```
import warnings
warnings.simplefilter(action='ignore', category=FutureWarning)

import numpy as np
import pandas as pd
pd.options.display.float_format = '{:.3f}'.format  # Sets float precision to 3 decimal places.

# Data Visualisation Libraries
import matplotlib.pyplot as plt
%config InlineBackend.figure_format = 'retina'

!pip install seaborn --upgrade
import seaborn as sns
sns.set_style('darkgrid')

# Statistics
from scipy.stats import chi2_contingency
from imblearn.over_sampling import SMOTE

# Machine Learning
from sklearn.model_selection import train_test_split, GridSearchCV
from sklearn.model_selection import cross_val_score, cross_val_predict
from sklearn.model_selection import learning_curve

from sklearn.preprocessing import LabelEncoder, StandardScaler

from sklearn.naive_bayes import GaussianNB
from sklearn.linear_model import LogisticRegression
from sklearn.svm import SVC
from sklearn.ensemble import RandomForestClassifier, GradientBoostingClassifier, VotingClassifier
from xgboost import XGBClassifier
from lightgbm import LGBMClassifier

from sklearn.metrics import accuracy_score, recall_score, precision_score, auc, roc_auc_score, roc_curve
from sklearn.metrics import confusion_matrix
import scikitplot as skplt

print('✔ Libraries Imported!')
```

```
Requirement already satisfied: seaborn in /usr/local/lib/python3.10/dist-packages (0.13.2)
Requirement already satisfied: numpy!=1.24.0,>=1.20 in /usr/local/lib/python3.10/dist-packages (from seaborn) (1.25.2)
Requirement already satisfied: pandas>=1.2 in /usr/local/lib/python3.10/dist-packages (from seaborn) (2.2.2)
Requirement already satisfied: matplotlib!=3.6.1,>=3.4 in /usr/local/lib/python3.10/dist-packages (from seaborn) (3.8.0)
Requirement already satisfied: contourpy>=1.0.1 in /usr/local/lib/python3.10/dist-packages (from matplotlib!=3.6.1,>=3.4->seaborn)
Requirement already satisfied: cycler>=0.10 in /usr/local/lib/python3.10/dist-packages (from matplotlib!=3.6.1,>=3.4->seaborn) (0.12
Requirement already satisfied: fonttools>=4.22.0 in /usr/local/lib/python3.10/dist-packages (from matplotlib!=3.6.1,>=3.4->seaborn)
Requirement already satisfied: kiwisolver>=1.0.1 in /usr/local/lib/python3.10/dist-packages (from matplotlib!=3.6.1,>=3.4->seaborn)
Requirement already satisfied: packaging>=20.0 in /usr/local/lib/python3.10/dist-packages (from matplotlib!=3.6.1,>=3.4->seaborn) (2
Requirement already satisfied: pillow>=6.2.0 in /usr/local/lib/python3.10/dist-packages (from matplotlib!=3.6.1,>=3.4->seaborn) (11
Requirement already satisfied: pyparsing>=2.3.1 in /usr/local/lib/python3.10/dist-packages (from matplotlib!=3.6.1,>=3.4->seaborn)
Requirement already satisfied: python-dateutil>=2.7 in /usr/local/lib/python3.10/dist-packages (from matplotlib!=3.6.1,>=3.4->seabor
Requirement already satisfied: pytz>=2020.1 in /usr/local/lib/python3.10/dist-packages (from pandas>=1.2->seaborn) (2024.2)
Requirement already satisfied: tzdata>=2022.7 in /usr/local/lib/python3.10/dist-packages (from pandas>=1.2->seaborn) (2024.2)
Requirement already satisfied: six>=1.5 in /usr/local/lib/python3.10/dist-packages (from python-dateutil>=2.7->matplotlib!=3.6.1,>=3
✔ Libraries Imported!
```

```
font_size = 20
plt.rcParams['axes.labelsize'] = font_size
plt.rcParams['axes.titlesize'] = font_size + 2
plt.rcParams['xtick.labelsize'] = font_size - 2
plt.rcParams['ytick.labelsize'] = font_size - 2
plt.rcParams['legend.fontsize'] = font_size - 2

colors = ['#00A5E0', '#DD403A']
colors_cat = ['#E8907E', '#D5CABD', '#7A6F86', '#C34A36', '#B0A8B9', '#845EC2', '#8f9aaa', '#FFB86F', '#63BAAA', '#9D88B3', '#38c4e3']
colors_comp = ['steelblue', 'seagreen', 'black', 'darkorange', 'purple', 'firebrick', 'slategrey']

random_state = 42
scoring_metric = 'recall'
comparison_dict, comparison_test_dict = {}, {}

print('✔ Default Parameters and Variables Set!')
```

```
✔ Default Parameters and Variables Set!
```

```
def plot_continuous(feature):
    '''Plot a histogram and boxplot for the churned and retained distributions for the specified feature.'''
    df_func = train_df.copy()
    df_func['Exited'] = df_func['Exited'].astype('category')
    fig, (ax1, ax2) = plt.subplots(2,
                               figsize=(9, 7),
                               sharex=True,
                               gridspec_kw={'height_ratios': (.7, .3)})

    for df, color, label in zip([df_retained, df_churned], colors, ['Retained', 'Churned']):
        sns.histplot(data=df,
                     x=feature,
                     bins=15,
                     color=color,
                     alpha=0.66,
                     edgecolor='firebrick',
                     label=label,
                     kde=False,
                     ax=ax1)
    ax1.legend()

    sns.boxplot(x=feature, y='Exited', data=df_func, palette=colors, ax=ax2)
    ax2.set_ylabel('')
    ax2.set_yticklabels(['Retained', 'Churned'])

    plt.tight_layout();


print('✔ Function Defined!')
```

```
✔ Function Defined!
```

```
def plot_categorical(feature):
    '''For a categorical feature, plot a seaborn.countplot for the total counts of each category next to a barplot for the churn rate.'
    fig, (ax1, ax2) = plt.subplots(1, 2, figsize=(12, 4))

    sns.countplot(x=feature,
                  hue='Exited',
                  data=train_df,
                  palette=colors,
                  ax=ax1)
    ax1.set_ylabel('Count')
    ax1.legend(labels=['Retained', 'Churned'])

    sns.barplot(x=feature,
                y='Exited',
                data=train_df,
                palette=colors_cat,
                ax=ax2)
    ax2.set_ylabel('Churn rate')

    if (feature == 'HasCrCard' or feature == 'IsActiveMember'):
        ax1.set_xticklabels(['No', 'Yes'])
        ax2.set_xticklabels(['No', 'Yes'])

    plt.tight_layout();


print('✔ Function Defined!')
```

```
✔ Function Defined!
```

```
def plot_conf_mx(cm, ax):
    '''Plot a confusion matrix in the specified axes object.'''
    sns.heatmap(data=cm,
                annot=True,
                cmap='Blues',
                annot_kws={'fontsize': 30},
                ax=ax)

    ax.set_xlabel('Predicted Label')
    ax.set_xticks([0.5, 1.5])
    ax.set_xticklabels(['Retained', 'Churned'])

    ax.set_ylabel('True Label')
    ax.set_yticks([0.25, 1.25])
    ax.set_yticklabels(['Retained', 'Churned']);


print('✔ Function Defined!')
```

```
✔ Function Defined!
```

```
def plot_learning_curve(estimator,
                        X,
                        y,
                        ax,
                        cv=None,
                        train_sizes=np.linspace(0.1, 1.0, 5)):
    '''Plot the learning curves for an estimator in the specified axes object.'''
    train_sizes, train_scores, test_scores = learning_curve(
        estimator,
        X,
        y,
        cv=cv,
        n_jobs=-1,
        train_sizes=train_sizes,
        scoring='accuracy')

    train_scores_mean = np.mean(train_scores, axis=1)
    train_scores_std = np.std(train_scores, axis=1)
    test_scores_mean = np.mean(test_scores, axis=1)
    test_scores_std = np.std(test_scores, axis=1)

    ax.fill_between(train_sizes,
                    train_scores_mean - train_scores_std,
                    train_scores_mean + train_scores_std,
                    alpha=0.1,
                    color='dodgerblue')
    ax.fill_between(train_sizes,
                    test_scores_mean - test_scores_std,
                    test_scores_mean + test_scores_std,
                    alpha=0.1,
                    color='darkorange')

    ax.plot(train_sizes,
            train_scores_mean,
            color='dodgerblue',
            marker='o',
            linestyle='-',
            label='Training Score')
    ax.plot(train_sizes,
            test_scores_mean,
            color='darkorange',
            marker='o',
            linestyle='-',
            label='Cross-validation Score')

    ax.set_xlabel('Training Examples')
    ax.set_ylabel('Score')
    ax.legend(loc='best', fontsize=14);


print('✔ Function Defined!')
```

```
✔ Function Defined!
```

```
def clf_performance(classifier, classifier_name, classifier_name_abv):
    '''Display the overall performance of a classifier with this template.'''
    print('\n', classifier_name)
    print('-------------------------------')
    print('   Best Score ({}): '.format(scoring_metric) + str(np.round(classifier.best_score_, 3)))
    print('   Best Parameters: ')
    for key, value in classifier.best_params_.items():
        print('      {}: {}'.format(key, value))

    y_pred_pp = cross_val_predict(estimator=classifier.best_estimator_,
                                  X=X_train,
                                  y=y_train,
                                  cv=5,
                                  method='predict_proba')[:, 1]
    y_pred = y_pred_pp.round()

    cm = confusion_matrix(y_train, y_pred, normalize='true')

    fpr, tpr, _ = roc_curve(y_train, y_pred_pp)
    comparison_dict[classifier_name_abv] = [
        accuracy_score(y_train, y_pred),
        precision_score(y_train, y_pred),
        recall_score(y_train, y_pred),
        roc_auc_score(y_train, y_pred_pp), fpr, tpr
    ]

    fig, (ax1, ax2) = plt.subplots(1, 2, figsize=(12, 5))
    plot_conf_mx(cm, ax1)
    plot_learning_curve(classifier.best_estimator_, X_train, y_train, ax2)

    plt.tight_layout();


print('✔ Function Defined!')
```

```
✔ Function Defined!
```

```
def plot_feature_imp(classifier, classifier_name, color, ax):
    '''Plot the importance of features for a classifier as a barplot.'''
    importances = pd.DataFrame({'Feature': X_train.columns,
                                'Importance': np.round(classifier.best_estimator_.feature_importances_, 3)})

    importances = importances.sort_values('Importance', ascending=True).set_index('Feature')

    importances.plot.barh(color=color,
                          edgecolor='firebrick',
                          legend=False,
                          ax=ax)
    ax.set_title(classifier_name)
    ax.set_xlabel('Importance');


print('✔ Function Defined!')
```

```
✔ Function Defined!
```

```
def test_func(classifier, classifier_name, ax):
    '''Assess the performance on the test set and plot the confusion matrix.'''
    y_pred = classifier.predict(X_test)
    cm = confusion_matrix(y_test, y_pred, normalize='true')

    comparison_test_dict[classifier_name] = [accuracy_score(y_test, y_pred),
                                             precision_score(y_test, y_pred),
                                             recall_score(y_test, y_pred)]

    sns.heatmap(cm,
                annot=True,
                annot_kws={'fontsize': 24},
                cmap='Blues',
                ax=ax)

    ax.set_title(classifier_name)

    ax.set_xlabel('Predicted Label')
    ax.set_xticks([0.5, 1.5])
    ax.set_xticklabels(['Retained', 'Churned'])

    ax.set_ylabel('True Label')
    ax.set_yticks([0.2, 1.4])
    ax.set_yticklabels(['Retained', 'Churned']);


print('✔ Function Defined!')
```

```
✔ Function Defined!
```

```
from google.colab import files
uploaded = files.upload()
```

