pca_project

December 7, 2020

[1]:
```
import numpy as np
import pandas as pd
import scipy.stats as stats
import matplotlib.pyplot as plt
np.set_printoptions(linewidth=100)


from sklearn import datasets
from sklearn.decomposition import PCA
from sklearn.model_selection import GridSearchCV
from sklearn.ensemble import RandomForestClassifier
from sklearn.cluster import KMeans
from sklearn.neighbors import KNeighborsClassifier
from sklearn.datasets import load_iris, fetch_lfw_people, load_breast_cancer
from sklearn.model_selection import train_test_split
```

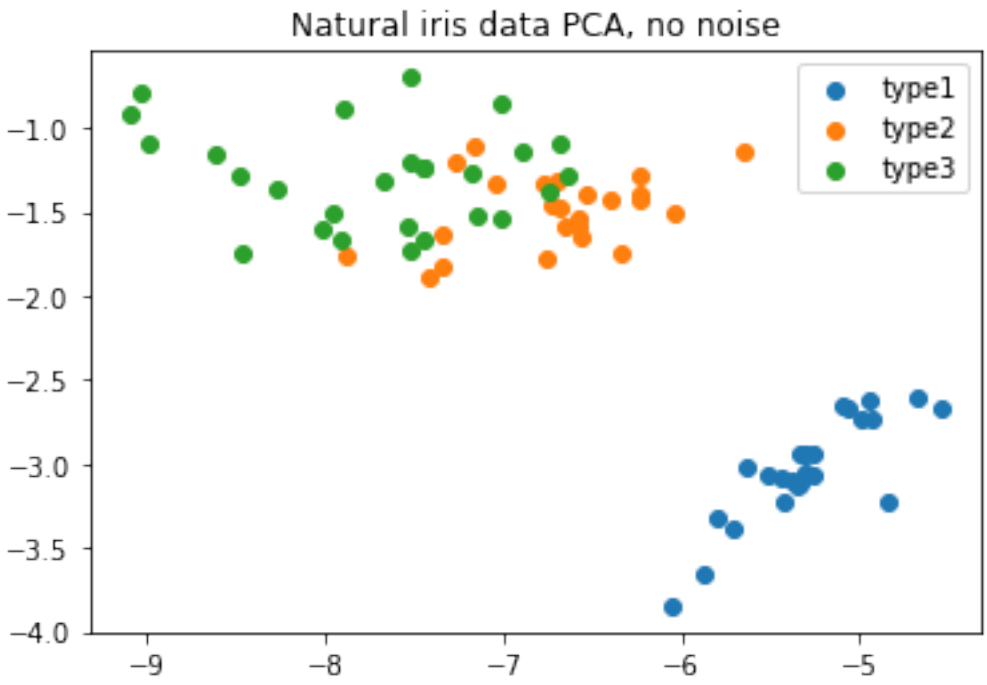
[2]:
```
def pca(A,n_components=2):
    '''
    Perform principal component analysis on a matrix A and
    return the desired principal components
    '''

    U,S,Vh = np.linalg.svd(A, full_matrices=False)

    return A@Vh[:,:n_components]
```

[3]:
```
# import data
# iris
iris = load_iris()

iris_X_train, iris_X_test, iris_y_train, iris_y_test = train_test_split(
    iris.data, iris.target, test_size=.5
)

# breast cancer
can = load_breast_cancer()
```

```
can_X_train, can_X_test, can_y_train, can_y_test = train_test_split(
    can.data, can.target, test_size=.5
)

# faces
peo = fetch_lfw_people()

peo_X_train, peo_X_test, peo_y_train, peo_y_test = train_test_split(peo.data,␣
↪peo.target, test_size=.7)
```

[4]:
```
def plot_data(X, y, classes, title):

    for c in range(classes):
        mask = y == c

        plt.scatter(X[mask, 0], X[mask, 1], label=f'type {c}',marker='.',lw=.3)
        plt.legend()
        plt.title(title)
    plt.savefig(f'./images/{title}.pdf')
    plt.show()
```

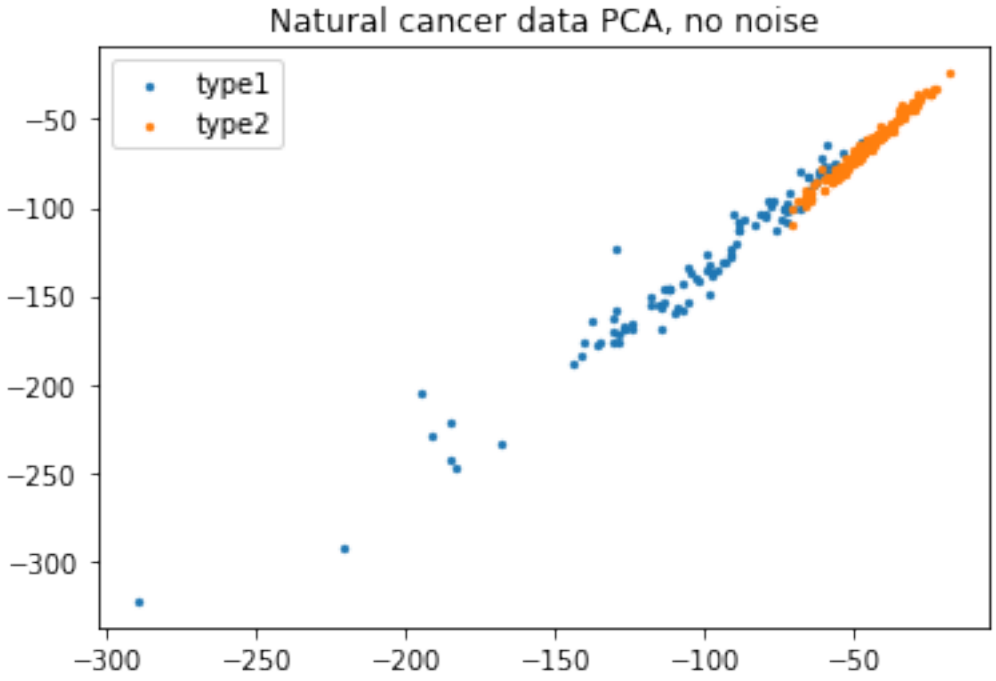
[5]:
```
# give background on how well PCA works for each data set
trans_iris_train = pca(iris_X_train)
trans_iris_test = pca(iris_X_test)

c1 = iris_y_train == 0
c2 = iris_y_train == 1
c3 = iris_y_train == 2

plt.scatter(trans_iris_train[c1,0], trans_iris_train[c1,1], label='type1')
plt.scatter(trans_iris_train[c2,0], trans_iris_train[c2,1], label='type2')
plt.scatter(trans_iris_train[c3,0], trans_iris_train[c3,1], label='type3')
plt.title('Natural iris data PCA, no noise')
plt.savefig('Unaltered_iris.pdf')
plt.legend()
plt.show()

RFC = RandomForestClassifier(n_estimators=50, max_depth=10)
RFC = RFC.fit(trans_iris_train, iris_y_train)
score = sum(RFC.predict(trans_iris_test) == iris_y_test) / len(iris_y_test)
print(f'Iris + random forest baseline = {score}')

KNC = KNeighborsClassifier(n_neighbors=3)
KNC.fit(trans_iris_train, iris_y_train)
score = sum(KNC.predict(trans_iris_test) == iris_y_test) / len(iris_y_test)
print(f'Iris + K-Neighbors baseline = {score}')
```




```
Iris + random forest baseline = 0.7066666666666667
Iris + K-Neighbors baseline = 0.72
```

[50]:
```
trans_can_train = pca(can_X_train)
trans_can_test = pca(can_X_test)
c1 = can_y_train == 0
c2 = can_y_train == 1


plt.scatter(trans_can_train[c1,0], trans_can_train[c1,1],␣
 ↪label='type1',marker='.',lw=.3)
plt.scatter(trans_can_train[c2,0], trans_can_train[c2,1],␣
 ↪label='type2',marker='.',lw=.3)
plt.title('Natural cancer data PCA, no noise')
plt.legend()
plt.savefig('Unaltered_cancer.pdf')
plt.show()

RFC = RandomForestClassifier(**{'n_estimators':20, 'max_depth':10})
RFC.fit(trans_can_train, can_y_train)
score = sum(RFC.predict(trans_can_test) == can_y_test) / len(can_y_test)
print(f'Cancer + random forest baseline = {score}')

KNC = KNeighborsClassifier(**{'n_neighbors':3})
```

```
KNC.fit(trans_can_train, can_y_train)
score = sum(KNC.predict(trans_can_test) == can_y_test) / len(can_y_test)
print(f'Cancer + K-Neighbors baseline = {score}')
```




```
Cancer + random forest baseline = 0.6175438596491228
Cancer + K-Neighbors baseline = 0.6175438596491228
```

[32]:
```
def noiser(A,noise,params):
    '''

    Add noise of type `noise` to the data
    noise may be:
        normal, beta, student-t, uniform,
        gamma
    '''

    noise_dict = {
        'normal': stats.norm, 'student-t': stats.t,
        'beta': stats.beta, 'gamma': stats.gamma,
        'uniform': stats.uniform
    }

    n_func = noise_dict[noise](*params)
```

```
    return A + n_func.rvs(A.shape)
```

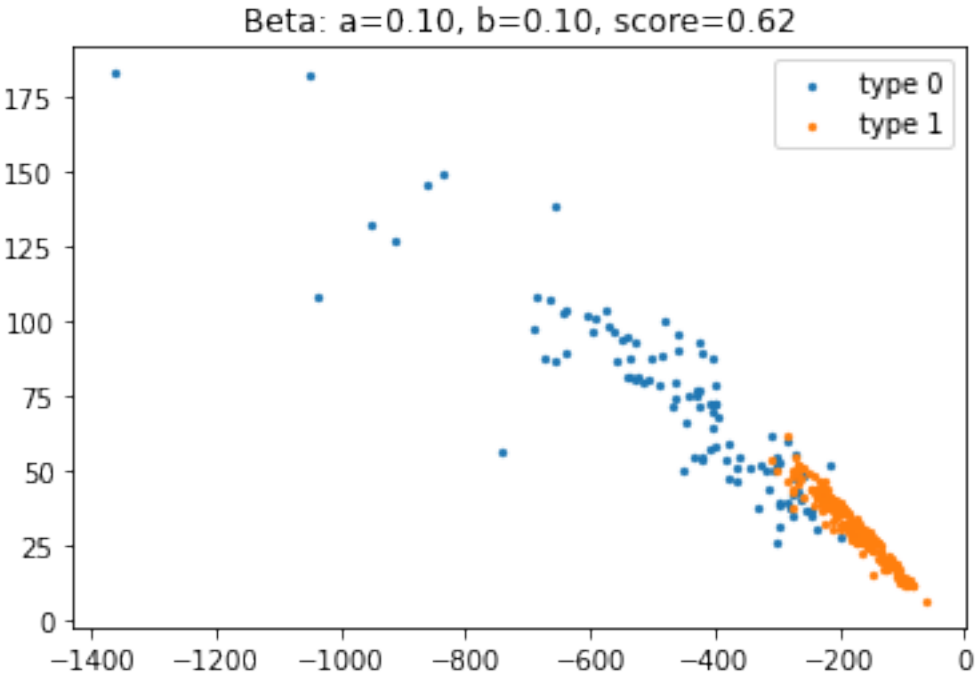
[33]:
```
# set up the parameters grids I will use to test PCA
beta_params = {
    'a': np.linspace(.1,5,15),
    'b': np.linspace(.1,5,15)
}
normal_params = {
    'mean': np.linspace(-1,1,15),
    'std': np.linspace(0,1,15)
}
uniform_params = {
    'a': np.linspace(0,2,15),
    'length': np.linspace(.5,2,15)
}
student_t_params = {
    'df': np.linspace(.2,7,100),
    'mean': np.linspace(0,10,50),
    'std': np.linspace(0,10,20)
}
gamma_params = {
    'a': np.linspace(.1,10,15),
    'scale': np.linspace(.1,10,15)
}
```

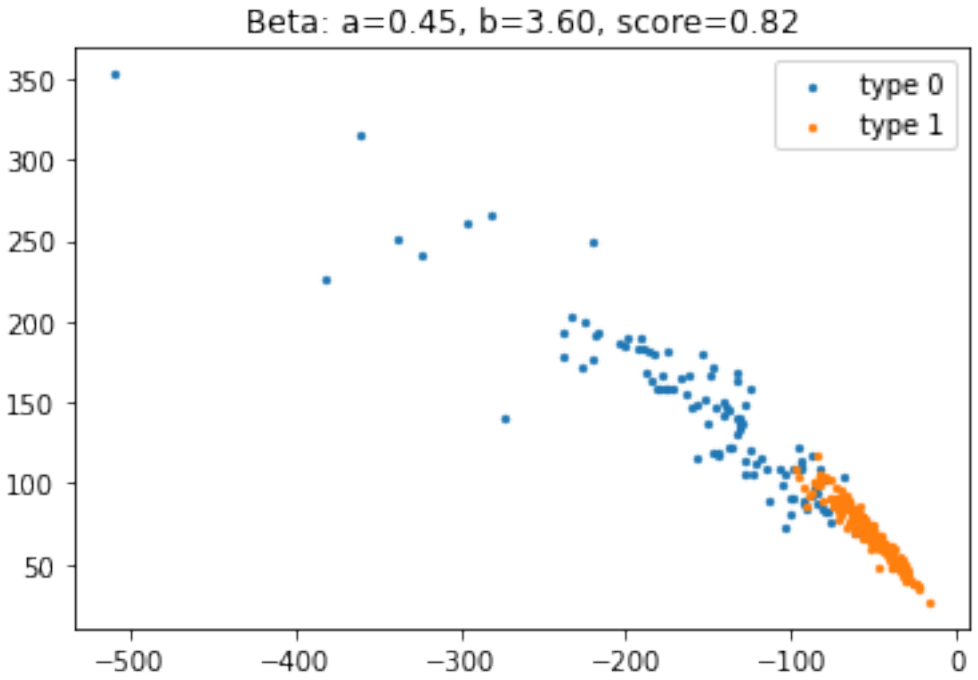
[34]:
```
def beta_testing(X_train,y_train,X_test,y_test,n,Classifier,params,plot=True):
    # do beta testing
    as_ = beta_params['a']
    bs = beta_params['b']
    i=0

    scores = np.zeros((len(as_)*len(bs),3))


    for a in as_:
        for b in bs:
            # first we apply noise
            X_train_noise = noiser(X_train, 'beta', (a,b))
            X_test_noise = noiser(X_test, 'beta', (a,b))

            # next we apply pca
            train_data = pca(X_train_noise)
            test_data = pca(X_test_noise)

            # finally we test and train a classifier and examine the
            # score
            classifier = Classifier(**params)
```

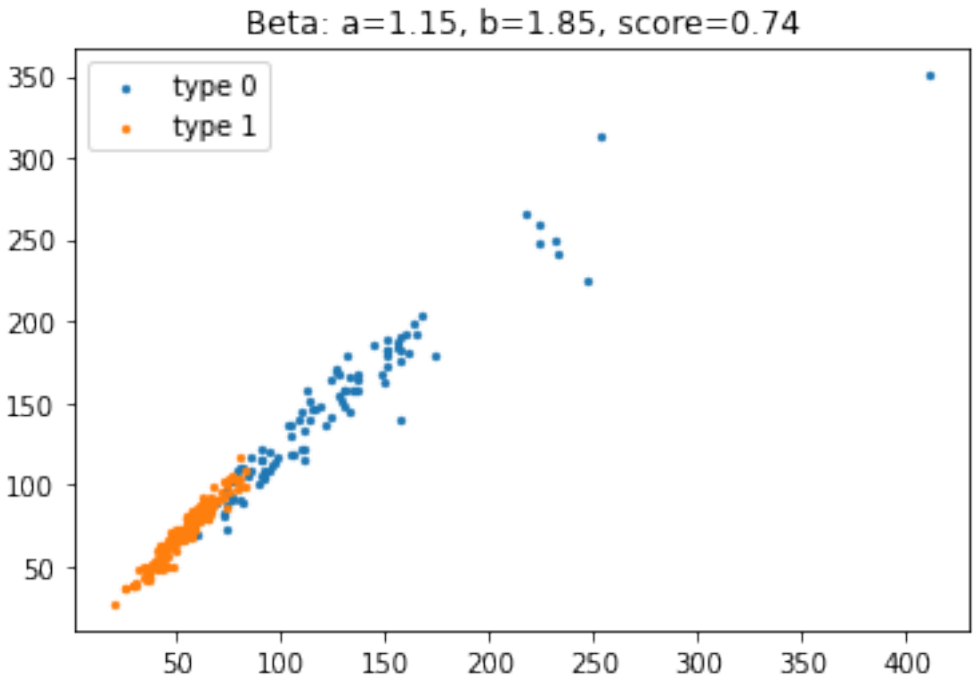
```
            classifier.fit(train_data, y_train)

            # score the classifier and record it
            score = sum(classifier.predict(test_data) == y_test) / len(y_test)
            scores[i] = (a,b,score)


            # every once and a while we plot the results
            if i%25 == 0 and plot:
                title_format = 'Beta: a={a:.2f}, b={b:.2f}, score={score:.2f}'
                title = title_format.format(a=a, b=b, score=scores[i,2])
                plot_data(train_data, y_train, n, title)


            i+=1

    return scores
```

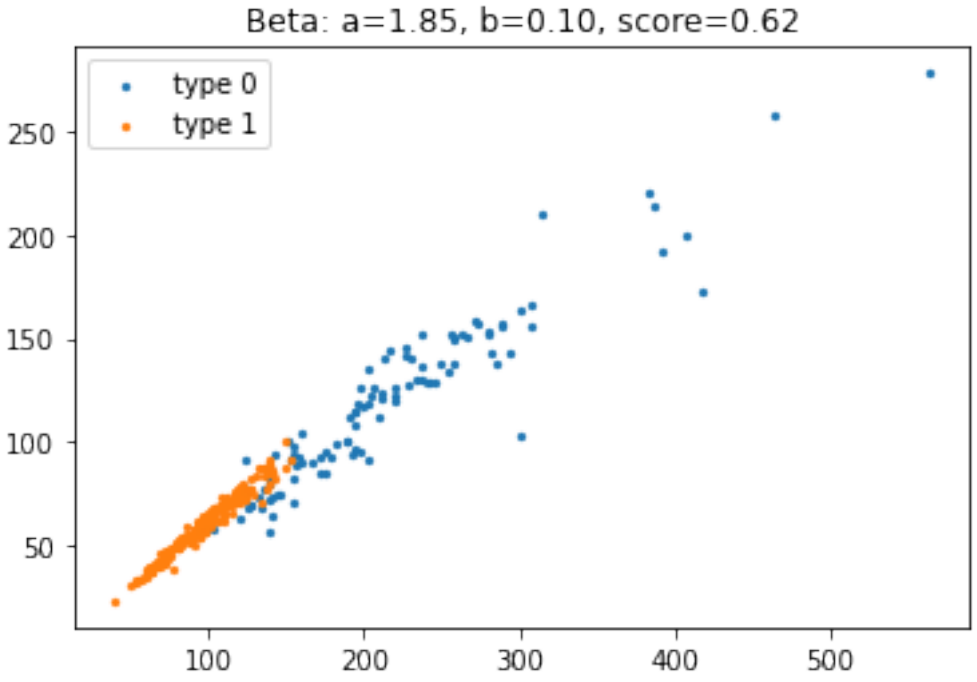
[35]:
```
# test beta with random forest
# get the scores
scores = beta_testing(
    can_X_train, can_y_train, can_X_test, can_y_test, 2,
    RandomForestClassifier, {'n_estimators':50, 'max_depth':10}
)

print('\nBETA NOISE WITH RANDOM FOREST\n')

# print the best results
best_performance = np.argsort(scores[:,2])[::-1][:10]
print(f'The 10 best performing parameters are :')
print('\ta\tb\tscore')
print('\t'+'--'*len('\ta\tb\tscore'))
row_format = '\t{a:.2f}&\t{b:.2f}&\t{score:.3f}\\\\'
for best in best_performance:
    a,b,score = scores[best]
    print(row_format.format(a=a,b=b,score=score))

print()

# print the worst results
worst_performance = np.argsort(scores[:,2])[::-1][-10:]
print(f'The 10 worst performing parameters are :')
print('\ta\tb\tscore')
print('\t'+'--'*len('\ta\tb\tscore'))
row_format = '\t{a:.2f}&\t{b:.2f}&\t{score:.3f}\\\\'
for worst in worst_performance:
    a,b,score = scores[worst]
```

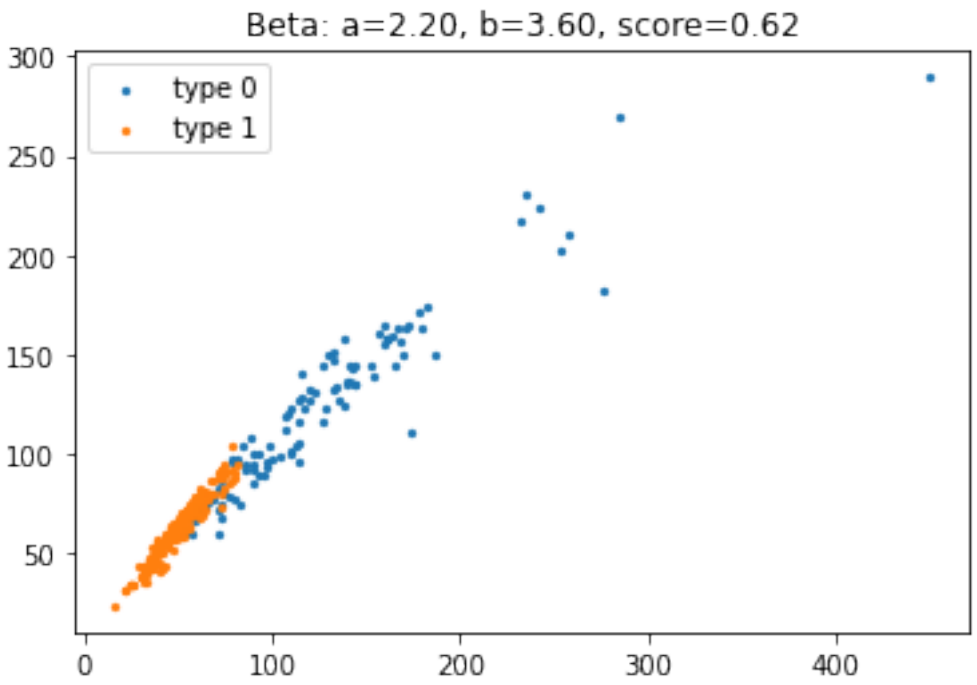
```
    print(row_format.format(a=a,b=b,score=score))
```

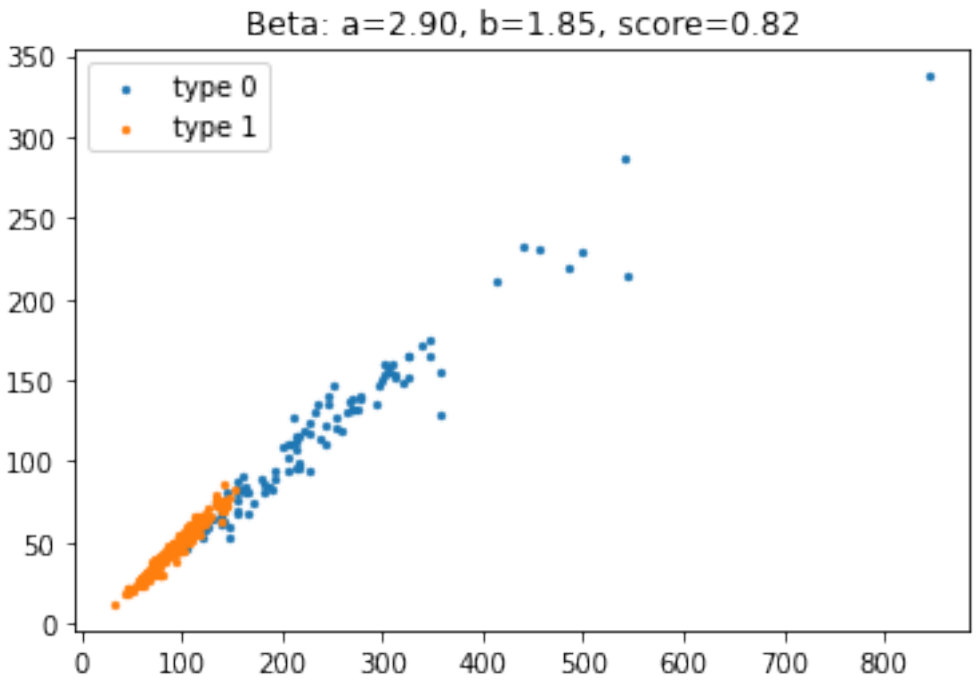


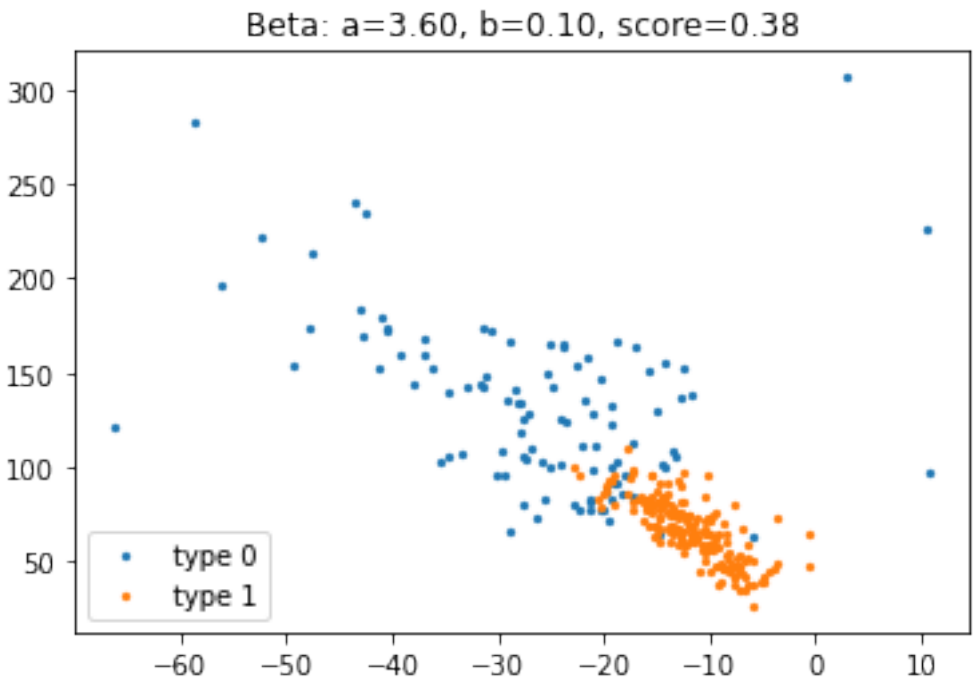


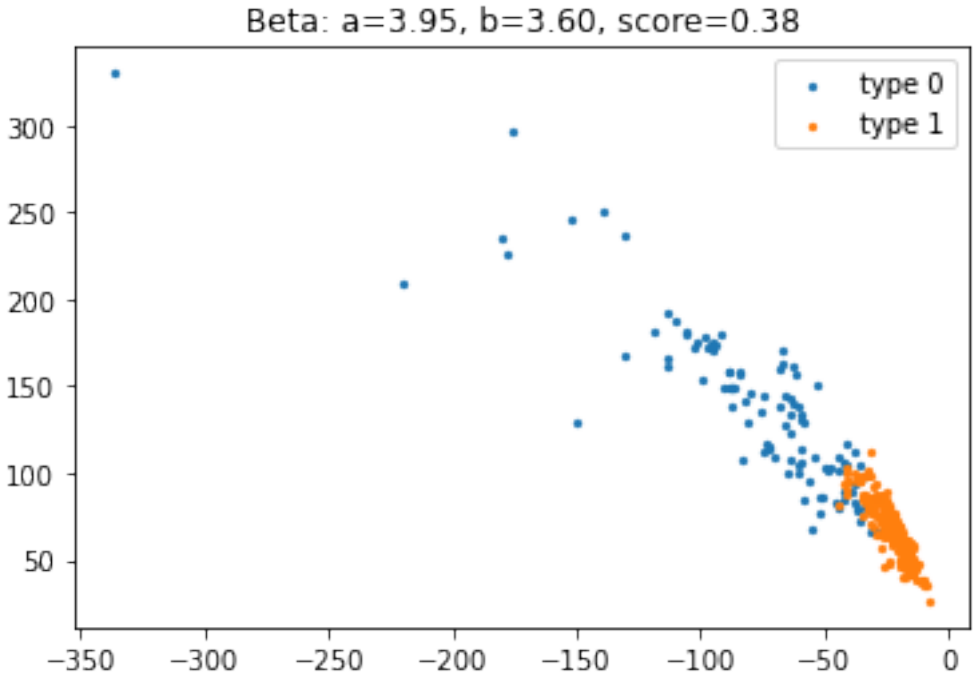

Beta: a=1.15, b=1.85, score=0.74
type 0
type 1
350
300
250
200
150
100
50
50
100
150
200
250
300
350
400

