In [ ]:

```
# install dependencies
%pip install -q \
  matplotlib \
  pandas \
  pycaret \
  'pycaret[analysis]' \
  seaborn
```

```
WARNING: visions 0.7.5 does not provide the extra 'type-image-path'
Note: you may need to restart the kernel to use updated packages.
```

In [ ]:

```
# global parameters
DATA_DIR = '../datasets/swell/final/'
TEST_DATA_NAME = 'test'
DO_SAVE_RESULTS = True
DO_COMPARE_MODELS = True
DO_PLOT_DATA = True
```

In [ ]:

```
# set up the environment for the notebook
import os
os.environ['PYCARET_CUSTOM_LOGGING_LEVEL'] = 'CRITICAL'

import pandas as pd
pd.set_option('display.max_columns', 128)
```

In [ ]:

```
# prepare the data
from pathlib import Path
from pycaret.datasets import get_data
from zipfile import ZipFile

DATA = {
  name: None
  for name in ['train', TEST_DATA_NAME]
}

for data_name in DATA.keys():
  data_path = DATA_DIR + data_name
  # extract the compressed data files
  if Path(f'{data_path}.csv').exists():
    print(f'Data file "{data_name}" was already extracted')
  else:
    ZipFile(f'{data_path}.zip', 'r').extract(
      f'{data_path}.csv', '..'
    )
    print(f'Data file "{data_name}" has been extracted successfully')
  # load the data
  print(f'Loading data file "{data_name}"')
  DATA[data_name] = get_data(dataset=f'{data_path}')
```

```
Data file "train" was already extracted
Loading data file "train"
```

| | MEAN_RR | MEDIAN_RR | SDRR | RMSSD | SDSD | SDRR_RMSSD | HR | pNN |
|---|---|---|---|---|---|---|---|---|
| 0 | 885.157845 | 853.763730 | 140.972741 | 15.554505 | 15.553371 | 9.063146 | 69.499952 | 11.1333 |
| 1 | 939.425371 | 948.357865 | 81.317742 | 12.964439 | 12.964195 | 6.272369 | 64.363150 | 5.6000 |
| 2 | 898.186047 | 907.006860 | 84.497236 | 16.305279 | 16.305274 | 5.182201 | 67.450066 | 13.0666 |
| 3 | 881.757865 | 893.460030 | 90.370537 | 15.720468 | 15.720068 | 5.748591 | 68.809562 | 11.8000 |
| 4 | 809.625331 | 811.184865 | 62.766242 | 19.213819 | 19.213657 | 3.266724 | 74.565728 | 20.2000 |

```
Data file "test" was already extracted
Loading data file "test"
```

|  | MEAN_RR | MEDIAN_RR | SDRR | RMSSD | SDSD | SDRR_RMSSD | HR | pNN |
|---|---|---|---|---|---|---|---|---|
| **0** | 721.901897 | 727.267280 | 74.722315 | 12.361264 | 12.361069 | 6.044877 | 84.121868 | 4.9333 |
| **1** | 843.538633 | 844.407930 | 58.499429 | 19.298880 | 19.298795 | 3.031234 | 71.478642 | 21.0000 |
| **2** | 958.523868 | 966.671125 | 132.849110 | 21.342715 | 21.342653 | 6.224565 | 63.874293 | 24.1333 |
| **3** | 824.838669 | 842.485905 | 117.822094 | 11.771814 | 11.771248 | 10.008830 | 74.330531 | 4.7333 |
| **4** | 756.707933 | 747.941620 | 143.968457 | 13.357748 | 13.356388 | 10.777899 | 82.092049 | 5.9333 |

In [ ]:

```
# set column specifications
TARGET_NAME = 'condition'
IGNORE_NAMES = ['datasetId']
```