Choose Files No file chosen Upload widget is only available when the cell has been executed in the current browser session. Please rerun this cell to

```
df = pd.read_csv('Churn_Modelling.csv')

print('✔ Dataset Imported Successfully!\n')
print('It contains {} rows and {} columns.'.format(df.shape[0], df.shape[1]))
df.head()
```

```
✔ Dataset Imported Successfully!

It contains 10000 rows and 14 columns.
```

	RowNumber	CustomerId	Surname	CreditScore	Geography	Gender	Age	Tenure	Balance	NumOfProducts	HasCrCard	IsActiveMember
0	1	15634602	Hargrave	619	France	Female	42	2	0.000	1	1	1
1	2	15647311	Hill	608	Spain	Female	41	1	83807.860	1	0	1
2	3	15619304	Onio	502	France	Female	42	8	159660.800	3	1	0
3	4	15701354	Boni	699	France	Female	39	1	0.000	2	0	0
4	5	15737888	Mitchell	850	Spain	Female	43	2	125510.820	1	1	1

```
df.drop(['RowNumber', 'CustomerId', 'Surname'], axis=1, inplace=True)
df.columns
```

```
Index(['CreditScore', 'Geography', 'Gender', 'Age', 'Tenure', 'Balance',
       'NumOfProducts', 'HasCrCard', 'IsActiveMember', 'EstimatedSalary',
       'Exited'],
      dtype='object')
```

```
df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 10000 entries, 0 to 9999
Data columns (total 11 columns):
 #   Column           Non-Null Count  Dtype  
---  ------           --------------  -----  
 0   CreditScore      10000 non-null  int64  
 1   Geography        10000 non-null  object 
 2   Gender           10000 non-null  object 
 3   Age              10000 non-null  int64  
 4   Tenure           10000 non-null  int64  
 5   Balance          10000 non-null  float64
 6   NumOfProducts    10000 non-null  int64  
 7   HasCrCard        10000 non-null  int64  
 8   IsActiveMember   10000 non-null  int64  
 9   EstimatedSalary  10000 non-null  float64
 10  Exited           10000 non-null  int64  
dtypes: float64(2), int64(7), object(2)
memory usage: 859.5+ KB
```

```
df.describe().T
```

	count	mean	std	min	25%	50%	75%	max
CreditScore	10000.000	650.529	96.653	350.000	584.000	652.000	718.000	850.000
Age	10000.000	38.922	10.488	18.000	32.000	37.000	44.000	92.000
Tenure	10000.000	5.013	2.892	0.000	3.000	5.000	7.000	10.000
Balance	10000.000	76485.889	62397.405	0.000	0.000	97198.540	127644.240	250898.090
NumOfProducts	10000.000	1.530	0.582	1.000	1.000	1.000	2.000	4.000
HasCrCard	10000.000	0.706	0.456	0.000	0.000	1.000	1.000	1.000
IsActiveMember	10000.000	0.515	0.500	0.000	0.000	1.000	1.000	1.000
EstimatedSalary	10000.000	100090.240	57510.493	11.580	51002.110	100193.915	149388.247	199992.480
Exited	10000.000	0.204	0.403	0.000	0.000	0.000	0.000	1.000