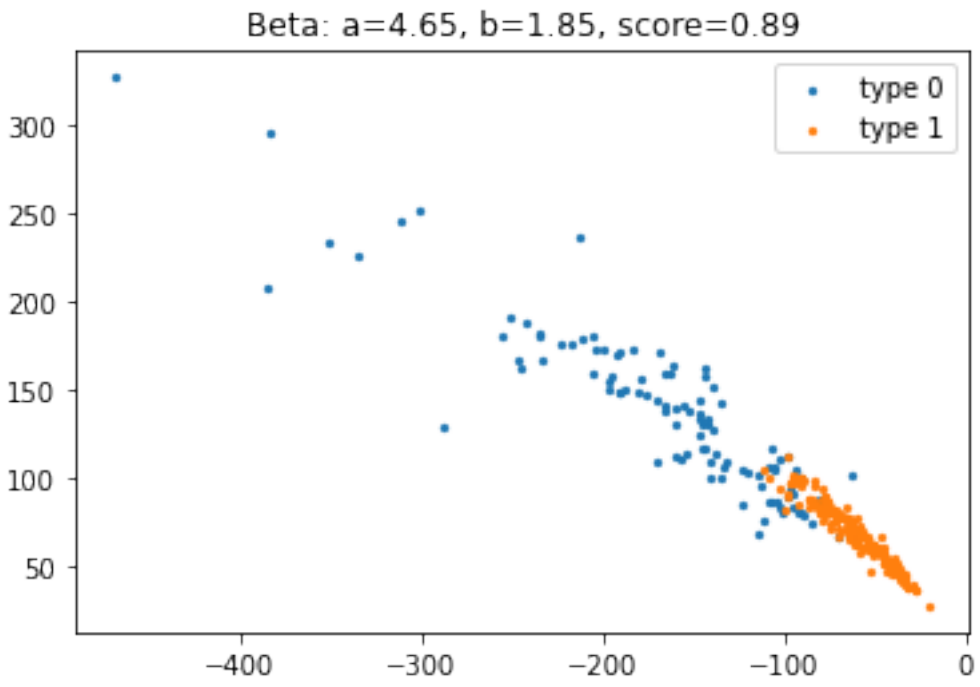

Beta: a=1.85, b=0.10, score=0.62
type 0
type 1
250
200
150
100
50
100
200
300
400
500


Beta: a=2.20, b=3.60, score=0.62
type 0
type 1
300
250
200
150
100
50
0
100
200
300
400


Beta: a=2.90, b=1.85, score=0.82
type 0
type 1
350
300
250
200
150
100
50
0
0
100
200
300
400
500
600
700
800


Beta: a=3.60, b=0.10, score=0.38
type 0
type 1
300
250
200
150
100
50
−60
−50
−40
−30
−20
−10
0
10


Beta: a=3.95, b=3.60, score=0.38
type 0
type 1
300
250
200
150
100
50
−350
−300
−250
−200
−150
−100
−50
0



BETA NOISE WITH RANDOM FOREST

The 10 best performing parameters are :

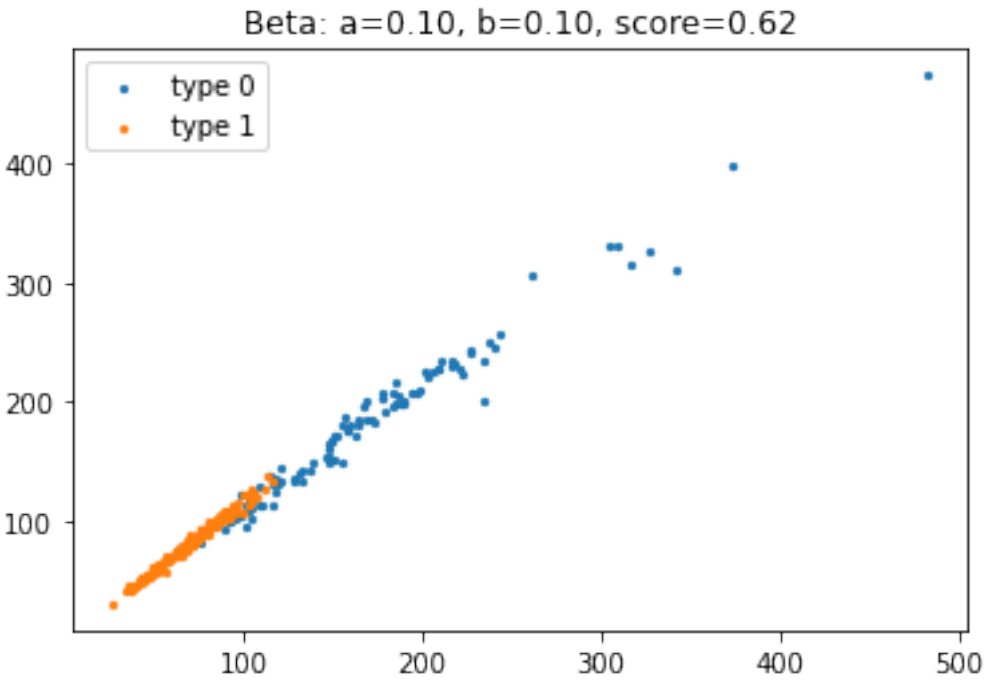
a	b	score
4.65&	1.85&	0.891\\
2.55&	0.10&	0.888\\
3.95&	4.65&	0.881\\
0.80&	3.60&	0.881\\
4.65&	1.15&	0.877\\
2.55&	4.30&	0.874\\
2.90&	0.10&	0.874\\
1.50&	4.30&	0.867\\
4.30&	5.00&	0.867\\
0.80&	5.00&	0.863\\

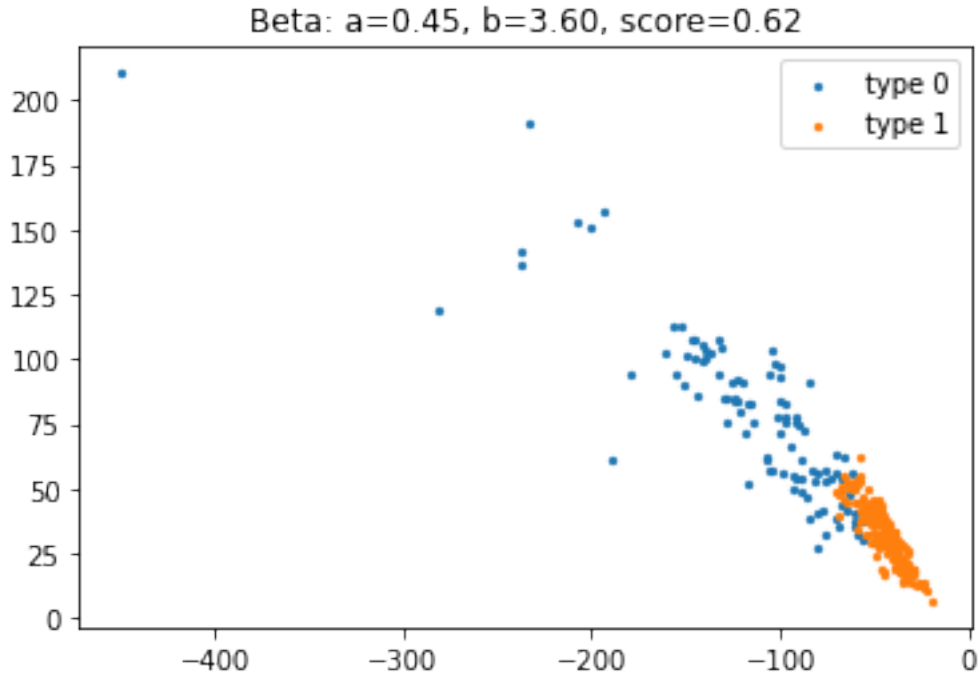
The 10 worst performing parameters are :

a	b	score
1.15&	3.95&	0.382\\
2.55&	1.15&	0.382\\
3.95&	1.15&	0.382\\
3.95&	2.20&	0.382\\
3.95&	3.60&	0.382\\

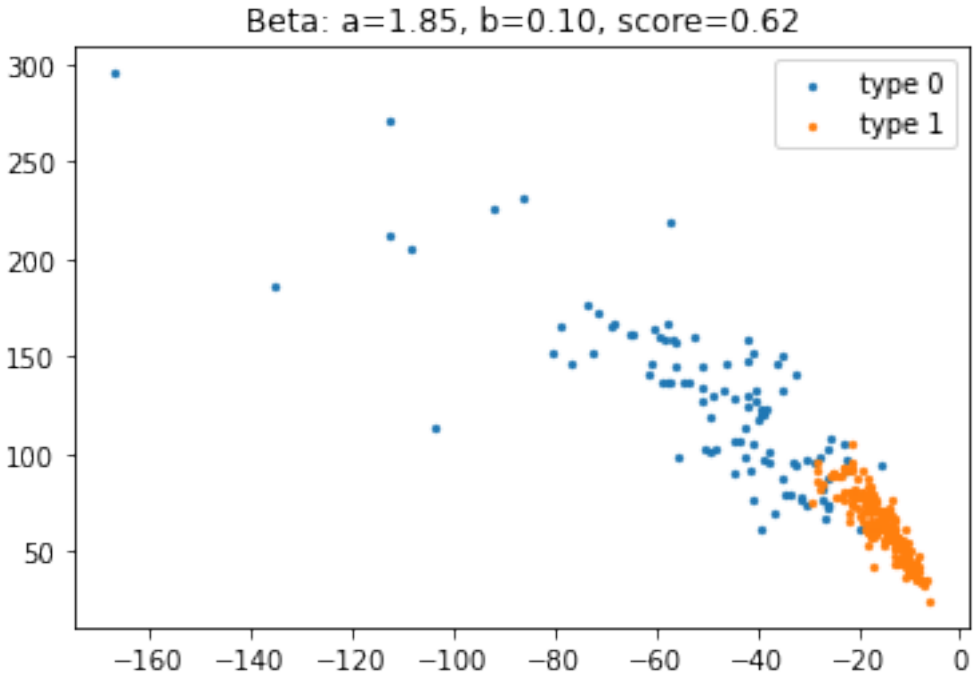
```
3.95&   5.00&   0.382\\
0.80&   0.45&   0.382\\
2.90&   3.60&   0.382\\
3.95&   0.80&   0.382\\
2.55&   2.20&   0.309\\
```

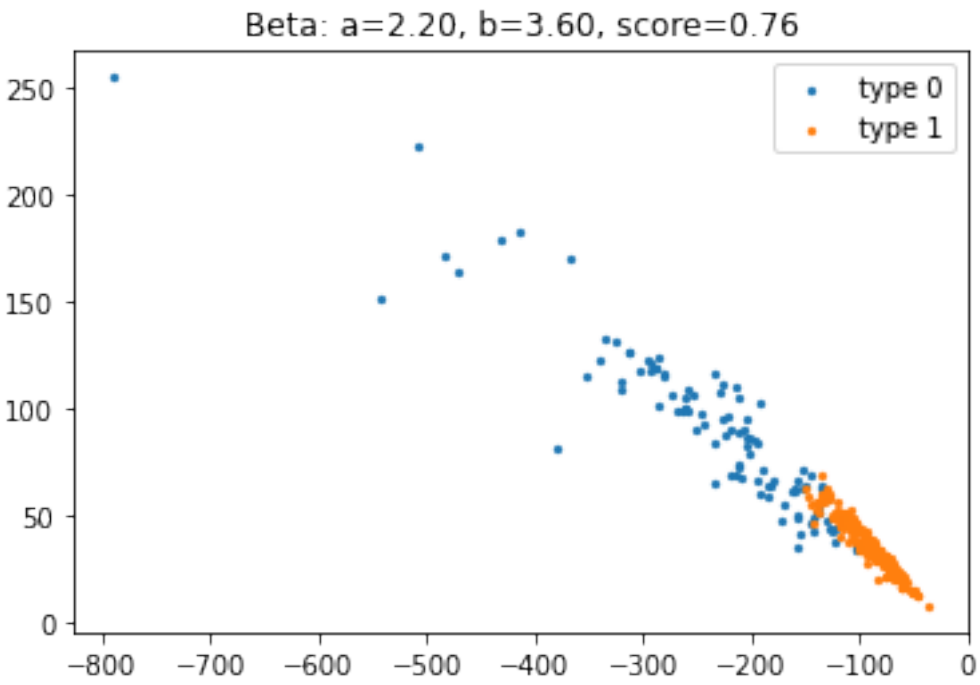
[36]:
```
# test beta with k-neighbors classifier
scores = beta_testing(
    can_X_train, can_y_train, can_X_test, can_y_test, 2,
    KNeighborsClassifier, {'n_neighbors':3}, plot=True
)

print('\nBETA NOISE WITH K-NEIGHBORS\n')

# print the best results
best_performance = np.argsort(scores[:,2])[::-1][:10]
print(f'The 10 best performing parameters are :')
print('\ta\tb\tscore')
print('\t'+'--'*len('\ta\tb\tscore'))
row_format = '\t{a:.2f}&\t{b:.2f}&\t{score:.3f}\\\\'
for best in best_performance:
    a,b,score = scores[best]
    print(row_format.format(a=a,b=b,score=score))

print()

# print the worst results
worst_performance = np.argsort(scores[:,2])[::-1][-10:]
print(f'The 10 worst performing parameters are :')
print('\ta\tb\tscore')
print('\t'+'--'*len('\ta\tb\tscore'))
row_format = '\t{a:.2f}&\t{b:.2f}&\t{score:.3f}\\\\'
for worst in worst_performance:
    a,b,score = scores[worst]
    print(row_format.format(a=a,b=b,score=score))
```

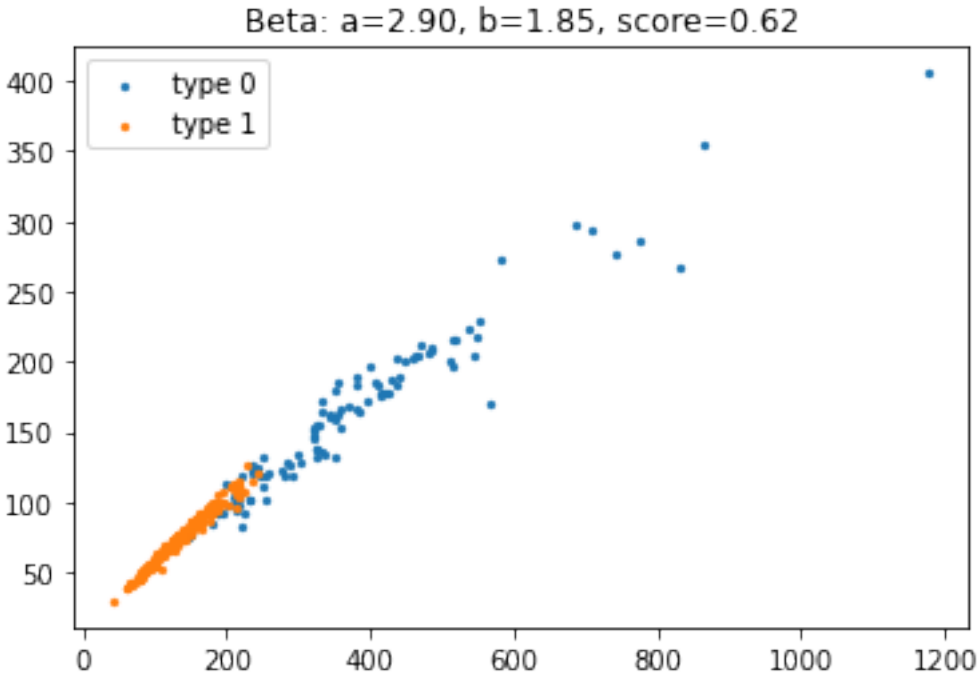

Beta: a=0.10, b=0.10, score=0.62
type 0
type 1
400
300
200
100
100
200
300
400
500

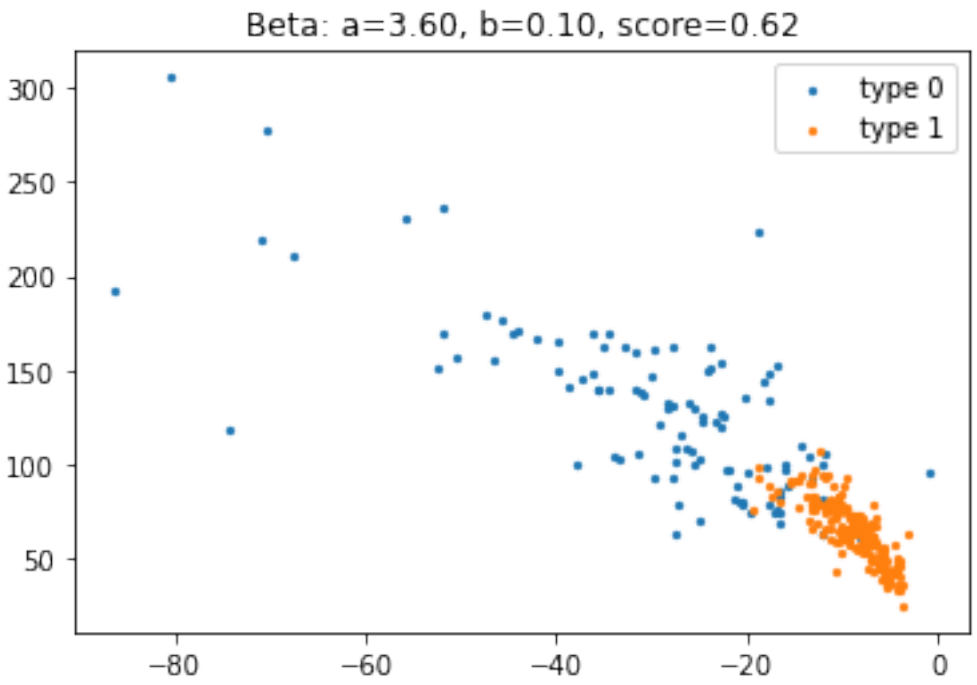

Beta: a=0.45, b=3.60, score=0.62
type 0
type 1
200
175
150
125
100
75
50
25
0
−400
−300
−200
−100
0

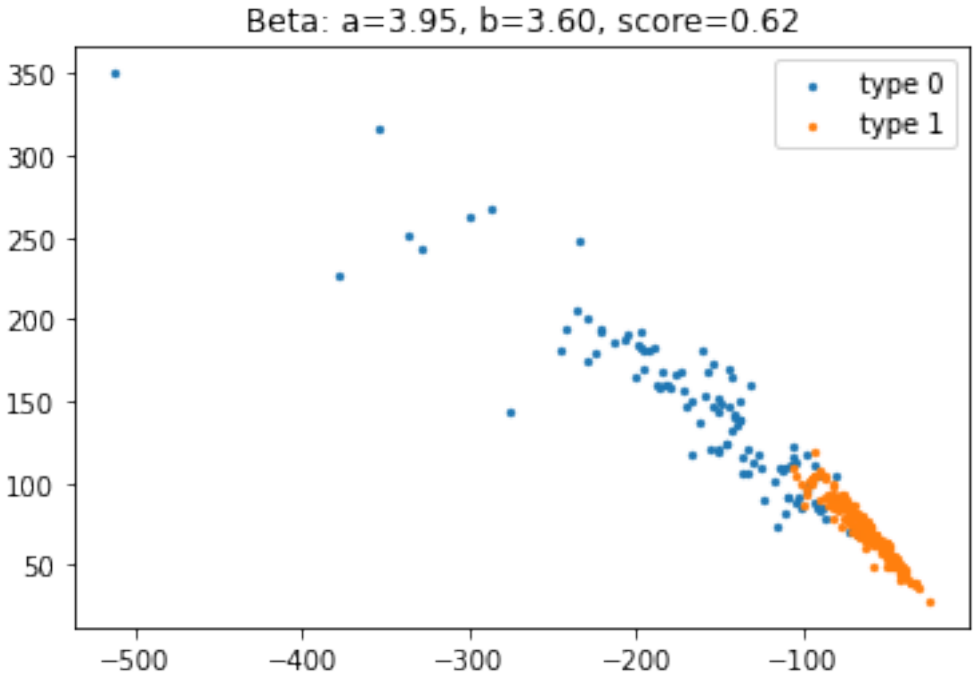

Beta: a=1.15, b=1.85, score=0.62
type 0
type 1
350
300
250
200
150
100
50
50
100
150
200
250
300

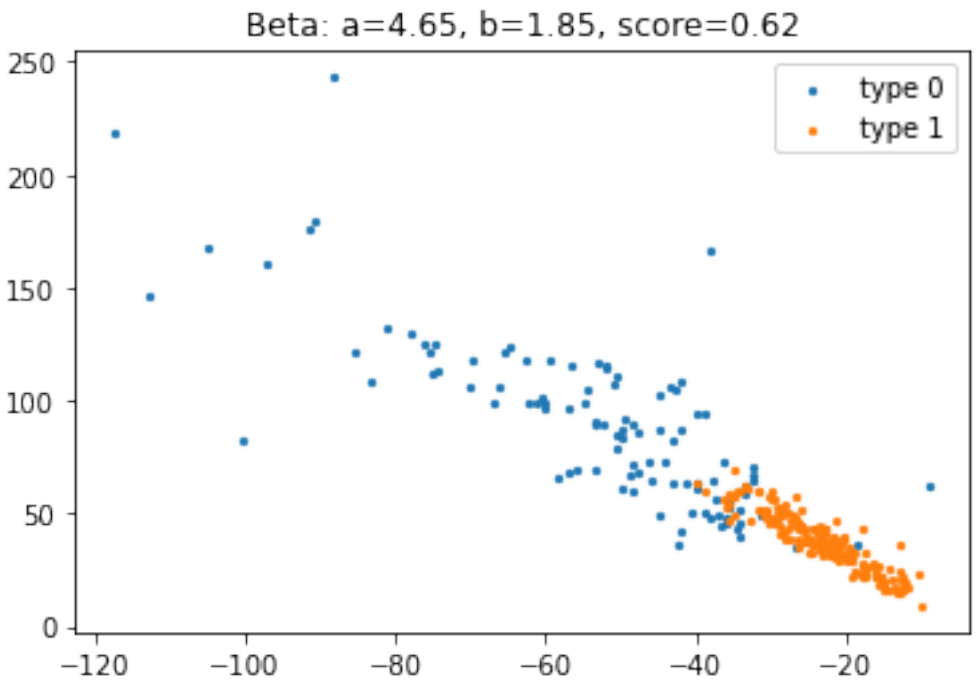

Beta: a=1.85, b=0.10, score=0.62
type 0
type 1
300
250
200
150
100
50
−160
−140
−120
−100
−80
−60
−40
−20
0


Beta: a=2.20, b=3.60, score=0.76
type 0
type 1
250
200
150
100
50
0
−800
−700
−600
−500
−400
−300
−200
−100
0


Beta: a=2.90, b=1.85, score=0.62
type 0
type 1
400
350
300
250
200
150
100
50
0
200
400
600
800
1000
1200


Beta: a=3.60, b=0.10, score=0.62
type 0
type 1
300
250
200
150
100
50
−80
−60
−40
−20
0


Beta: a=3.95, b=3.60, score=0.62
type 0
type 1
350
300
250
200
150
100
50
−500
−400
−300
−200
−100



BETA NOISE WITH K-NEIGHBORS

The 10 best performing parameters are :

a	b	score
4.30&	4.65&	0.919\\
4.30&	1.50&	0.909\\
0.10&	1.50&	0.902\\
1.85&	3.95&	0.902\\
1.50&	1.85&	0.902\\
1.15&	3.25&	0.898\\
0.45&	4.30&	0.895\\
0.45&	1.50&	0.895\\
0.45&	0.45&	0.881\\
1.15&	0.80&	0.870\\

