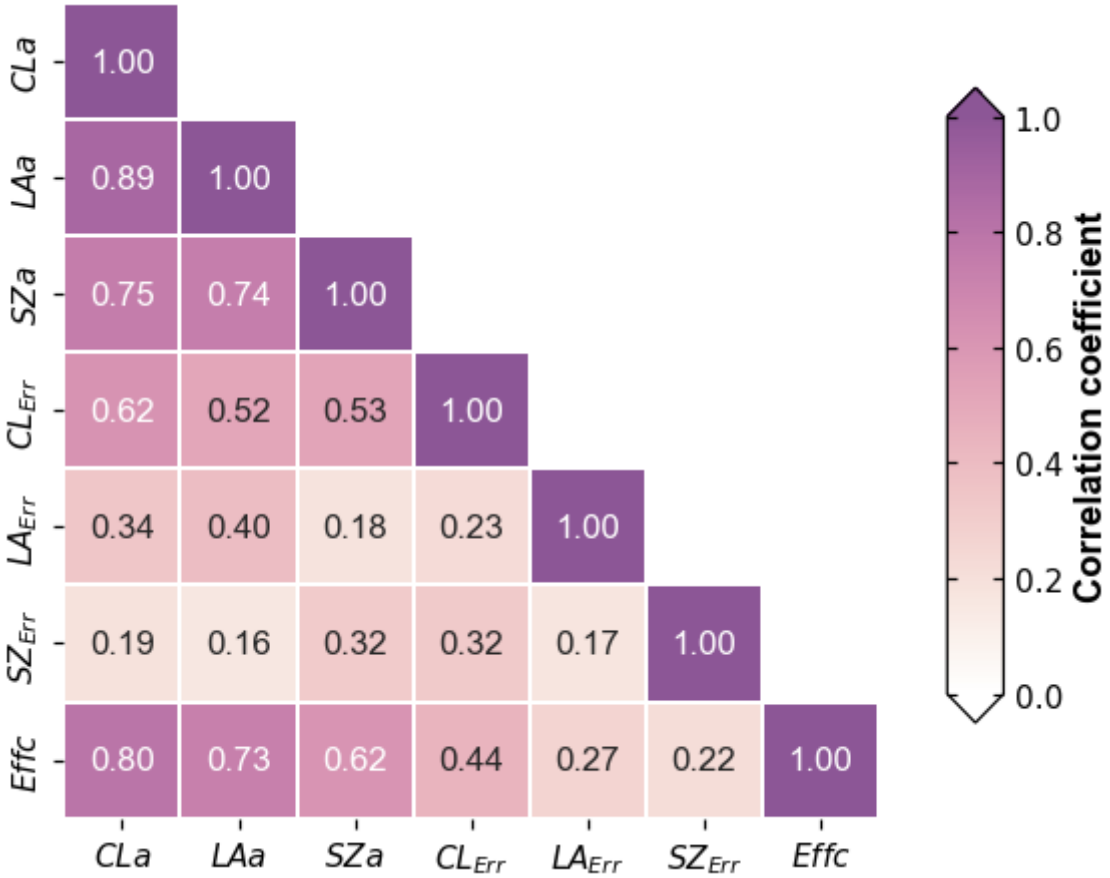
Visualization

In [5]:
```
index3 = ["CLa","LAa","SZa","CLErr","LAErr","SZErr","effc"]
df_c = df.loc[:, index3]
corr_matrix = df_c.corr()
corr_matrix["effc"].sort_values(ascending=False)
```

Out[5]:
```
effc     1.000000
CLa      0.796878
LAa      0.730532
SZa      0.615968
CLErr    0.441411
LAErr    0.267801
SZErr    0.216525
Name: effc, dtype: float64
```

In [11]:
```
fig = plt.figure(dpi=110, )
ax1 = fig.add_subplot(111)
cmap = sns.cubehelix_palette(rot=0.4, hue=0.9, gamma=0.7, dark=0.3, light=1, as_cmap=True)
mask = np.triu(np.ones_like(corr_matrix, dtype=bool), 1)
g=sns.heatmap(data=corr_matrix, vmax=1, vmin=0, linewidth=1, linecolor="w", cmap=cmap,
              annot = True, fmt="0.2f", square=True, mask=mask, cbar=False,
              ax=ax1, annot_kws={'size':11, 'family':"Arial"},)
```

```
rect = [0.85, 0.2, 0.04, 0.6]   #x, y, x_width, y_height
cbar_ax = fig.add_axes(rect)
cb = g.figure.colorbar(g.collections[0], cax=cbar_ax, extend="both")  #share colorbar
cb.ax.tick_params(direction='in', color="k", length=3, left=True, right=True)
cb.set_label('Correlation coefficient', font={'family':'Arial', 'size':12, 'weight': 'bold'})
labels = ['$CLa$','$LAa$','$SZa$','$CL_{Err}$','$LA_{Err}$','$SZ_{Err}$',"$Effc$"]
ax1.set_yticklabels(labels);
ax1.set_xticklabels(labels);
#fig.savefig(os.path.join(save_dir, str(time.time())+'.png'), dpi=150, bbox_inches='tight')
```



In [97]:
```
#PCA
pca = skldec.PCA()
pca.fit(df3)
```

```
result = pca.transform(df3)

data = pd.DataFrame(result)
data['label'] = np.array(df.effc)
data
```

Out[97]:

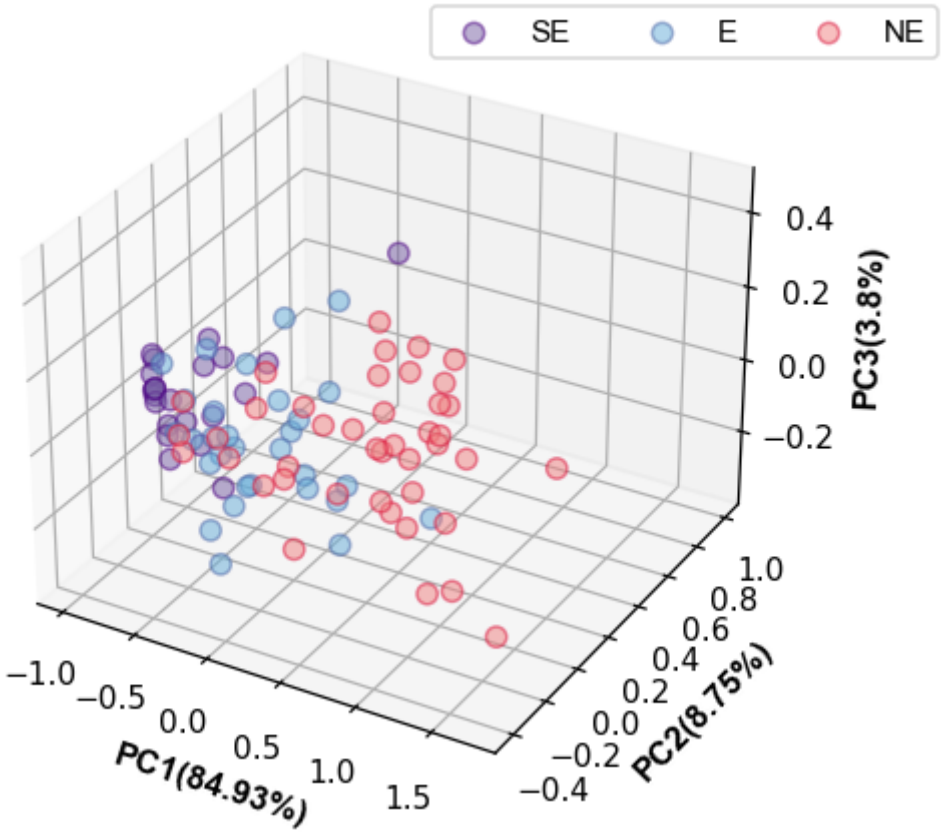
	0	1	2	3	4	5	label
0	1.716002	0.035878	0.096184	-0.075637	0.030290	0.066523	2
1	0.693676	0.447050	-0.164975	0.000187	0.155484	0.054385	2
2	-0.382791	0.994978	0.081704	-0.052080	0.068707	-0.002045	0
3	0.644134	0.411908	0.115701	-0.068697	-0.004609	-0.032591	2
4	1.459682	-0.078248	-0.342719	0.014896	0.255272	0.043671	2
...	...	...	...	...	...	...	...
89	-0.932429	-0.016139	0.000975	-0.049787	-0.014419	0.018728	0
90	-0.917494	-0.027223	0.025770	-0.043373	0.002811	0.022065	0
91	-0.941914	-0.014663	0.013553	-0.044438	0.003312	0.022242	0
92	-0.968697	-0.001484	0.049589	-0.049317	0.004837	0.020648	0
93	-0.900291	-0.038045	-0.005015	-0.052099	-0.017647	0.020763	0