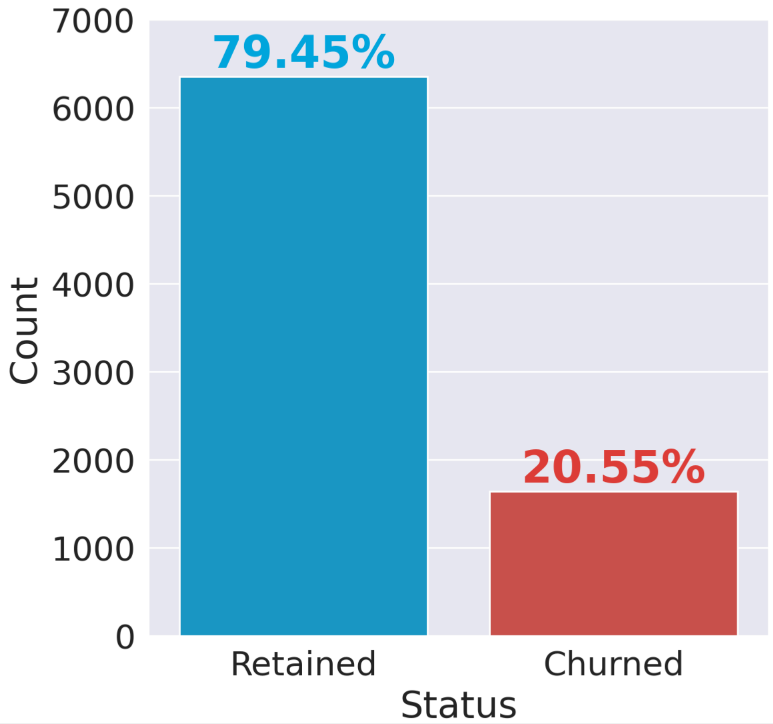
```
train_df, test_df = train_test_split(df, test_size=0.2, random_state=random_state)

train_df.reset_index(drop=True, inplace=True)
test_df.reset_index(drop=True, inplace=True)

print('Train set: {} rows x {} columns'.format(train_df.shape[0],
                                               train_df.shape[1]))
print(' Test set: {} rows x {} columns'.format(test_df.shape[0],
                                               test_df.shape[1]))
```

```
Train set: 8000 rows x 11 columns
 Test set: 2000 rows x 11 columns
```

```
fig, ax = plt.subplots(figsize=(6, 6))

sns.countplot(x='Exited', data=train_df, palette=colors, ax=ax)
```

```
for index, value in enumerate(train_df['Exited'].value_counts()):
    label = '{}%'.format(round((value / train_df['Exited'].shape[0]) * 100, 2))
    ax.annotate(label,
                xy=(index, value + 250),
                ha='center',
                va='center',
                color=colors[index],
                fontweight='bold',
                size=font_size + 4)

ax.set_xticklabels(['Retained', 'Churned'])
ax.set_xlabel('Status')
ax.set_ylabel('Count')
ax.set_ylim([0, 7000]);
```

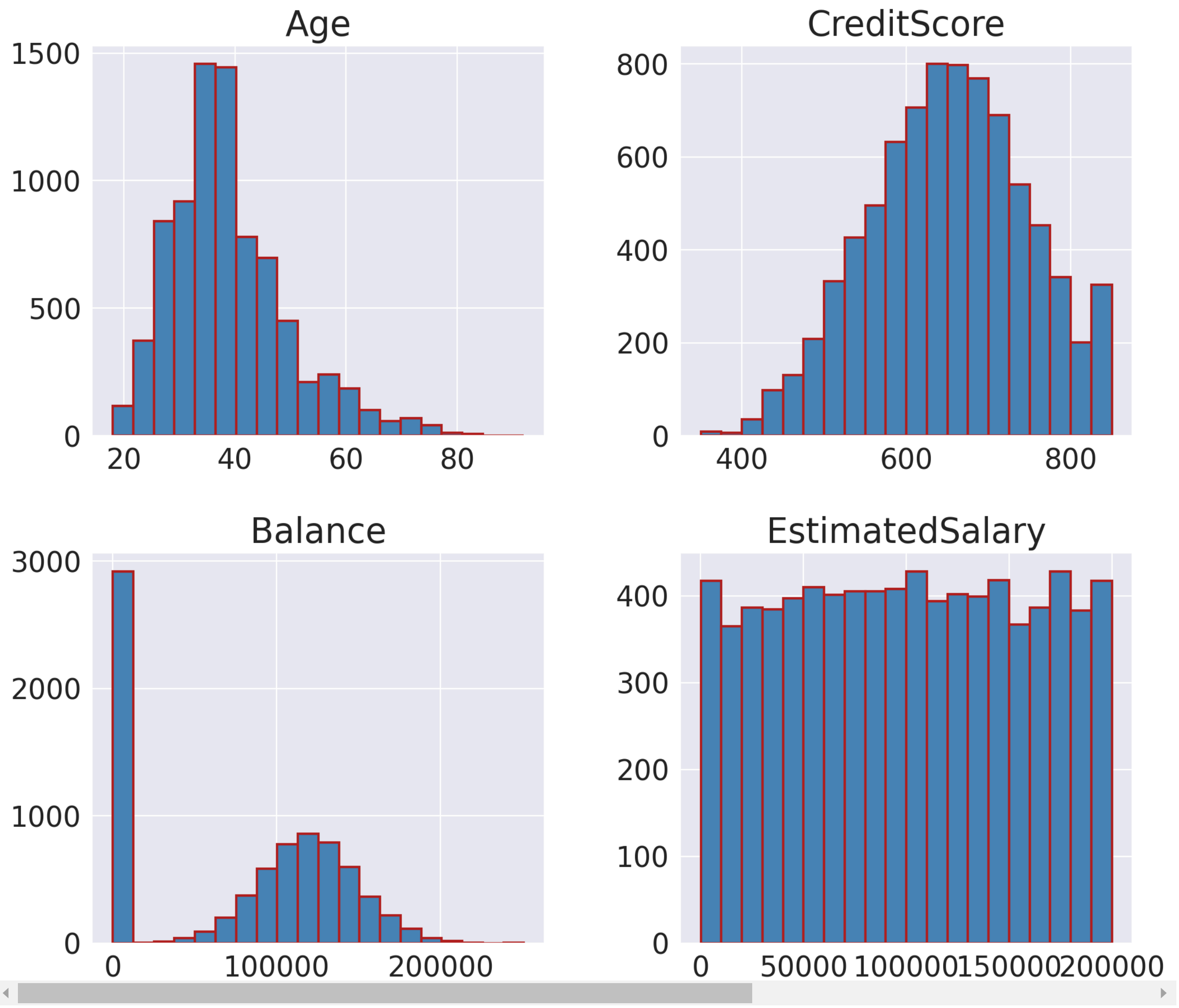
```
<ipython-input-17-817ade87d9b9>:15: UserWarning: set_ticklabels() should only be used with a fixed number of ticks, i.e. after set_t
  ax.set_xticklabels(['Retained', 'Churned'])
```