In [ ]:

```
# establish an experiment
from pycaret.classification import ClassificationExperiment

exp = ClassificationExperiment()
exp.setup(
  data=DATA['train'],
  test_data=DATA[TEST_DATA_NAME],
  target=TARGET_NAME,
  ignore_features=IGNORE_NAMES,
  index=False,
  session_id=123,
  remove_multicollinearity=True,
  multicollinearity_threshold=0.999,
)
exp.dataset_transformed.head(5)
```

|  | Description | Value |
|---|---|---|
| **0** | Session id | 123 |
| **1** | Target | condition |
| **2** | Target type | Multiclass |
| **3** | Target mapping | interruption: 0, no stress: 1, time pressure: 2 |
| **4** | Original data shape | (410322, 36) |
| **5** | Transformed data shape | (410322, 29) |
| **6** | Transformed train set shape | (369289, 29) |
| **7** | Transformed test set shape | (41033, 29) |
| **8** | Ignore features | 1 |
| **9** | Numeric features | 34 |
| **10** | Preprocess | True |
| **11** | Imputation type | simple |
| **12** | Numeric imputation | mean |
| **13** | Categorical imputation | mode |
| **14** | Remove multicollinearity | True |
| **15** | Multicollinearity threshold | 0.999000 |
| **16** | Fold Generator | StratifiedKFold |
| **17** | Fold Number | 10 |
| **18** | CPU Jobs | -1 |
| **19** | Use GPU | False |
| **20** | Log Experiment | False |
| **21** | Experiment Name | clf-default-name |
| **22** | USI | 2517 |

Out[ ]:

|  | MEAN_RR | MEDIAN_RR | RMSSD | SDRR_RMSSD | HR | pNN25 | pNN50 |  |
|---|---|---|---|---|---|---|---|---|
| **0** | 885.157837 | 853.763733 | 15.554504 | 9.063146 | 69.499954 | 11.133333 | 0.533333 | 199.061 |
| **1** | 939.425354 | 948.357849 | 12.964439 | 6.272368 | 64.363152 | 5.600000 | 0.000000 | 114.634 |
| **2** | 898.186035 | 907.006836 | 16.305279 | 5.182201 | 67.450066 | 13.066667 | 0.200000 | 118.939 |
| **3** | 881.757874 | 893.460022 | 15.720469 | 5.748590 | 68.809563 | 11.800000 | 0.133333 | 127.318 |
| **4** | 809.625305 | 811.184875 | 19.213820 | 3.266724 | 74.565727 | 20.200001 | 0.200000 | 87.718 |

In [ ]:

```
('Removed columns: ', list(
  set(IGNORE_NAMES) |
  (set(exp.dataset.columns) - set(exp.dataset_transformed.columns))
))
```

Out[ ]:

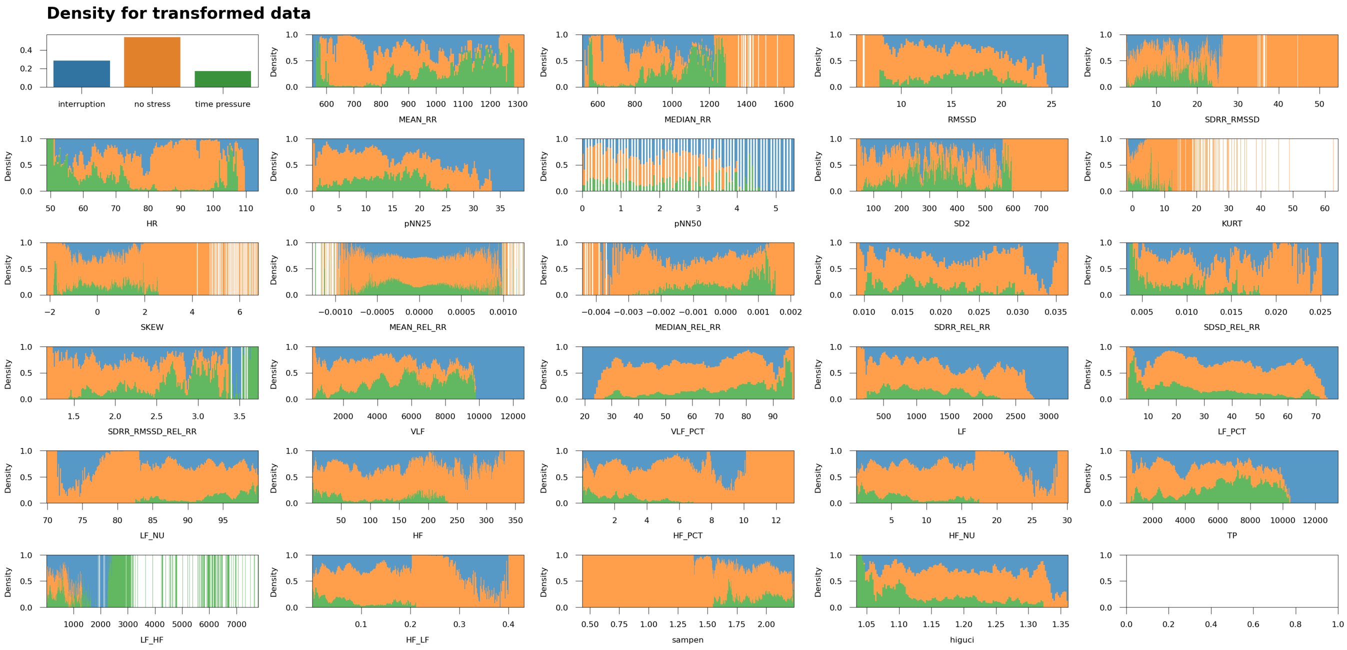
```
('Removed columns: ',
 ['RMSSD_REL_RR',
  'KURT_REL_RR',
  'SDRR',
  'datasetId',
  'SKEW_REL_RR',
  'SD1',
  'SDSD'])
```