94 rows × 7 columns

In [100…

```
#3D scatter
fig_a = plt.figure(dpi=110)
ax = fig_a.add_subplot(111, projection='3d')
d1 = data.loc[data['label']==0] #SE
d2 = data.loc[data['label']==1] #E
d3 = data.loc[data['label']==2] #NE

ax.scatter(d1.iloc[:, 0], d1.iloc[:, 1], d1.iloc[:, 2], c="#765EA3", alpha=0.5,
           edgecolor="indigo", s=45, label='SE')
ax.scatter(d2.iloc[:, 0], d2.iloc[:, 1], d2.iloc[:, 2], c="#64ADD9", alpha=0.5,
```

```
            edgecolor="#4F6AAA", s=45, label='E')
ax.scatter(d3.iloc[:, 0], d3.iloc[:, 1], d3.iloc[:, 2], c="lightcoral", alpha=0.5,
            edgecolor="crimson", s=45, label='NE')

x_label = 'PC1(%s%%)' % round(pca.explained_variance_ratio_[0]*100.0, 2);
y_label = 'PC2(%s%%)' % round(pca.explained_variance_ratio_[1]*100.0, 2);
z_label = 'PC3(%s%%)' % round(pca.explained_variance_ratio_[2]*100.0, 2);
font1 = {'family':'Arial', 'size':11, "color":"k", 'weight':'bold',}
ax.legend(bbox_to_anchor=(1.2, 1), ncol=3, prop={"size":10, 'family':'Arial'})
ax.tick_params(labelsize=10, color="k")
ax.set_xlabel(x_label, font1)
ax.set_ylabel(y_label, font1)
ax.set_zlabel(z_label, font1)
plt.show()
fig_a.savefig(os.path.join(save_dir, str(time.time())+'.png'), dpi=150, )
```



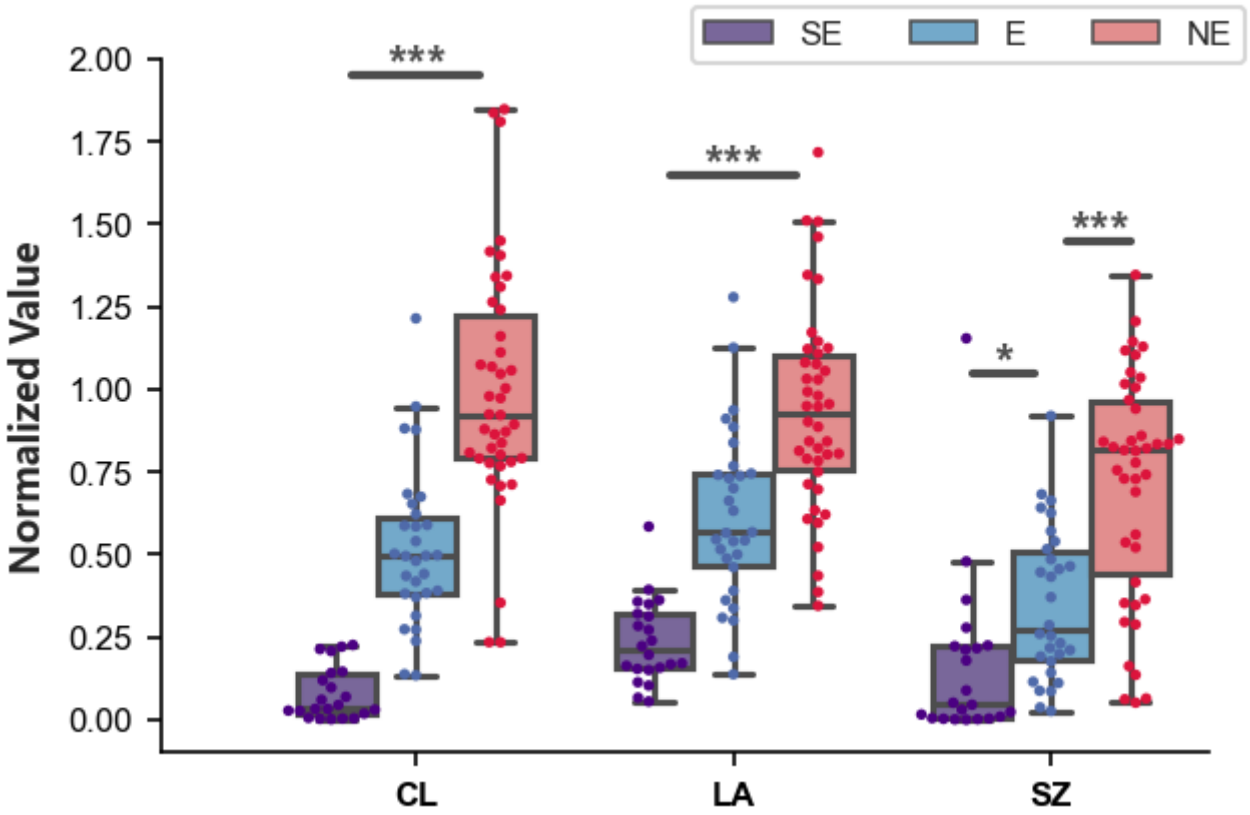
In [54]:
```
def plot_sig(xstart, xend, ystart, yend, sig, ax, vert=True):
    '''
    to draw significance markers *
    sig: list. Control the shape of these annotation
    vert: bool. whether draw vertical line.
    '''
    for i in range(len(xstart)):
        if vert[i] == True:
            x = np.ones((2)) * xstart[i]
            y = np.arange(ystart[i], yend[i]+0.1, yend[i]-ystart[i])
            ax.plot(x, y, label="$y$", linewidth=1, color="0.3")
            x = np.ones((2))*xend[i]
            y = np.arange(ystart[i], yend[i]+0.1, yend[i]-ystart[i])
            ax.plot(x, y, label="$y$", linewidth=1, color="0.3")
```

```
        x = np.arange(xstart[i], xend[i]+0.1, xend[i]-xstart[i])#draw horizontal line
        y = yend[i] + 0*x
        ax.plot(x, y, label="$y$", linewidth=2, color="0.3")

        x0 = (xstart[i] + xend[i])/2
        y0=yend[i]
        ax.annotate(r'%s'% sig[i], xy=(x0, y0),   # %s string
                     fontsize=10, fontweight="bold", fontfamily="Microsoft YaHei",
                    color="0.3", va="baseline", ha="center")
    plt.show()
```

In [342…

```
#boxplot
df4 = pd.read_excel(os.path.join(save_dir,'boxplot.xlsx'),
                    sheet_name="kill_adj_3t", index_col=0)
fig = plt.figure(figsize=(4.5,3), dpi=150)
ax1 = fig.add_subplot(111)

c1 = ["#765EA3", "#64ADD9", "lightcoral"]
c2 = ["indigo", "#4F6AAA", "crimson"]
a = sns.boxplot(x="Attri", y="val", hue="effc", dodge=True, #dots won't overlap
                data=df4, ax=ax1, showfliers=False, #Don't display outliers
                linewidth=1.5, width=0.75, palette=c1);
b = sns.swarmplot(x="Attri", y="val", hue="effc", data=df4,  palette=c2,
                  size=2.6, dodge=True, ax=ax1);

handles = ax1.get_legend_handles_labels()
ax1.legend(handles = handles[0][0:3], bbox_to_anchor=(1.05, 1.1), ncol=3,
           labels=["SE","E","NE"], prop={"size":8},)
plt.ylabel("Normalized Value", fontsize=9, fontweight="600", fontfamily="Microsoft YaHei")
plt.xlabel(None)
ax1.set_xticklabels(["CL","LA","SZ"], fontweight="600", fontfamily="Arial")
plt.tick_params(axis='both', direction='out', labelsize=8)
plt.ylim(-0.1,2)
plt.xlim(-0.8,2.5)
ax1.spines['right'].set_visible(False)
ax1.spines['top'].set_visible(False)
plot_sig([-0.2, 0.8, 1.75, 2.05], [0.2, 1.2, 1.95, 2.25], [1.7, 1.5,1.5, 1.8], [1.95, 1.65, 1.05, 1.45],
         ['***','***','*','***'], ax1, [0, 0, 0, 0])
```

```
fig.savefig(os.path.join(save_dir, str(time.time())+'.png'), dpi=200, bbox_inches='tight')
```



SE/E/NE ML classifier

for multiple classification task, automatically run One-versus-All (OvA) strategy

data process & Visualization

use average to fill nan. 1-CLa as kill if kill == nan

In [30]:
```
from sklearn.model_selection import StratifiedShuffleSplit

def split_train_test(dataframe, dataframe_y, test_size=0.2, random_state=42):
    split = StratifiedShuffleSplit(test_size=test_size, random_state=random_state)
    for train_index, test_index in split.split(dataframe, dataframe_y):
        train_set = dataframe.iloc[train_index]
        test_set = dataframe.iloc[test_index]
    return train_set, test_set
```

In [344…
```
start_train_set, start_test_set = split_train_test(df, df["effc"])
start_train_set.head()
```

Out[344]:

id	cancer	sample_id	LAa	LAErr	SZa	SZErr	CLa	CLErr	effc	kill
34	STS	A7	0.78969	0.00890	0.77784	0.11739	1.24140	0.11865	2	0.00000
46	GCa	A3	0.35725	0.02128	0.08857	0.03031	0.22092	0.01727	0	0.77908
61	KC	A7	0.82205	0.06581	1.11752	0.08848	0.87915	0.04157	2	0.12085
98	BCp	A3	1.12507	0.03723	0.72970	0.14415	1.04687	0.15024	2	0.21000
120	BCh	A8	0.84253	0.18808	0.28831	0.00454	0.89369	0.09183	2	0.24000

In [345…
```
index3 = ["LAa","LAErr","SZa","SZErr","CLa","CLErr","effc"]
train_set_3 = start_train_set.loc[:, index3]
test_set_3 = start_test_set.loc[:, index3]
train_set_3.head()
```