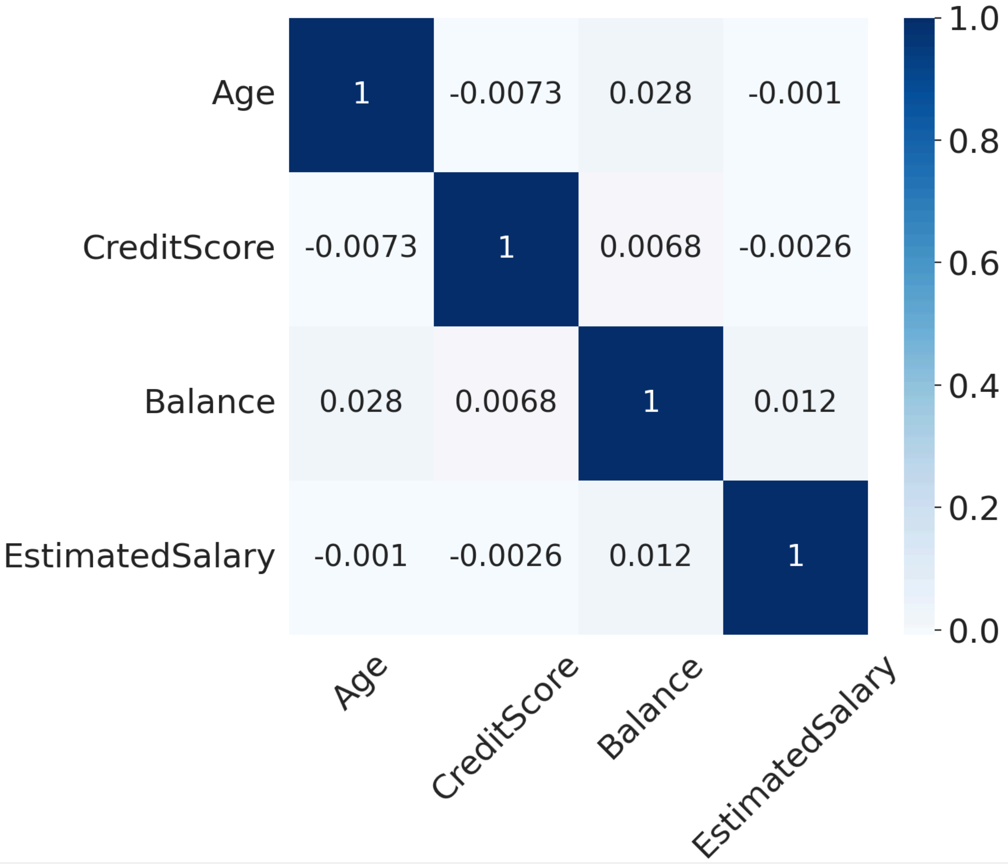
```
continuous = ['Age', 'CreditScore', 'Balance', 'EstimatedSalary']
categorical = ['Geography', 'Gender', 'Tenure', 'NumOfProducts', 'HasCrCard', 'IsActiveMember']

print('Continuous: ', ', '.join(continuous))
print('Categorical: ', ', '.join(categorical))
```

```
Continuous:  Age, CreditScore, Balance, EstimatedSalary
Categorical:  Geography, Gender, Tenure, NumOfProducts, HasCrCard, IsActiveMember
```

```
train_df[continuous].hist(figsize=(12, 10),
                          bins=20,
                          layout=(2, 2),
                          color='steelblue',
                          edgecolor='firebrick',
                          linewidth=1.5);
```

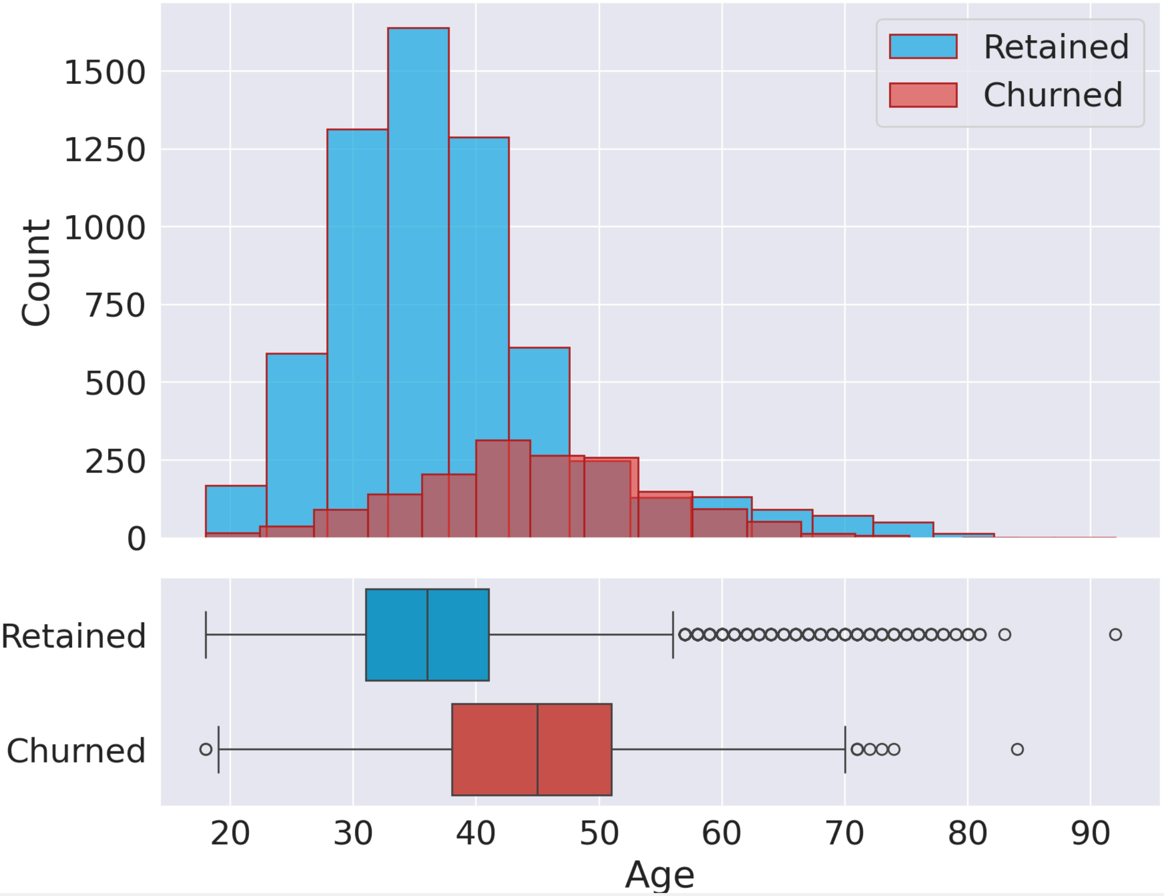


```
fig, ax = plt.subplots(figsize=(7, 6))

sns.heatmap(train_df[continuous].corr(),
            annot=True,
            annot_kws={'fontsize': 16},
            cmap='Blues',
            ax=ax)

ax.tick_params(axis='x', rotation=45)
ax.tick_params(axis='y', rotation=360);
```