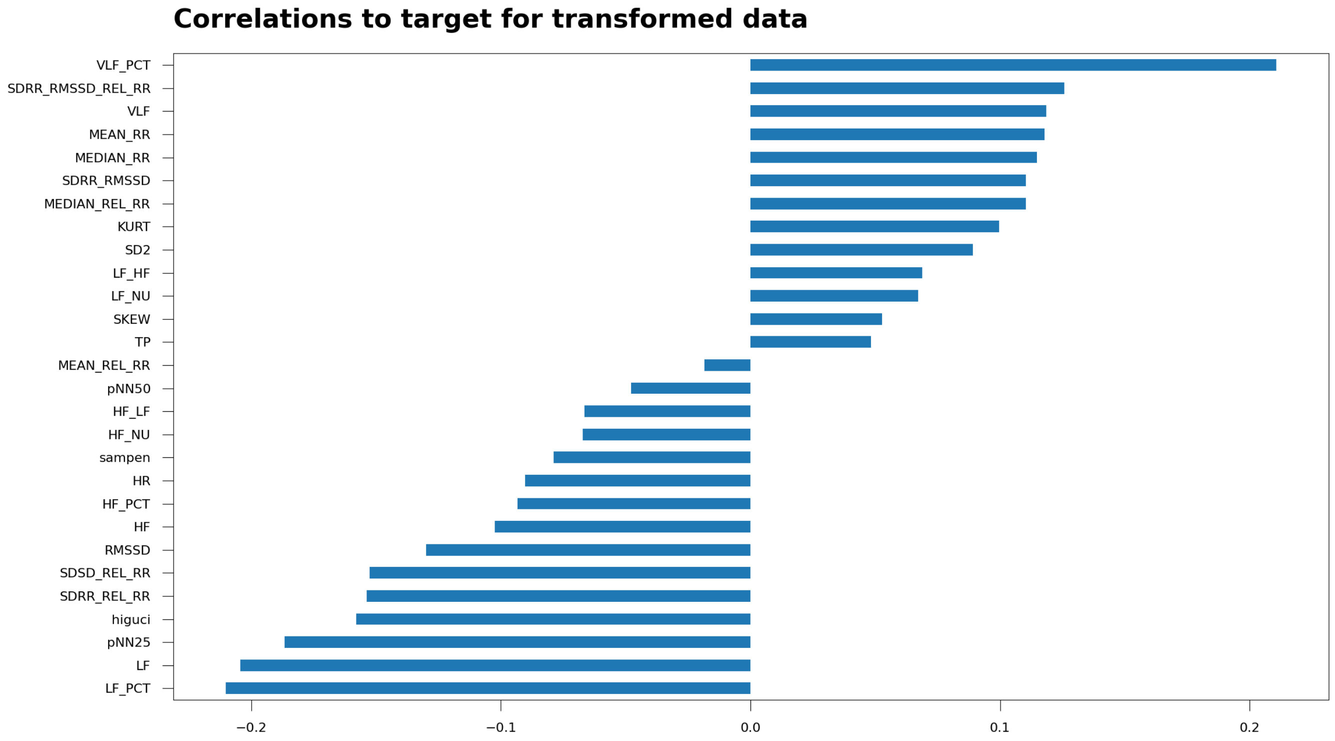
In [ ]:

```python
# show the distributions of the data

# DO_PLOT_DATA = True
if DO_PLOT_DATA:
  # set plot parameters
  from pathlib import Path
  import matplotlib.pyplot as plt
  import seaborn as sns

  # reset old global plot parameters
  plt.rcdefaults()

  # adjustable global plot parameters
  COLORMAP = sns.color_palette()
  DPI = 400
  OUTLINE_WIDTH = 0.2
  plt.rcParams['axes.grid'] = False
  plt.rcParams['axes.linewidth'] = OUTLINE_WIDTH
  plt.rcParams['figure.dpi'] = DPI
  plt.rcParams['font.size'] = 4
  plt.rcParams['xtick.major.width'] = OUTLINE_WIDTH
  plt.rcParams['xtick.minor.width'] = OUTLINE_WIDTH
  plt.rcParams['ytick.major.width'] = OUTLINE_WIDTH
  plt.rcParams['ytick.minor.width'] = OUTLINE_WIDTH
  plot_dir = Path(f'../images/{TEST_DATA_NAME}')
  plot_dir.mkdir(parents=True, exist_ok=True)

  from math import ceil

  # adjustable local plot parameters
  TITLE = 'Density for transformed data'
  SUBPLOT_SIZE = (750, 300)

  # setting local plot parameters
  plots_per_col = 5
  shape = (plots_per_col, ceil(exp.dataset_transformed.shape[1] / plots_per_col))
  figsize = tuple(pxs[0] * pxs[1] / DPI for pxs in zip(SUBPLOT_SIZE, shape))
  title_params = {
    'label': TITLE,
    'fontdict': {
      'fontsize': plt.rcParams['font.size'] * 2,
      'fontweight': 'bold',
    },
    'loc': 'left',
    'pad': plt.rcParams['font.size'] * 2,
  }

  # plot grid
  axs = plt.subplots(
    nrows=shape[1],
    ncols=shape[0],