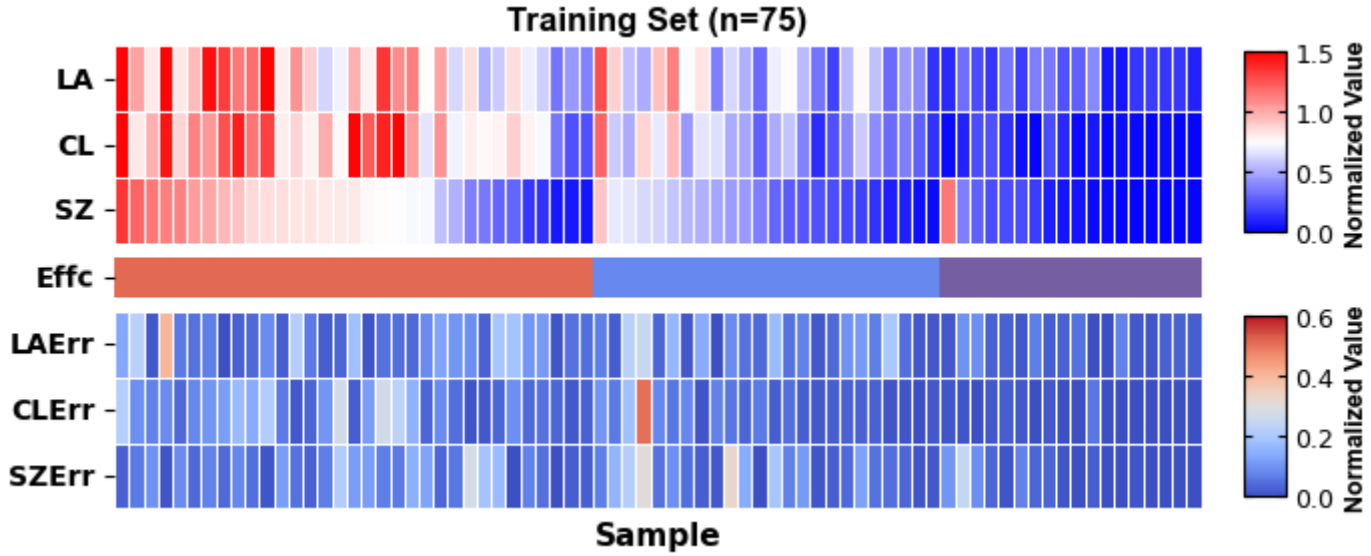
Out[345]:

id	LAa	LAErr	SZa	SZErr	CLa	CLErr	effc
34	0.78969	0.00890	0.77784	0.11739	1.24140	0.11865	2
46	0.35725	0.02128	0.08857	0.03031	0.22092	0.01727	0
61	0.82205	0.06581	1.11752	0.08848	0.87915	0.04157	2
98	1.12507	0.03723	0.72970	0.14415	1.04687	0.15024	2
120	0.84253	0.18808	0.28831	0.00454	0.89369	0.09183	2

In [94]:

```
fig = plt.figure(dpi=100, figsize=(7,3))
grid = fig.add_gridspec(3, 1, hspace=0.1, height_ratios=[4,0.8,4])
ax1 = plt.subplot(grid[0,:])
ax2 = plt.subplot(grid[2,:])
ax0 = plt.subplot(grid[1,:])
############## heatmap123
data=train_set_3.sort_values(by = ['effc',"SZa"], ascending=False)
h=sns.heatmap(data=data[["LAa","CLa","SZa"]].T,
              ax=ax1,
              vmin=0,vmax=1.5,
              linewidth=0.7,
              linecolor="w",
              cmap=sns.color_palette('bwr',n_colors=100),
              cbar=False,
              cbar_kws={ 'label': 'Normalized Value',
                         'extend':'both',},
             )
g=sns.heatmap(data=data[["LAErr","CLErr","SZErr"]].T,
              ax=ax2,
              linewidth=0.7,
              vmin=0, vmax=0.6,
              linecolor="w",
              cmap=sns.color_palette('coolwarm',n_colors=100),
              cbar=False
             )
cmap1 = ["#765EA3", sns.color_palette('coolwarm')[0], sns.color_palette('coolwarm')[-1]]
```

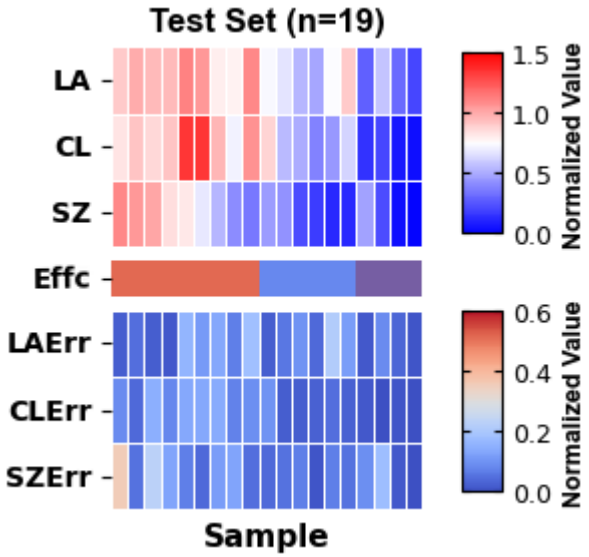
```
sns.heatmap(data=np.array(data["effc"]).reshape(1,-1), ax=ax0,
            linewidth=0, linecolor="w", cmap=cmap1, cbar=False,
           )
ax0.set_xlabel(None)
ax0.set_xticks([]);
ax0.set_yticklabels(["Effc"], rotation=1, fontweight="bold")
############ cbar
rect = [0.93, 0.57, 0.03, 0.3]
cbar_ax = fig.add_axes(rect)
cb = h.figure.colorbar(h.collections[0], cax=cbar_ax)
cb.ax.tick_params(direction='in', labelsize=9, color="k", length=3,
                  left=True, right=True)
font1 = {'family': 'Arial',
         'weight': 'bold',
         'size':9}
cb.ax.set_ylabel( 'Normalized Value', font1)
####################
rect2 = [0.93, 0.13, 0.03, 0.3]
cbar_ax2 = fig.add_axes(rect2)
cb2 = g.figure.colorbar(g.collections[0], cax=cbar_ax2)
cb2.ax.tick_params(direction='in', labelsize=9, color="k", length=3,
                  left=True,right=True)
cb2.ax.set_ylabel( 'Normalized Value', font1)
################### set axis
font2 = {'family': 'Arial',
         'weight': 'bold',}
ax1.set_title("Training Set (n=%s)" % train_set_3.shape[0], font2);
ax1.set_yticklabels(["LA","CL","SZ"], fontweight="bold", rotation=0)
ax2.set_yticklabels(["LAErr","CLErr","SZErr"], fontweight="bold")
ax1.set_xlabel(None)
ax2.set_xlabel("Sample", fontweight="bold", fontsize=11)
ax1.set_xticks([]);
ax2.set_xticks([]);

fig.savefig(os.path.join(save_dir, str(time.time())+'.svg'), bbox_inches='tight', dpi=150)
```



In [95]:
```
fig = plt.figure(dpi=100, figsize=(2,3))
grid = fig.add_gridspec(3, 1, hspace=0.1, height_ratios=[4,0.7,4])
ax1 = plt.subplot(grid[0,:])
ax2 = plt.subplot(grid[2,:])
ax0 = plt.subplot(grid[1,:])
############### heatmap123
data = test_set_3.sort_values(by = ['effc',"SZa"], ascending=False)
h=sns.heatmap(data=data[["LAa","CLa","SZa"]].T,
              ax=ax1,
              vmin=0,vmax=1.5,
              linewidth=0.7,
              linecolor="w",
              cmap=sns.color_palette('bwr',n_colors=100),
              cbar=False,
              cbar_kws={ 'label': 'Normalized Value',
                         'extend':'both',},
             )
g=sns.heatmap(data=data[["LAErr","CLErr","SZErr"]].T,
              ax=ax2,
              linewidth=0.7,
              vmin=0,vmax=0.6,
              linecolor="w",
```

```
            cmap=sns.color_palette('coolwarm',n_colors=100),
            cbar=False
           )
cmap1 = ["#765EA3", sns.color_palette('coolwarm')[0], sns.color_palette('coolwarm')[-1]]
sns.heatmap(data=np.array(data["effc"]).reshape(1,-1), ax=ax0,
            linewidth=0, linecolor="w", cmap=cmap1, cbar=False,
           )
ax0.set_xlabel(None)
ax0.set_xticks([]);
ax0.set_yticklabels(["Effc"], rotation=1, fontweight="bold")
############ cbar
rect = [1, 0.57, 0.1, 0.3]
cbar_ax = fig.add_axes(rect)
cb = h.figure.colorbar(h.collections[0], cax=cbar_ax)
cb.ax.tick_params(direction='in', labelsize=9, color="k", length=3,
                  left=True, right=True)
font1 = {'family': 'Arial',
         'weight': 'bold',
         'size':9}
cb.ax.set_ylabel( 'Normalized Value', font1)
####################
rect2 = [1, 0.14, 0.1, 0.3]
cbar_ax2 = fig.add_axes(rect2)
cb2 = g.figure.colorbar(g.collections[0], cax=cbar_ax2)
cb2.ax.tick_params(direction='in', labelsize=9, color="k", length=3,
                  left=True, right=True)
cb2.ax.set_ylabel( 'Normalized Value', font1)
################### set axis
font2 = {'family': 'Arial',
            'color': 'k',
            'weight': 'bold',
            }
ax1.set_title("Test Set (n=%s)" % test_set_3.shape[0], font2);
ax1.set_yticklabels(["LA","CL","SZ"], fontweight="bold", rotation=0)
ax2.set_yticklabels(["LAErr","CLErr","SZErr"], fontweight="bold")
ax1.set_xlabel(None)
ax2.set_xlabel("Sample", fontweight="bold", fontsize=11)
ax1.set_xticks([]);
ax2.set_xticks([]);
```

```
fig.savefig(os.path.join(save_dir, str(time.time())+'.svg'), bbox_inches='tight', dpi=150)
```



In [33]:
```
def num_cat(dataframe, column="effc"):
    data_num = dataframe.drop(column, axis=1)
    list_cat = dataframe[column].tolist()
    data_cat = np.array(list_cat)
    return data_num, data_cat
```

In [34]:
```
X_train, y_train = num_cat(train_set_3, column="effc")
X_test, y_test = num_cat(test_set_3, column="effc")
```

Model Training

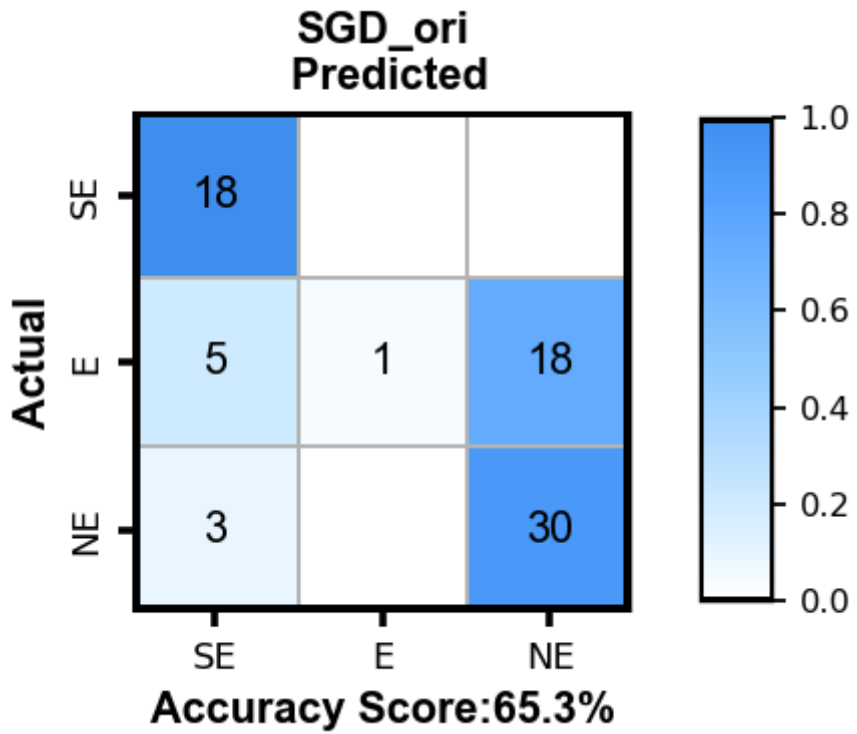
3 algorithms: SGD, RF, SVM. mulitmode (=3) data

without parameter tuning

SGD

In [203…
```
sgd_clf = SGDClassifier(random_state=42)
r_s = ML_result(sgd_clf, X_train, y_train, "SGD_ori", cv=3, ifprint=1)

conf_mat_heatmap(r_s['conf_mat'], rect_set=rect_set2, title="SGD_ori", density=0,
                 cmap=cmap2, save_dir=save_dir)
```

```
{'conf_mat': array([[18,  0,  0],
       [ 5,  1, 18],
       [ 3,  0, 30]], dtype=int64), 'accu': 0.6533333333333333}
```

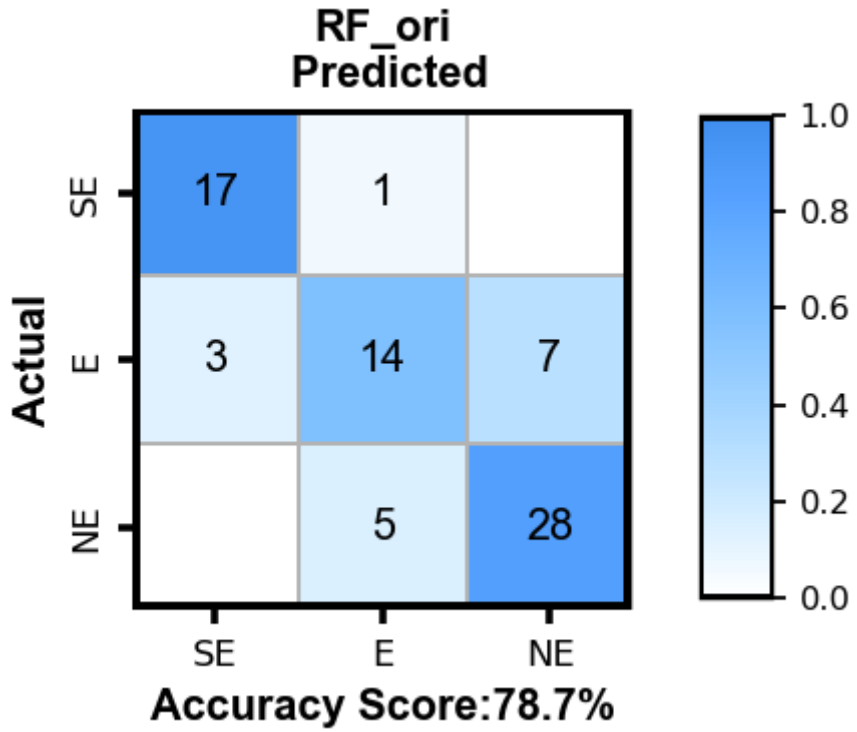


RF

In [204…
```
forest_clf = RandomForestClassifier(random_state=42)
r_f = ML_result(forest_clf, X_train, y_train, "RF_ori", cv=3, ifprint=1)
```

```
conf_mat_heatmap(r_f['conf_mat'], rect_set=rect_set2, title="RF_ori", density=0,
                 cmap=cmap2, save_dir=save_dir)
```

```
{'conf_mat': array([[17,  1,  0],
       [ 3, 14,  7],
       [ 0,  5, 28]], dtype=int64), 'accu': 0.7866666666666666}
```



SVM

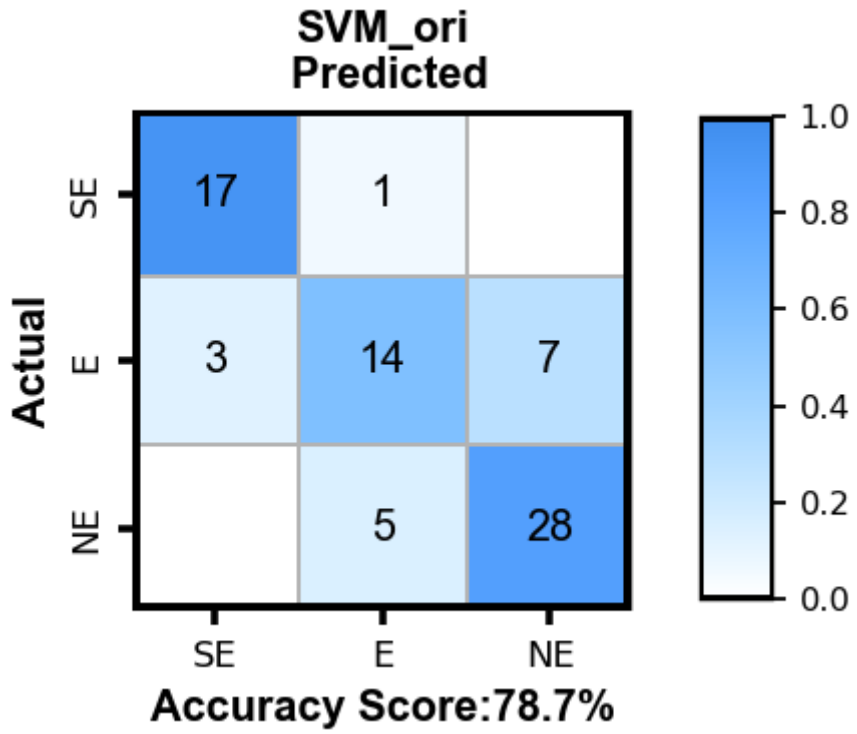
SVM was originally designed for binary classification. When dealing with multi-class problems, it's necessary to construct suitable classifiers:
'ovr' one-versus-rest / 'ovo' one-versus-one

In [205…

```
svc_1 = SVC(probability=True, random_state=42, decision_function_shape="ovr")
r_c = ML_result(forest_clf, X_train, y_train, "SVM_ori", cv=3, ifprint=1)
```

```
conf_mat_heatmap(r_c['conf_mat'], rect_set=rect_set2, title="SVM_ori", density=0,
                 cmap=cmap2, save_dir=save_dir)
```

```
{'conf_mat': array([[17,  1,  0],
       [ 3, 14,  7],
       [ 0,  5, 28]], dtype=int64), 'accu': 0.7866666666666666}
```