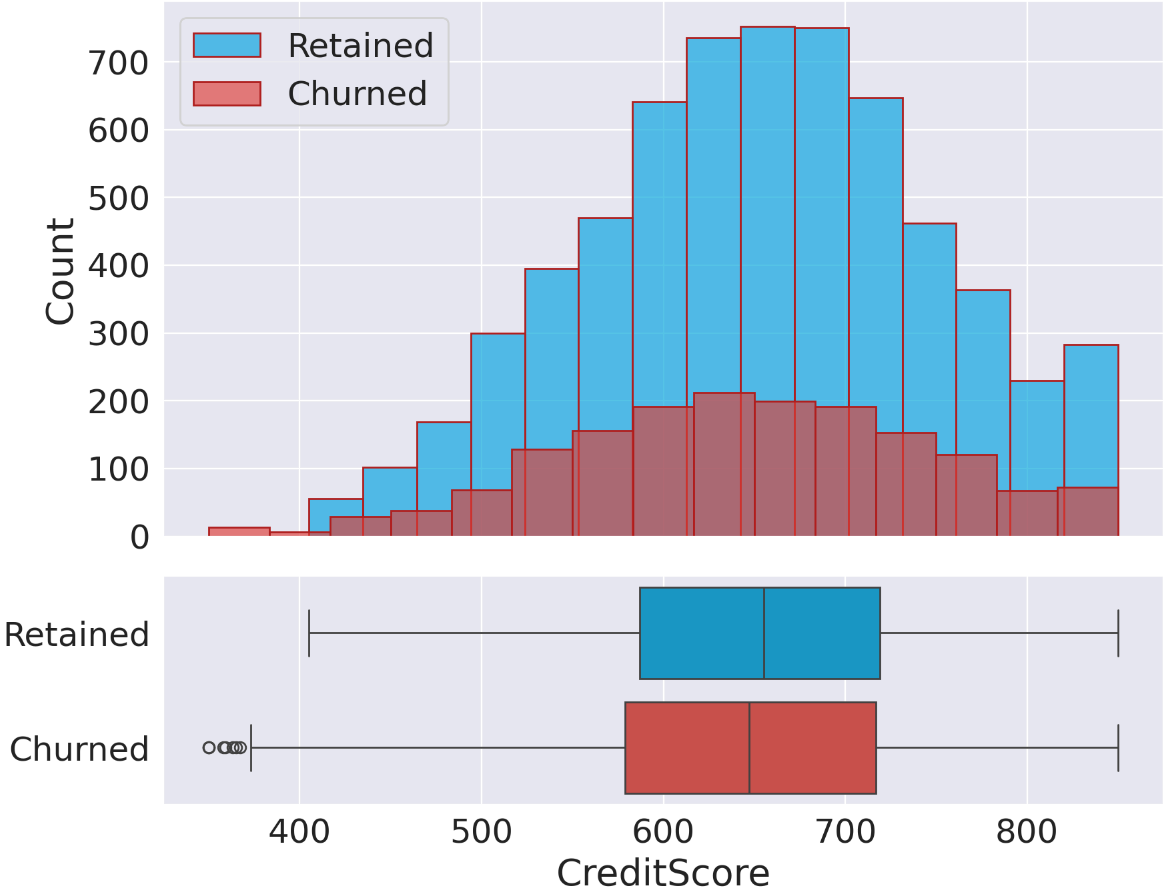
```
df_churned = train_df[train_df['Exited'] == 1]
df_retained = train_df[train_df['Exited'] == 0]

plot_continuous('Age')
```

```
<ipython-input-4-942a9264b999>:25: UserWarning: set_ticklabels() should only be used with a fixed number of ticks, i.e. after set_ti
  ax2.set_yticklabels(['Retained', 'Churned'])
```



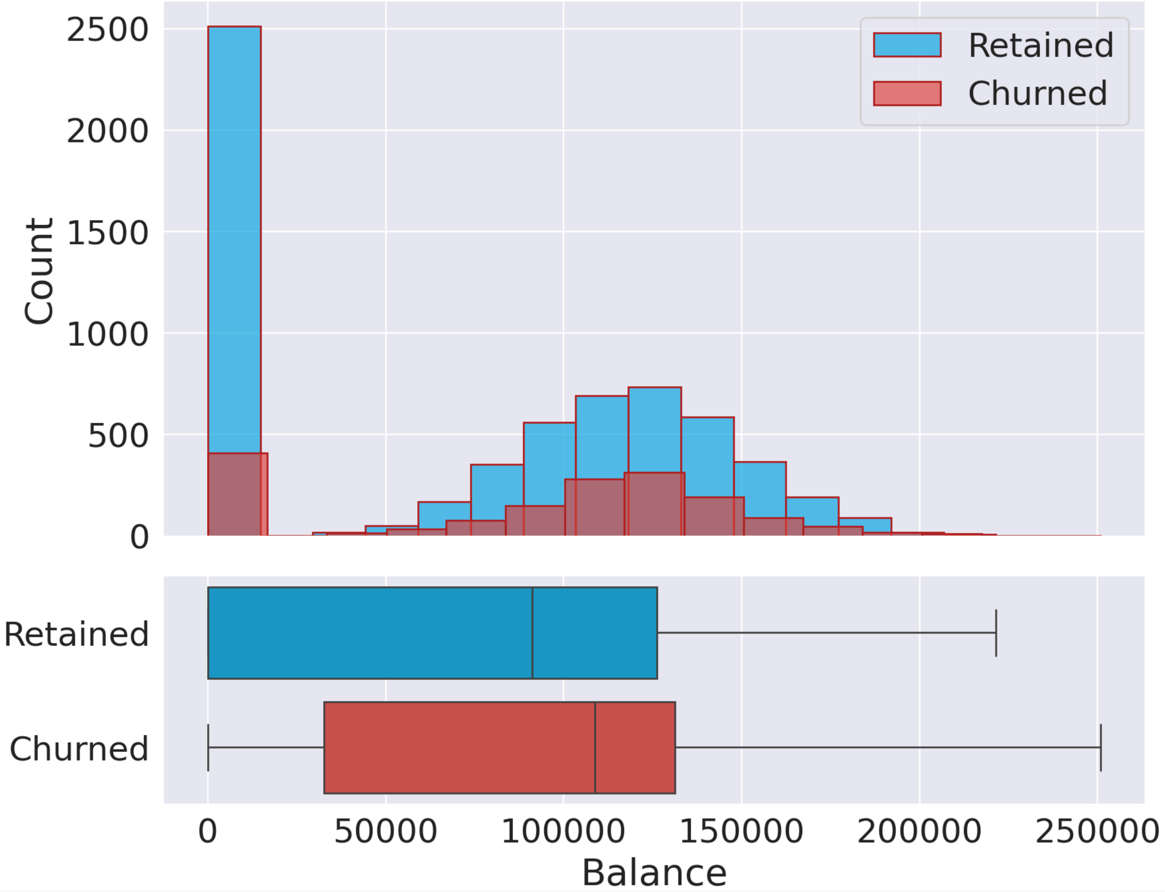
```
plot_continuous('CreditScore')
```

```
<ipython-input-4-942a9264b999>:25: UserWarning: set_ticklabels() should only be used with a fixed number of ticks, i.e. after set_ti
  ax2.set_yticklabels(['Retained', 'Churned'])
```



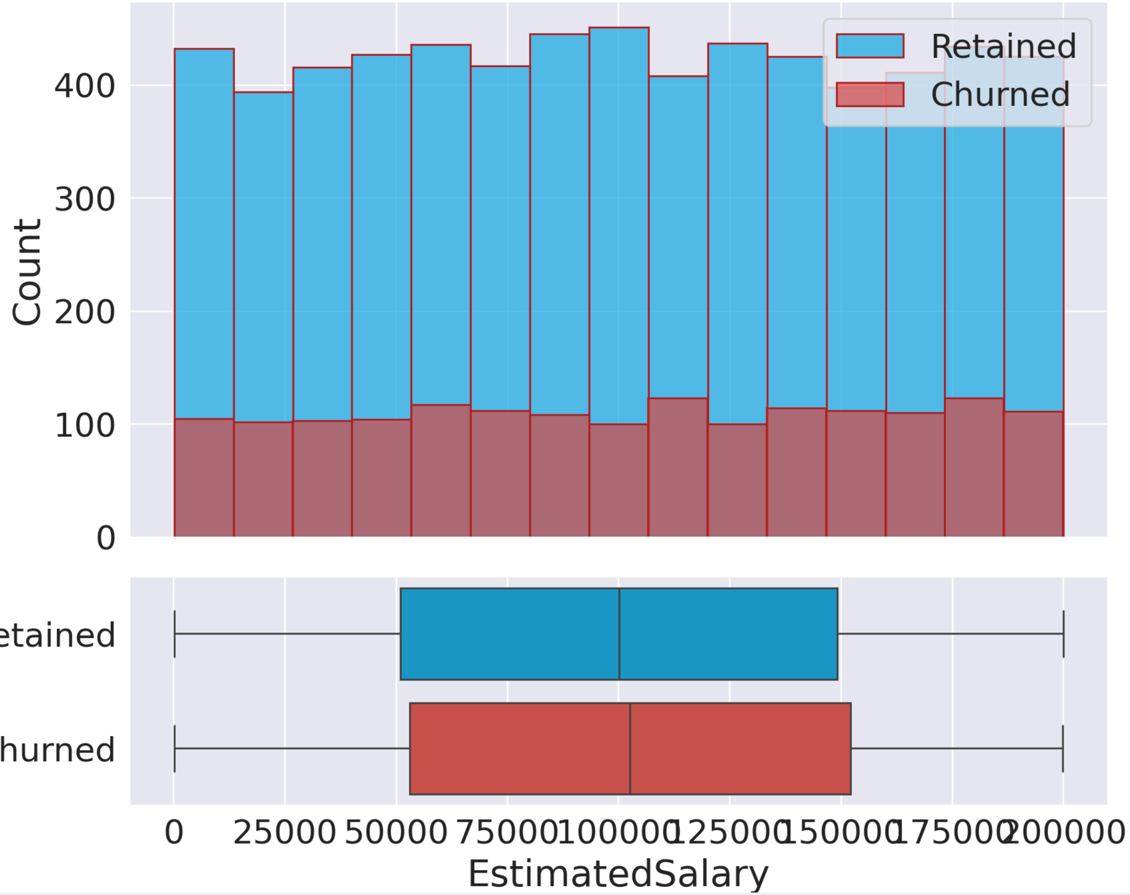
```
plot_continuous('Balance')
```

```
<ipython-input-4-942a9264b999>:25: UserWarning: set_ticklabels() should only be used with a fixed number of ticks, i.e. after set_ti
  ax2.set_yticklabels(['Retained', 'Churned'])
```