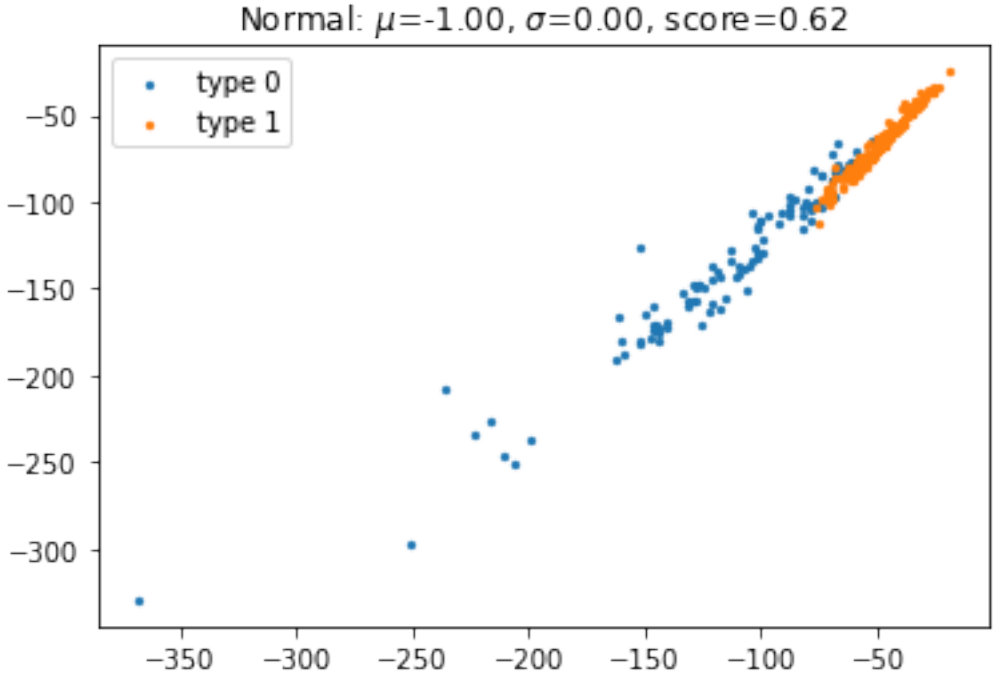
The 10 worst performing parameters are :

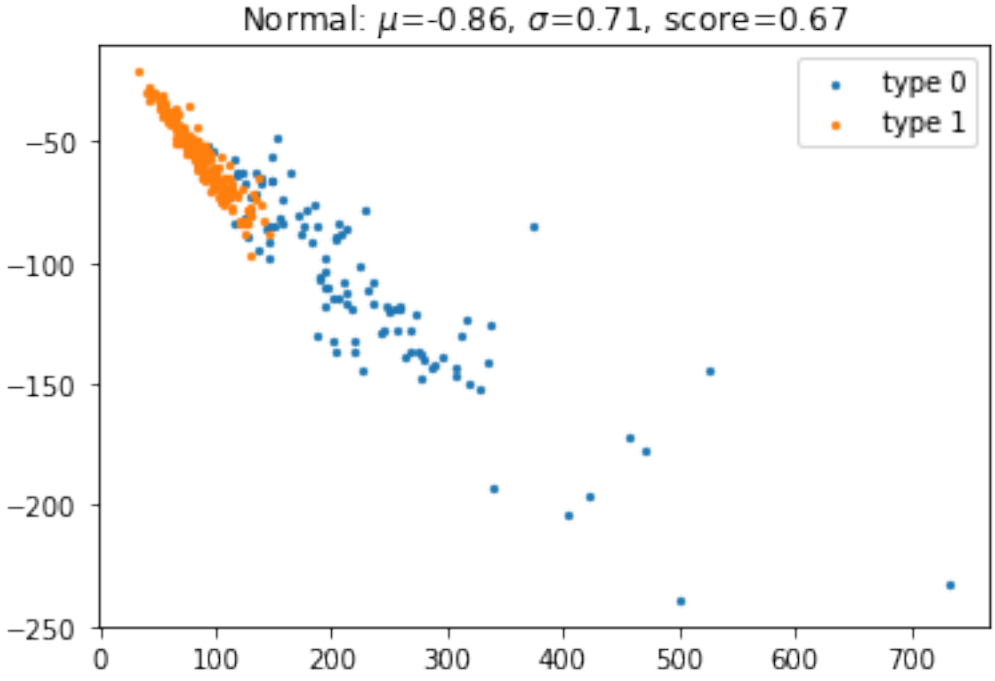
a	b	score
1.15&	4.65&	0.484\\
3.95&	1.85&	0.474\\
4.30&	1.85&	0.463\\
1.85&	2.55&	0.442\\
4.65&	2.90&	0.421\\

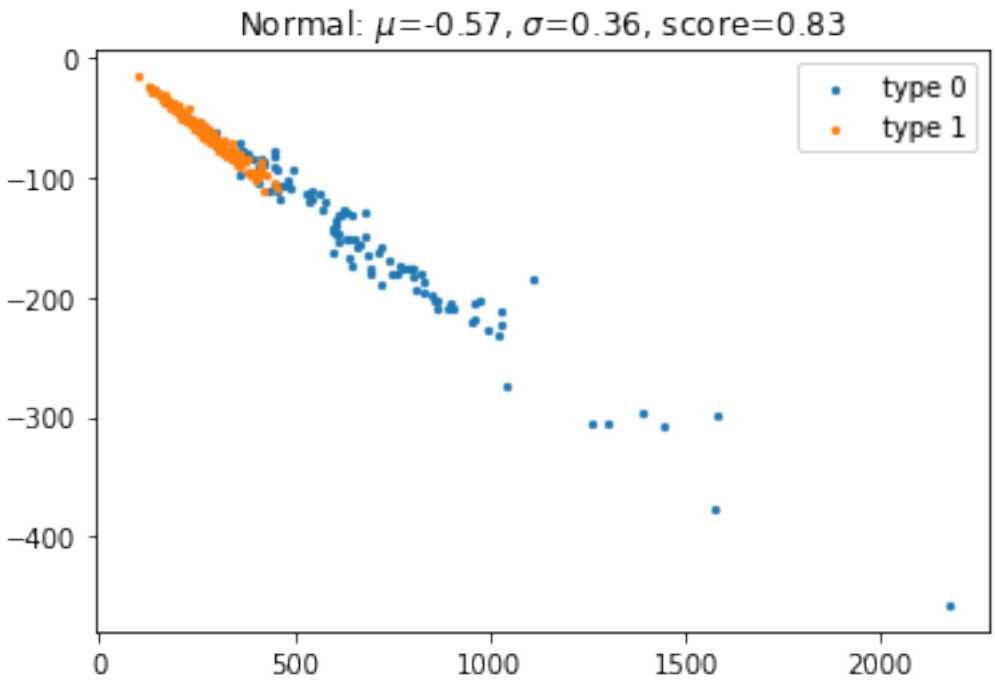
```
0.80&   1.15&   0.418\\
1.85&   4.30&   0.411\\
1.85&   1.50&   0.400\\
3.60&   5.00&   0.386\\
0.10&   1.85&   0.382\\
```

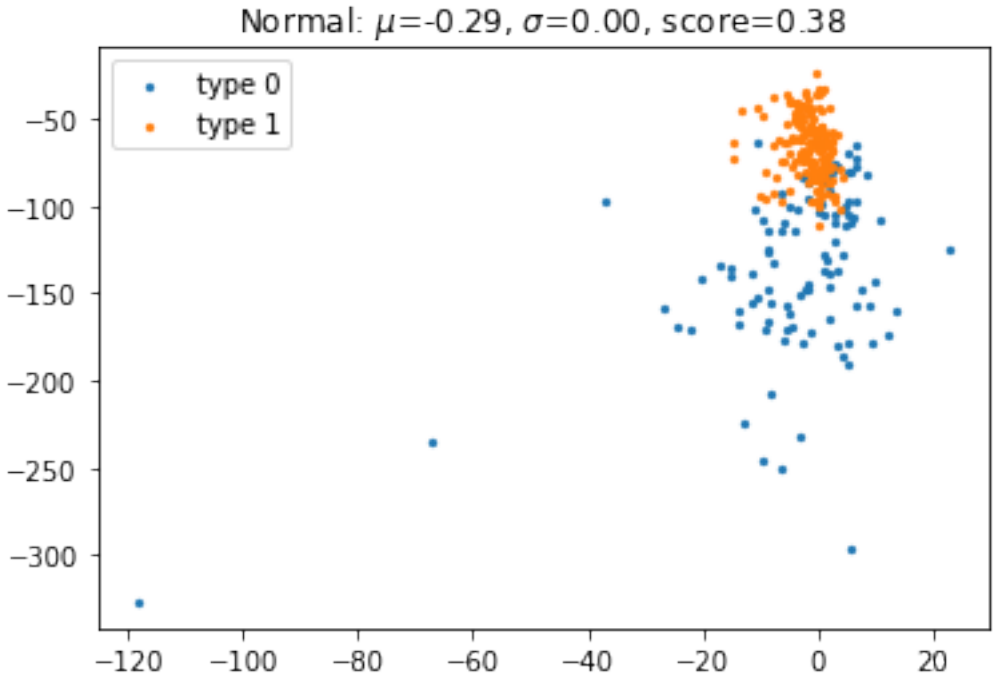
[37]:
```
# do normal testing
def normal_testing(X_train,y_train,X_test,y_test,n,Classifier,params,plot=True):


    means = normal_params['mean']
    stds = normal_params['std']
    i=0
    scores = np.zeros((len(means)*len(stds),3))


    for mean in means:
        for std in stds:
            # first we apply noise
            X_train_noise = noiser(X_train, 'normal', (mean,std))
            X_test_noise = noiser(X_test, 'normal', (mean,std))

            # next we apply pca
            train_data = pca(X_train_noise)
            test_data = pca(X_test_noise)

            # finally we test and train a classifier and examine the
            # score
            classifier = Classifier(**params)
            classifier.fit(train_data, y_train)

            # score the classifier and record it
            score = sum(classifier.predict(test_data) == y_test) / len(y_test)
            scores[i] = (mean,std,score)

            # every once and a while we plot the results
            if i%25 == 0 and plot:
                title_format = 'Normal: $\mu$={a:.2f}, $\sigma$={b:.2f},␣
↪score={score:.2f}'
                title = title_format.format(a=mean, b=std, score=scores[i,2])
                plot_data(train_data, y_train, n, title)


            i+=1

    return scores
```

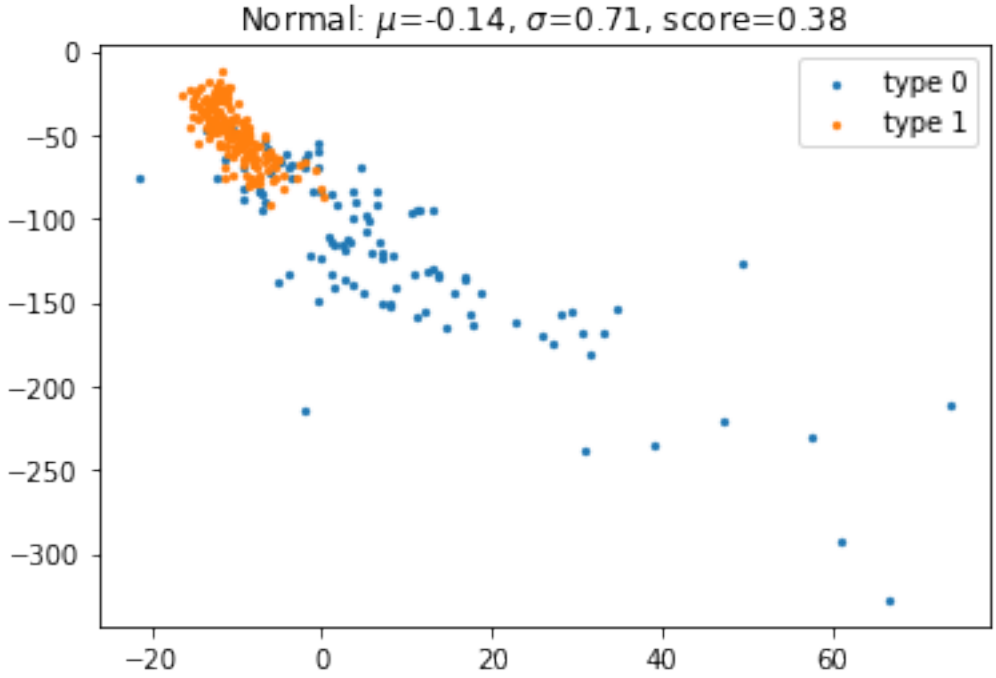
[38]:
```
# test normal with random forest
# get the scores
scores = normal_testing(
    can_X_train, can_y_train, can_X_test, can_y_test, 2,
    RandomForestClassifier, {'n_estimators':50, 'max_depth':10}
)

print('\nNORMAL NOISE WITH RANDOM FOREST\n')

# print the best results
best_performance = np.argsort(scores[:,2])[::-1][:10]
print(f'The 10 best performing parameters are :')
print('\tMean\tStd\tscore')
print('\t'+'--'*len('\ta\tb\tscore'))
row_format = '\t{a:.2f}&\t{b:.2f}&\t{score:.3f}\\\\'
for best in best_performance:
    a,b,score = scores[best]
    print(row_format.format(a=a,b=b,score=score))

print()

# print the worst results
worst_performance = np.argsort(scores[:,2])[::-1][-10:]
print(f'The 10 worst performing parameters are :')
print('\tMean\tStd\tscore')
print('\t'+'--'*len('\ta\tb\tscore'))
row_format = '\t{a:.2f}&\t{b:.2f}&\t{score:.3f}\\\\'
for worst in worst_performance:
    a,b,score = scores[worst]
    print(row_format.format(a=a,b=b,score=score))
```

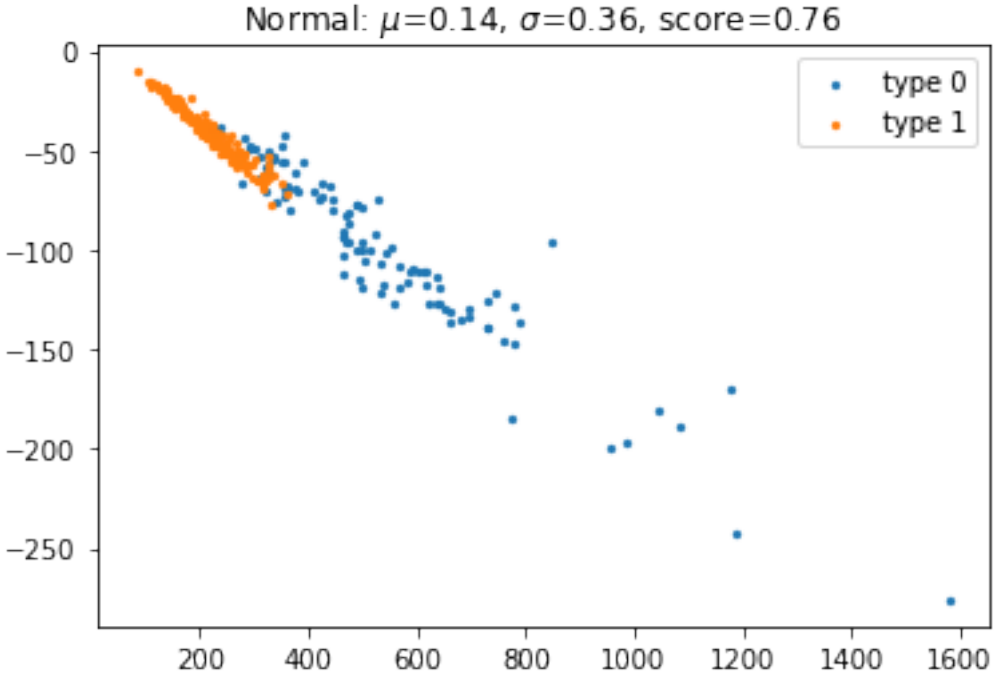

Normal: μ=-1.00, σ=0.00, score=0.62
type 0
type 1
−50
−100
−150
−200
−250
−300
−350
−300
−250
−200
−150
−100
−50

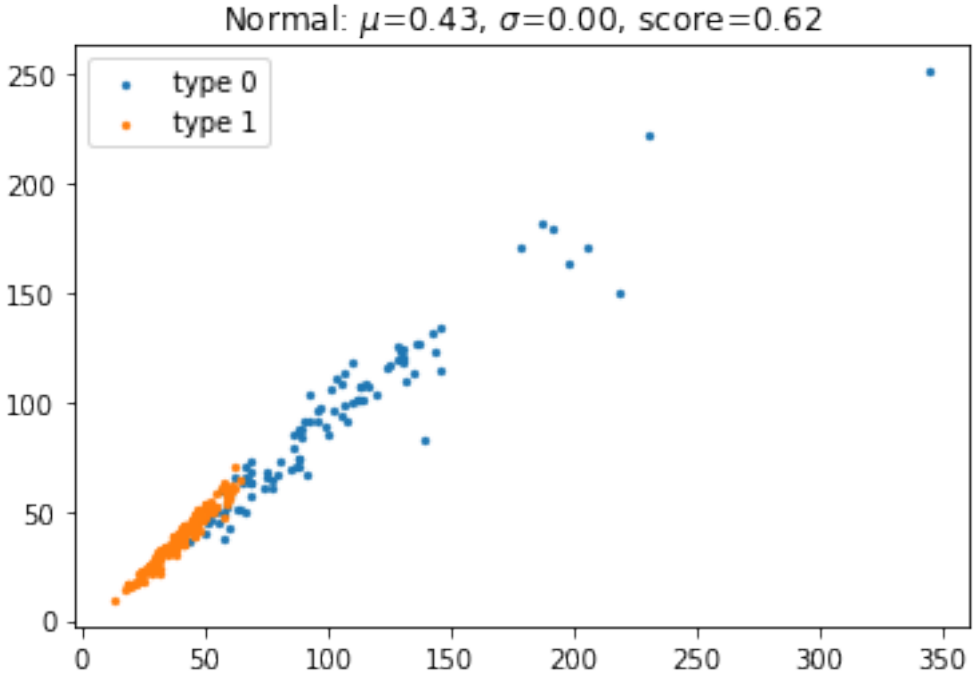

Normal: μ=-0.86, σ=0.71, score=0.67
type 0
type 1
−50
−100
−150
−200
−250
0
100
200
300
400
500
600
700

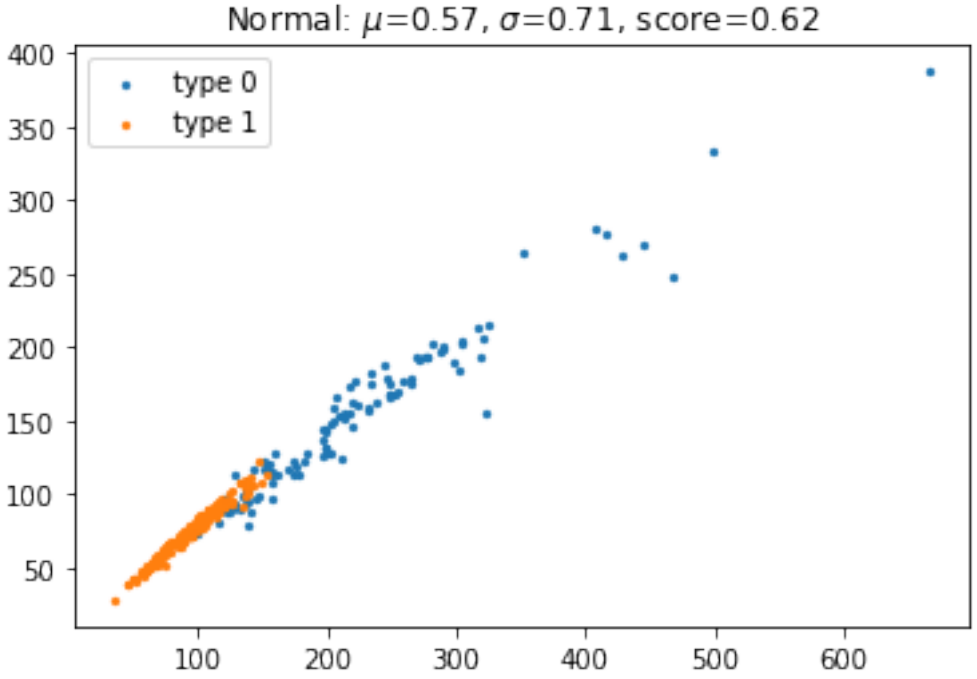

Normal: μ=-0.57, σ=0.36, score=0.83
type 0
type 1
0
−100
−200
−300
−400
0
500
1000
1500
2000

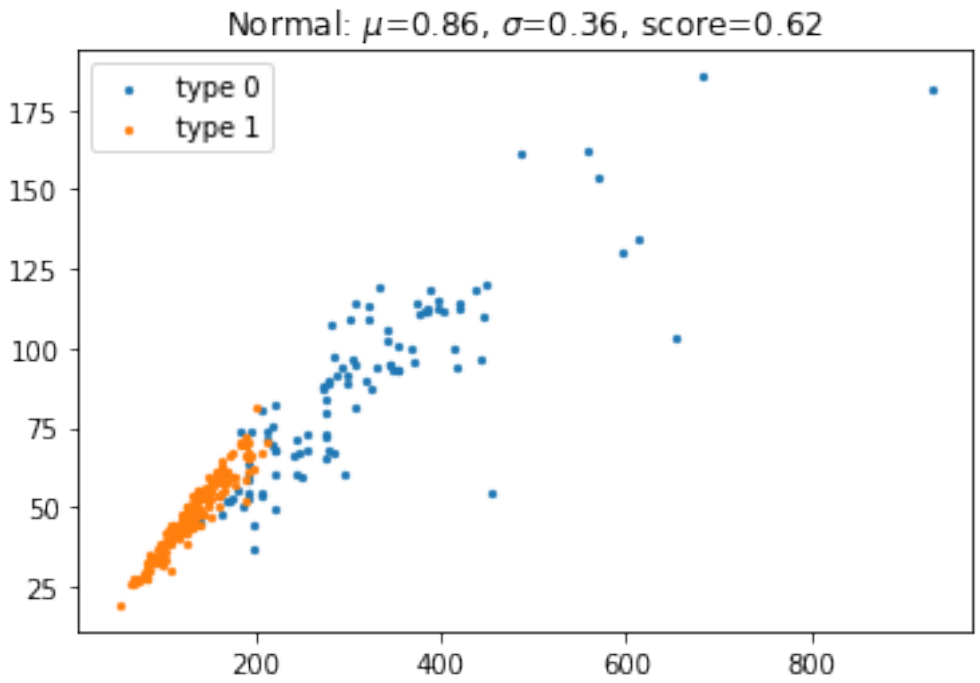

Normal: μ=-0.29, σ=0.00, score=0.38
type 0
type 1
−50
−100
−150
−200
−250
−300
−120
−100
−80
−60
−40
−20
0
20


Normal: μ=-0.14, σ=0.71, score=0.38
type 0
type 1
0
−50
−100
−150
−200
−250
−300
−20
0
20
40
60


Normal: μ=0.14, σ=0.36, score=0.76
type 0
type 1
0
−50
−100
−150
−200
−250
200
400
600
800
1000
1200
1400
1600


Normal: μ=0.43, σ=0.00, score=0.62
type 0
type 1
250
200
150
100
50
0
0
50
100
150
200
250
300
350


Normal: μ=0.57, σ=0.71, score=0.62
type 0
type 1
400
350
300
250
200
150
100
50
100
200
300
400
500
600



NORMAL NOISE WITH RANDOM FOREST

The 10 best performing parameters are :

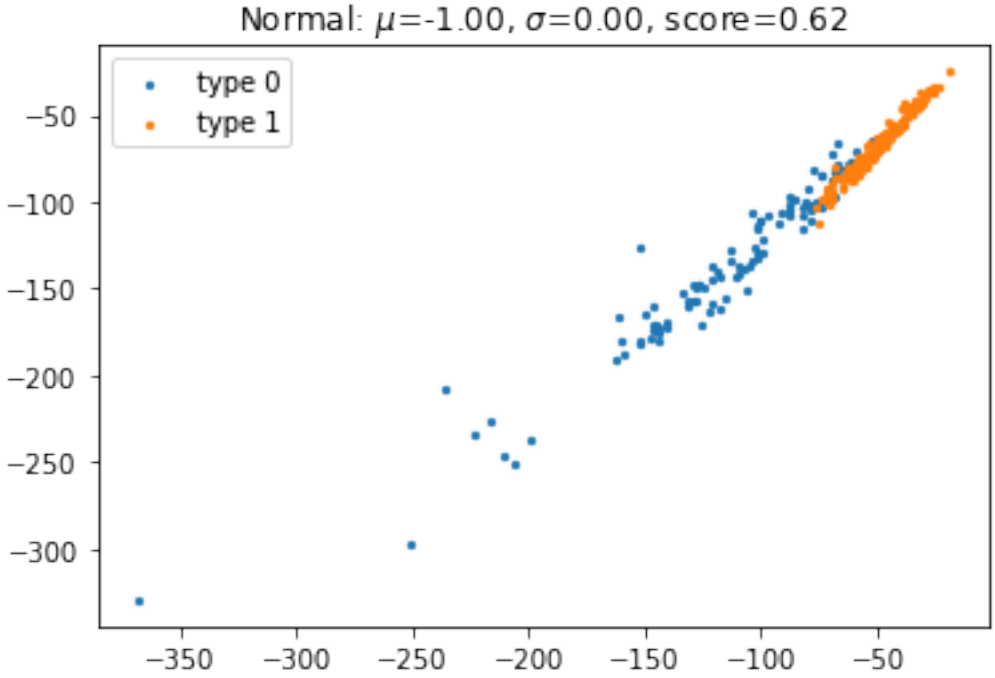
Mean	Std	score
1.00&	0.71&	0.916\\
0.86&	0.57&	0.912\\
-0.29&	0.71&	0.912\\
-0.43&	0.86&	0.909\\
0.00&	0.21&	0.898\\
-0.71&	0.21&	0.891\\
0.00&	0.79&	0.891\\
-0.86&	0.86&	0.891\\
0.29&	0.36&	0.888\\
0.86&	0.71&	0.877\\

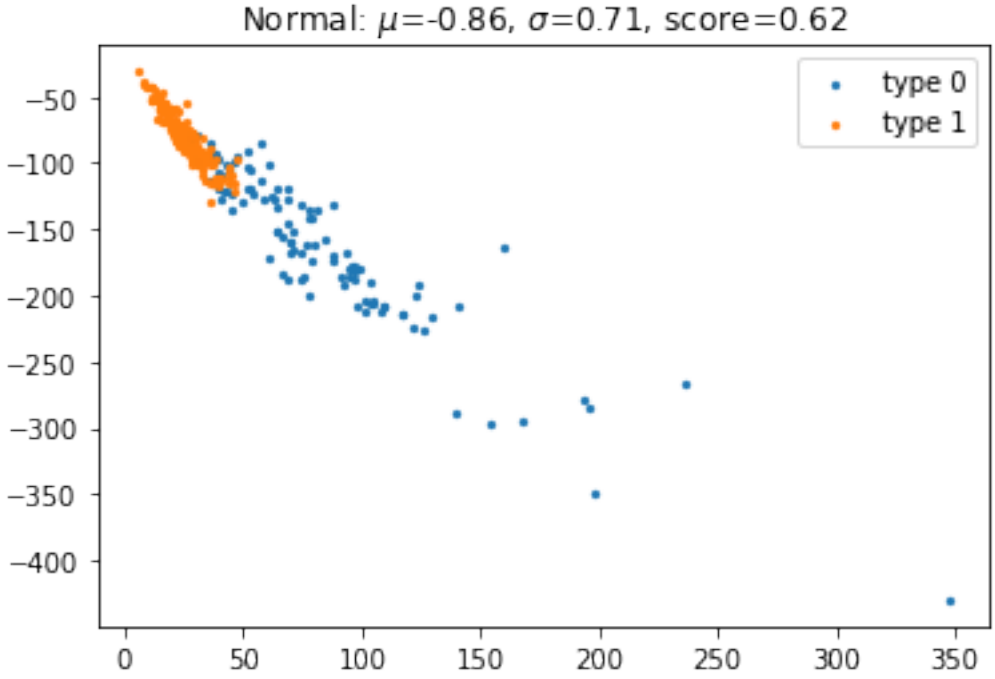
The 10 worst performing parameters are :