GridSearch

triple modal data

SGD

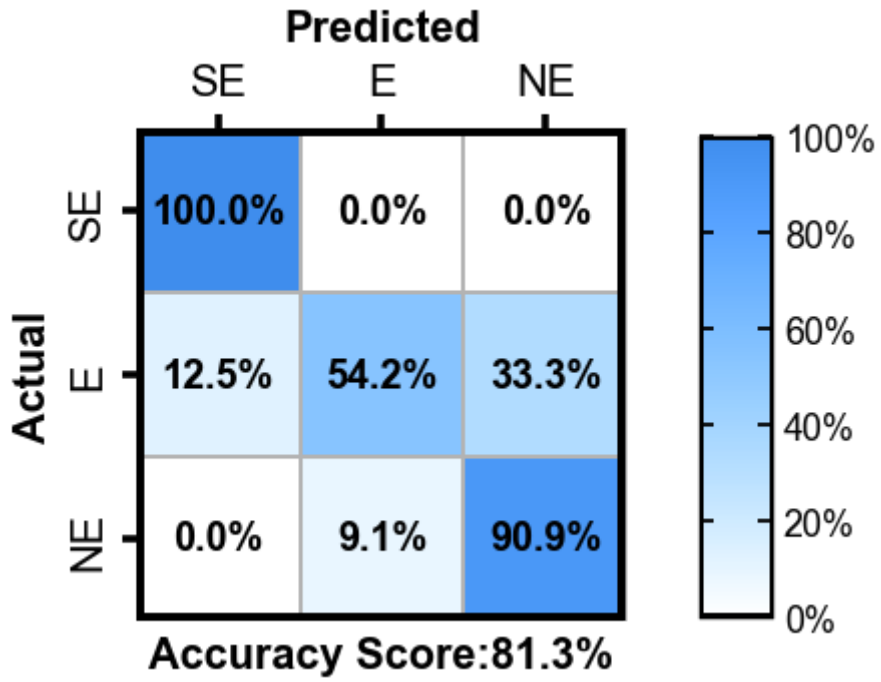
best_SGDClassifier(eta0=0.36, learning_rate='constant', loss='log', n_jobs=-1, random_state=42)

In [31]:
```
sgd_clf = SGDClassifier(random_state=42,n_jobs=-1)
param=[{"learning_rate": ['constant','optimal','invscaling'], 'penalty': ['l2','l1','elasticnet'],
         "loss":["hinge","modified_huber","log"], "eta0":np.linspace(0.25,0.45,num=21),
         "class_weight":[None,"balanced"],
       }]
sgdbest = GridSearch_result(sgd_clf, X_train, y_train, param)
print(sgdbest)
r_sgd3=ML_result(sgdbest[1], X_train, y_train, "SGD",roc=0)
print(r_sgd3['conf_mat'],r_sgd3['accu'])
```

```
Run Time:443.56542468070984 s
[{'class_weight': None, 'eta0': 0.36, 'learning_rate': 'constant', 'loss': 'log', 'penalty': 'l2'}, SGDClassifier(eta0=0.36, le
arning_rate='constant', loss='log', n_jobs=-1,
              random_state=42)]
[[18  0  0]
 [ 3 13  8]
 [ 0  3 30]] 0.8133333333333334
```

In [34]:
```
conf_mat_heatmap(r_sgd3['conf_mat'], rect_set=rect_set2, title="SDG", density=0,
                 save_dir=save_dir)
```

```
D:\Anaconda\lib\site-packages\ipykernel_launcher.py:42: UserWarning: FixedFormatter should only be used together with FixedLoca
tor
```



SVM

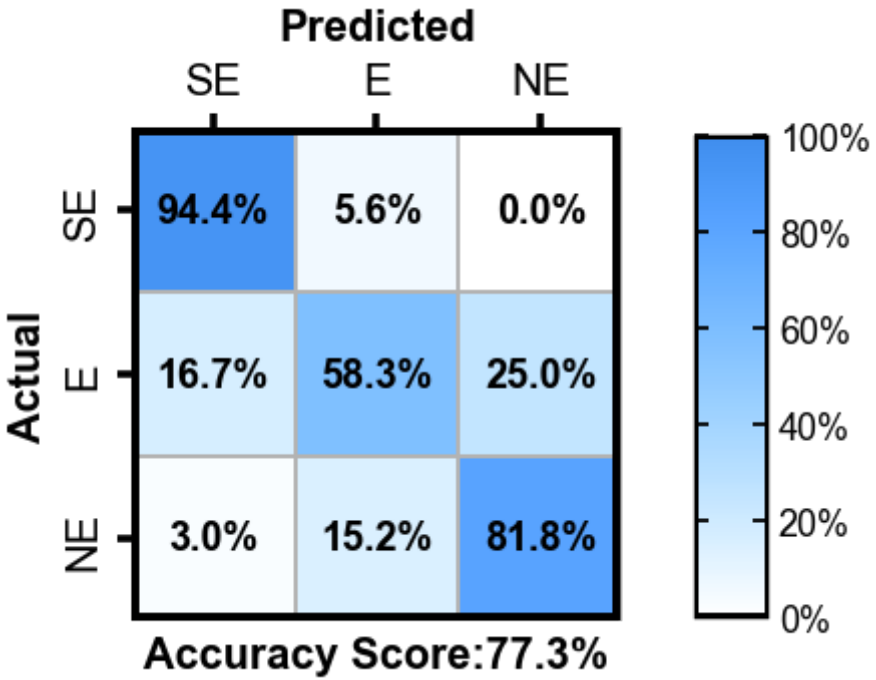
best_SVC(C=1.2, degree=1, gamma='auto', probability=True, random_state=42)]

In [36]:
```
svc_clf = SVC(probability=True, random_state=42)
param3 = [{'kernel':["rbf","poly","linear"], "C":[0.8, 0.9, 1, 1.1, 1.2, 1.3],
           "degree":[1,2,3,4,5], "class_weight":[None,"balanced"],
          "gamma":["auto",1/7,1/6,1/8,1/9], }]
svcbest = GridSearch_result(svc_clf, X_train, y_train, param3,)
print(svcbest)
r_svm3=ML_result(svcbest[1], X_train, y_train, "svc", roc=0)
print(r_svm3['conf_mat'], r_svm3['accu'])
```

```
Run Time:33.97535467147827 s
[{'C': 1.2, 'class_weight': None, 'degree': 1, 'gamma': 'auto', 'kernel': 'rbf'}, SVC(C=1.2, degree=1, gamma='auto', probabilit
y=True, random_state=42)]
[[17  1  0]
 [ 4 14  6]
 [ 1  5 27]] 0.7733333333333333
```

In [37]:
```
conf_mat_heatmap(r_svm3['conf_mat'], rect_set=rect_set2, title="SVM", density=0,
                 save_dir=save_dir)
```

```
D:\Anaconda\lib\site-packages\ipykernel_launcher.py:42: UserWarning: FixedFormatter should only be used together with FixedLoca
tor
```



RF

best_RandomForestClassifier(max_depth=2, max_features=6, n_estimators=9, n_jobs=-1, random_state=42)

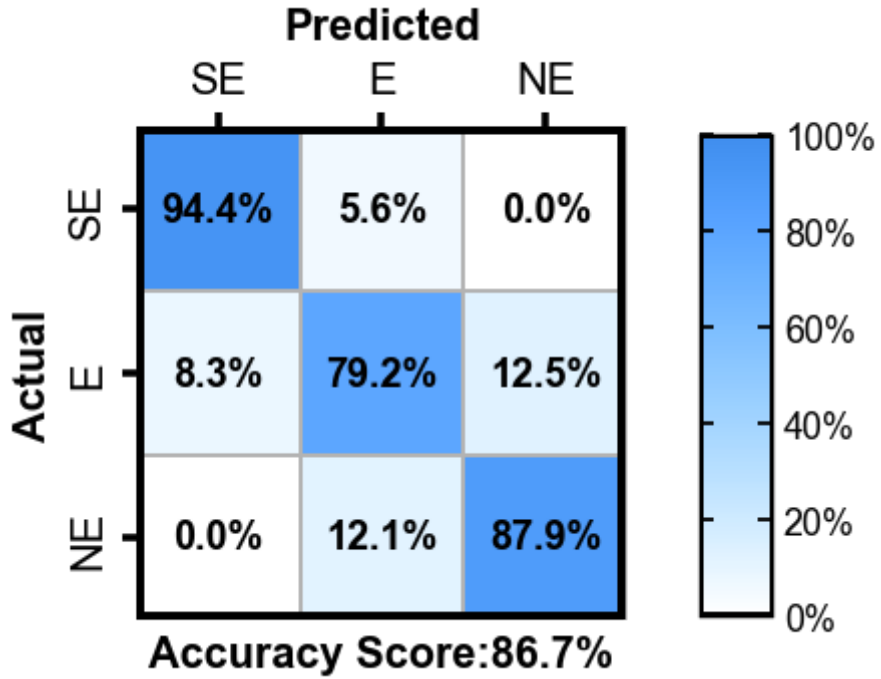
In [84]:
```
forest_clf = RandomForestClassifier(n_jobs=-1,random_state=42,)
param2 = [{'n_estimators': range(2,18), "max_depth":[None,2,3,4,5], "max_features":["auto",6,5],
```

```
        }]
rfbest = GridSearch_result(forest_clf, X_train, y_train, param2,)
print(rfbest)
r_rf3 = ML_result(rfbest[1], X_train, y_train, "RF", roc=0)
print(r_rf3['conf_mat'], r_rf3['accu'])
```

```
Run Time:99.9494776725769 s
[{'max_depth': 2, 'max_features': 6, 'n_estimators': 9}, RandomForestClassifier(max_depth=2, max_features=6, n_estimators=9, n_
jobs=-1,
                       random_state=42)]
[[17  1  0]
 [ 2 19  3]
 [ 0  4 29]] 0.8666666666666667
```