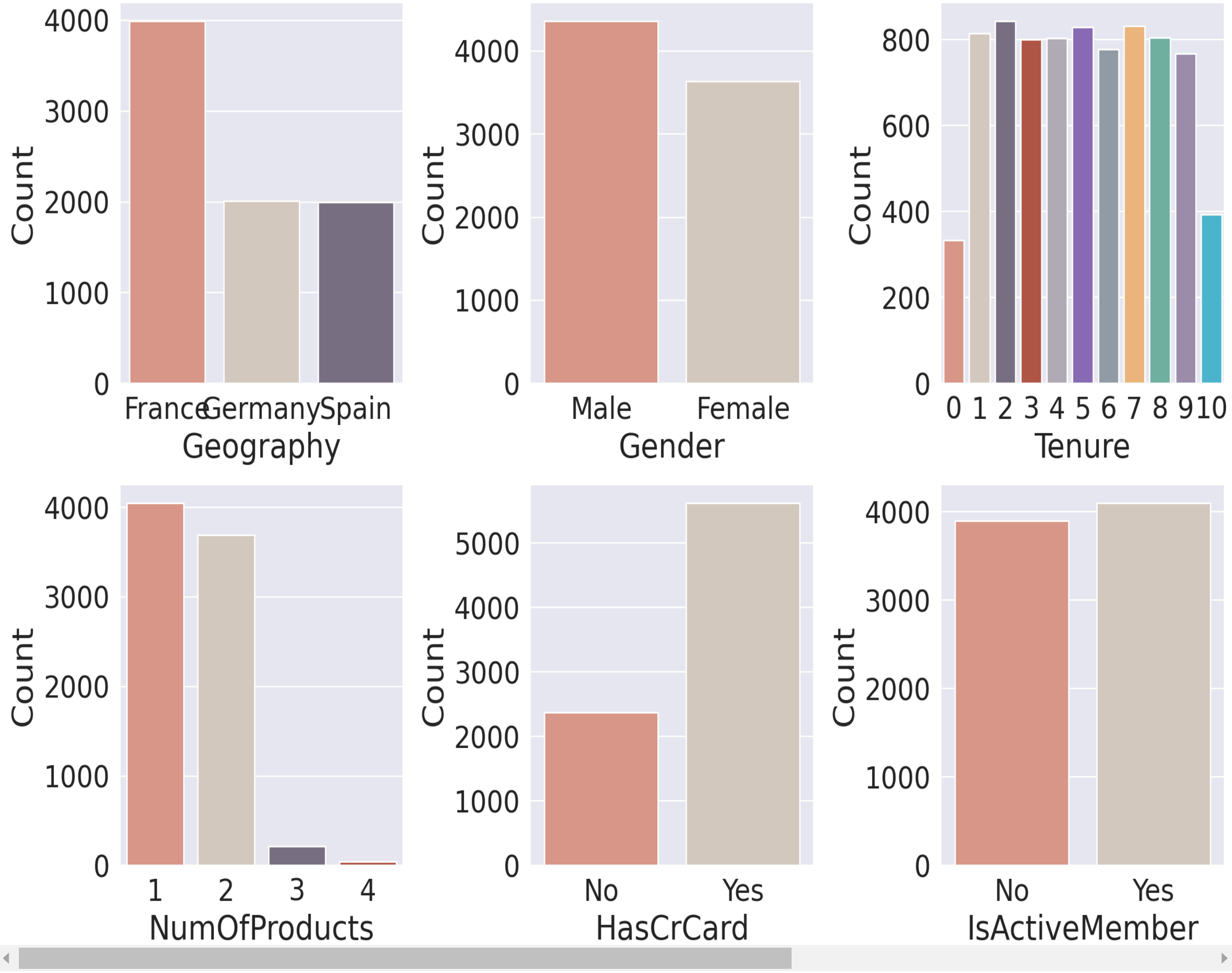
```
plot_continuous('EstimatedSalary')
```

```
<ipython-input-4-942a9264b999>:25: UserWarning: set_ticklabels() should only be used with a fixed number of ticks, i.e. after set_ti
  ax2.set_yticklabels(['Retained', 'Churned'])
```



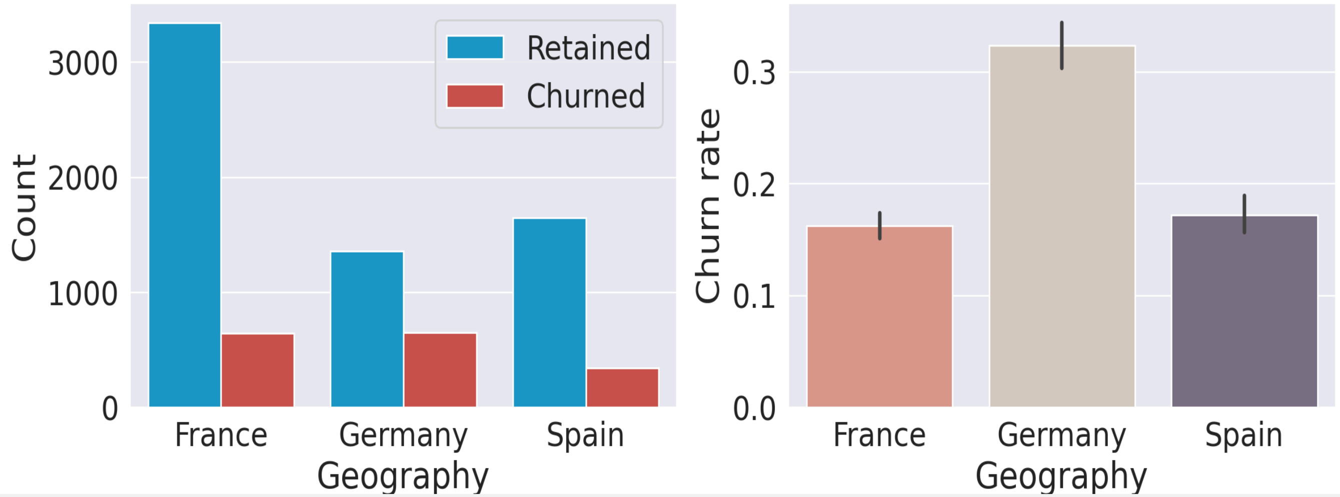
```
df_cat = train_df[categorical]

fig, ax = plt.subplots(2, 3, figsize=(12, 8))

for index, column in enumerate(df_cat.columns):

    plt.subplot(2, 3, index + 1)
    sns.countplot(x=column, data=train_df, palette=colors_cat)

    plt.ylabel('Count')
    if (column == 'HasCrCard' or column == 'IsActiveMember'):
        plt.xticks([0, 1], ['No', 'Yes'])

plt.tight_layout();
```

```
<ipython-input-25-8fcd12c181bb>:8: UserWarning: The palette list has more values (11) than needed (3), which may not be intended.
  sns.countplot(x=column, data=train_df, palette=colors_cat)
<ipython-input-25-8fcd12c181bb>:8: UserWarning: The palette list has more values (11) than needed (2), which may not be intended.
  sns.countplot(x=column, data=train_df, palette=colors_cat)
<ipython-input-25-8fcd12c181bb>:8: UserWarning: The palette list has more values (11) than needed (4), which may not be intended.
  sns.countplot(x=column, data=train_df, palette=colors_cat)
<ipython-input-25-8fcd12c181bb>:8: UserWarning: The palette list has more values (11) than needed (2), which may not be intended.
  sns.countplot(x=column, data=train_df, palette=colors_cat)
<ipython-input-25-8fcd12c181bb>:8: UserWarning: The palette list has more values (11) than needed (2), which may not be intended.
  sns.countplot(x=column, data=train_df, palette=colors_cat)
```