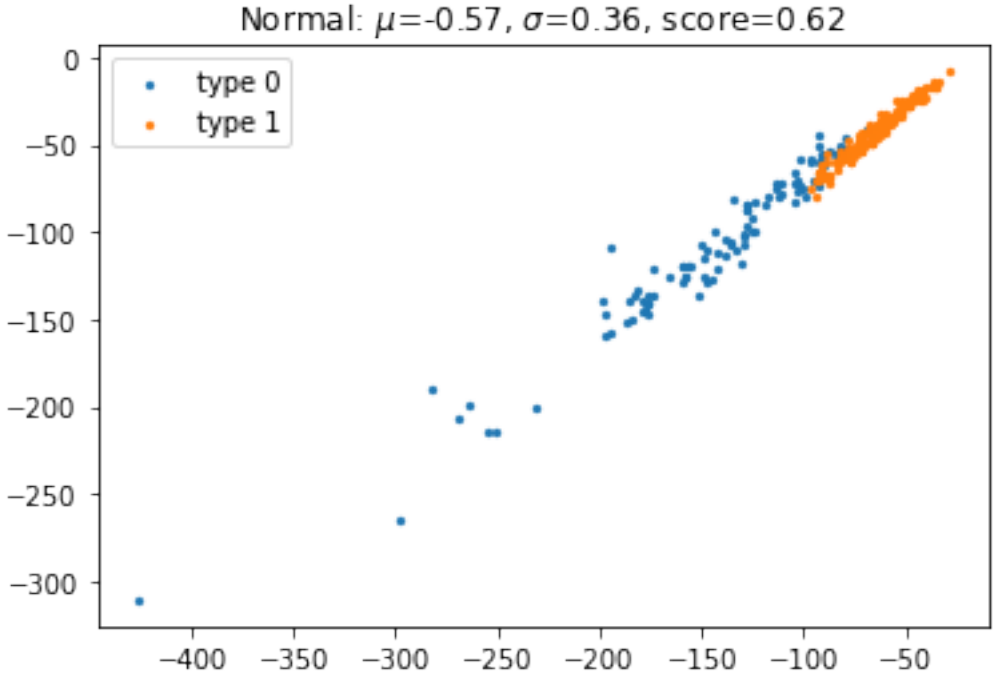
Mean	Std	score
0.43&	0.36&	0.382\\
-0.29&	0.00&	0.382\\
0.14&	0.43&	0.382\\
-0.29&	0.43&	0.382\\
-0.14&	0.71&	0.382\\

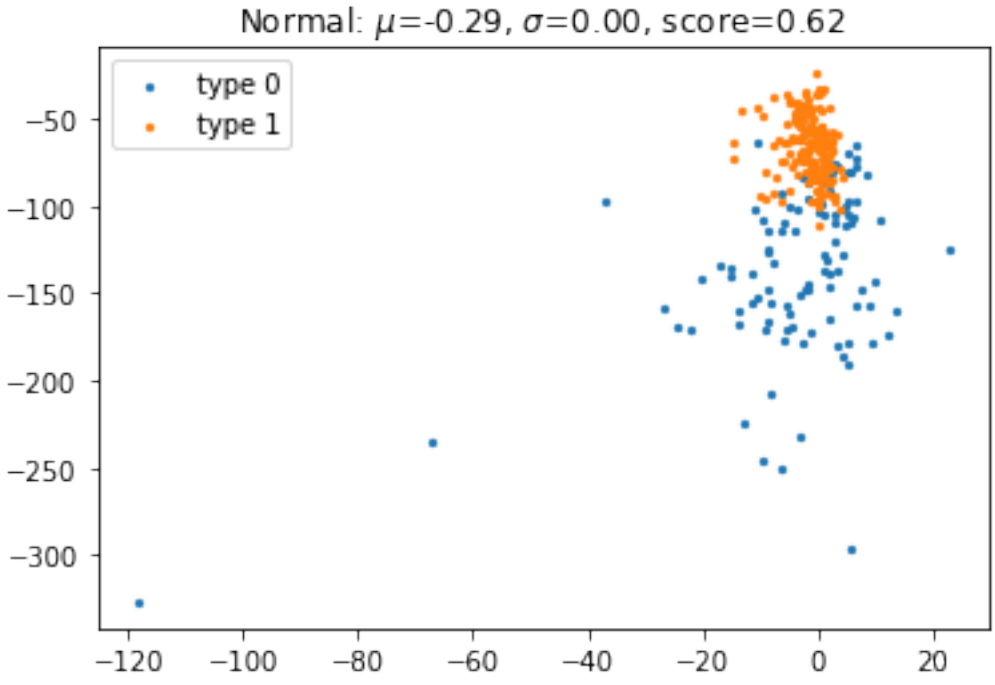
```
        -0.71&  0.29&   0.382\\
        -0.29&  0.64&   0.382\\
        0.29&   0.79&   0.382\\
        -0.14&  0.93&   0.382\\
        -0.43&  0.57&   0.382\\
```

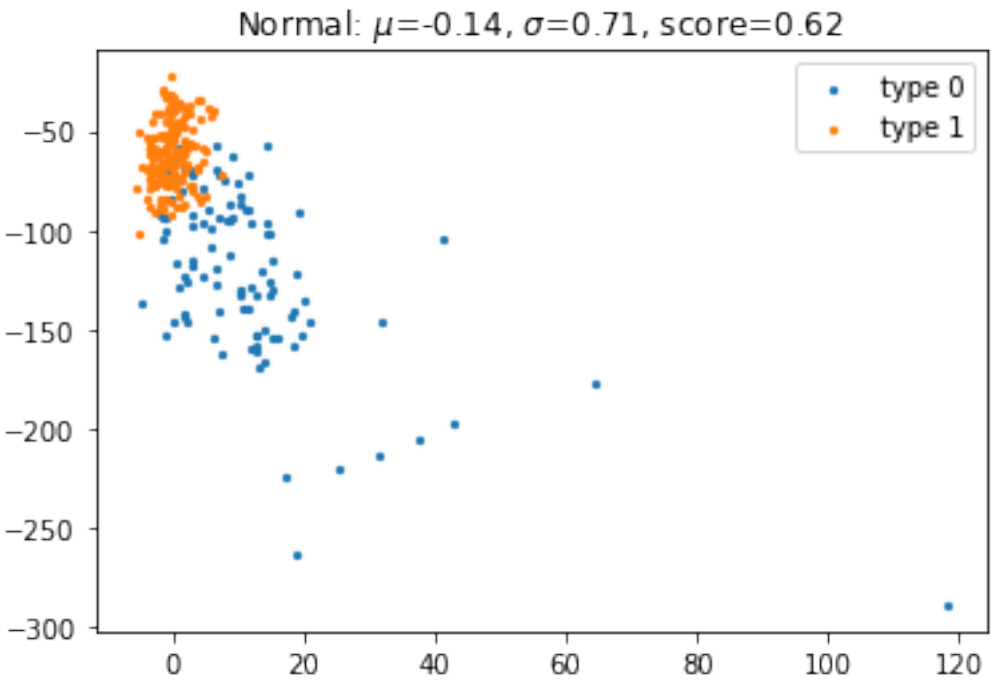
[39]:
```python
# test normal with k-neighbors classifier
scores = normal_testing(
    can_X_train, can_y_train, can_X_test, can_y_test, 2,
    KNeighborsClassifier, {'n_neighbors':3}, plot=True
)

print('\nNORMAL NOISE WITH K-NEIGHBORS\n')

# print the best results
best_performance = np.argsort(scores[:,2])[::-1][:10]
print(f'The 10 best performing parameters are :')
print('\tMean\tStd\tscore')
print('\t'+'--'*len('\ta\tb\tscore'))
row_format = '\t{a:.2f}&\t{b:.2f}&\t{score:.3f}\\\\'
for best in best_performance:
    a,b,score = scores[best]
    print(row_format.format(a=a,b=b,score=score))

print()

# print the worst results
worst_performance = np.argsort(scores[:,2])[::-1][-10:]
print(f'The 10 worst performing parameters are :')
print('\tMean\tStd\tscore')
print('\t'+'--'*len('\ta\tb\tscore'))
row_format = '\t{a:.2f}&\t{b:.2f}&\t{score:.3f}\\\\'
for worst in worst_performance:
    a,b,score = scores[worst]
    print(row_format.format(a=a,b=b,score=score))
```

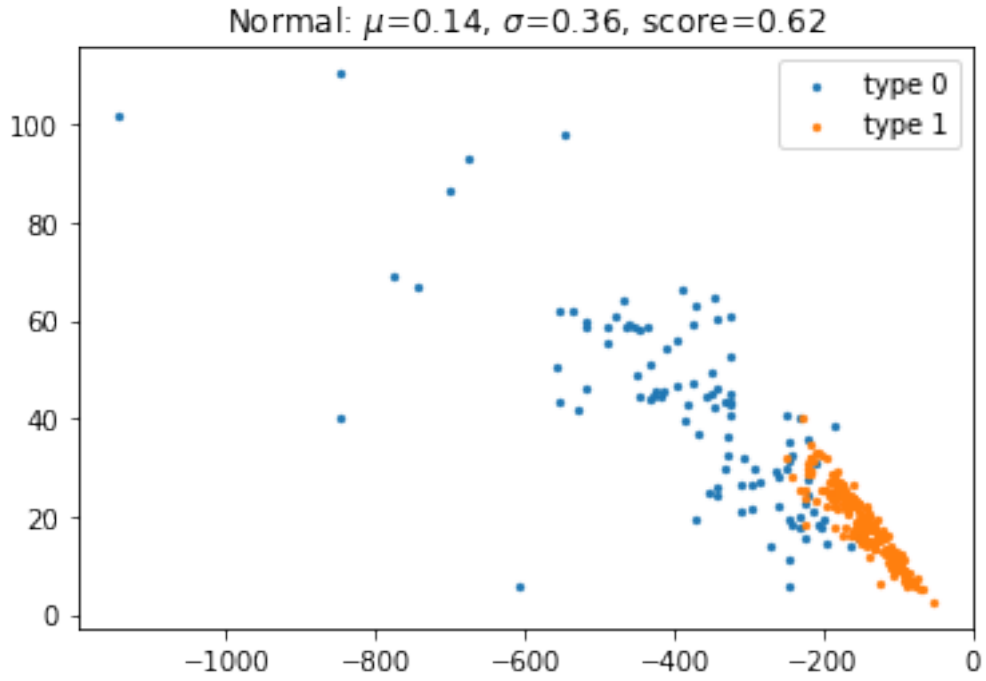

Normal: μ=-1.00, σ=0.00, score=0.62
type 0
type 1
−50
−100
−150
−200
−250
−300
−350
−300
−250
−200
−150
−100
−50

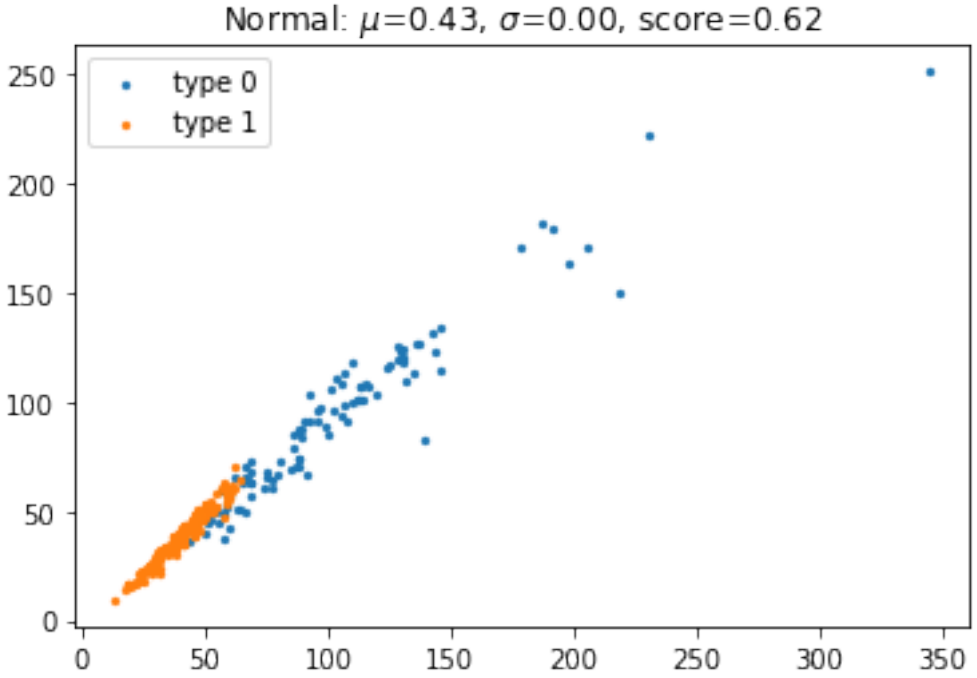

Normal: μ=-0.86, σ=0.71, score=0.62
type 0
type 1
−50
−100
−150
−200
−250
−300
−350
−400
0
50
100
150
200
250
300
350

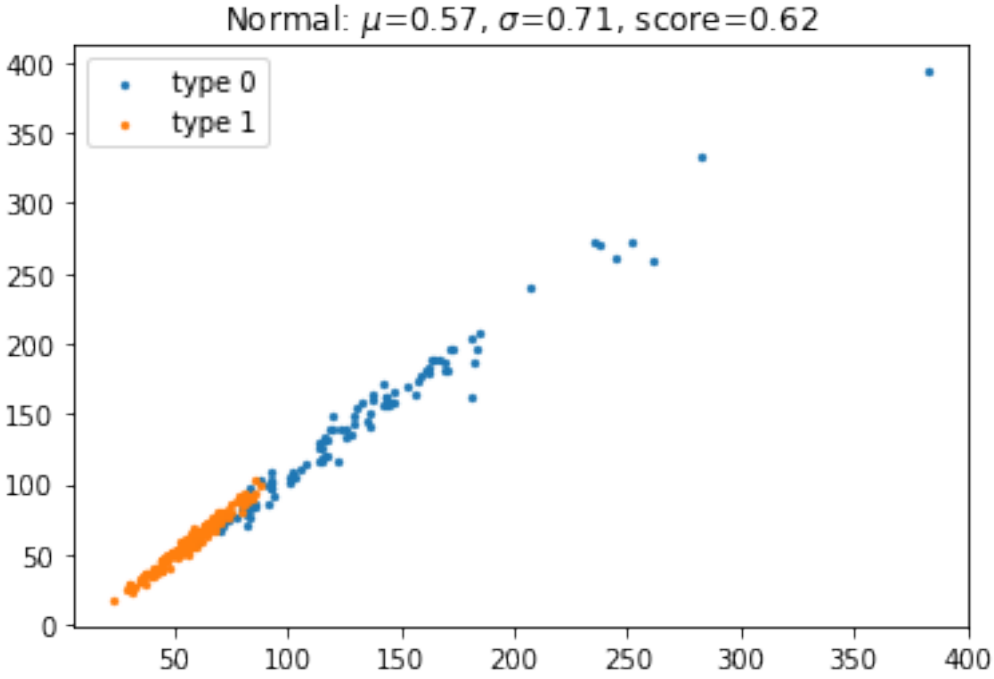

Normal: μ=-0.57, σ=0.36, score=0.62
type 0
type 1
0
−50
−100
−150
−200
−250
−300
−400
−350
−300
−250
−200
−150
−100
−50

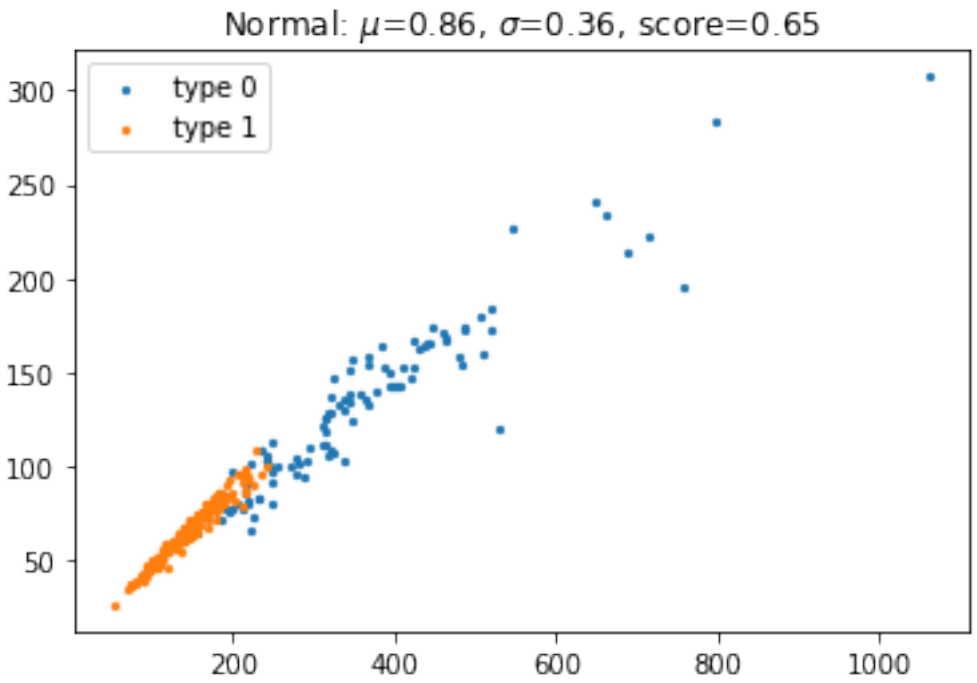

Normal: μ=-0.29, σ=0.00, score=0.62
type 0
type 1
−50
−100
−150
−200
−250
−300
−120
−100
−80
−60
−40
−20
0
20


Normal: μ=-0.14, σ=0.71, score=0.62
type 0
type 1
−50
−100
−150
−200
−250
−300
0
20
40
60
80
100
120


Normal: μ=0.14, σ=0.36, score=0.62
type 0
type 1
100
80
60
40
20
0
−1000
−800
−600
−400
−200
0


Normal: μ=0.43, σ=0.00, score=0.62
type 0
type 1
0
50
100
150
200
250
300
350


Normal: μ=0.57, σ=0.71, score=0.62
type 0
type 1
0
50
100
150
200
250
300
350
400



NORMAL NOISE WITH K-NEIGHBORS

The 10 best performing parameters are :

Mean	Std	score
0.14&	0.14&	0.930\\
1.00&	0.57&	0.912\\
-0.71&	0.43&	0.905\\
-0.14&	0.50&	0.905\\
-0.86&	0.79&	0.902\\
0.86&	0.50&	0.902\\
-0.43&	0.64&	0.895\\
0.57&	0.50&	0.884\\
-0.71&	0.64&	0.874\\
-0.29&	0.57&	0.867\\

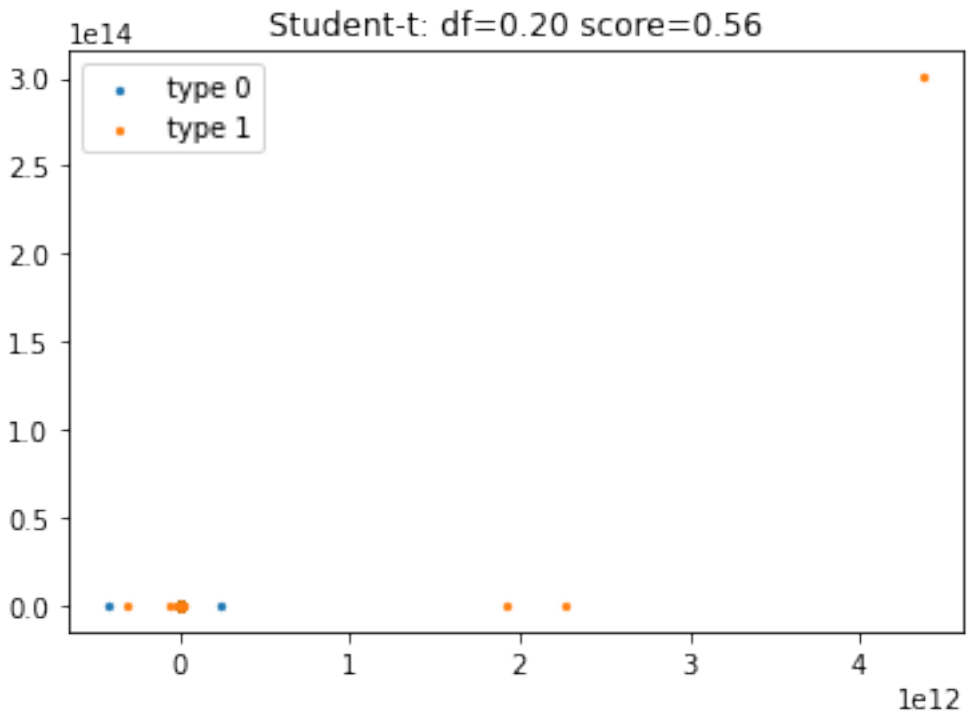
The 10 worst performing parameters are :

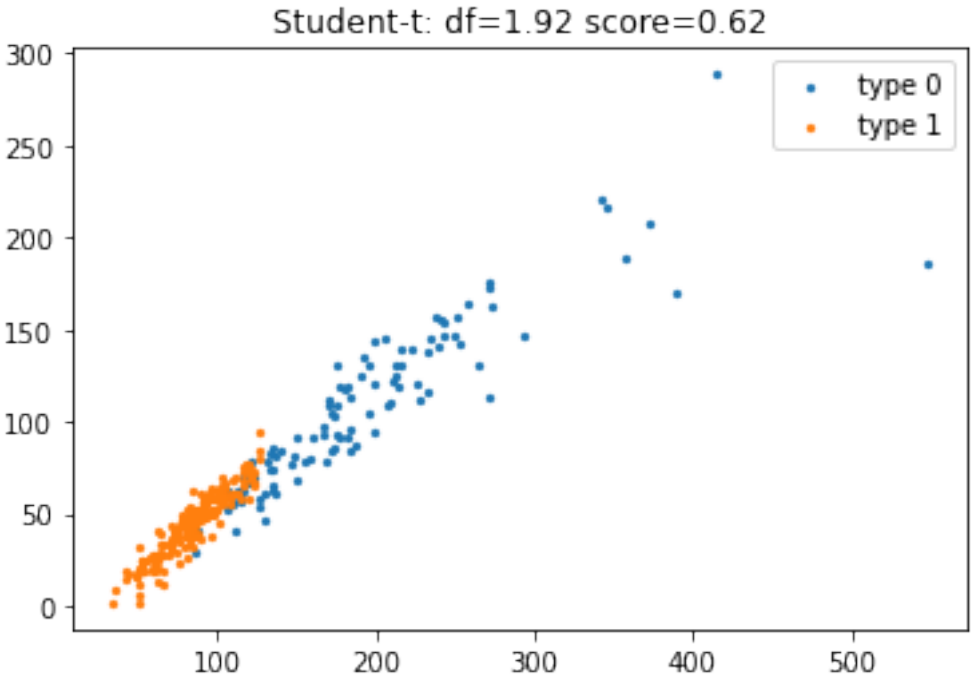
Mean	Std	score
0.14&	0.21&	0.477\\
1.00&	0.50&	0.442\\
0.57&	0.93&	0.425\\
0.00&	0.71&	0.421\\
-0.14&	0.79&	0.421\\

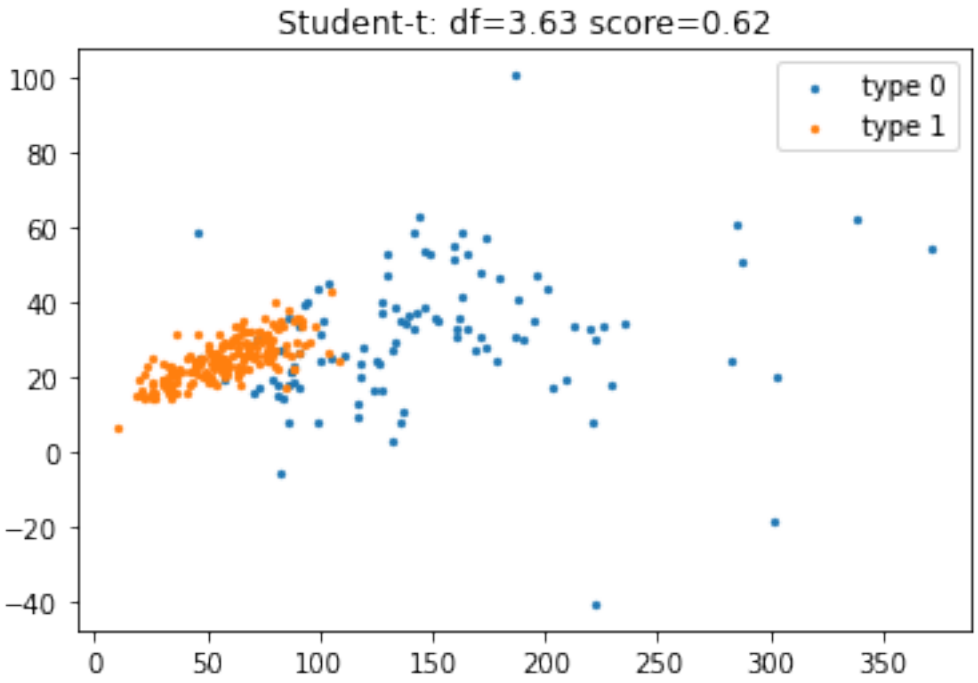
```
0.71&   0.93&   0.400\\
0.43&   0.71&   0.396\\
-0.29&  0.79&   0.386\\
0.14&   1.00&   0.382\\
-0.43&  0.50&   0.382\\
```