    layout='constrained',
    figsize=figsize,
  )[1].flat

  # plot target distribution
```

```python
target_dist_data = exp.y.value_counts(normalize=True)
ax = sns.barplot(
  x=target_dist_data.index,
  y=target_dist_data.values,
  ax=axs[0],
  palette=COLORMAP,
)

# plot data title
axs[0].set_title(**title_params)

# plot features distribution
for x, ax in zip(exp.X_transformed.columns, axs[1:]):
  sns.histplot(
    data=exp.dataset_transformed,
    x=x,
    ax=ax,
    hue=TARGET_NAME,
    legend=False,
    linewidth=0,
    multiple='fill',
    palette=COLORMAP,
    stat='density',
  )

# save the plot
plt.savefig(
  fname=plot_dir.joinpath(f'{TITLE}.png'),
  bbox_inches='tight',
)
plt.show()

# check correlation between target and features
# adjustable plot parameters
TITLE = 'Correlations to target for transformed data'
PLOT_SIZE = (2560, 1440)

# setting plot parameters
figsize = tuple(px / DPI for px in PLOT_SIZE)
title_params = {
  'label': TITLE,
  'fontdict': {
    'fontsize': plt.rcParams['font.size'] * 2,
    'fontweight': 'bold',
  },
  'loc': 'left',
  'pad': plt.rcParams['font.size'] * 2,
}

# plot correlation to target
target_corr_data = (exp.dataset_transformed
  .corr()[TARGET_NAME]
  .drop(TARGET_NAME)
  .sort_values())
ax = target_corr_data.plot.barh(figsize=figsize)
ax.set_title(**title_params)

# save the plot
plt.savefig(
  fname=plot_dir.joinpath(f'{TITLE}.png'),
  bbox_inches='tight',
)
plt.show()
```

```
# reset plot parameters
plt.rcdefaults()
```


Density for transformed data


Correlations to target for transformed data

```
In [ ]: # compare models with AUROC

        # DO_COMPARE_MODELS = True
        if DO_COMPARE_MODELS:
          exp.compare_models(
            exclude=[ # excludes slow and unsuitable models
              'ada',
              'catboost',
              'gbc',
              'knn',
              'lr',
              'ridge',
              'rf',
              'svm',
            ],
            sort='auc',
            cross_validation=False,
          )
          None
```

| | Model | Accuracy | AUC | Recall | Prec. | F1 | Kappa | MCC | TT (Sec) |
|---|---|---|---|---|---|---|---|---|---|
| **et** | Extra Trees Classifier | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 5.2000 |
| **xgboost** | Extreme Gradient Boosting | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 4.3100 |
| **lightgbm** | Light Gradient Boosting Machine | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 6.0400 |
| **dt** | Decision Tree Classifier | 0.9997 | 0.9997 | 0.9997 | 0.9997 | 0.9997 | 0.9994 | 0.9994 | 15.4000 |
| **qda** | Quadratic Discriminant Analysis | 0.6271 | 0.8479 | 0.6271 | 0.7081 | 0.6277 | 0.4415 | 0.4707 | 1.8200 |
| **lda** | Linear Discriminant Analysis | 0.6255 | 0.7425 | 0.6255 | 0.6113 | 0.5972 | 0.3084 | 0.3273 | 2.4500 |
| **nb** | Naive Bayes | 0.5411 | 0.6898 | 0.5411 | 0.5587 | 0.5415 | 0.2505 | 0.2544 | 1.5000 |
| **dummy** | Dummy Classifier | 0.5400 | 0.0000 | 0.5400 | 0.2916 | 0.3787 | 0.0000 | 0.0000 | 1.3400 |

In [ ]:

```
# assign the best model id manually
BEST_MODEL_ID = 'xgboost'

best_model = exp.create_model(
  estimator=BEST_MODEL_ID,
  cross_validation=False,
)
best_model
```

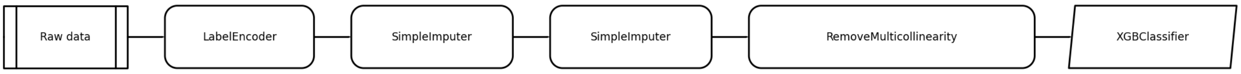
| | Accuracy | AUC | Recall | Prec. | F1 | Kappa | MCC |
|---|---|---|---|---|---|---|---|
| **Test** | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |

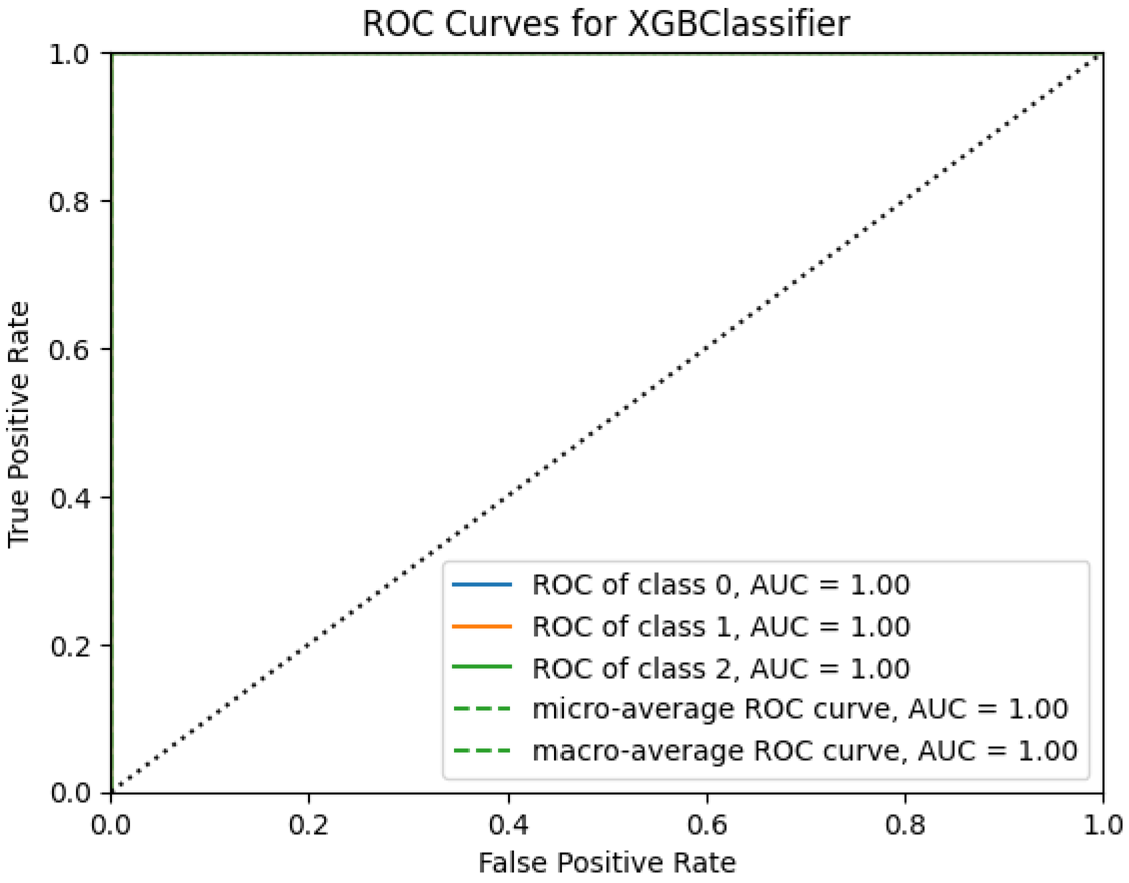
Out[ ]:

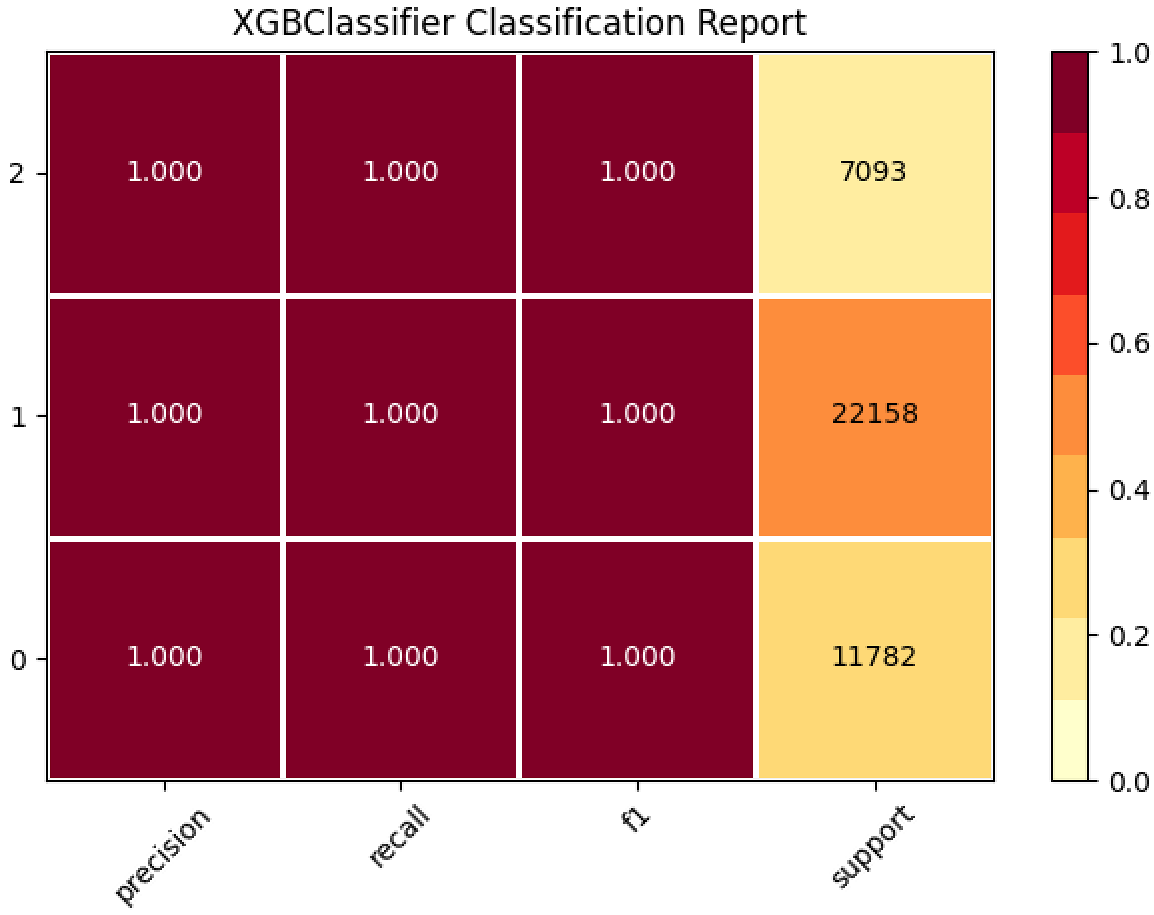
```
▾                             XGBClassifier
XGBClassifier(base_score=None, booster='gbtree', callbacks=None,
              colsample_bylevel=None, colsample_bynode=None,
              colsample_bytree=None, device='cpu', early_stopping_rounds=Non
e,
              enable_categorical=False, eval_metric=None, feature_types=Non
e,
              gamma=None, grow_policy=None, importance_type=None,
              interaction_constraints=None, learning_rate=None, max_bin=Non
e,
```

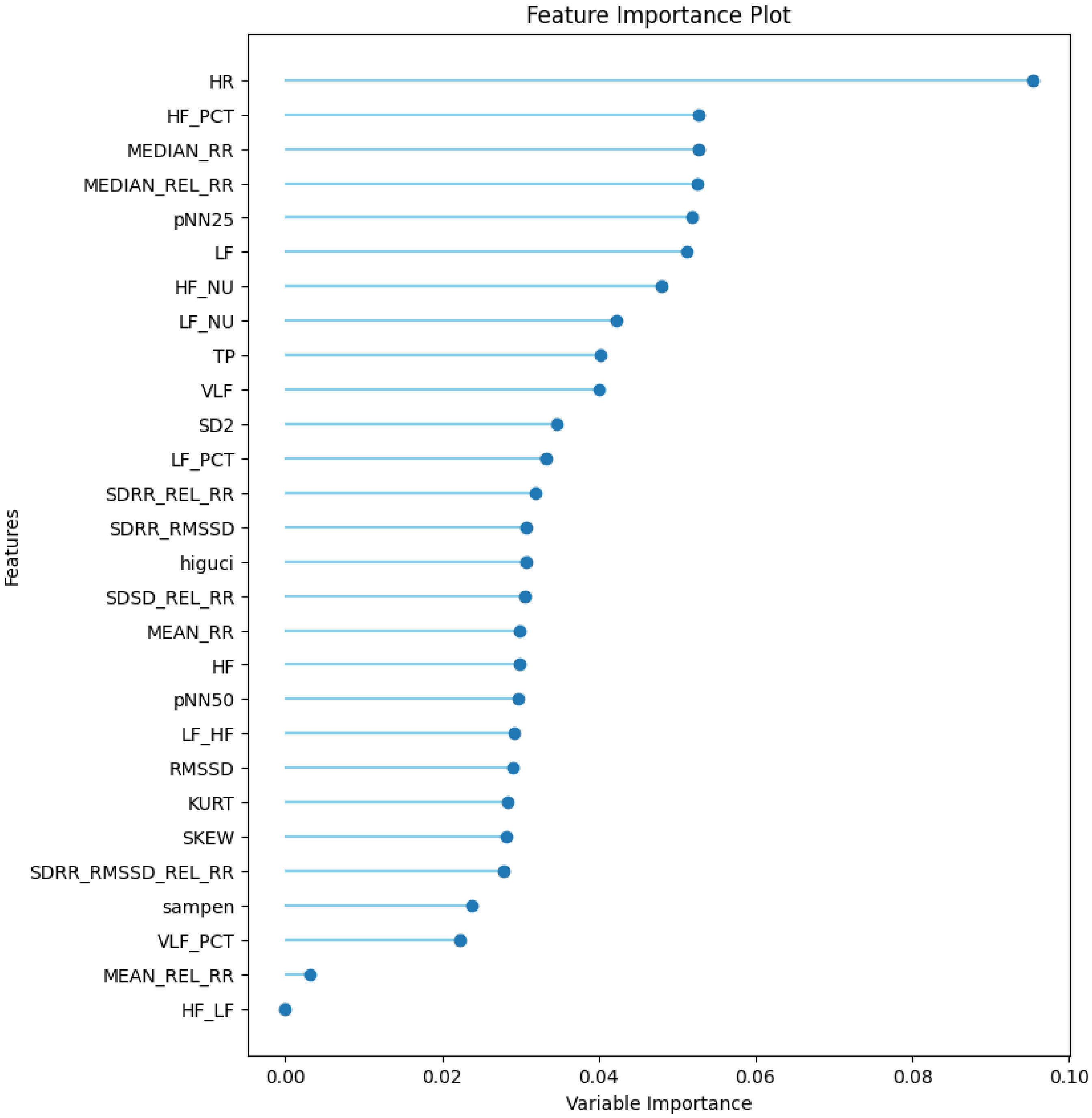
In [ ]:

```
plot_types = [
  'pipeline',
  'auc',
  'class_report',
  'feature_all',
  'parameter',
]
for plot_type in plot_types:
  exp.plot_model(
    estimator=best_model,
    plot=plot_type,
)
```








Feature Importance Plot
Features
HR
HF_PCT
MEDIAN_RR
MEDIAN_REL_RR
pNN25
LF
HF_NU
LF_NU
TP
VLF
SD2
LF_PCT
SDRR_REL_RR
SDRR_RMSSD
higuci
SDSD_REL_RR
MEAN_RR
HF
pNN50
LF_HF
RMSSD
KURT
SKEW
SDRR_RMSSD_REL_RR
sampen
VLF_PCT
MEAN_REL_RR
HF_LF
0.00
0.02
0.04
0.06
0.08
0.10
Variable Importance

| | Parameters |
|---:|---:|
| **objective** | multi:softprob |
| **base_score** | None |
| **booster** | gbtree |
| **callbacks** | None |
| **colsample_bylevel** | None |
| **colsample_bynode** | None |
| **colsample_bytree** | None |
| **device** | cpu |
| **early_stopping_rounds** | None |
| **enable_categorical** | False |
| **eval_metric** | None |
| **feature_types** | None |
| **gamma** | None |
| **grow_policy** | None |
| **importance_type** | None |
| **interaction_constraints** | None |
| **learning_rate** | None |
| **max_bin** | None |
| **max_cat_threshold** | None |
| **max_cat_to_onehot** | None |
| **max_delta_step** | None |
| **max_depth** | None |
| **max_leaves** | None |
| **min_child_weight** | None |
| **missing** | nan |
| **monotone_constraints** | None |
| **multi_strategy** | None |
| **n_estimators** | None |
| **n_jobs** | -1 |
| **num_parallel_tree** | None |
| **random_state** | 123 |
| **reg_alpha** | None |
| **reg_lambda** | None |
| **sampling_method** | None |
| **scale_pos_weight** | None |
| **subsample** | None |
| **tree_method** | auto |

|  | Parameters |
|---|---|
| **validate_parameters** | None |
| **verbosity** | 0 |

In [ ]:
```python
# show hold-out predictions
predictions = exp.predict_model(
  estimator=best_model,
  raw_score=True,
)
display(predictions[filter(
  lambda name: name.startswith('prediction_'),
  predictions.columns,
)].sample(
  n=15,
  random_state=123,
))
predictions = None
```

|  | Model | Accuracy | AUC | Recall | Prec. | F1 | Kappa | MCC |
|---|---|---|---|---|---|---|---|---|
| **0** | Extreme Gradient Boosting | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |

|  | prediction_label | prediction_score_interruption | prediction_score_no stress | prediction_score_tim pressur |
|---|---|---|---|---|
| **380118** | interruption | 0.9997 | 0.0003 | 0.000 |
| **369536** | no stress | 0.0002 | 0.9997 | 0.000 |
| **399645** | no stress | 0.0001 | 0.9999 | 0.000 |
| **375878** | no stress | 0.0009 | 0.9987 | 0.000 |
| **385576** | no stress | 0.0001 | 0.9999 | 0.000 |
| **402199** | time pressure | 0.0001 | 0.0000 | 0.999 |
| **391050** | interruption | 0.9996 | 0.0004 | 0.000 |
| **397656** | no stress | 0.0004 | 0.9982 | 0.001 |
| **398352** | no stress | 0.0002 | 0.9994 | 0.000 |
| **398153** | no stress | 0.0025 | 0.9968 | 0.000 |
| **394973** | time pressure | 0.0002 | 0.0000 | 0.999 |
| **400474** | interruption | 0.9998 | 0.0002 | 0.000 |
| **398507** | no stress | 0.0003 | 0.9996 | 0.000 |
| **385040** | interruption | 0.9986 | 0.0006 | 0.000 |
| **395651** | interruption | 0.9960 | 0.0008 | 0.003 |

In [ ]:
```python
# save the experiment and model

# DO_SAVE_RESULTS = True
if DO_SAVE_RESULTS:
  from pathlib import Path

  result_dir = Path(f'../models/{TEST_DATA_NAME}')
  result_dir.mkdir(
    parents=True,
    exist_ok=True,
  )
  exp.save_experiment(
    path_or_file=result_dir.joinpath('experiment.pkl'),
  )
  exp.save_model(
    model=best_model,
    model_name=result_dir.joinpath('model'),
  )
```

```
Transformation Pipeline and Model Successfully Saved
```