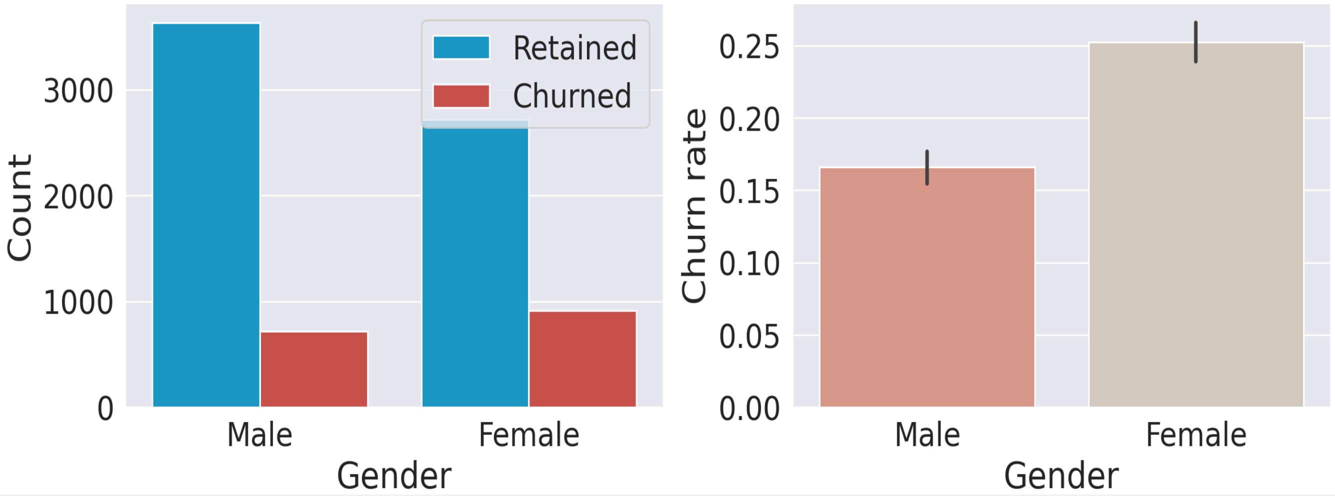
```
plot_categorical('Geography')
```

```
<ipython-input-5-bffbe343df06>:13: UserWarning: The palette list has more values (11) than needed (3), which may not be intended.
  sns.barplot(x=feature,
```

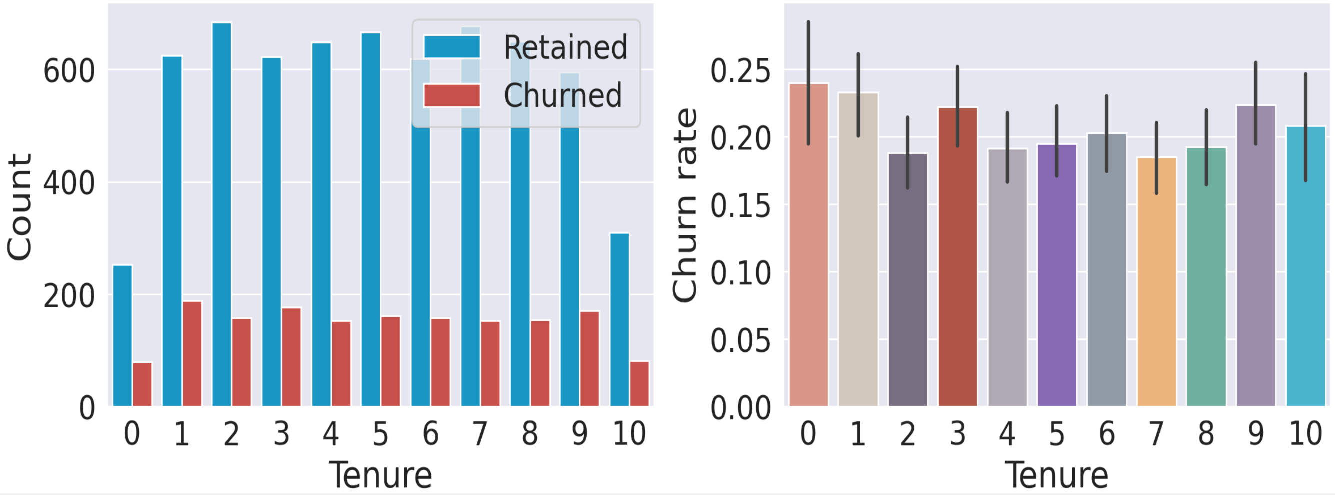


```
plot_categorical('Gender')
```

```
<ipython-input-5-bffbe343df06>:13: UserWarning: The palette list has more values (11) than needed (2), which may not be intended.
  sns.barplot(x=feature,
```