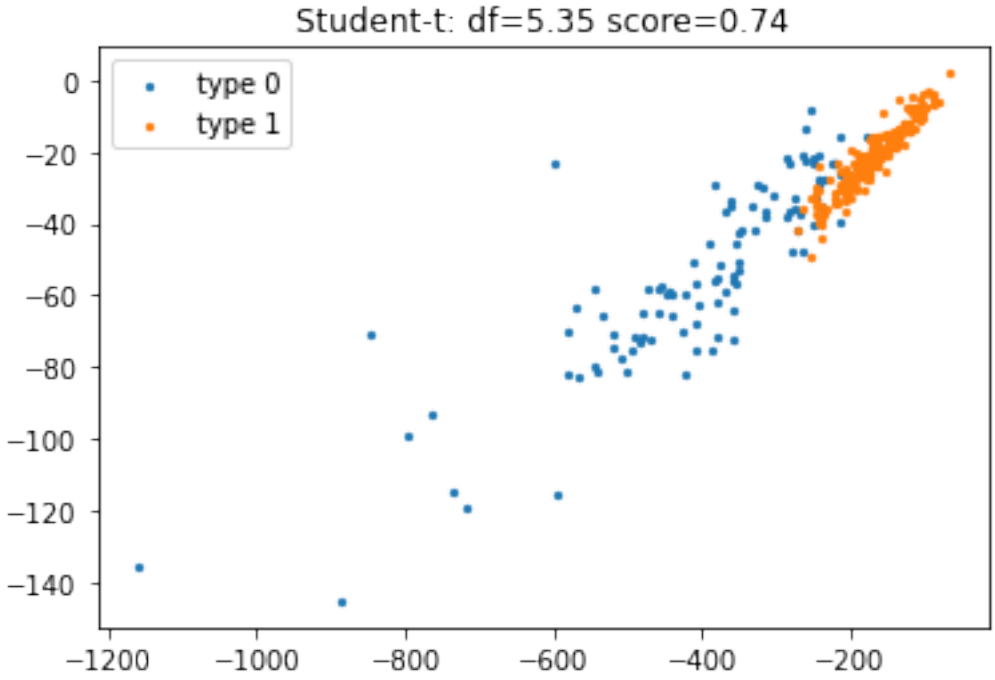
[40]:
```
# do student t testing
def␣
↪student_t_testing(X_train,y_train,X_test,y_test,n,Classifier,params,plot=True):
↪


    dfs = student_t_params['df']
    i=0
    scores = np.zeros((len(dfs),2))


    for df in dfs:
            # first we apply noise
            X_train_noise = noiser(X_train, 'student-t', (df,))
            X_test_noise = noiser(X_test, 'student-t', (df,))

            # next we apply pca
            train_data = pca(X_train_noise)
            test_data = pca(X_test_noise)

            # finally we test and train a classifier and examine the
            # score
            classifier = Classifier(**params)
            classifier.fit(train_data, y_train)

            # score the classifier and record it
            score = sum(classifier.predict(test_data) == y_test) / len(y_test)
            scores[i] = (df,score)

            # every once and a while we plot the results
            if i%25 == 0 and plot:
                title_format = 'Student-t: df={a:.2f} score={score:.2f}'
                title = title_format.format(a=df, score=scores[i,1])
                plot_data(train_data, y_train, n, title)


            i+=1

    return scores
```

[41]:
```
# test student-t with random forest
# get the scores
scores = student_t_testing(
    can_X_train, can_y_train, can_X_test, can_y_test, 2,
    RandomForestClassifier, {'n_estimators':50, 'max_depth':10}
)

print('\nSTUDENT-T WITH RANDOM FOREST\n')

# print the best results
best_performance = np.argsort(scores[:,1])[::-1][:10]
print(f'The 10 best performing parameters are :')
print('\tdf\tscore')
print('\t'+'--'*len('\tdf\tscore'))
row_format = '\t{a:.2f}&\t{score:.3f}\\\\'
for best in best_performance:
    df,score = scores[best]
    print(row_format.format(a=df,score=score))

# print the worst results
worst_performance = np.argsort(scores[:,1])[::-1][-10:]
print(f'The 10 worst performing parameters are :')
print('\tdf\tscore')
print('\t'+'--'*len('\tdf\tscore'))
row_format = '\t{a:.2f}&\t{score:.3f}\\\\'
for worst in worst_performance:
    df,score = scores[worst]
    print(row_format.format(a=df,score=score))
```


Student-t: df=0.20 score=0.56
1e14
type 0
type 1
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
1
2
3
4
1e12


Student-t: df=1.92 score=0.62
type 0
type 1
300
250
200
150
100
50
0
100
200
300
400
500



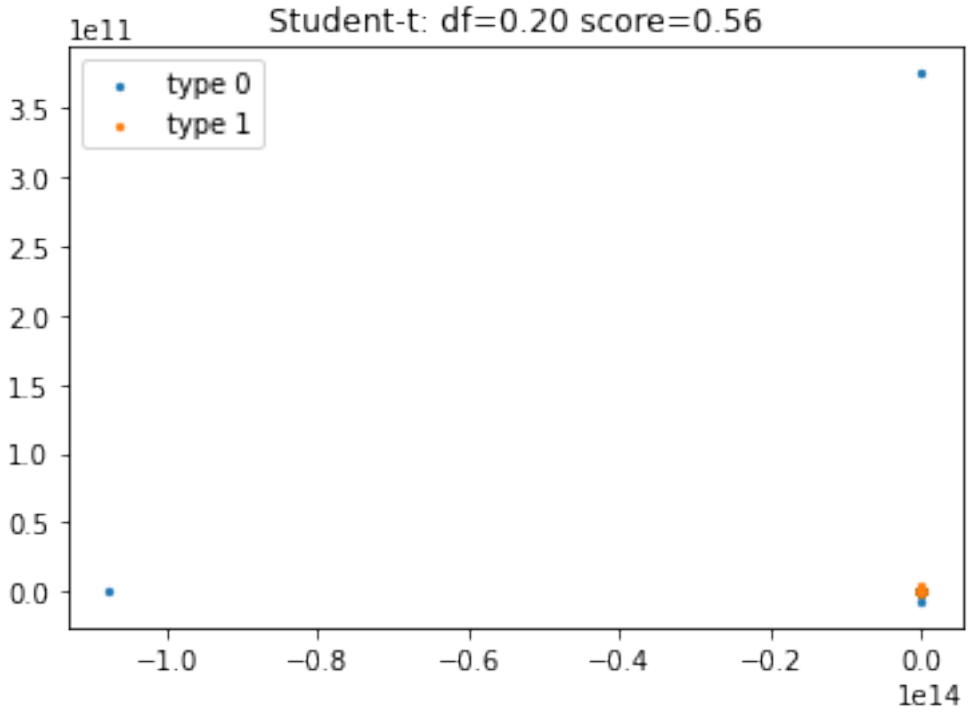


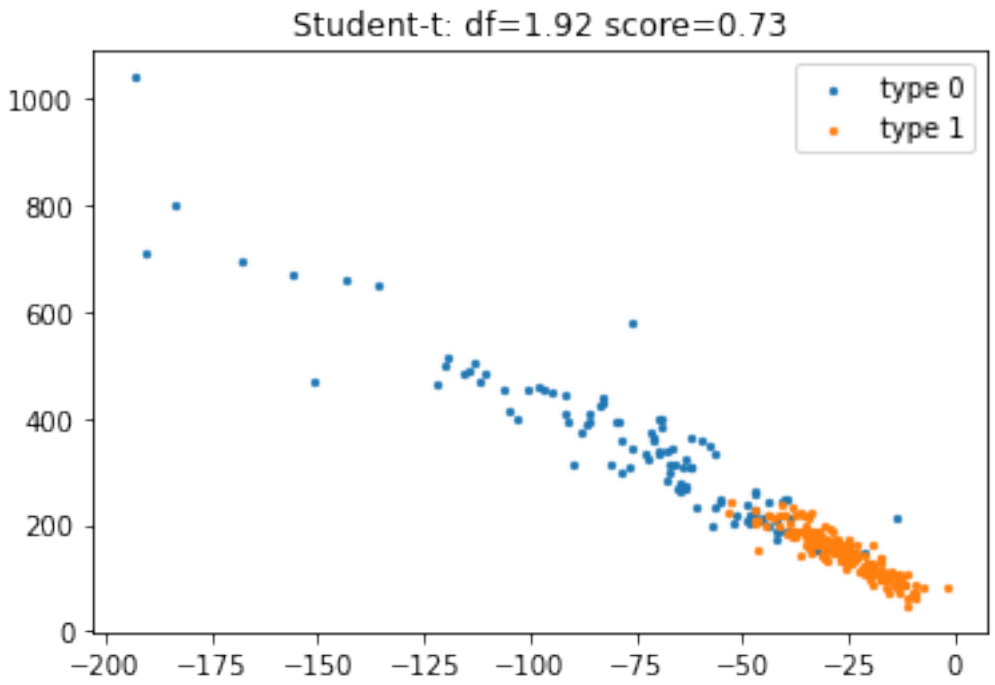
STUDENT-T WITH RANDOM FOREST

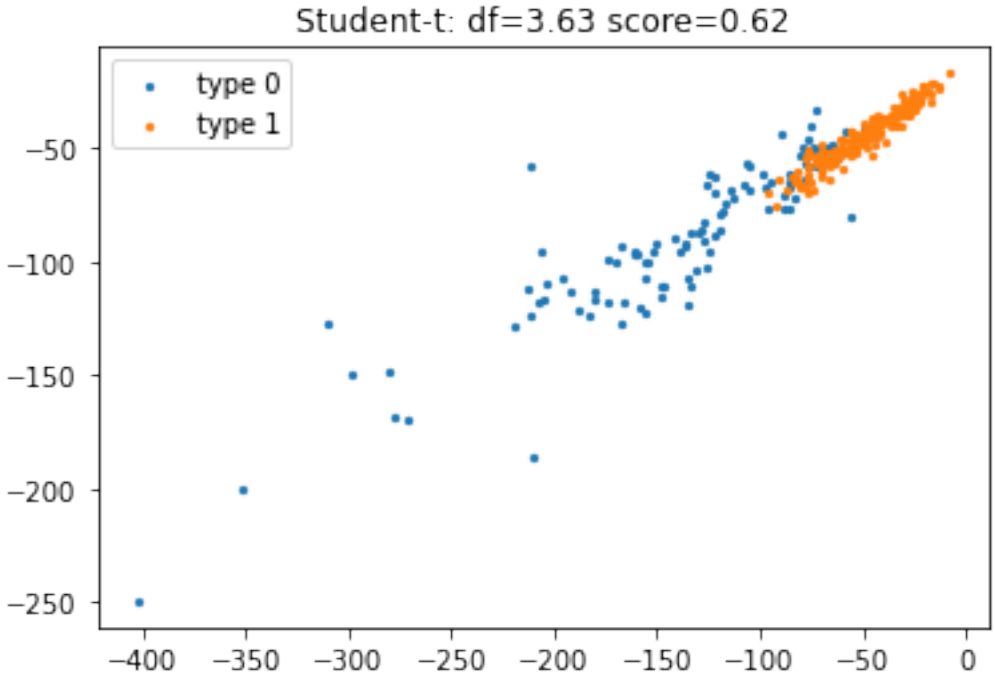
```
The 10 best performing parameters are :
        df      score
        ------------------
        4.66&   0.898\\
        6.79&   0.895\\
        3.15&   0.891\\
        3.22&   0.884\\
        4.53&   0.881\\
        3.43&   0.867\\
        4.12&   0.860\\
        4.94&   0.832\\
        1.37&   0.804\\
        3.91&   0.779\\
The 10 worst performing parameters are :
        df      score
        ------------------
        4.60&   0.396\\
        1.51&   0.396\\
        4.18&   0.396\\
        3.08&   0.393\\
        5.56&   0.382\\
        6.66&   0.382\\
        3.02&   0.382\\
        4.25&   0.382\\
        5.21&   0.382\\
        0.68&   0.211\\
```

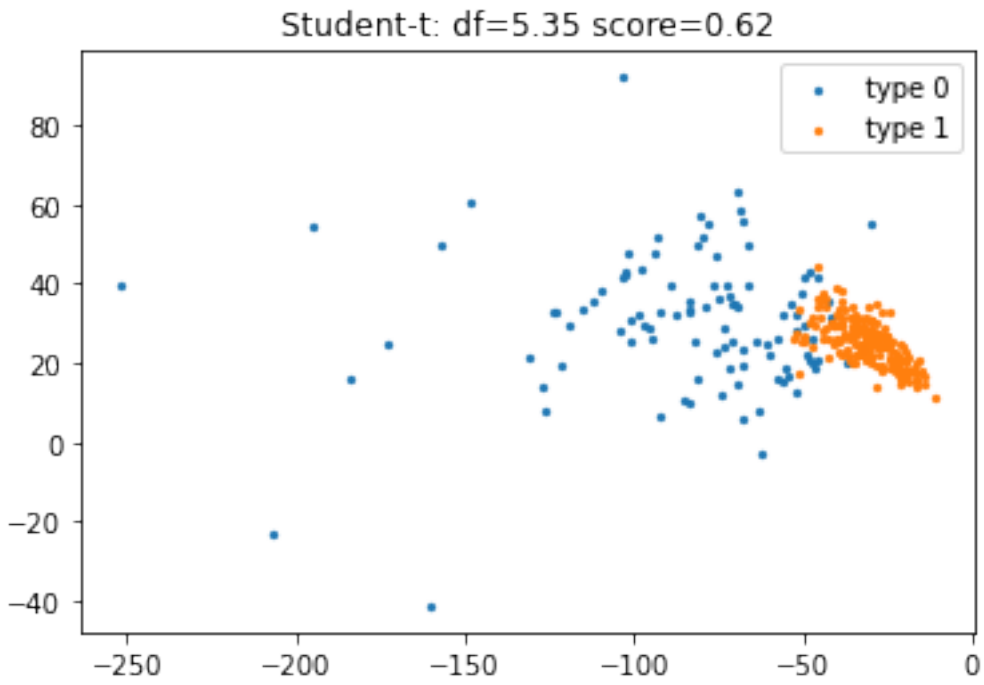
[42]:
```python
# test student-t with k-neighbors classifier
scores = student_t_testing(
    can_X_train, can_y_train, can_X_test, can_y_test, 2,
    KNeighborsClassifier, {'n_neighbors':3}, plot=True
)

print('\nSTUDENT-T WITH K-NEIGHBORS\n')

# print the best results
best_performance = np.argsort(scores[:,1])[::-1][:10]
print(f'The 10 best performing parameters are :')
print('\tdf\tscore')
print('\t'+'--'*len('\tdf\tscore'))
row_format = '\t{a:.2f}&\t{score:.3f}\\\\'
for best in best_performance:
    df,score = scores[best]
    print(row_format.format(a=df,score=score))

# print the worst results
```

```
worst_performance = np.argsort(scores[:,1])[::-1][-10:]
print(f'The 10 worst performing parameters are :')
print('\tdf\tscore')
print('\t'+'--'*len('\tdf\tscore'))
row_format = '\t{a:.2f}&\t{score:.3f}\\\\'
for worst in worst_performance:
    df,score = scores[worst]
    print(row_format.format(a=df,score=score))
```




Student-t: df=1.92 score=0.73
type 0
type 1
1000
800
600
400
200
0
−200
−175
−150
−125
−100
−75
−50
−25
0


Student-t: df=3.63 score=0.62
type 0
type 1
−50
−100
−150
−200
−250
−400
−350
−300
−250
−200
−150
−100
−50
0

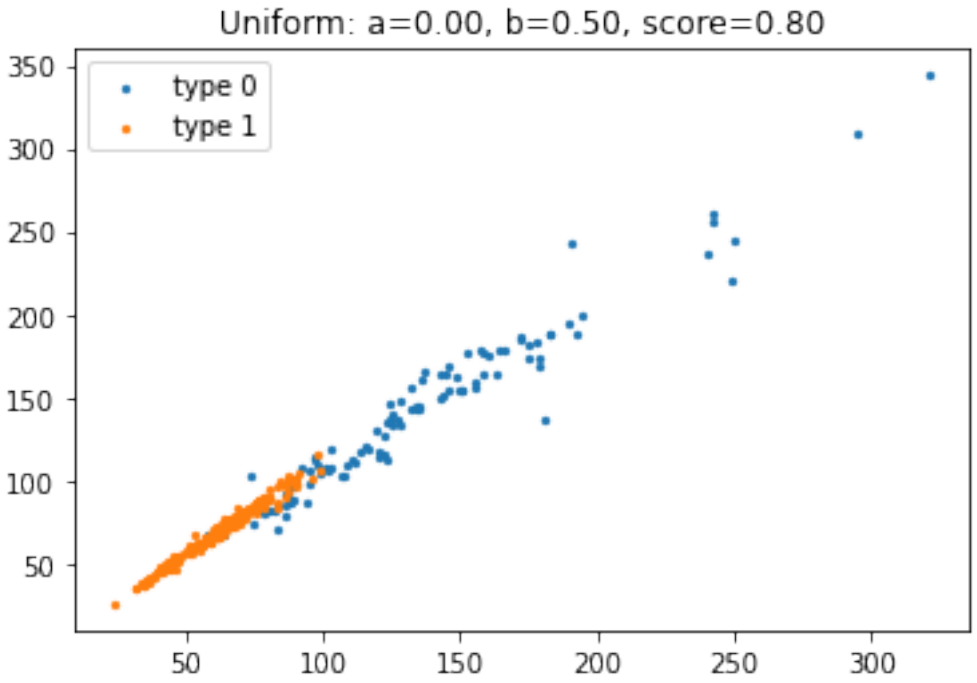


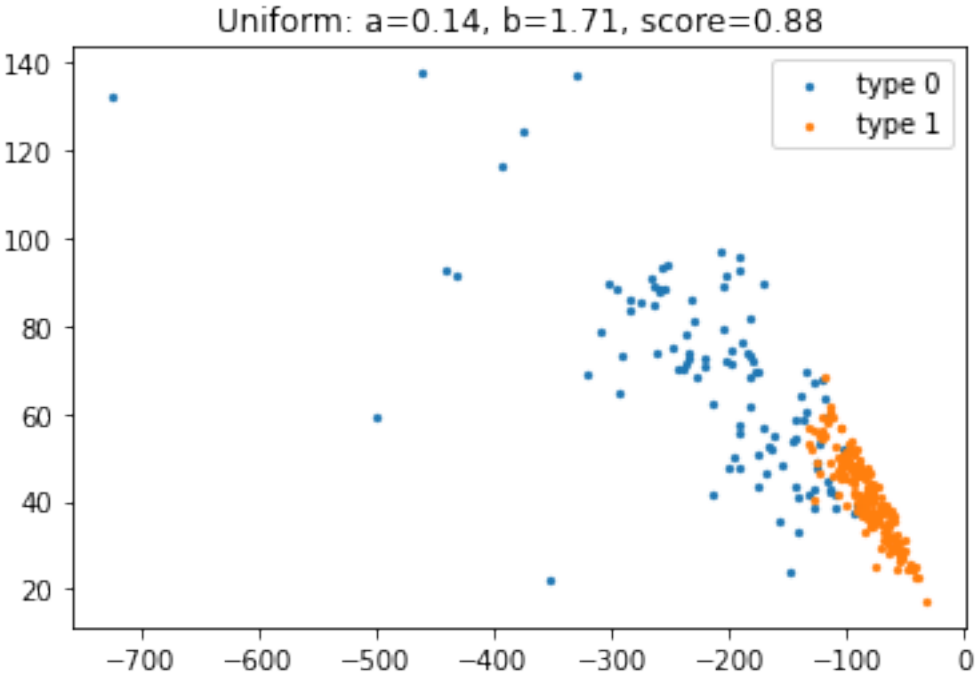

```
STUDENT-T WITH K-NEIGHBORS

The 10 best performing parameters are :
        df      score
        ------------------
        6.38&   0.923\\
        2.67&   0.916\\
        6.59&   0.902\\
        6.73&   0.898\\
        1.23&   0.877\\
        3.15&   0.863\\
        5.28&   0.860\\
        1.99&   0.853\\
        2.19&   0.853\\
        6.31&   0.846\\
The 10 worst performing parameters are :
        df      score
        ------------------
        4.05&   0.477\\
        2.05&   0.442\\
        0.89&   0.404\\
        5.97&   0.396\\
        4.66&   0.393\\
        4.53&   0.393\\
```

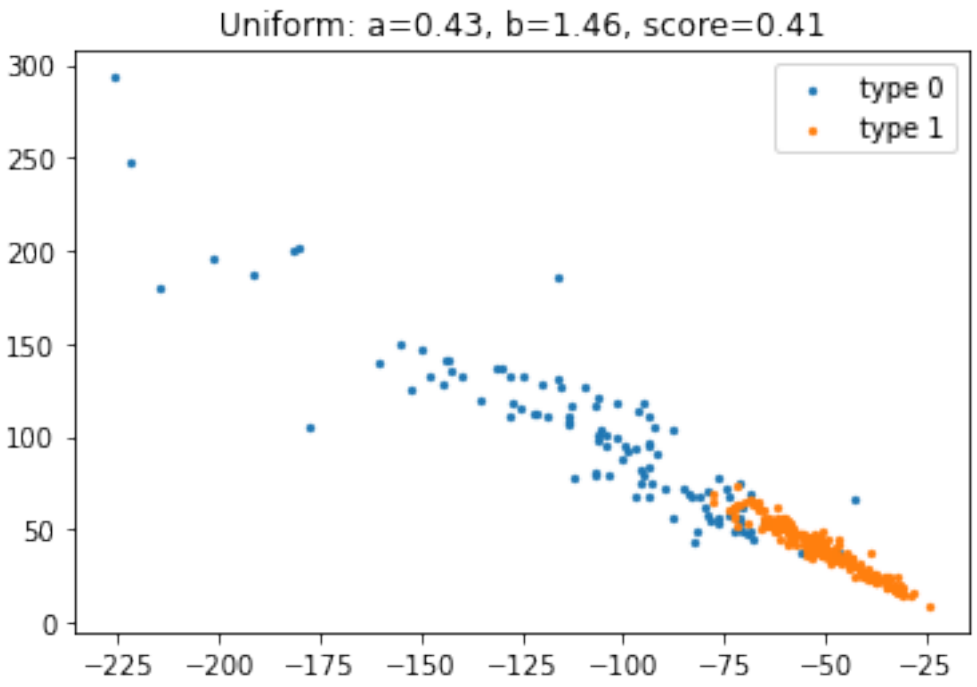
```
5.15&    0.386\\
1.02&    0.386\\
3.77&    0.386\\
6.24&    0.382\\
```

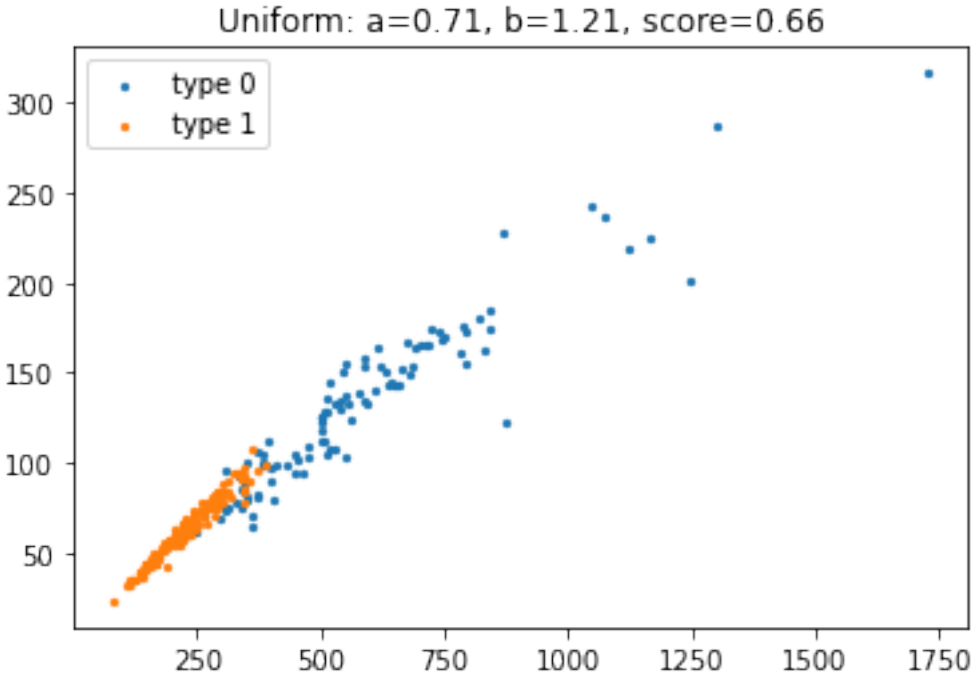
[43]:
```
# do uniform testing
def␣
↪uniform_testing(X_train,y_train,X_test,y_test,n,Classifier,params,plot=True):


    as_ = uniform_params['a']
    lengths = uniform_params['length']
    i=0
    scores = np.zeros((len(as_)*len(lengths),3))


    for a in as_:
        for length in lengths:
            b = a + length
            # first we apply noise
            X_train_noise = noiser(X_train, 'uniform', (a,b))
            X_test_noise = noiser(X_test, 'uniform', (a,b))

            # next we apply pca
            train_data = pca(X_train_noise)
            test_data = pca(X_test_noise)

            # finally we test and train a classifier and examine the
            # score
            classifier = Classifier(**params)
            classifier.fit(train_data, y_train)

            # score the classifier and record it
            score = sum(classifier.predict(test_data) == y_test) / len(y_test)
            scores[i] = (a,b,score)

            # every once and a while we plot the results
            if i%25 == 0 and plot:
                title_format = 'Uniform: a={a:.2f}, b={b:.2f}, score={score:.
↪2f}'
                title = title_format.format(a=a, b=b, score=scores[i,2])
                plot_data(train_data, y_train, n, title)


            i+=1

    return scores
```

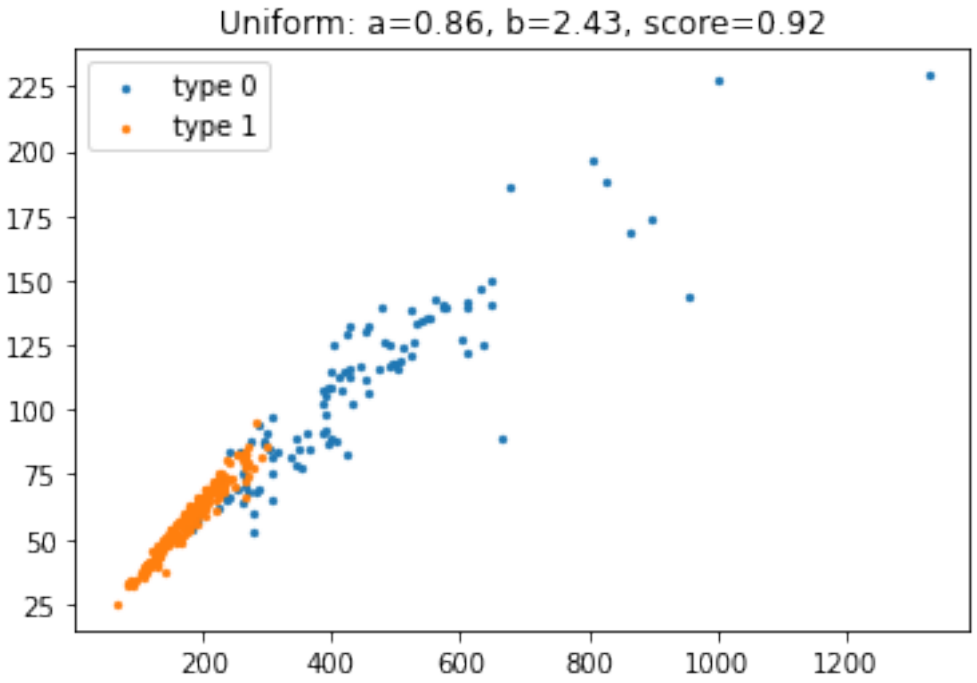
[44]:
```
# test uniform with random forest
# get the scores
scores = uniform_testing(
    can_X_train, can_y_train, can_X_test, can_y_test, 2,
    RandomForestClassifier, {'n_estimators':50, 'max_depth':10}
)

print('\nUNIFORM WITH RANDOM FOREST\n')

# print the best results
best_performance = np.argsort(scores[:,2])[::-1][:10]
print(f'The 10 best performing parameters are :')
print('\ta\tb\tscore')
print('\t'+'--'*len('\ta\tb\tscore'))
row_format = '\t{a:.2f}&\t{b:.2f}&\t{score:.3f}\\\\'
for best in best_performance:
    a,b,score = scores[best]
    print(row_format.format(a=a,b=b,score=score))

# print the worst results
worst_performance = np.argsort(scores[:,2])[::-1][-10:]
print(f'The 10 worst performing parameters are :')
print('\ta\tb\tscore')
print('\t'+'--'*len('\ta\tb\tscore'))
row_format = '\t{a:.2f}&\t{b:.2f}&\t{score:.3f}\\\\'
for worst in worst_performance:
    a,b,score = scores[worst]
    print(row_format.format(a=a,b=b,score=score))
```