In [18]:
```
conf_mat_heatmap(r_rf3['conf_mat'], rect_set=rect_set2, title="RF", density=0,
                 save_dir=save_dir)
```

```
D:\Anaconda\lib\site-packages\ipykernel_launcher.py:44: UserWarning: FixedFormatter should only be used together with FixedLoca
tor
```



Dual-mode data

LA+SZ

SGD

best_SGDClassifier(eta0=1.03, learning_rate='constant', loss='log', n_jobs=-1, penalty='l1', random_state=42)

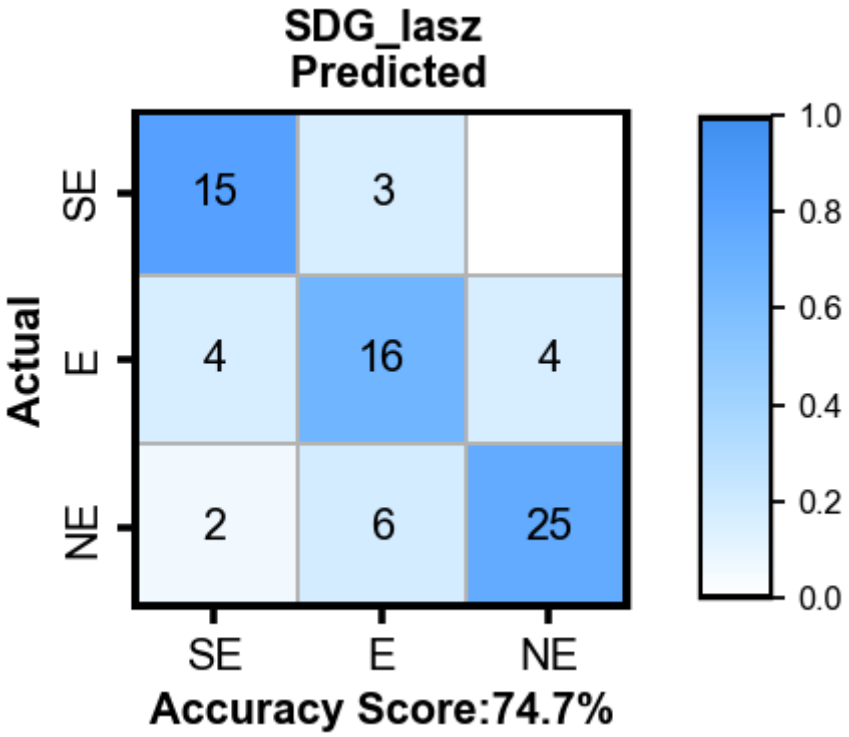
In [47]:
```
#ori
sgd_clf3 = SGDClassifier(random_state=42, n_jobs=-1)
index4 = ["LAa","LAErr","SZa","SZErr"]
ML_result(sgd_clf3, X_train[index4], y_train, "SGD_2atri" )
```

Out[47]:
```
{'conf_mat': array([[11,  5,  2],
        [ 4,  7, 13],
        [ 2,  8, 23]], dtype=int64),
 'accu': 0.5466666666666666}
```

In [80]:
```
sgd_clf_lasz = SGDClassifier(random_state=42, n_jobs=-1)

param=[{"learning_rate": ['constant','optimal','invscaling'], 'penalty': ['l2','l1','elasticnet'],
        "eta0":np.linspace(0.9,1.1,num=21), "loss":["hinge","modified_huber","log"],
        "class_weight":[None,"balanced"],
       }]
sgdbest_lasz = GridSearch_result(sgd_clf_lasz, X_train[index4], y_train, param, )
print(sgdbest_lasz)
r_s_lasz=ML_result(sgdbest_lasz[1], X_train[index4], y_train, "SGD_lasz",roc=0)
print(r_s_lasz['conf_mat'],r_s_lasz['accu'])
```

```
Run Time:375.6672716140747 s
[{'class_weight': None, 'eta0': 1.03, 'learning_rate': 'constant', 'loss': 'log', 'penalty': 'l1'}, SGDClassifier(eta0=1.03, le
arning_rate='constant', loss='log', n_jobs=-1,
              penalty='l1', random_state=42)]
[[15  3  0]
 [ 4 16  4]
 [ 2  6 25]] 0.7466666666666667
```

In [221…
```
conf_mat_heatmap(r_s_lasz['conf_mat'], rect_set=rect_set2, title="SDG_lasz",
                 density=0, save_dir=save_dir)
```



RF

best_RandomForestClassifier(max_depth=3, max_features=4, n_estimators=5, n_jobs=-1, random_state=42)

In [83]:
```
forest_clf_lasz = RandomForestClassifier(random_state=42, n_jobs=-1)
param2 = [{'n_estimators': range(2,18), "max_depth":[None,3,4,5],
          "max_features":["auto",3,4,2],}]
rfbest_lasz = GridSearch_result(forest_clf_lasz, X_train[index4], y_train, param2,)
print(rfbest_lasz)
r_f_lasz=ML_result(rfbest_lasz[1], X_train[index4], y_train,"RF_lasz", roc=0)
print(r_f_lasz['conf_mat'],r_f_lasz['accu'])
```

```
Run Time:113.5271201133728 s
[{'max_depth': 3, 'max_features': 4, 'n_estimators': 5}, RandomForestClassifier(max_depth=3, max_features=4, n_estimators=5, n_
jobs=-1,
                       random_state=42)]
[[15  2  1]
 [ 5 10  9]
 [ 1  5 27]] 0.6933333333333334
```

SVM

best_SVC(C=0.7, degree=1, gamma='auto', kernel='linear', probability=True, random_state=42)]

In [82]:
```
svc_lasz = SVC(probability=True,random_state=42)
param3 = [{'C':[0.8,0.9,1.0,0.7,0.5,0.6], "class_weight":[None,"balanced"],
           "gamma":["auto",1/10,1/9,1/11,1/8,1/7], "degree":[1,2,3,4],
           "kernel":['linear',"poly","rbf",],
          }]
svcbest_lasz = GridSearch_result(svc_lasz, X_train[index4], y_train, param3,)
print(svcbest_lasz)
r_v_lasz=ML_result(svcbest_lasz[1], X_train[index4], y_train, "SVM_lasz", roc=0)
print(r_v_lasz['conf_mat'],r_v_lasz['accu'])
```

```
Run Time:11.591997861862183 s
[{'C': 0.7, 'class_weight': None, 'degree': 1, 'gamma': 'auto', 'kernel': 'linear'}, SVC(C=0.7, degree=1, gamma='auto', kernel
='linear', probability=True,
    random_state=42)]
[[15  2  1]
 [ 4 14  6]
 [ 2  8 23]] 0.6933333333333334
```

LA+CL

RF

best_RandomForestClassifier(max_depth=3, max_features=3, n_estimators=13, n_jobs=-1, random_state=42)]

In [87]:
```
index6=["LAa","LAErr","CLa","CLErr"]
forest_clf_lacl = RandomForestClassifier(n_jobs=-1, random_state=42)
param2 = [{'n_estimators': range(2,20), "max_depth":[None,2,3,4],
```

```
            "max_features":["auto",3,4,2],
           }]
rfbest_lacl = GridSearch_result(forest_clf_lacl, X_train[index6], y_train, param2,)
print(rfbest_lacl)
r_f_lacl=ML_result(rfbest_lacl[1], X_train[index6], y_train,"RF_lacl", roc=0)
print(r_f_lacl['conf_mat'],r_f_lacl['accu'])
```

```
Run Time:123.95243310928345 s
[{'max_depth': 3, 'max_features': 3, 'n_estimators': 13}, RandomForestClassifier(max_depth=3, max_features=3, n_estimators=13,
n_jobs=-1,
                       random_state=42)]
[[15  2  1]
 [ 5 10  9]
 [ 1  5 27]] 0.6933333333333334
```

SDG

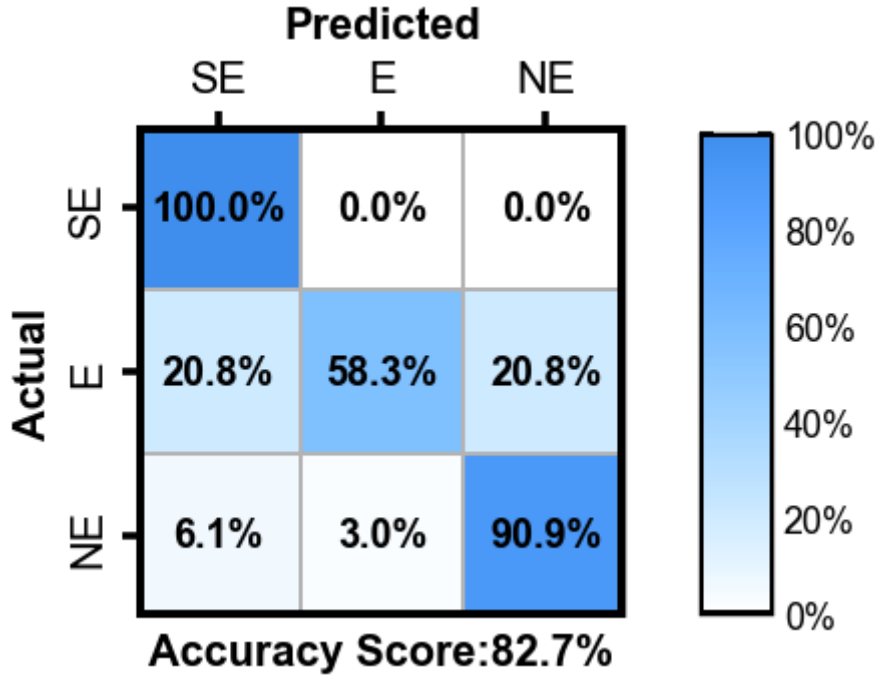
best_SGDClassifier(class_weight='balanced', eta0=0.31, learning_rate='constant', loss='log', n_jobs=-1, random_state=42)

In [98]:
```
sgd_clf_lacl = SGDClassifier(random_state=42,n_jobs=-1)

param=[{"learning_rate":['constant','optimal','invscaling'],
        "eta0":np.linspace(0.2,0.4,num=21), "loss":["hinge","modified_huber","log"],
         'penalty': ['l2','l1','elasticnet'], "class_weight":[None,"balanced"],
       }]
sgdbest_lacl = GridSearch_result(sgd_clf_lacl, X_train[index6], y_train, param, )
print(sgdbest_lacl)
r_s_lacl=ML_result(sgdbest_lacl[1], X_train[index6], y_train, "SGD_lacl",roc=0)
print(r_s_lacl['conf_mat'],r_s_lacl['accu'])
```

```
Run Time:376.61925411224365 s
[{'class_weight': 'balanced', 'eta0': 0.31, 'learning_rate': 'constant', 'loss': 'log', 'penalty': 'l2'}, SGDClassifier(class_w
eight='balanced', eta0=0.31, learning_rate='constant',
              loss='log', n_jobs=-1, random_state=42)]
[[18  0  0]
 [ 5 14  5]
 [ 2  1 30]] 0.8266666666666667
```

In [120…
```
conf_mat_heatmap(r_s_lacl['conf_mat'], rect_set=rect_set2, title="SDG_lacl",
                 density=0, cmap=cmap2, save_dir=save_dir)
```

```
D:\Anaconda\lib\site-packages\ipykernel_launcher.py:42: UserWarning: FixedFormatter should only be used together with FixedLoca
tor
```



SZ+CL

SGD

best_SGDClassifier(eta0=0.22, learning_rate='constant', loss='log', n_jobs=-1, random_state=42)]

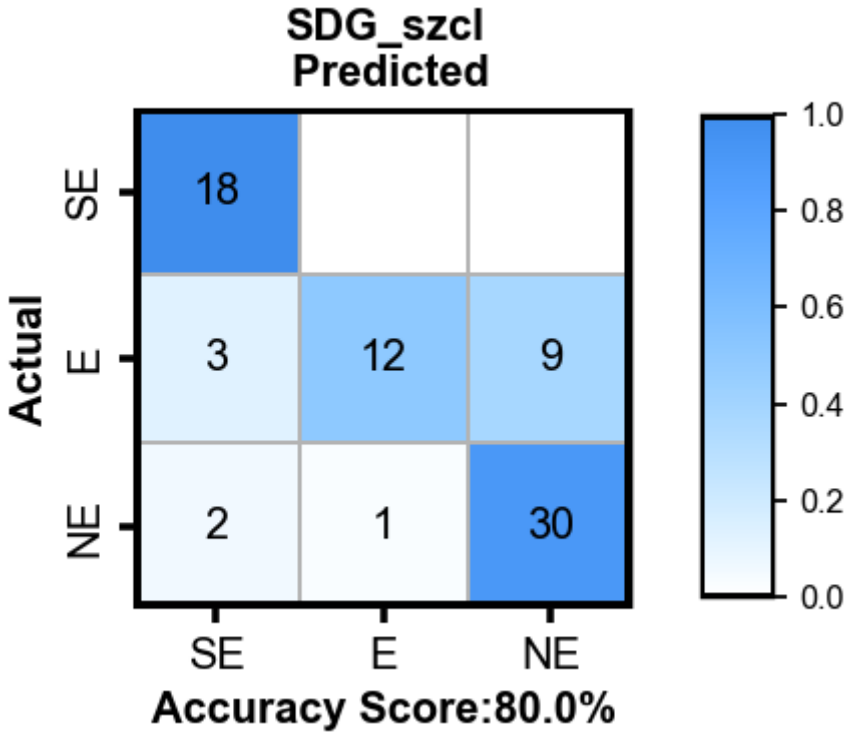
In [99]:
```
#ori
sgd_clf_clsz = SGDClassifier(random_state=42)
ML_result(sgd_clf_clsz, X_train[index5], y_train, "clsz-ori")
```

Out[99]:
```
{'conf_mat': array([[18,  0,  0],
        [ 4,  7, 13],
        [ 1,  3, 29]], dtype=int64),
 'accu': 0.72}
```

In [100…
```
index5 = ["CLa","CLErr","SZa","SZErr"]
sgd_clf_szcl = SGDClassifier(random_state=42,n_jobs=-1)

param=[{"learning_rate":['constant','optimal','invscaling'],
        "eta0":np.linspace(0.2,0.4,num=11), "loss":["hinge","modified_huber","log"],
         'penalty':['l2','l1','elasticnet'], "class_weight":[None,"balanced"],
       }]
sgdbest_szcl = GridSearch_result(sgd_clf_szcl, X_train[index5], y_train, param, )
print(sgdbest_szcl)
r_s_clsz=ML_result(sgdbest_szcl[1], X_train[index5], y_train, "SGD_szcl",roc=0)
print(r_s_clsz['conf_mat'], r_s_lasz['accu'])
```

```
Run Time:197.00132203102112 s
[{'class_weight': None, 'eta0': 0.22, 'learning_rate': 'constant', 'loss': 'log', 'penalty': 'l2'}, SGDClassifier(eta0=0.22, le
arning_rate='constant', loss='log', n_jobs=-1,
              random_state=42)]
[[18  0  0]
 [ 3 12  9]
 [ 2  1 30]] 0.8
```

In [329…
```
conf_mat_heatmap(r_s_clsz['conf_mat'], rect_set=rect_set2, title="SDG_szcl",
                 density=0, cmap=cmap2, save_dir=save_dir)
```



RF

best_RandomForestClassifier(max_features=4, n_estimators=12, n_jobs=-1, random_state=42)]

In [101…
```
#ori
forest_clf_clsz = RandomForestClassifier(random_state=42)
ML_result(forest_clf_clsz, X_train[index5], y_train,"clsz_ori")
```

Out[101]:
```
{'conf_mat': array([[16,  2,  0],
        [ 3, 18,  3],
        [ 0,  3, 30]], dtype=int64),
 'accu': 0.8533333333333334}
```

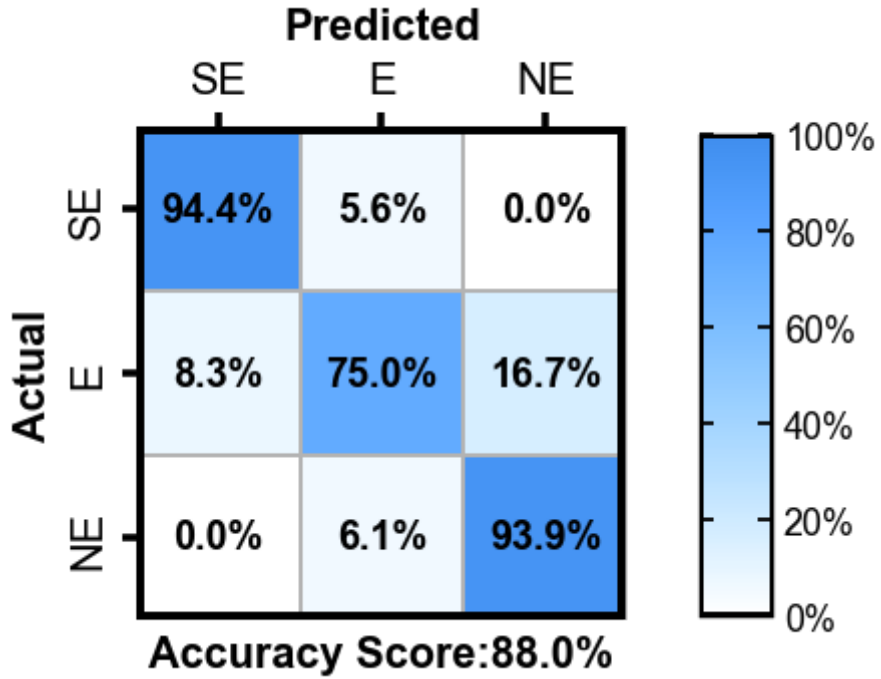
In [90]:
```
forest_clf_szcl = RandomForestClassifier(n_jobs=-1,random_state=42)
param2 = [{'n_estimators': range(2,20), "max_depth":[None,2,3,4],
           "max_features":["auto",3,4,2],  }]
```

```
rfbest_szcl = GridSearch_result(forest_clf_szcl, X_train[index5], y_train, param2,)
print(rfbest_szcl)
r_f_szcl=ML_result(rfbest_szcl[1], X_train[index5], y_train,"RF_szcl", roc=0)
print(r_f_szcl['conf_mat'], r_f_szcl['accu'])
```

```
Run Time:126.29723453521729 s
[{'max_depth': None, 'max_features': 4, 'n_estimators': 12}, RandomForestClassifier(max_features=4, n_estimators=12, n_jobs=-1,
                       random_state=42)]
[[17  1  0]
 [ 2 18  4]
 [ 0  2 31]] 0.88
```