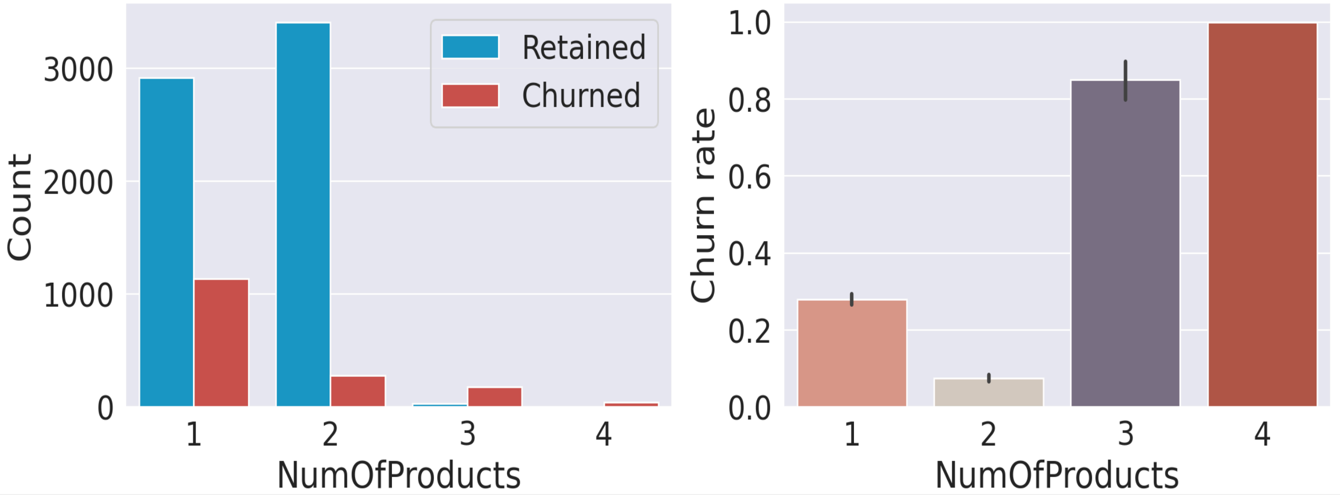


```
plot_categorical('Tenure')
```



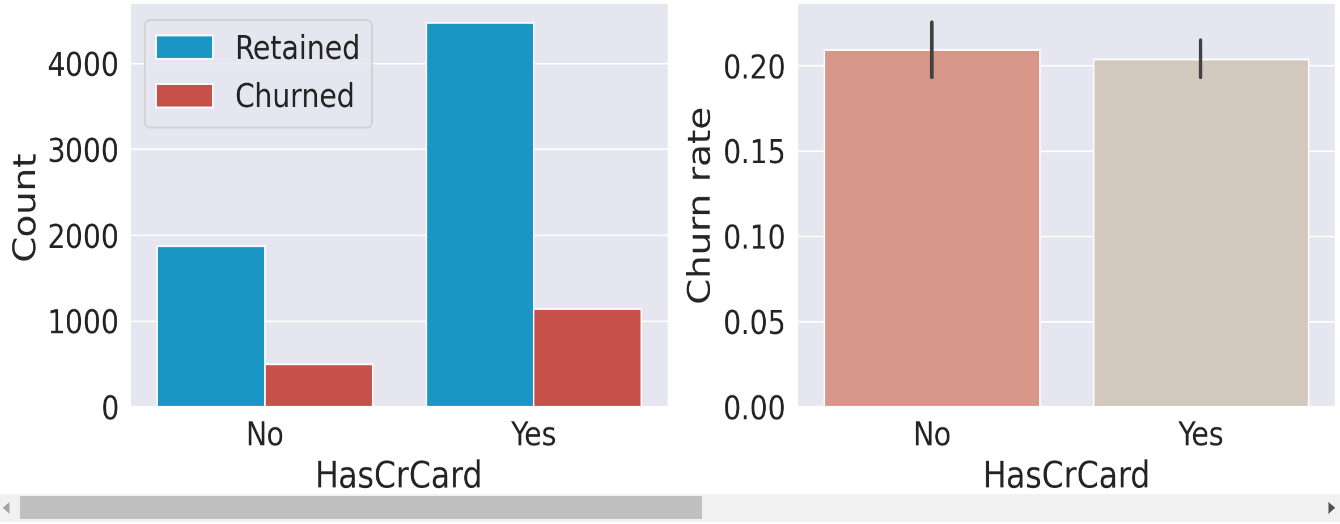
```
plot_categorical('NumOfProducts')
```

```
<ipython-input-5-bffbe343df06>:13: UserWarning: The palette list has more values (11) than needed (4), which may not be intended.
  sns.barplot(x=feature,
```



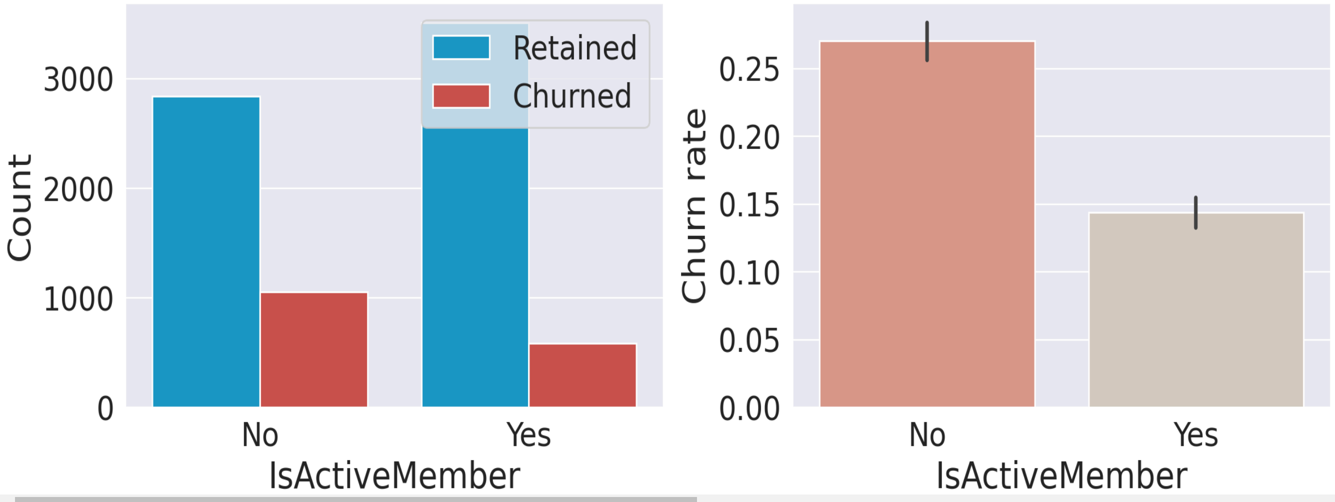
```
plot_categorical('HasCrCard')
```

```
<ipython-input-5-bffbe343df06>:13: UserWarning: The palette list has more values (11) than needed (2), which may not be intended.
  sns.barplot(x=feature,
<ipython-input-5-bffbe343df06>:21: UserWarning: set_ticklabels() should only be used with a fixed number of ticks, i.e. after set_ti
  ax1.set_xticklabels(['No', 'Yes'])
<ipython-input-5-bffbe343df06>:22: UserWarning: set_ticklabels() should only be used with a fixed number of ticks, i.e. after set_ti
  ax2.set_xticklabels(['No', 'Yes'])
```



```
plot_categorical('IsActiveMember')
```

```
<ipython-input-5-bffbe343df06>:13: UserWarning: The palette list has more values (11) than needed (2), which may not be intended.
  sns.barplot(x=feature,
<ipython-input-5-bffbe343df06>:21: UserWarning: set_ticklabels() should only be used with a fixed number of ticks, i.e. after set_ti
  ax1.set_xticklabels(['No', 'Yes'])
<ipython-input-5-bffbe343df06>:22: UserWarning: set_ticklabels() should only be used with a fixed number of ticks, i.e. after set_ti
  ax2.set_xticklabels(['No', 'Yes'])
```



```
chi2_array, p_array = [], []
for column in categorical:

    crosstab = pd.crosstab(train_df[column], train_df['Exited'])
    chi2, p, dof, expected = chi2_contingency(crosstab)
    chi2_array.append(chi2)
    p_array.append(p)

df_chi = pd.DataFrame({
    'Variable': categorical,
    'Chi-square': chi2_array,
    'p-value': p_array
})
df_chi.sort_values(by='Chi-square', ascending=False)
```

```
        Variable  Chi-square  p-value
```

```
features_drop = ['Tenure', 'HasCrCard', 'EstimatedSalary']
train_df = train_df.drop(features_drop, axis=1)

print('✔ Features Dropped!')
```

```
✔ Features Dropped!
```

```
train_df['Gender'] = LabelEncoder().fit_transform(train_df['Gender'])

train_df['Geography'] = train_df['Geography'].map({
    'Germany': 1,
    'Spain': 0,
    'France': 0
})

print('✔ Features Encoded!')
```

```
✔ Features Encoded!
```

```
scaler = StandardScaler()

scl_columns = ['CreditScore', 'Age', 'Balance']
train_df[scl_columns] = scaler.fit_transform(train_df[scl_columns])

print('✔ Features Scaled!')
```

```
✔ Features Scaled!
```

```
y_train = train_df['Exited']
x_train = train_df.drop('Exited', axis=1)

print('✔ Sets Created!')
```