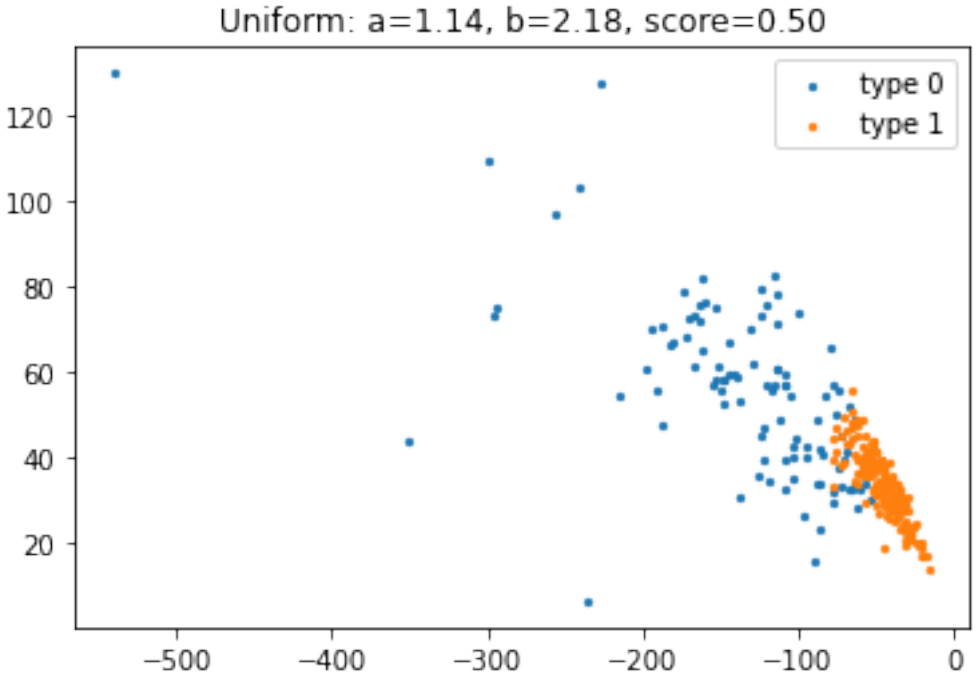

Uniform: a=0.00, b=0.50, score=0.80
type 0
type 1
350
300
250
200
150
100
50
50
100
150
200
250
300

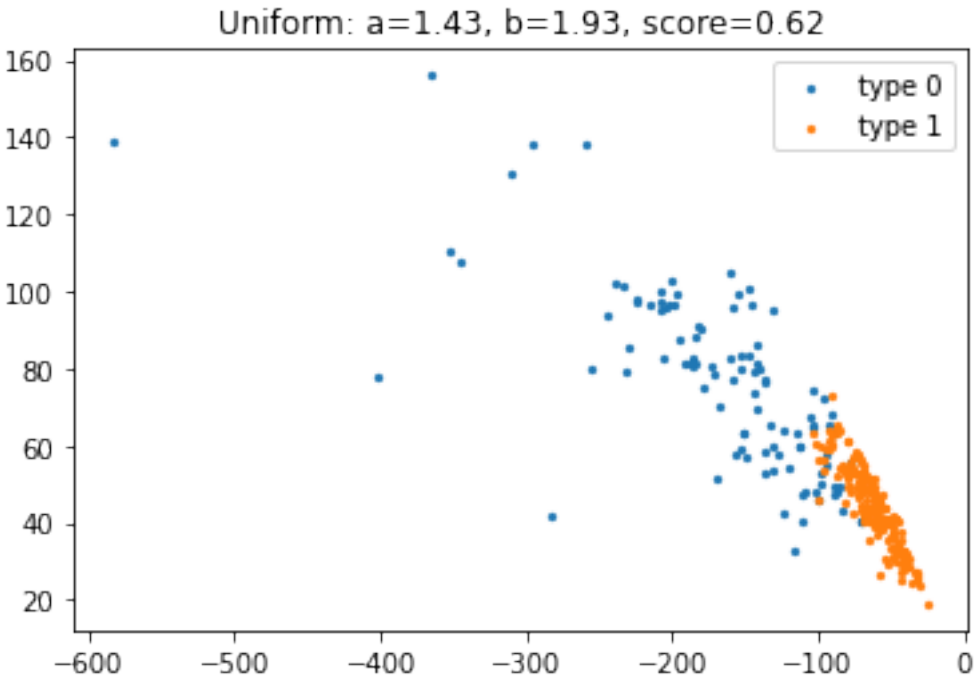

Uniform: a=0.14, b=1.71, score=0.88
type 0
type 1
140
120
100
80
60
40
20
−700
−600
−500
−400
−300
−200
−100
0

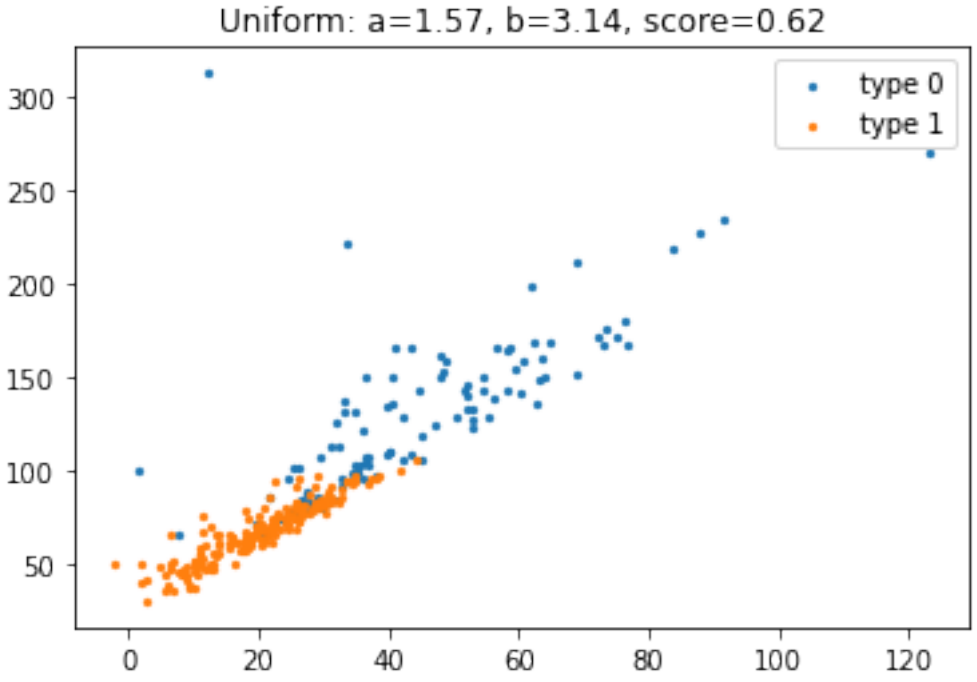

Uniform: a=0.43, b=1.46, score=0.41
type 0
type 1
300
250
200
150
100
50
0
−225
−200
−175
−150
−125
−100
−75
−50
−25

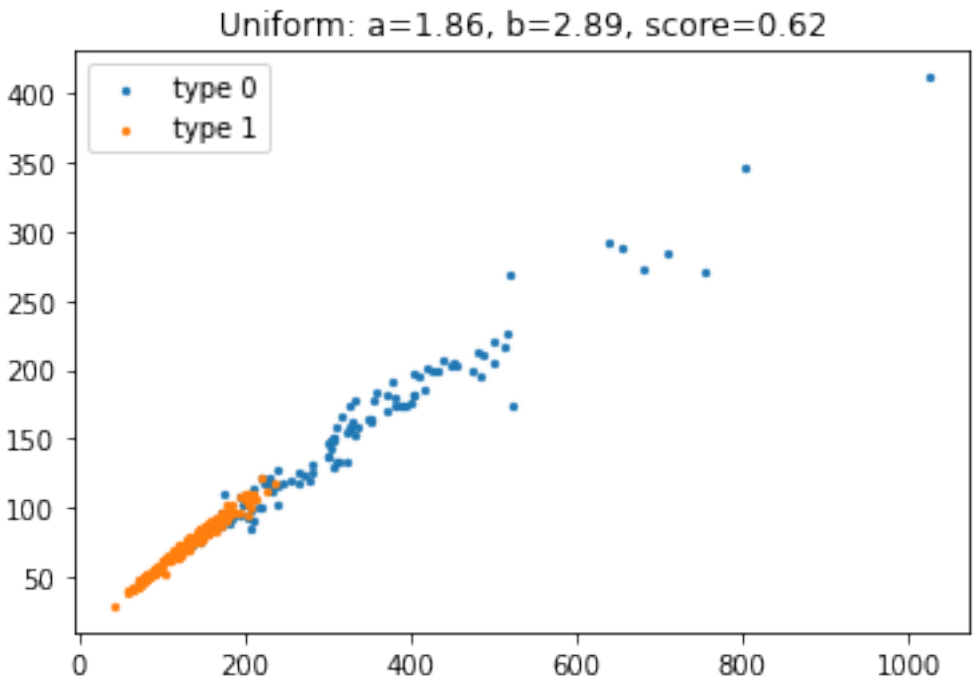

Uniform: a=0.71, b=1.21, score=0.66
type 0
type 1
300
250
200
150
100
50
250
500
750
1000
1250
1500
1750


Uniform: a=0.86, b=2.43, score=0.92
type 0
type 1
225
200
175
150
125
100
75
50
25
200
400
600
800
1000
1200


Uniform: a=1.14, b=2.18, score=0.50
type 0
type 1
120
100
80
60
40
20
−500
−400
−300
−200
−100
0


Uniform: a=1.43, b=1.93, score=0.62
type 0
type 1
160
140
120
100
80
60
40
20
−600
−500
−400
−300
−200
−100
0


Uniform: a=1.57, b=3.14, score=0.62
type 0
type 1
300
250
200
150
100
50
0
20
40
60
80
100
120



UNIFORM WITH RANDOM FOREST

The 10 best performing parameters are :

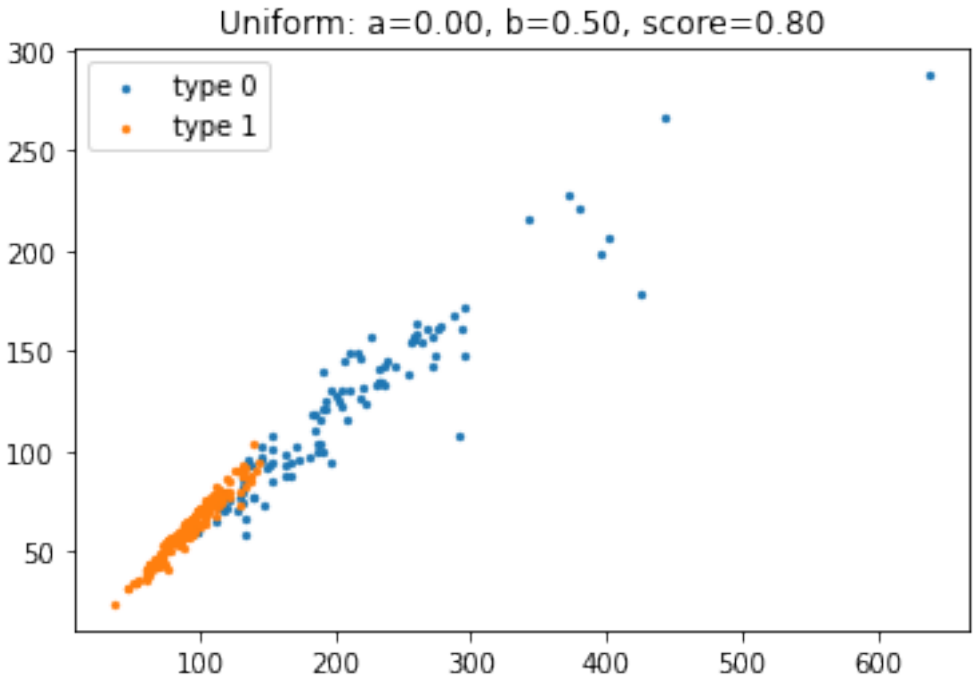
a	b	score
0.00&	1.25&	0.926\\
0.86&	2.43&	0.919\\
1.00&	1.93&	0.912\\
0.86&	1.89&	0.909\\
0.00&	1.68&	0.909\\
1.00&	2.46&	0.902\\
1.00&	2.68&	0.898\\
1.71&	2.54&	0.895\\
0.00&	1.46&	0.888\\
0.86&	2.54&	0.884\\

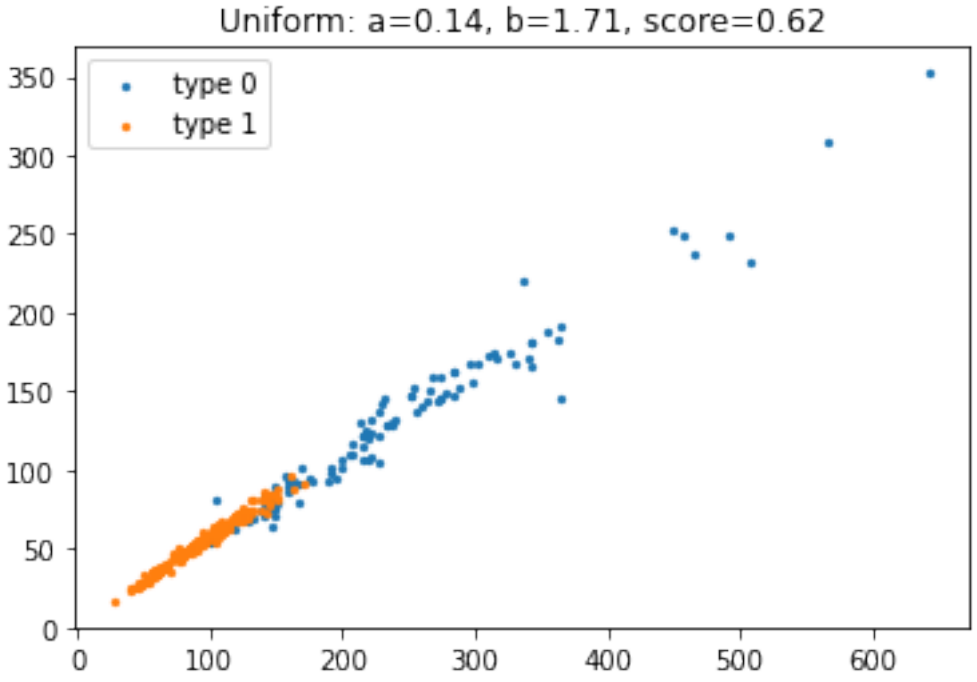
The 10 worst performing parameters are :

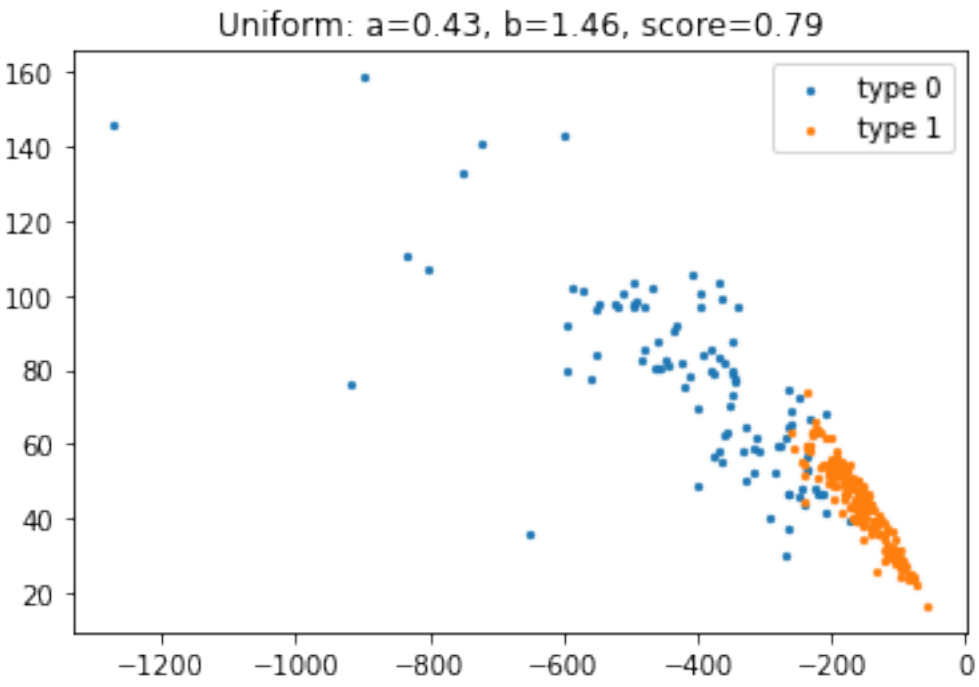
a	b	score
1.43&	2.46&	0.382\\
1.43&	2.04&	0.382\\
1.14&	2.82&	0.382\\
0.57&	1.07&	0.382\\
0.71&	1.32&	0.382\\
1.00&	2.04&	0.382\\

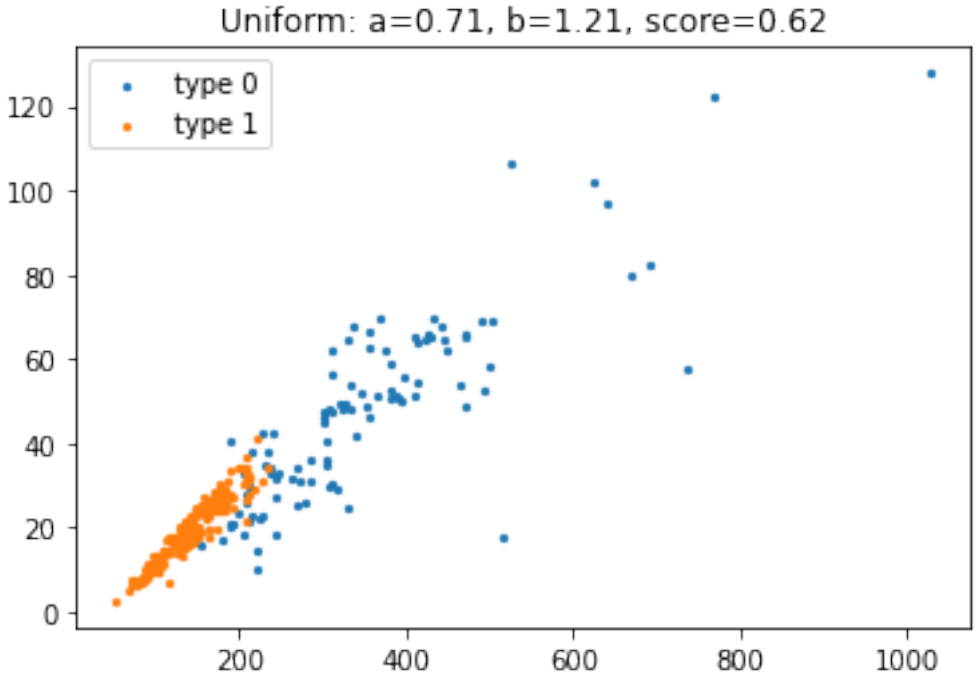
```
        0.86&   2.86&   0.382\\
        0.86&   1.57&   0.382\\
        1.29&   2.43&   0.372\\
        1.00&   2.89&   0.337\\
```

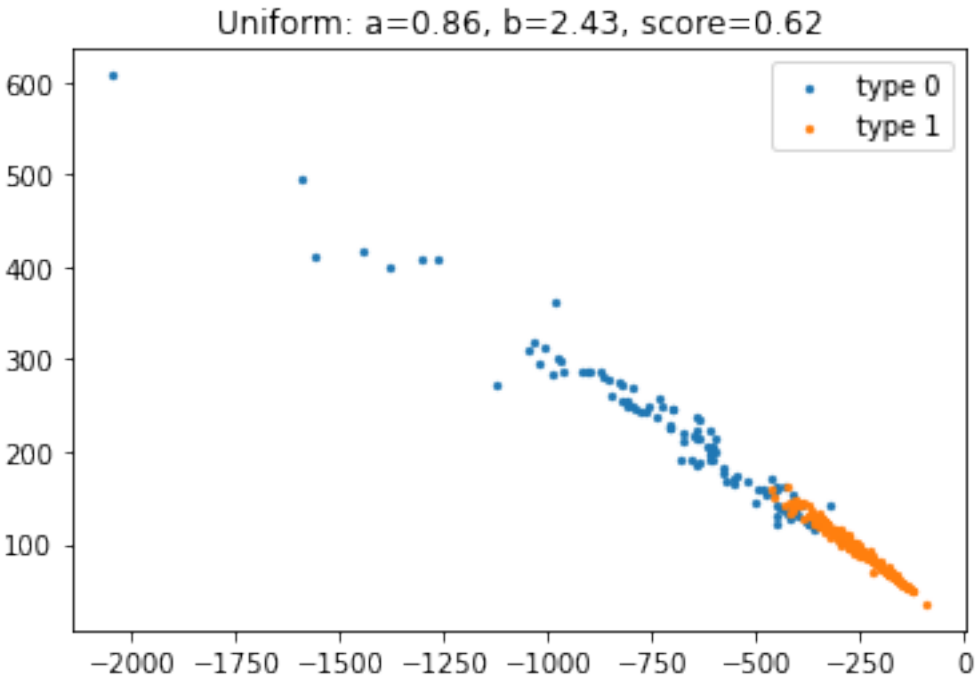
[45]:
```python
# test uniform with k-neighbors classifier
scores = uniform_testing(
    can_X_train, can_y_train, can_X_test, can_y_test, 2,
    KNeighborsClassifier, {'n_neighbors':3}, plot=True
)

print('\nUNIFORM WITH K-NEIGHBORS\n')

# print the best results
best_performance = np.argsort(scores[:,2])[::-1][:10]
print(f'The 10 best performing parameters are :')
print('\ta\tb\tscore')
print('\t'+'--'*len('\ta\tb\tscore'))
row_format = '\t{a:.2f}&\t{b:.2f}&\t{score:.3f}\\\\'
for best in best_performance:
    a,b,score = scores[best]
    print(row_format.format(a=a,b=b,score=score))

# print the worst results
worst_performance = np.argsort(scores[:,2])[::-1][-10:]
print(f'The 10 worst performing parameters are :')
print('\ta\tb\tscore')
print('\t'+'--'*len('\ta\tb\tscore'))
row_format = '\t{a:.2f}&\t{b:.2f}&\t{score:.3f}\\\\'
for worst in worst_performance:
    a,b,score = scores[worst]
    print(row_format.format(a=a,b=b,score=score))
```

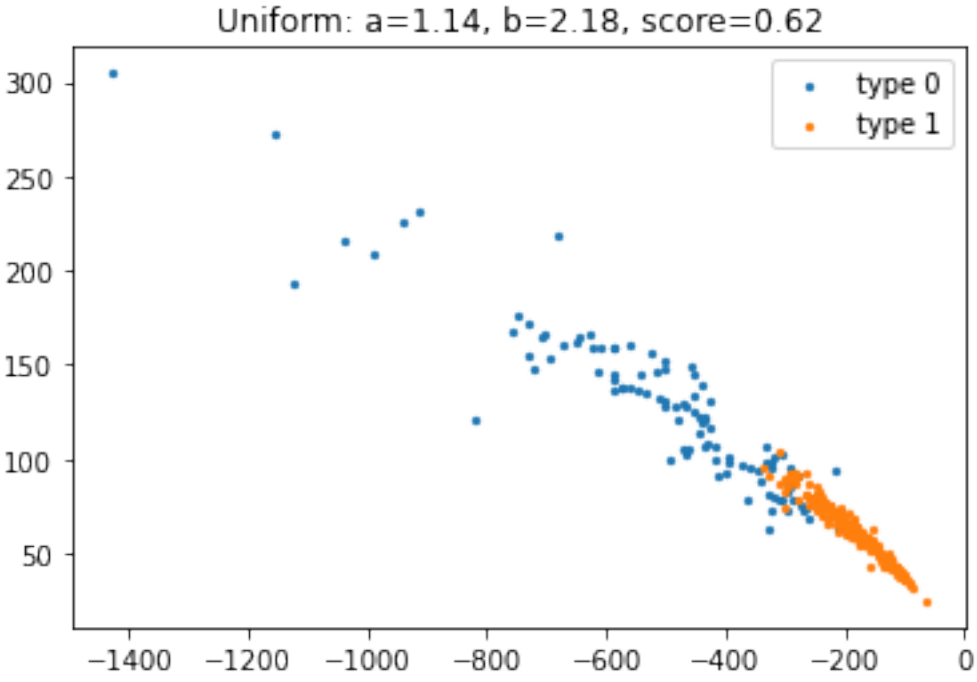

Uniform: a=0.00, b=0.50, score=0.80
type 0
type 1
300
250
200
150
100
50
100
200
300
400
500
600