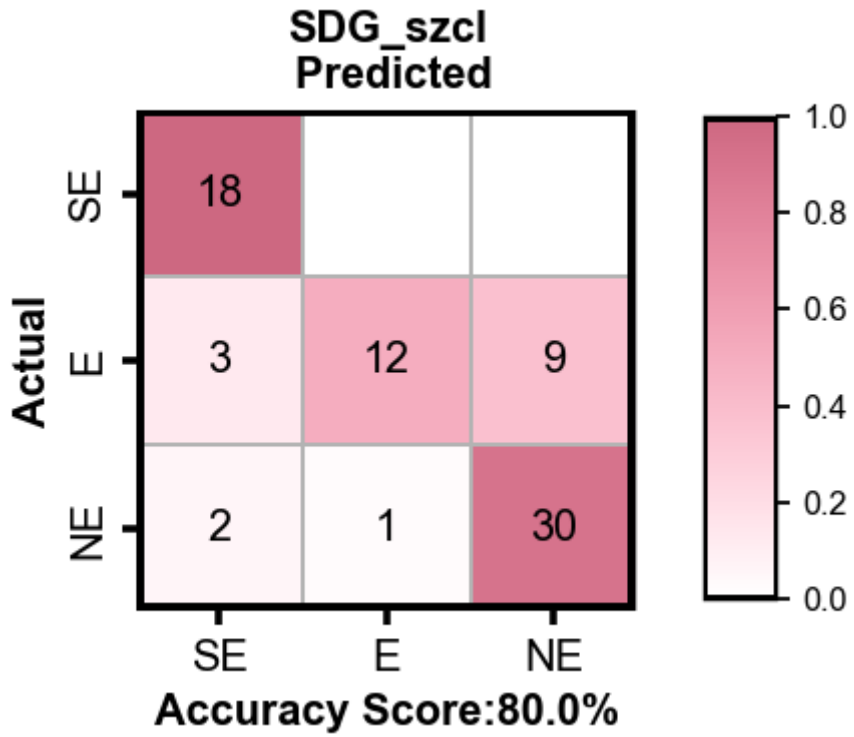
In [17]:
```
conf_mat_heatmap(r_f_szcl['conf_mat'], rect_set=rect_set2, title="RF_szcl", density=0,
                 cmap=cmap2, save_dir=save_dir)
```

```
D:\Anaconda\lib\site-packages\ipykernel_launcher.py:44: UserWarning: FixedFormatter should only be used together with FixedLoca
tor
```

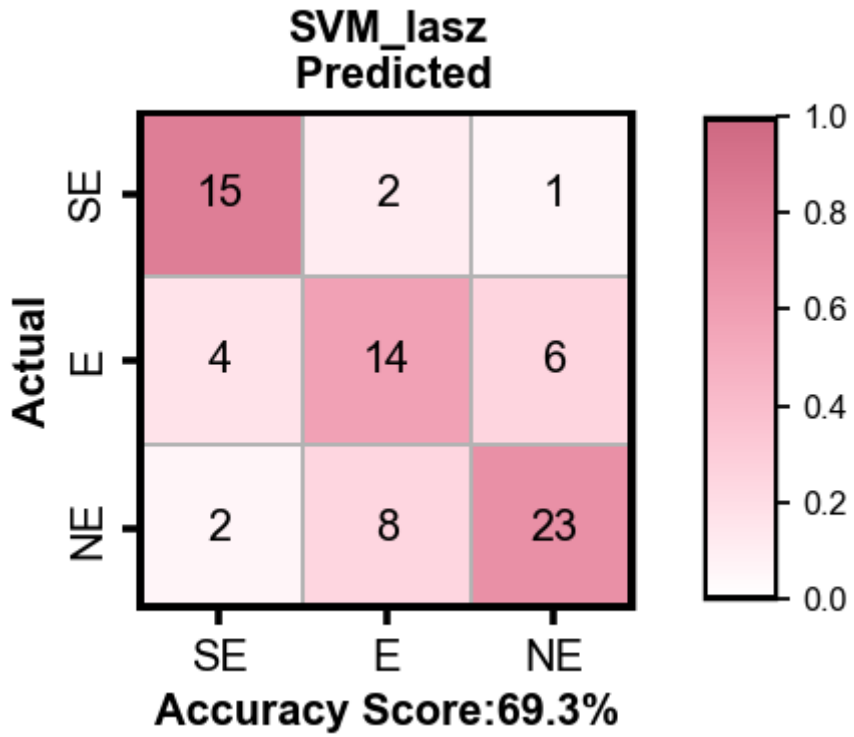


re_draw

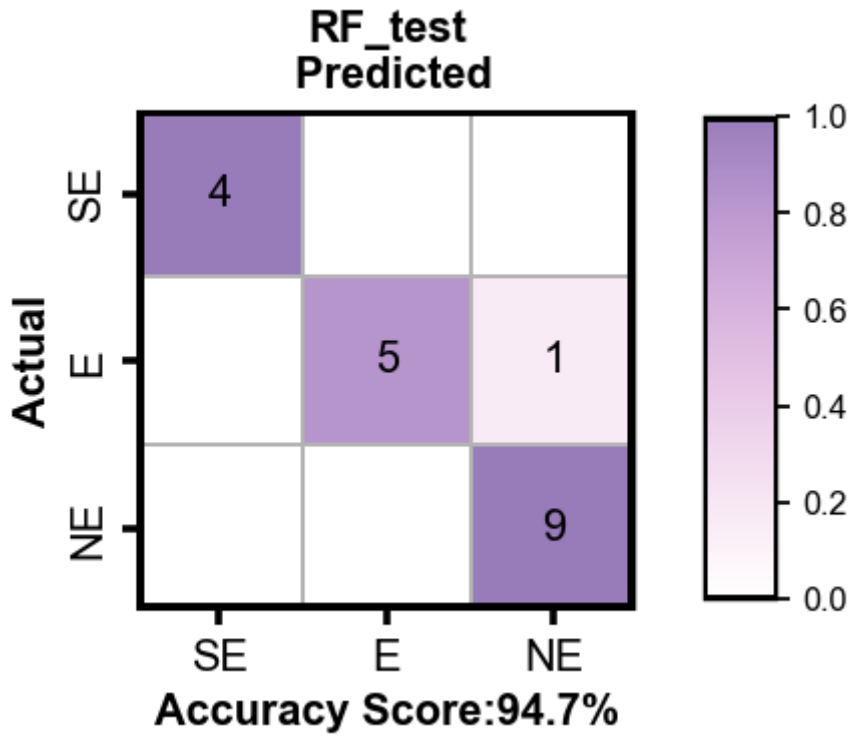
In [332…
```
x=np.array([[18 , 0 , 0],
 [ 3, 12,  9],
 [ 2,  1 ,30]])
conf_mat_heatmap(x, rect_set=rect_set2, title="SDG_szcl", density=0,
                 cmap=cmap3, save_dir=save_dir)
```



In [322…
```
x=np.array([[15,  2 , 1],
 [ 4, 14 , 6],
 [ 2 , 8 ,23]])
conf_mat_heatmap(x, rect_set=rect_set2, title="SVM_lasz", density=0,
                 cmap=cmap3, save_dir=save_dir)
```



In [ ]:
```
x=np.array([[4 ,0 ,0],
 [0, 5, 1],
 [0 ,0 ,9]])
conf_mat_heatmap(x, rect_set=rect_set2, title="RF_test", density=0,
                 cmap=None, save_dir=save_dir)
```



on Test Set

triple modal

In [341…

```
final_pred=sgdbest[1].predict(X_test)
conf_test=confusion_matrix(y_test, final_pred)
print(conf_test)
```

```
[[3 1 0]
 [0 5 1]
 [0 0 9]]
```

```
D:\Anaconda\lib\site-packages\sklearn\linear_model\_stochastic_gradient.py:163: FutureWarning: The loss 'log' was deprecated in v1.1 and will be removed in version 1.3. Use `loss='log_loss'` which is equivalent.
  warnings.warn(
```

In [340…
```
final_pred=svcbest[1].predict(X_test)
conf_test=confusion_matrix(y_test, final_pred)
print(conf_test)
```

```
[[3 1 0]
 [0 5 1]
 [0 1 8]]
```

In [106…
```
final_pred_rf=rfbest[1].predict(X_test.values)
conf_test=confusion_matrix(y_test, final_pred_rf)
print(conf_test)
```

```
[[4 0 0]
 [0 5 1]
 [0 0 9]]
```

```
D:\Anaconda\lib\site-packages\sklearn\base.py:451: UserWarning: X does not have valid feature names, but RandomForestClassifier was fitted with feature names
  "X does not have valid feature names, but"
```

cl / szcl

In [108…
```
#sgd_clf_cl.fit(X_train[["CLa","CLErr"]], y_train)
final_pred_c=rfbest_cl[1].predict(X_test[["CLa","CLErr"]])
conf_test_c=confusion_matrix(y_test, final_pred_c)
print(conf_test_c)
```

```
[[4 0 0]
 [0 5 1]
 [0 0 9]]
```

In [109…
```
final_pred_szcl=rfbest_szcl[1].predict(X_test[index5])
conf_test_szcl=confusion_matrix(y_test, final_pred_szcl)
print(conf_test_szcl)
```

```
[[4 0 0]
 [0 5 1]
 [0 0 9]]
```