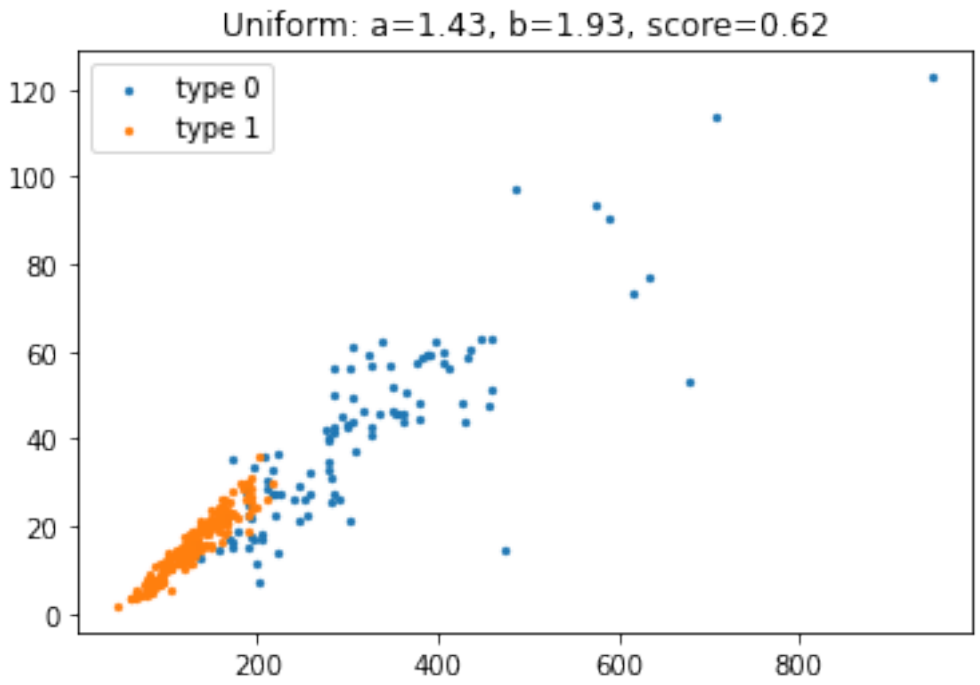

Uniform: a=0.14, b=1.71, score=0.62
type 0
type 1
350
300
250
200
150
100
50
0
0
100
200
300
400
500
600

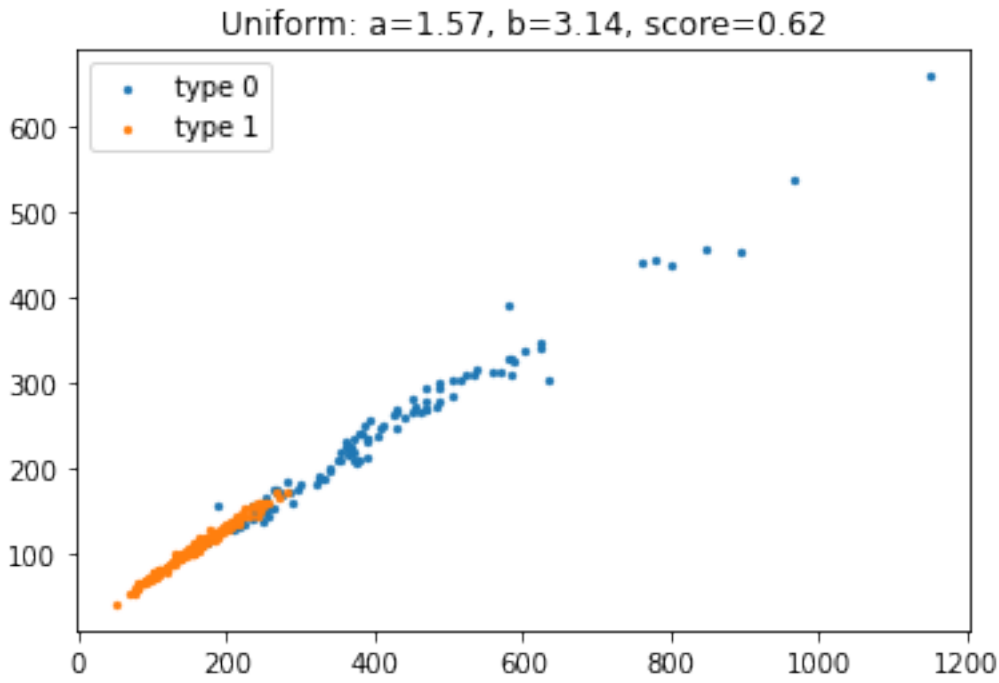

Uniform: a=0.43, b=1.46, score=0.79
type 0
type 1
160
140
120
100
80
60
40
20
−1200
−1000
−800
−600
−400
−200
0

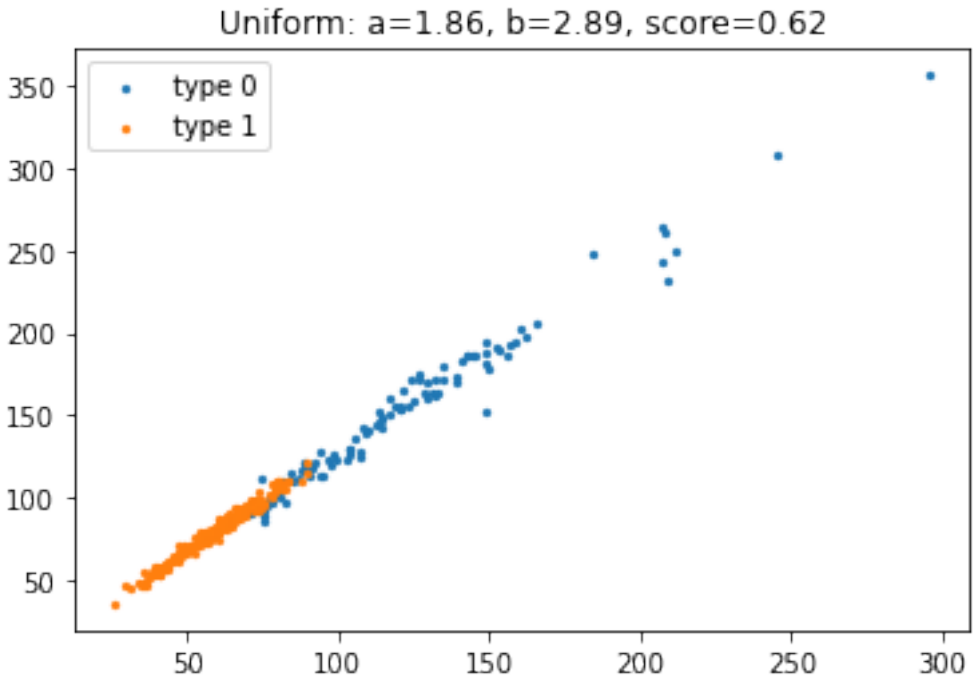

Uniform: a=0.71, b=1.21, score=0.62
type 0
type 1
120
100
80
60
40
20
0
200
400
600
800
1000


Uniform: a=0.86, b=2.43, score=0.62
type 0
type 1
600
500
400
300
200
100
−2000
−1750
−1500
−1250
−1000
−750
−500
−250
0


Uniform: a=1.14, b=2.18, score=0.62
type 0
type 1
300
250
200
150
100
50
−1400
−1200
−1000
−800
−600
−400
−200
0


Uniform: a=1.43, b=1.93, score=0.62
type 0
type 1
120
100
80
60
40
20
0
200
400
600
800


Uniform: a=1.57, b=3.14, score=0.62
type 0
type 1
600
500
400
300
200
100
0
200
400
600
800
1000
1200



UNIFORM WITH K-NEIGHBORS

The 10 best performing parameters are :

a	b	score
0.71&	1.32&	0.912\\
1.86&	2.46&	0.909\\
0.86&	1.46&	0.905\\
1.14&	2.29&	0.905\\
0.86&	2.86&	0.902\\
0.43&	2.00&	0.891\\
0.29&	2.07&	0.888\\
1.14&	2.07&	0.881\\
1.86&	2.68&	0.877\\
1.14&	3.14&	0.877\\

The 10 worst performing parameters are :

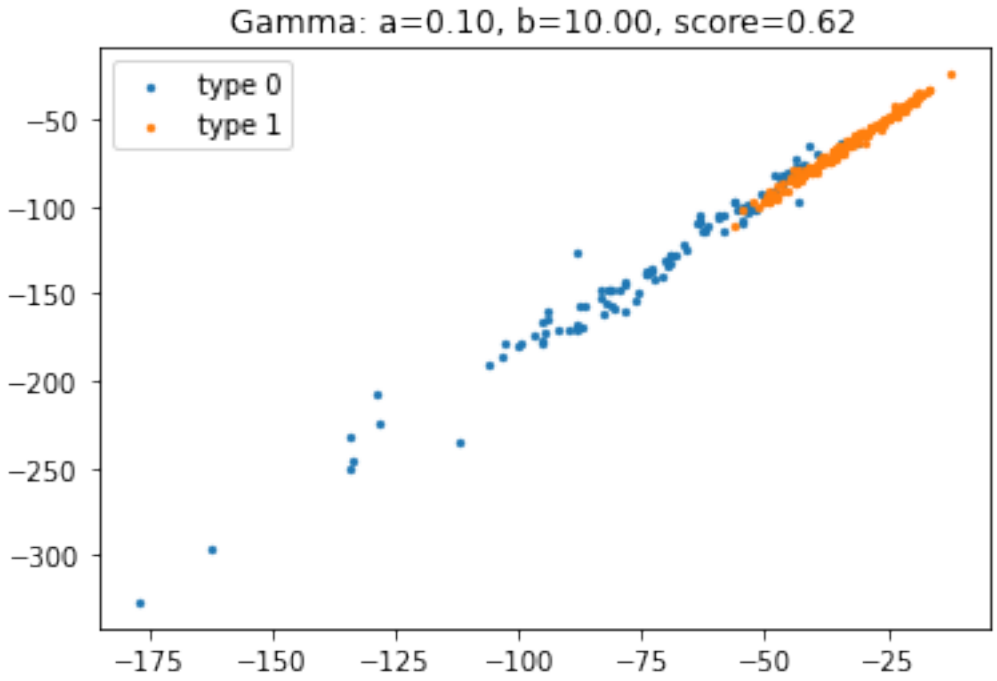
a	b	score
1.71&	2.43&	0.389\\
1.00&	2.68&	0.389\\
1.29&	2.54&	0.382\\
1.43&	3.32&	0.382\\
1.57&	3.04&	0.382\\
1.86&	3.21&	0.382\\

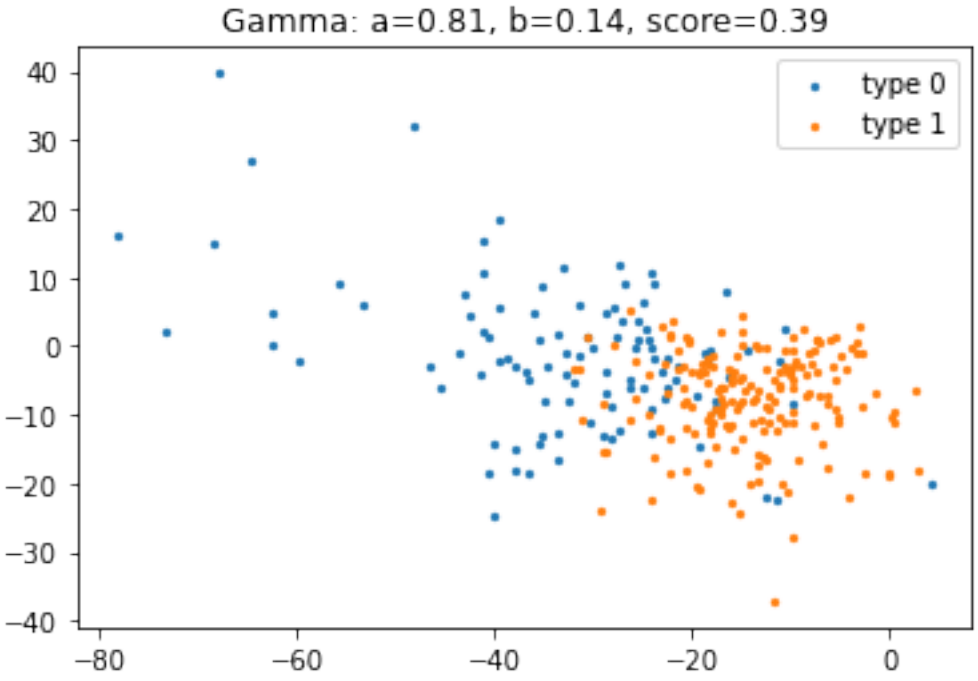
```
2.00&    3.04&    0.382\\
2.00&    3.14&    0.382\\
2.00&    3.57&    0.382\\
1.57&    2.71&    0.382\\
```

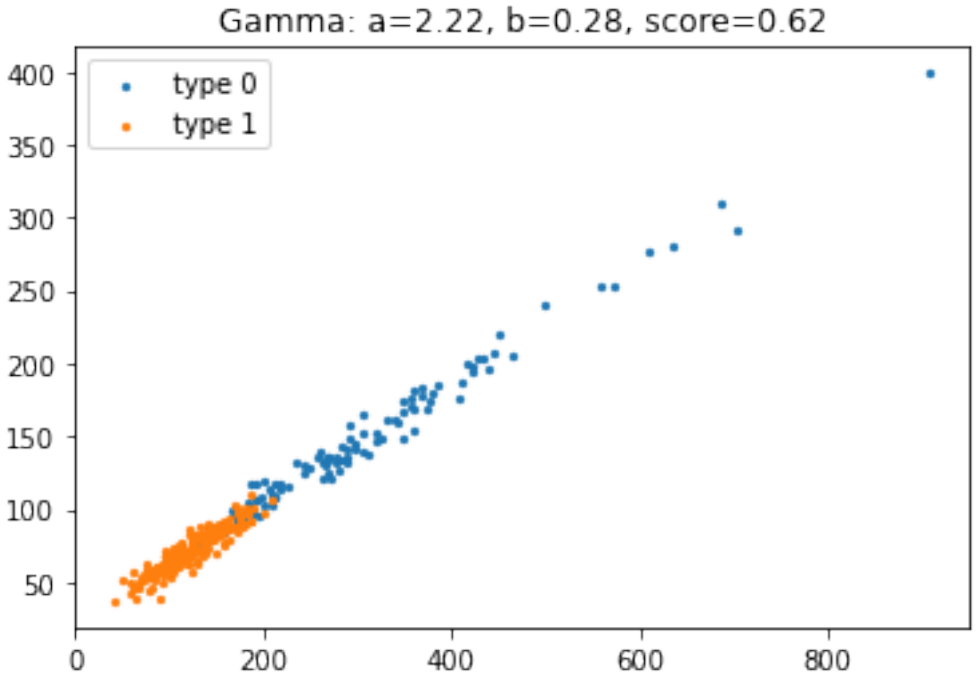
[46]:
```
# do gamma testing
def gamma_testing(X_train,y_train,X_test,y_test,n,Classifier,params,plot=True):


    as_ = gamma_params['a']
    scales = gamma_params['scale']
    i=0
    scores = np.zeros((len(as_)*len(scales),3))


    for a in as_:
        for scale in scales:
            # first we apply noise
            X_train_noise = noiser(X_train, 'gamma', (a,0,scale))
            X_test_noise = noiser(X_test, 'gamma', (a,0,scale))

            # next we apply pca
            train_data = pca(X_train_noise)
            test_data = pca(X_test_noise)

            # finally we test and train a classifier and examine the
            # score
            classifier = Classifier(**params)
            classifier.fit(train_data, y_train)

            # score the classifier and record it
            score = sum(classifier.predict(test_data) == y_test) / len(y_test)
            scores[i] = (a,1/scale,score)

            # every once and a while we plot the results
            if i%25 == 0 and plot:
                title_format = 'Gamma: a={a:.2f}, b={b:.2f}, score={score:.2f}'
                title = title_format.format(a=a, b=1/scale, score=scores[i,2])
                plot_data(train_data, y_train, n, title)


            i+=1

    return scores
```

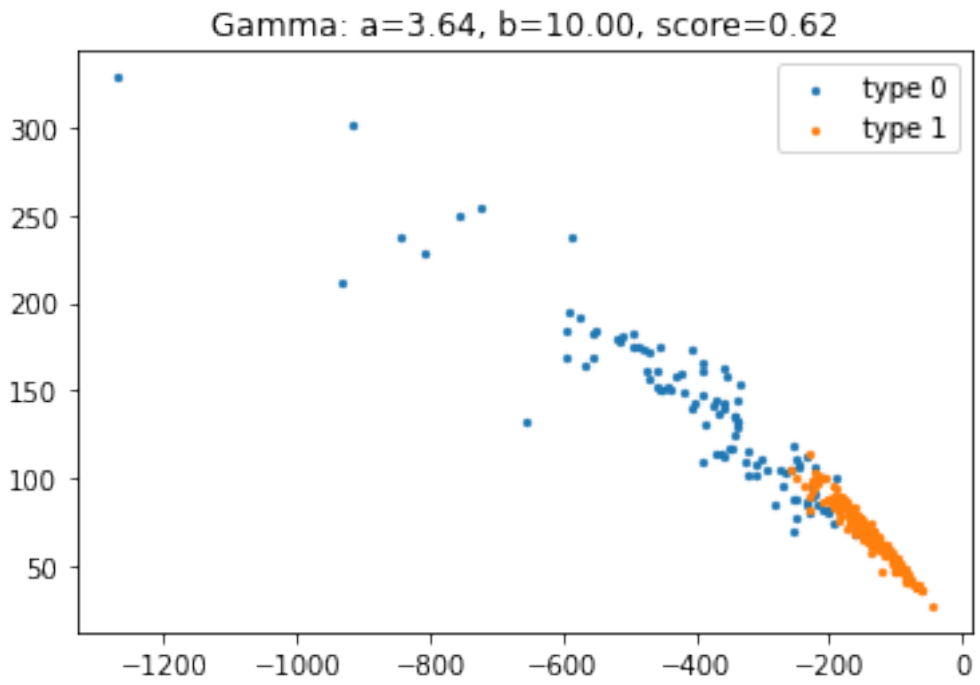
[47]:
```
# test gamma with random forest
# get the scores
```

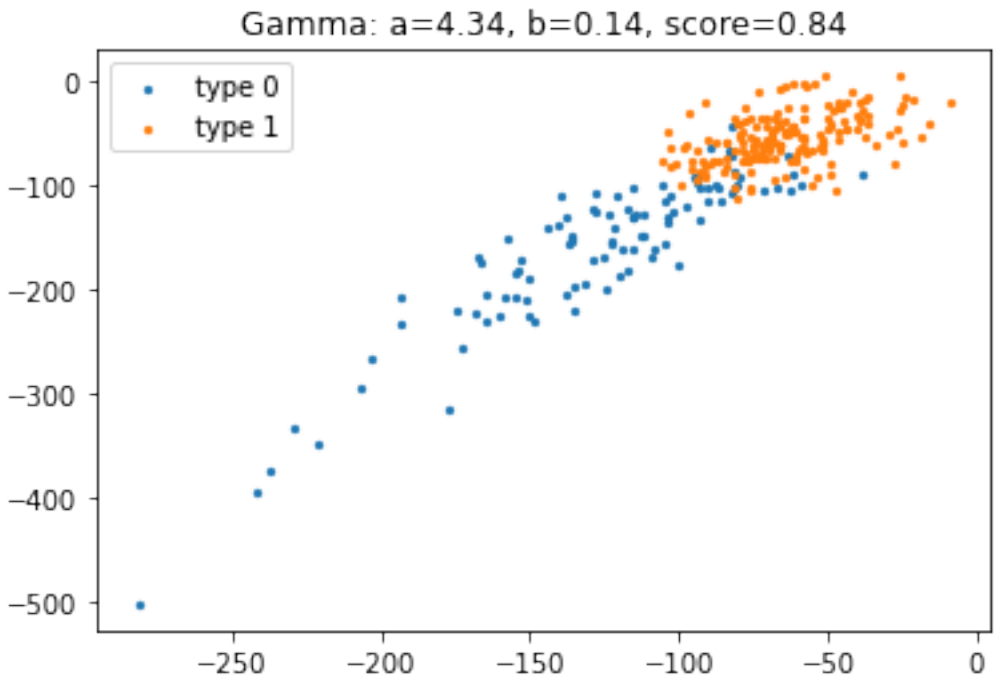
```
scores = gamma_testing(
    can_X_train, can_y_train, can_X_test, can_y_test, 2,
    RandomForestClassifier, {'n_estimators':50, 'max_depth':10}
)

print('\nGAMMA WITH RANDOM FOREST\n')

# print the best results
best_performance = np.argsort(scores[:,2])[::-1][:10]
print(f'The 10 best performing parameters are :')
print('\ta\tb\tscore')
print('\t'+'--'*len('\tdf\tscore'))
row_format = '\t{a:.2f}&\t{b:.2f}&\t{score:.3f}\\\\'
for best in best_performance:
    a,b,score = scores[best]
    print(row_format.format(a=a,b=b,score=score))

# print the worst results
worst_performance = np.argsort(scores[:,2])[::-1][-10:]
print(f'The 10 worst performing parameters are :')
print('\ta\tb\tscore')
print('\t'+'--'*len('\tdf\tscore'))
row_format = '\t{a:.2f}&\t{b:.2f}&\t{score:.3f}\\\\'
for worst in worst_performance:
    a,b,score = scores[worst]
    print(row_format.format(a=a,b=b,score=score))
```

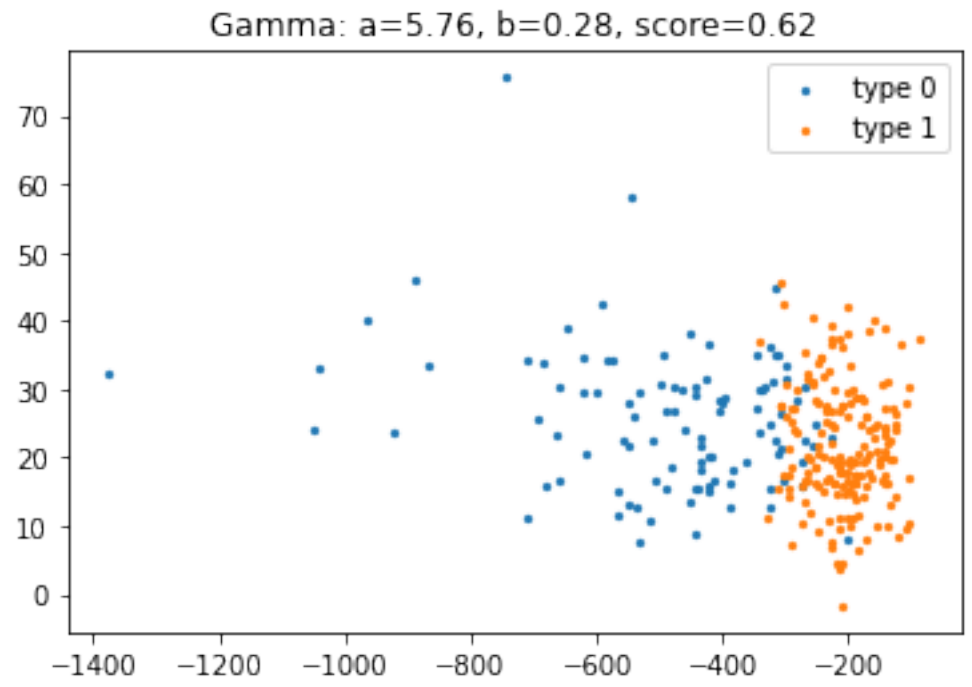


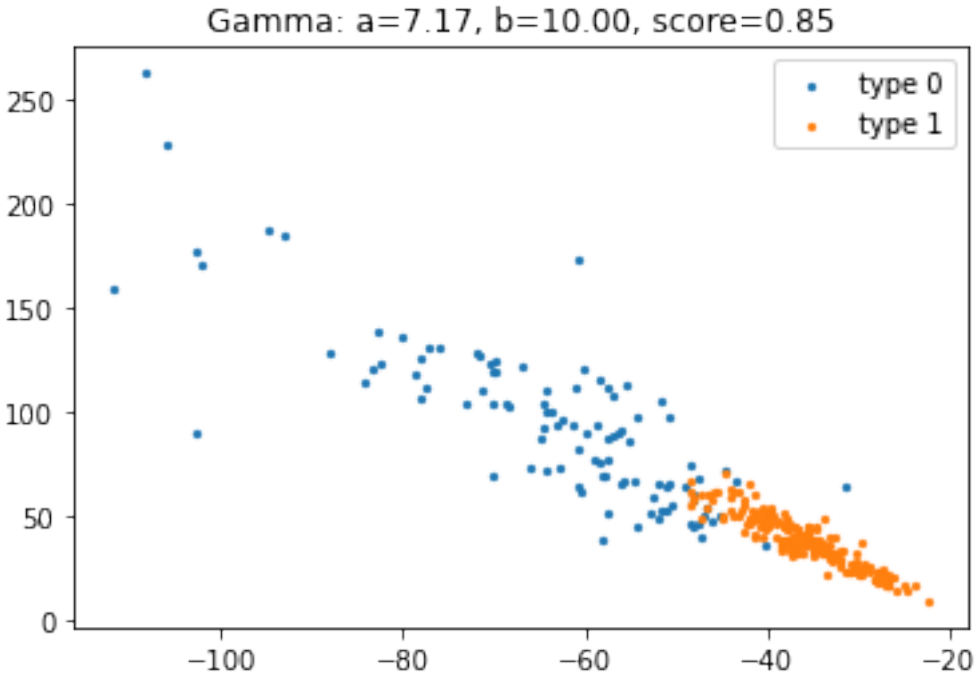

Gamma: a=0.81, b=0.14, score=0.39
type 0
type 1
40
30
20
10
0
−10
−20
−30
−40
−80
−60
−40
−20
0

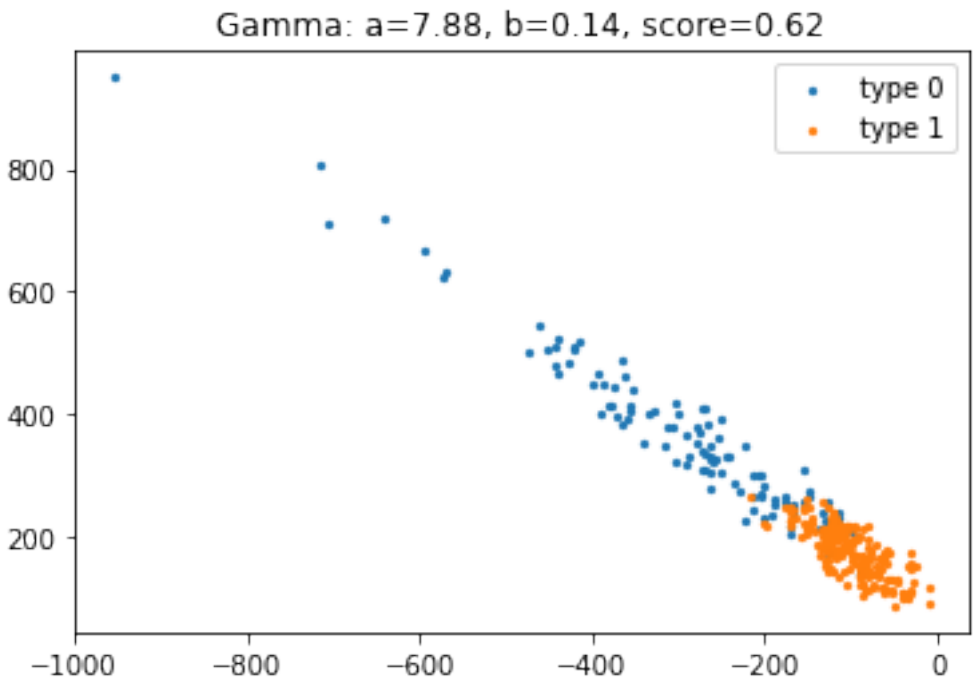

Gamma: a=2.22, b=0.28, score=0.62
type 0
type 1
400
350
300
250
200
150
100
50
0
200
400
600
800

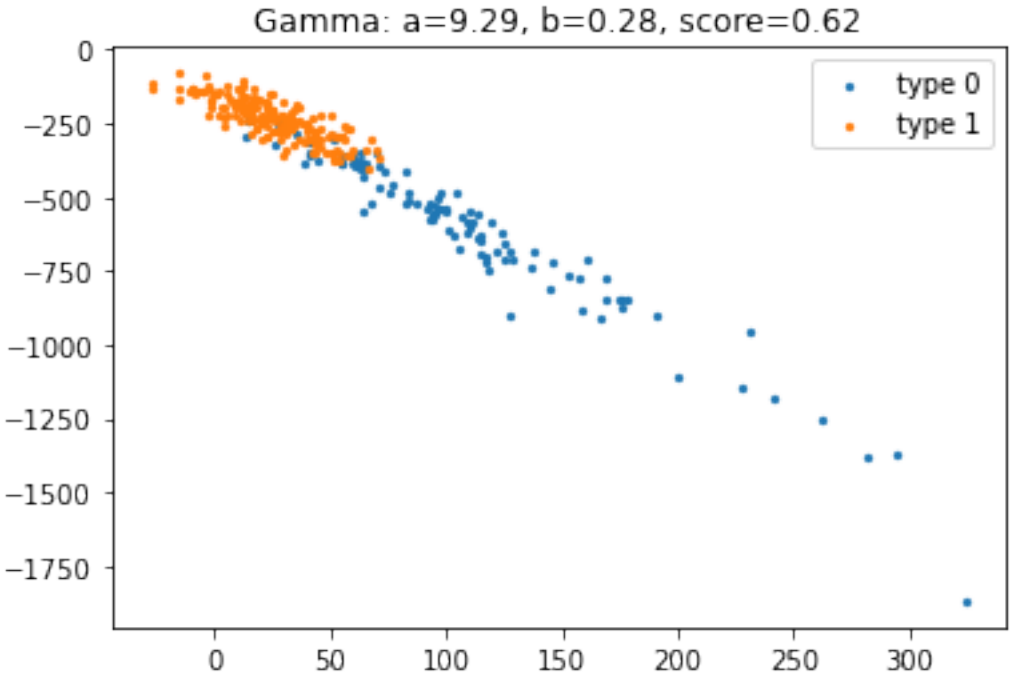

Gamma: a=3.64, b=10.00, score=0.62
type 0
type 1
300
250
200
150
100
50
−1200
−1000
−800
−600
−400
−200
0


Gamma: a=4.34, b=0.14, score=0.84
type 0
type 1
0
−100
−200
−300
−400
−500
−250
−200
−150
−100
−50
0


Gamma: a=5.76, b=0.28, score=0.62
type 0
type 1
70
60
50
40
30
20
10
0
−1400
−1200
−1000
−800
−600
−400
−200


Gamma: a=7.17, b=10.00, score=0.85
type 0
type 1
250
200
150
100
50
0
−100
−80
−60
−40
−20



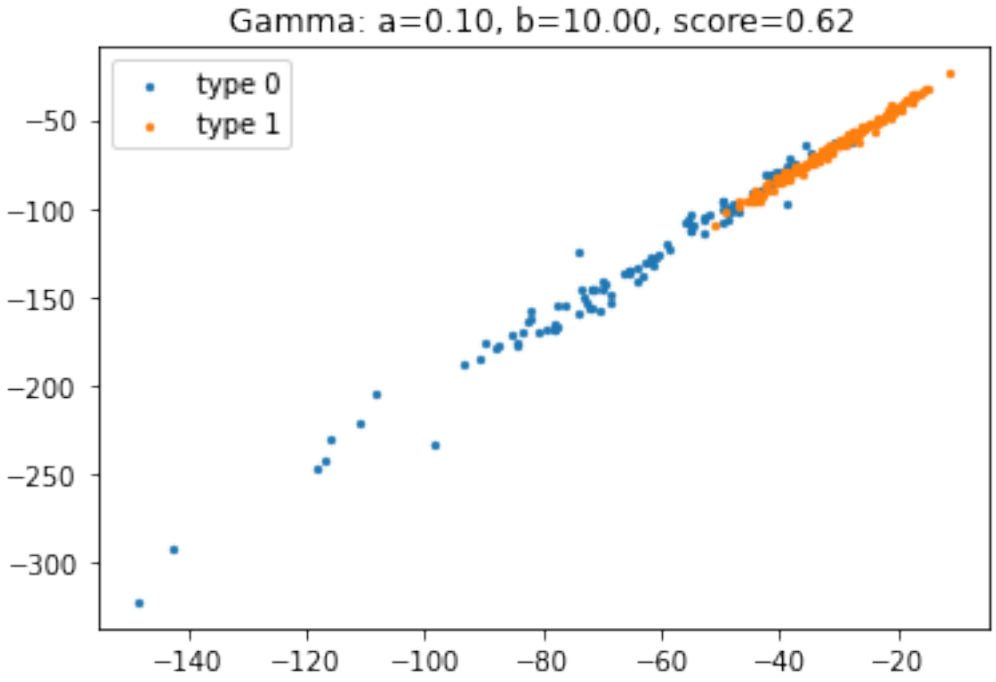


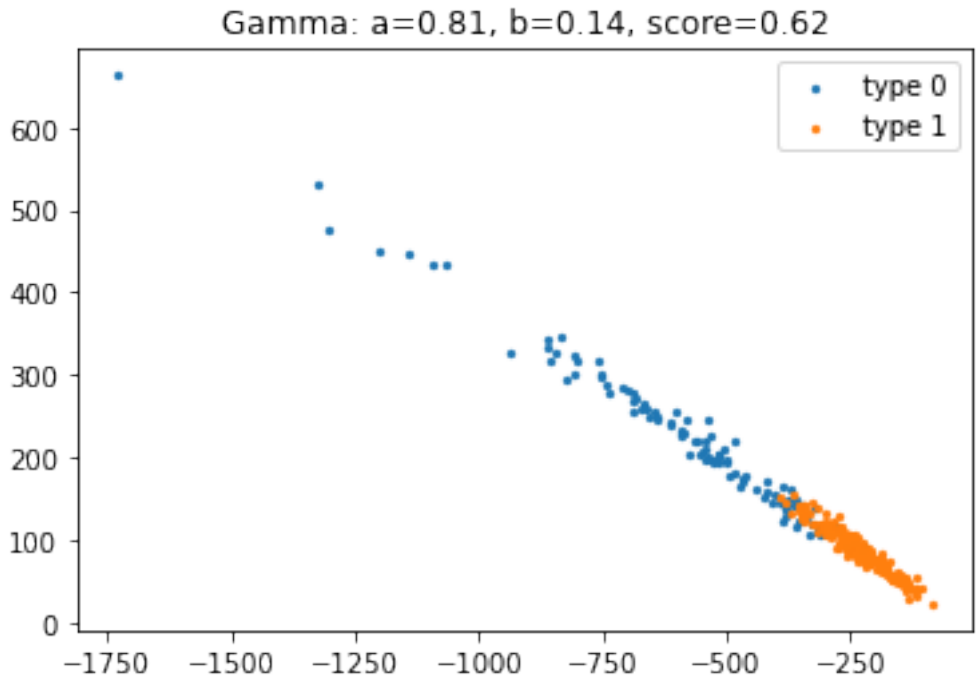
GAMMA WITH RANDOM FOREST

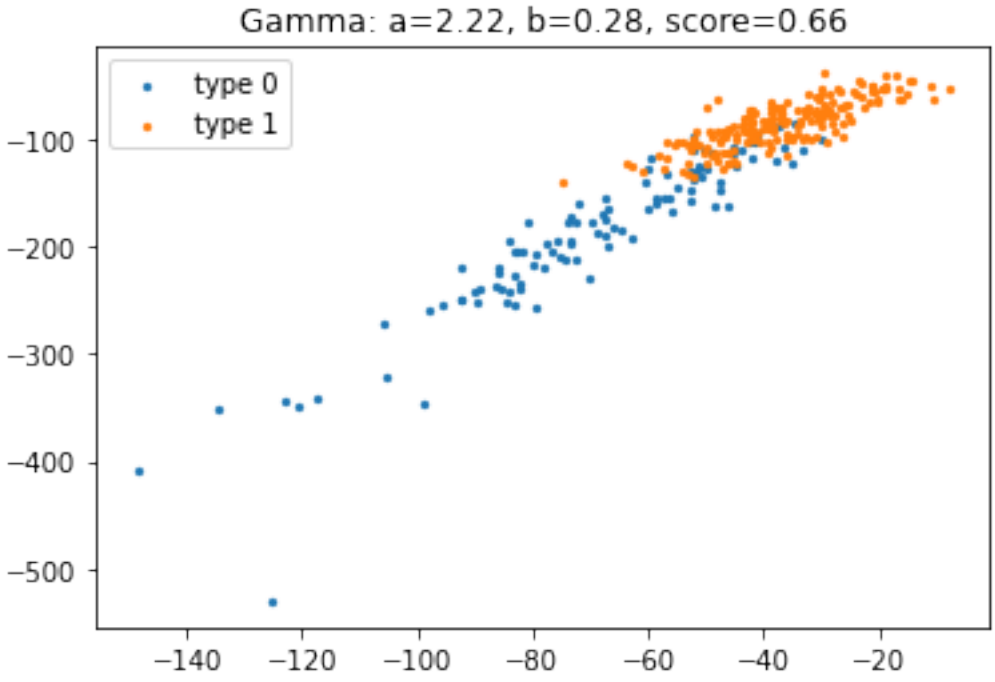
```
The 10 best performing parameters are :
        a       b       score
        ------------------
        2.22&   0.45&   0.909\\
        3.64&   0.34&   0.895\\
        10.00&  0.28&   0.891\\
        0.81&   0.23&   0.891\\
        0.81&   0.17&   0.881\\
        1.51&   0.14&   0.877\\
        0.10&   0.15&   0.870\\
        8.59&   0.11&   0.867\\
        1.51&   0.28&   0.867\\
        7.17&   10.00&  0.846\\
The 10 worst performing parameters are :
        a       b       score
        ------------------
        2.93&   0.20&   0.382\\
        8.59&   0.20&   0.382\\
        8.59&   1.24&   0.382\\
        7.88&   0.10&   0.382\\
        2.22&   10.00&  0.382\\
        7.88&   0.17&   0.382\\
        3.64&   1.24&   0.382\\
        9.29&   10.00&  0.382\\
        1.51&   0.66&   0.347\\
        5.76&   0.10&   0.249\\
```

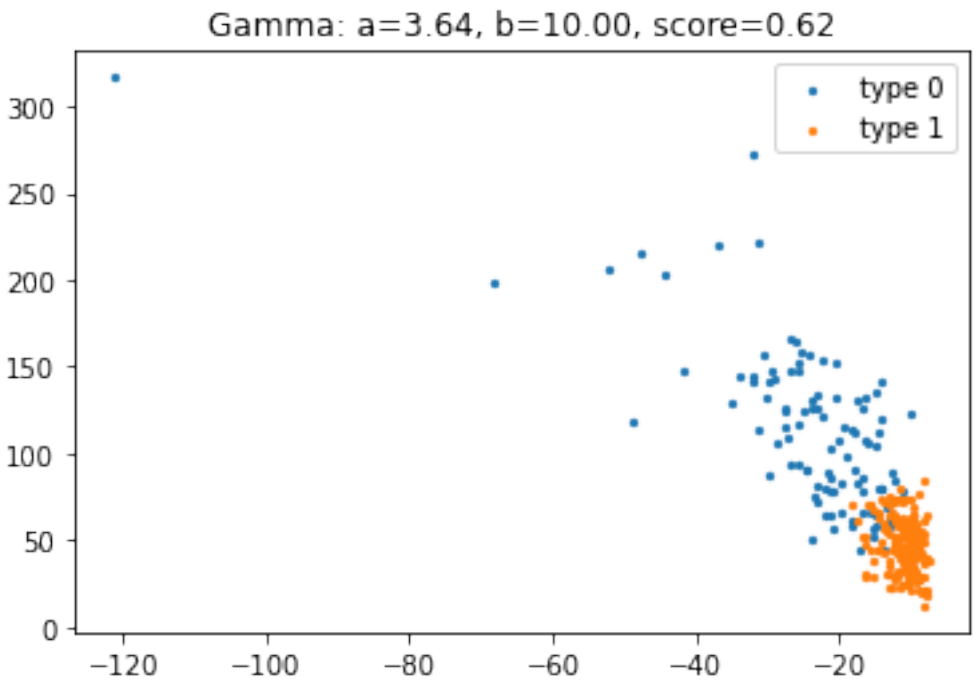
[48]:
```python
# test Gamma with k-neighbors classifier
scores = gamma_testing(
    can_X_train, can_y_train, can_X_test, can_y_test, 2,
    KNeighborsClassifier, {'n_neighbors':3}, plot=True
)

print('\nGAMMA WITH K-NEIGHBORS\n')

# print the best results
best_performance = np.argsort(scores[:,2])[::-1][:10]
print(f'The 10 best performing parameters are :')
print('\ta\tb\tscore')
print('\t'+'--'*len('\tdf\tscore'))
row_format = '\t{a:.2f}&\t{b:.2f}&\t{score:.3f}\\\\'
for best in best_performance:
    a,b,score = scores[best]
    print(row_format.format(a=a,b=b,score=score))

# print the worst results
```

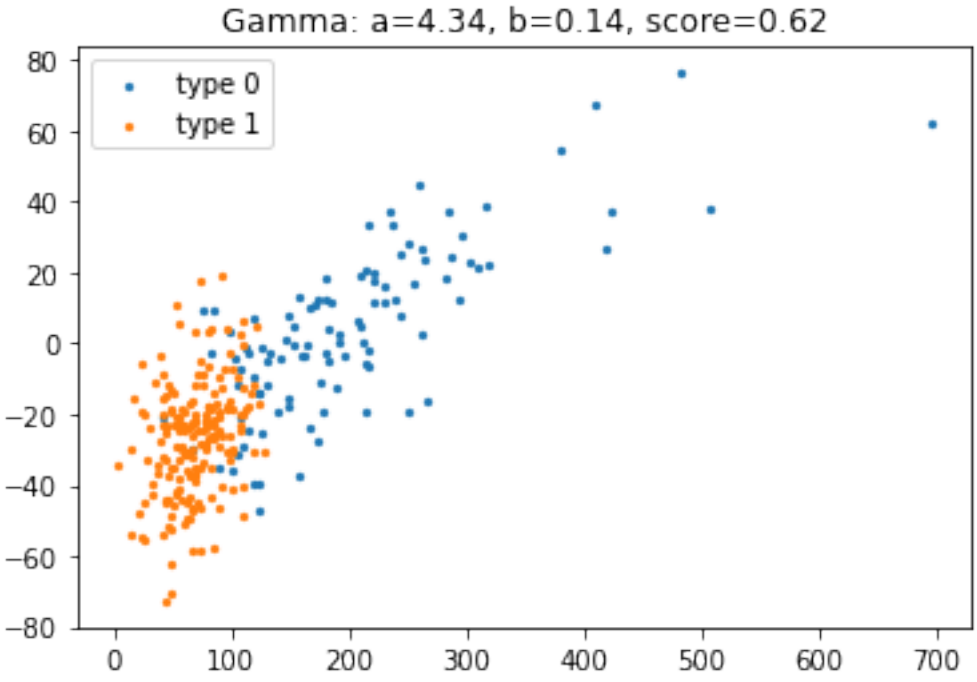
```
worst_performance = np.argsort(scores[:,2])[::-1][-10:]
print(f'The 10 worst performing parameters are :')
print('\ta\tb\tscore')
print('\t'+'--'*len('\tdf\tscore'))
row_format = '\t{a:.2f}&\t{b:.2f}&\t{score:.3f}\\\\'
for worst in worst_performance:
    a,b,score = scores[worst]
    print(row_format.format(a=a,b=b,score=score))
```

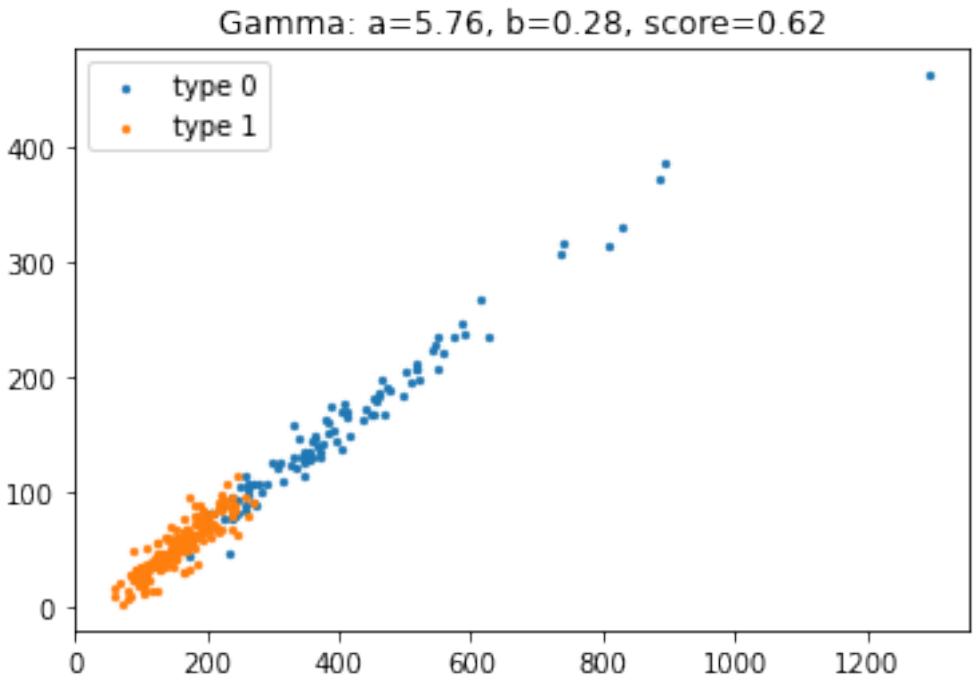


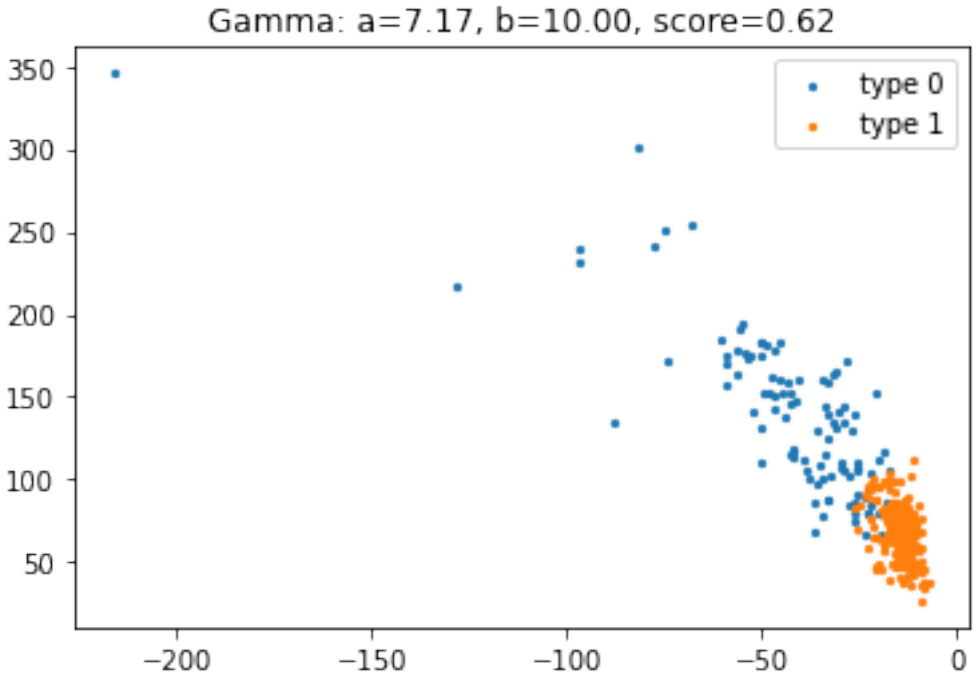

Gamma: a=0.81, b=0.14, score=0.62
type 0
type 1
600
500
400
300
200
100
0
−1750
−1500
−1250
−1000
−750
−500
−250

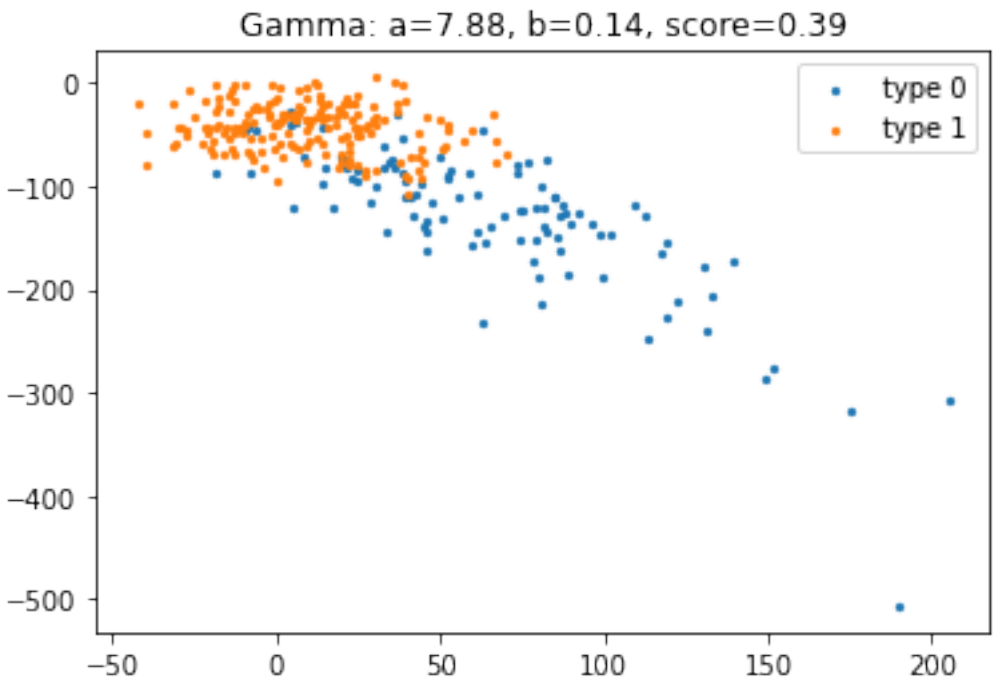

Gamma: a=2.22, b=0.28, score=0.66
type 0
type 1
−100
−200
−300
−400
−500
−140
−120
−100
−80
−60
−40
−20

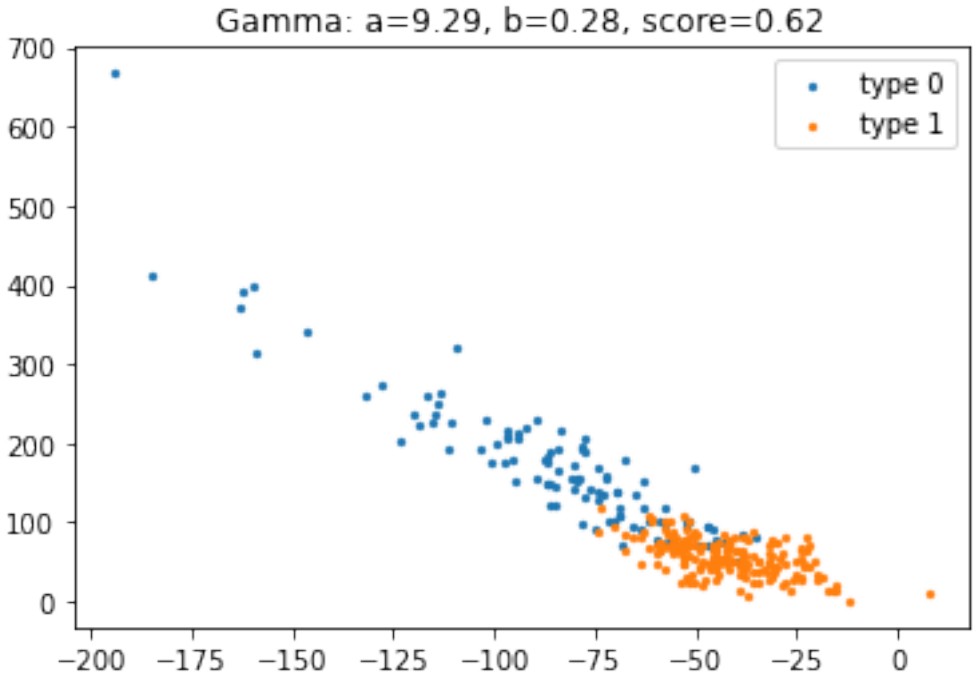

Gamma: a=3.64, b=10.00, score=0.62
type 0
type 1
300
250
200
150
100
50
0
−120
−100
−80
−60
−40
−20


Gamma: a=4.34, b=0.14, score=0.62
type 0
type 1
80
60
40
20
0
−20
−40
−60
−80
0
100
200
300
400
500
600
700


Gamma: a=5.76, b=0.28, score=0.62
type 0
type 1
400
300
200
100
0
0
200
400
600
800
1000
1200


Gamma: a=7.17, b=10.00, score=0.62
type 0
type 1
350
300
250
200
150
100
50
−200
−150
−100
−50
0





GAMMA WITH K-NEIGHBORS

```
The 10 best performing parameters are :
        a       b       score
        ------------------
        2.22&   0.66&   0.905\\
        1.51&   0.15&   0.898\\
        1.51&   0.20&   0.895\\
        7.88&   0.28&   0.891\\
        0.10&   0.12&   0.888\\
        2.93&   0.13&   0.888\\
        2.93&   0.12&   0.884\\
        4.34&   0.12&   0.881\\
        4.34&   0.23&   0.881\\
        7.17&   0.11&   0.877\\
The 10 worst performing parameters are :
        a       b       score
        ------------------
        5.05&   1.24&   0.407\\
        6.46&   0.15&   0.386\\
        4.34&   0.66&   0.386\\
        7.88&   0.14&   0.386\\
        4.34&   0.45&   0.382\\
        1.51&   0.17&   0.382\\
        9.29&   0.10&   0.382\\
        7.88&   1.24&   0.382\\
        0.10&   1.24&   0.382\\
        3.64&   0.28&   0.382\\
```

[ ]:

[ ]: