# vowels

April 17, 2022

[ ]:
```
import numpy as np
import pandas as pd
import math

import nltk


#load the csv of formant data from PRAAT
formants_df = pd.read_csv("formants.csv")
formants_df.head()
# formants_df["index"] =
# formants_df["stressed"] = " "
# for index in formants_df.index:
#     if formants_df.syllable[index] == 1 :
#         formants_df.stressed[index] = "stress"
#     else:
#         formants_df.stressed[index] = "unstressed"
# formants_df.tail()




formants_df = formants_df.astype({"syllable":"object","Filename":"object"})

# seg_freq = nltk.FreqDist(formants_df.segment)
# seg_freq
# segments = []
# for index, item in enumerate(seg_freq):
#     segments.append(item)
# print(len(segments))
# seg_freq


formants_df.info()
# Three measures of the relationship between the speaking style and vowel space␣
 ↪were used: vowel space area, vowel space dispersion (both following Bradlow␣
 ↪et al., 1996) and vowel peripheralization.
```

```
# Vowel space area was measured as the Euclidean area covered by the triangle␣
 ↪defined by the mean of each vowel category.
# Vowel space dispersion was measured as the distance of each vowel from the␣
 ↪central point in the talker's F1×F2 space.

# #An overall vowel space dispersion value for each talker was then calculated␣
 ↪as the mean of these distances. Finally, the extent of peripheralization in␣
 ↪clear speech relative to conversational speech was measured for each vowel␣
 ↪category separately. Here, the Euclidean distance in the F1×F2 space between␣
 ↪the average location of each vowel in conversational and in clear speech was␣
 ↪calculated separately for each talker and each vowel category.

# corners_df.head()
```

```
---------------------------------------------------------------------------
FileNotFoundError                         Traceback (most recent call last)
/var/folders/s2/hj078vmj60j2qr4wwsp2bgvm0000gp/T/ipykernel_85013/2837120326.py␣
 ↪in <module>
      7
      8 #load the csv of formant data from PRAAT
----> 9 formants_df = pd.read_csv("formants.csv")
     10 formants_df.head()
     11 # formants_df["index"] =

~/miniconda3/envs/soundmines/lib/python3.9/site-packages/pandas/util/_decorator␣
 ↪py in wrapper(*args, **kwargs)
    309                     stacklevel=stacklevel,
    310                 )
--> 311             return func(*args, **kwargs)
    312
    313         return wrapper

~/miniconda3/envs/soundmines/lib/python3.9/site-packages/pandas/io/parsers/
 ↪readers.py in read_csv(filepath_or_buffer, sep, delimiter, header, names,␣
 ↪index_col, usecols, squeeze, prefix, mangle_dupe_cols, dtype, engine,␣
 ↪converters, true_values, false_values, skipinitialspace, skiprows, skipfooter␣
 ↪nrows, na_values, keep_default_na, na_filter, verbose, skip_blank_lines,␣
 ↪parse_dates, infer_datetime_format, keep_date_col, date_parser, dayfirst,␣
 ↪cache_dates, iterator, chunksize, compression, thousands, decimal,␣
 ↪lineterminator, quotechar, quoting, doublequote, escapechar, comment,␣
 ↪encoding, encoding_errors, dialect, error_bad_lines, warn_bad_lines,␣
 ↪on_bad_lines, delim_whitespace, low_memory, memory_map, float_precision,␣
 ↪storage_options)
    584     kwds.update(kwds_defaults)
    585
--> 586     return _read(filepath_or_buffer, kwds)
    587
    588
```

```
~/miniconda3/envs/soundmines/lib/python3.9/site-packages/pandas/io/parsers/
↪readers.py in _read(filepath_or_buffer, kwds)
    480
    481     # Create the parser.
--> 482     parser = TextFileReader(filepath_or_buffer, **kwds)
    483
    484     if chunksize or iterator:

~/miniconda3/envs/soundmines/lib/python3.9/site-packages/pandas/io/parsers/
↪readers.py in __init__(self, f, engine, **kwds)
    809             self.options["has_index_names"] = kwds["has_index_names"]
    810
--> 811         self._engine = self._make_engine(self.engine)
    812
    813     def close(self):

~/miniconda3/envs/soundmines/lib/python3.9/site-packages/pandas/io/parsers/
↪readers.py in _make_engine(self, engine)
   1038             )
   1039         # error: Too many arguments for "ParserBase"
-> 1040         return mapping[engine](self.f, **self.options)  # type:␣
↪ignore[call-arg]
   1041
   1042     def _failover_to_python(self):

~/miniconda3/envs/soundmines/lib/python3.9/site-packages/pandas/io/parsers/
↪c_parser_wrapper.py in __init__(self, src, **kwds)
     49
     50         # open handles
---> 51         self._open_handles(src, kwds)
     52         assert self.handles is not None
     53

~/miniconda3/envs/soundmines/lib/python3.9/site-packages/pandas/io/parsers/
↪base_parser.py in _open_handles(self, src, kwds)
    220         Let the readers open IOHandles after they are done with their␣
↪potential raises.
    221         """
--> 222         self.handles = get_handle(

    223             src,
    224             "r",

~/miniconda3/envs/soundmines/lib/python3.9/site-packages/pandas/io/common.py in␣
↪get_handle(path_or_buf, mode, encoding, compression, memory_map, is_text,␣
↪errors, storage_options)
    700         if ioargs.encoding and "b" not in ioargs.mode:
    701             # Encoding
```

```
--> 702             handle = open(
    703                 handle,
    704                 ioargs.mode,

FileNotFoundError: [Errno 2] No such file or directory: 'formants.csv'
```

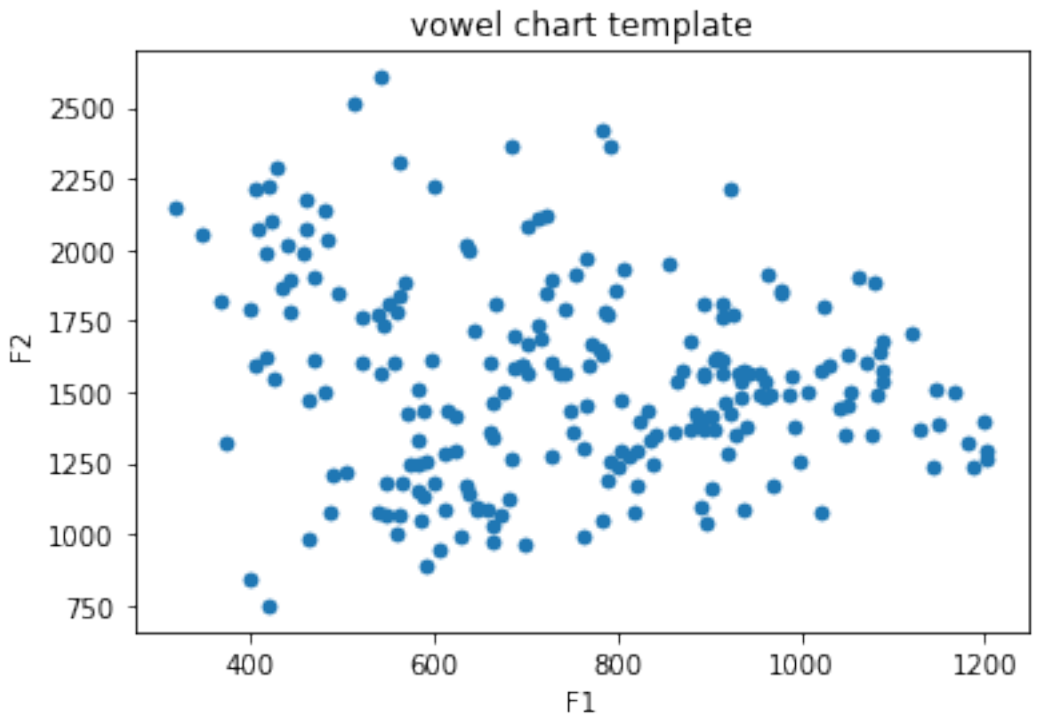
[ ]:
```
tilt_df = pd.read_csv("tilt.csv")
tilt_df.head()
```

[ ]:

| | Filename | label | segment | syllable | h1 | h2 | h1-h2 |
|---|---|---|---|---|---|---|---|
| 0 | 9 | ictus | | 1 | -25.737893 | -1.831221 | -23.906673 |
| 1 | 9 | ictus | i | 1 | -8.604446 | 11.610210 | -20.214656 |
| 2 | 9 | ictus | ui | 1 | -20.345912 | 3.949618 | -24.295530 |
| 3 | 9 | ictus | i | 1 | -9.482358 | 10.368143 | -19.850501 |
| 4 | 9 | ictus | æ | 1 | -40.308210 | -0.657925 | -39.650284 |

[ ]:
```
ictus_df = formants_df[formants_df.position=="ictus"]
ictus_df.head()


plotvar = ictus_df.plot.scatter(x="F1", y="F2",title="vowel chart template")
plotvar.set_xlabel("F1")
plotvar.set_ylabel("F2")
```

[ ]:
```
Text(0, 0.5, 'F2')
```



[ ]:

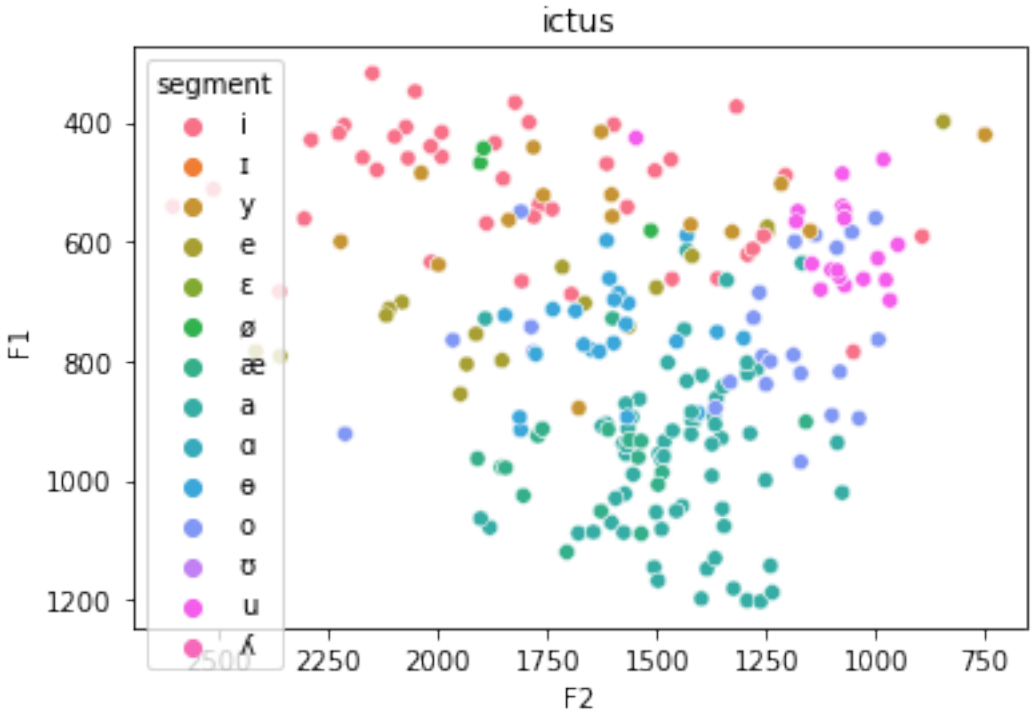
```
14
```

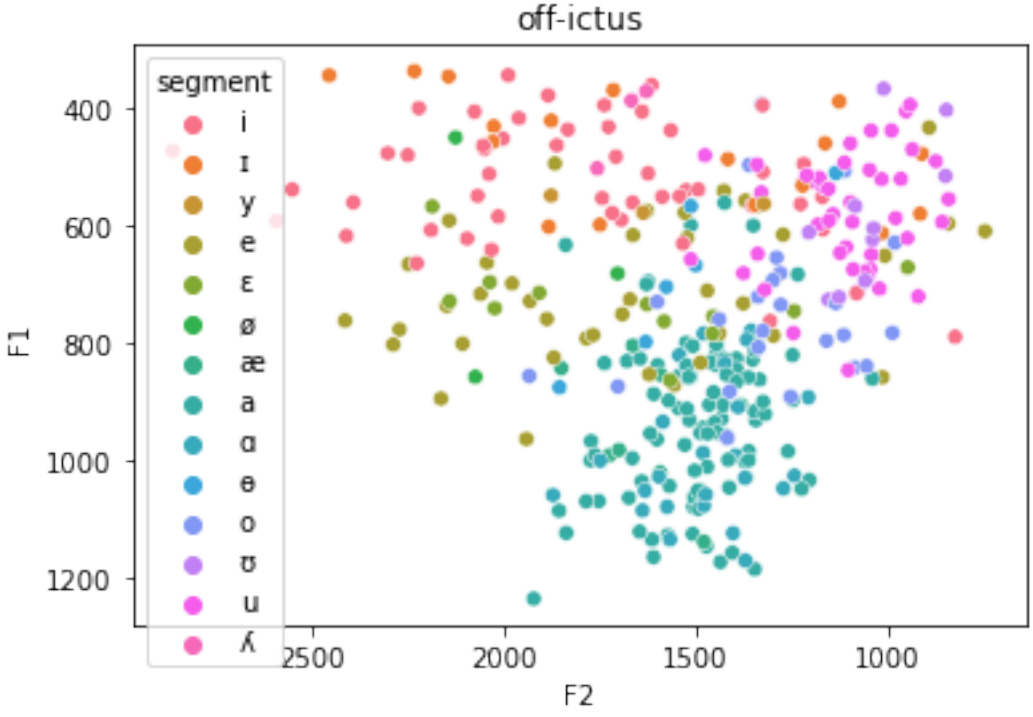
[ ]:
```
FreqDist({'a': 226, 'i': 135, 'u': 82, 'o': 75, 'e': 74, ' ': 50, 'æ': 42, 'y':
33, ' ': 25, ' ': 17, …})
```

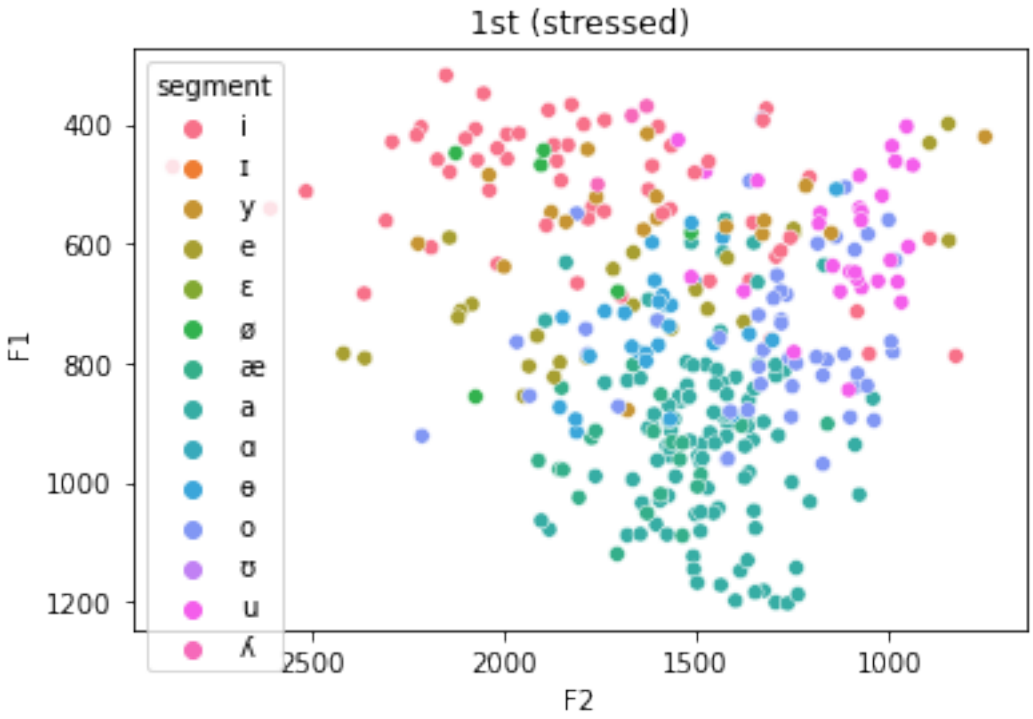
[ ]:
```
import numpy as np
import matplotlib.pyplot as plt
import matplotlib as mpl
import seaborn as sns
import pandas as pd


ictus_df = formants_df[formants_df.position=="ictus"]
off_ictus_df = formants_df[formants_df.position=="off"]


first_df = formants_df[formants_df.syllable==1]
second_df = formants_df[formants_df.syllable==2]

first_ictus_df = formants_df[(formants_df.syllable==1)& (formants_df.
↪position=="ictus")]
second_ictus_df = formants_df[(formants_df.syllable==2)& (formants_df.
↪position=="ictus")]
first_off_df = formants_df[(formants_df.syllable==1)& (formants_df.
↪position=="off")]
second_off_df = formants_df[(formants_df.syllable==2)& (formants_df.
↪position=="off")]

twoWay = [ictus_df,off_ictus_df,first_df,second_df,␣
↪first_ictus_df,second_ictus_df,first_off_df,second_off_df]
twoLabels = ["ictus","off-ictus","1st (stressed)","2nd (unstressed)","stressed␣
↪and ictus", "unstressed and ictus","stressed off-ictus", "unstressed␣
↪off-ictus"]

seg_order = ["i"," ","y","e"," ","ø","æ","a"," "," ","o"," ","u"," " ]
eesti_colors = ['#f77189', '#ef7d32', '#c69432', '#a79f31', '#82a931',␣
↪'#32b24e', '#34af8a', '#36ada4', '#37aabb', '#3aa6da', '#8197f4', '#c180f4',␣
↪'#f45deb', '#f669ba']
seg_colors = {}
for index,item in enumerate(seg_order):
    seg_colors[item] = eesti_colors

# # vowDict = vow_space_df.to_dict('index')
```

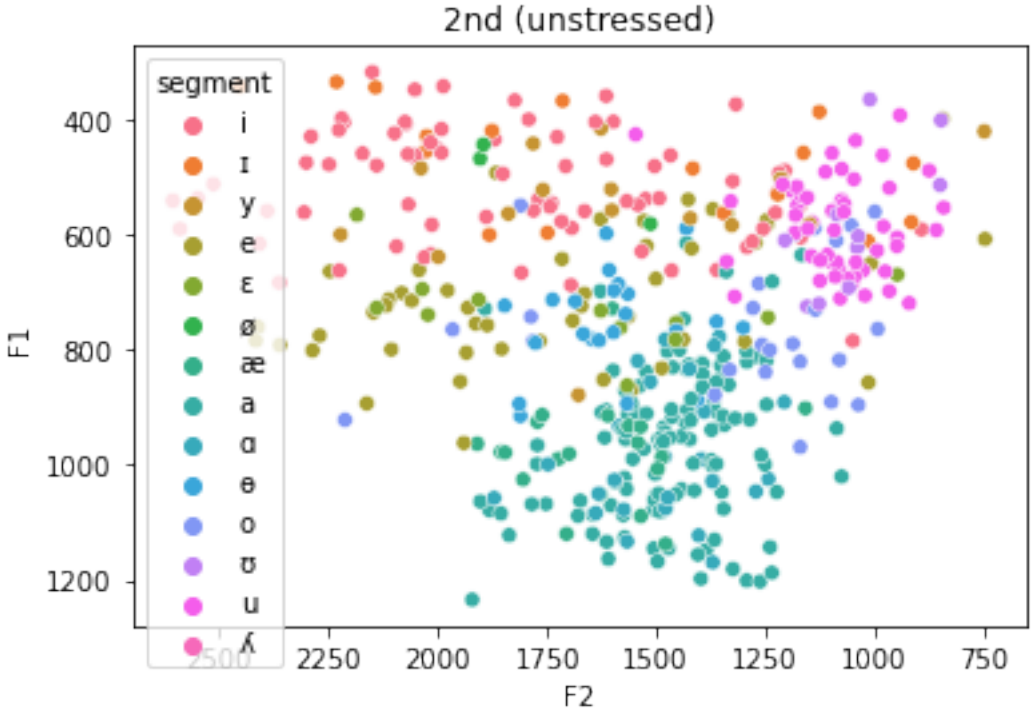
```
# # vowDict
def vowelCharter(data,colorby,label):
    fig, ax = plt.subplots()
    ax = sns.
 ↪scatterplot(x="F2",y="F1",data=data,hue=colorby,hue_order=seg_order)
    ax.set(title = label)
    ax.invert_xaxis()
    ax.invert_yaxis()
    # fig2, ax2 = plt.subplots()
    # ax2 = sns.kdeplot(data = data, x="F1",y="F2",hue=colorby)


def vowelChartOverlay(datalist,labellist,colorby):

    i = 0
    for item in datalist:
        fig1, ax1 = plt.subplots()
        fig1.suptitle("F1 and F2 measurements: " + labellist[i]+ " condition")
        ax1 = sns.scatterplot(x="F2",y="F1",data =␣
 ↪item,hue=colorby,hue_order=seg_colors.keys(),palette=seg_colors)
        ax2 = sns.kdeplot(data = item, x="F1",y="F2",hue=colorby)


        ax1.invert_xaxis()
        ax1.invert_yaxis()
        i += 1

def vowelSpaceArea(dataframe):
    vowel_groups = dataframe.groupby("segment")

    vow_df = vowel_groups.aggregate(np.mean)

    F1_i = vow_df.at["i","F1"]
    F2_i = vow_df.at["i","F2"]

    F1_u = vow_df.at["u","F1"]
    F2_u = vow_df.at["u","F2"]

    F1_a = vow_df.at["a","F1"]
    F2_a = vow_df.at["a","F2"]

    euc_iu = math.sqrt((F1_i - F1_u)**2 + (F2_i-F2_u)**2)
    euc_ia = math.sqrt((F1_i - F1_a)**2 + (F2_i-F2_a)**2)
    euc_au = math.sqrt((F1_a - F1_u)**2 + (F2_a-F2_u)**2)
    s = (euc_au+euc_ia+euc_iu)/2
    vsa = math.sqrt(s*(s-euc_iu)*(s-euc_au)*(s-euc_ia))
```

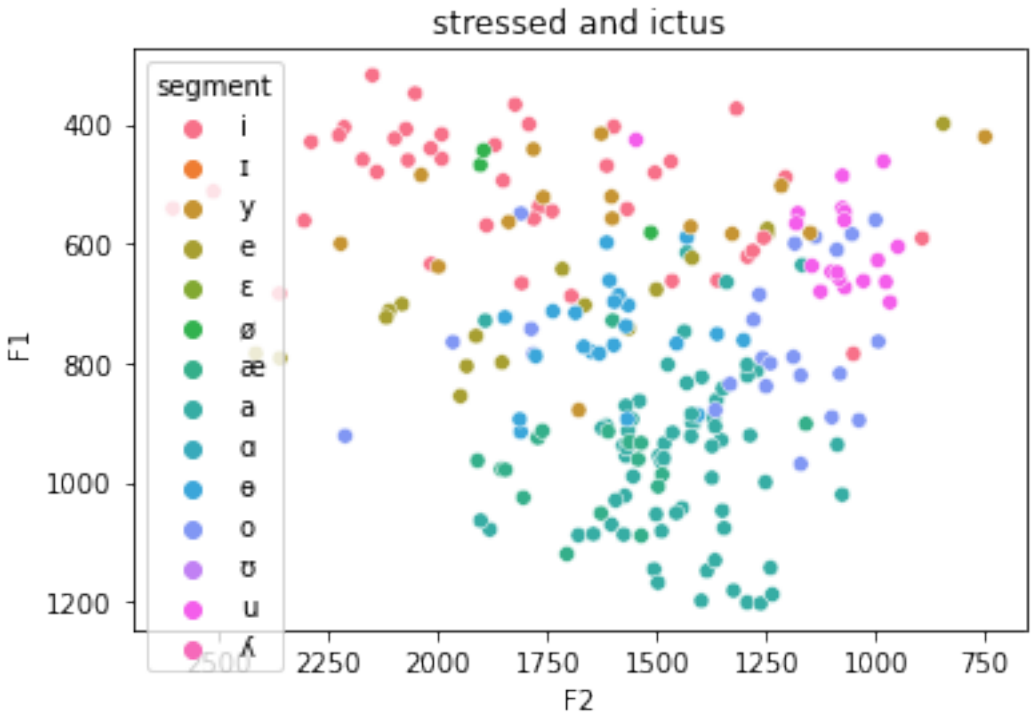
```
    return vsa

# cat_vsa = []
# for  item in twoWay:


#     mean = vowelSpaceArea(item)
#     cat_vsa.append(mean)
# cat_vsa

# vsa_dict = dict(zip(twoLabels,cat_vsa))
# vsa_dict



i = 0
for item in twoWay:
    vowelCharter(item,"segment",twoLabels[i])
    i += 1


#vowelChartOverlay(twoWay,twoLabels,"segment")
# sylchart = sns.pairplot(vow_space_df,hue="syllable")
# icKchart = sns.pairplot(vow_space_df, hue="position")

#newChart = sns.kdeplot(data = vow_space_df, x="F1",y="F2",hue="segment")

# vowelCharter(vow_space_df[vow_space_df.segment=="a"],"position")

#for item in segments:
    #vowelCharter(vow_space_df[vow_space_df.segment==item],"syllable",item)
```

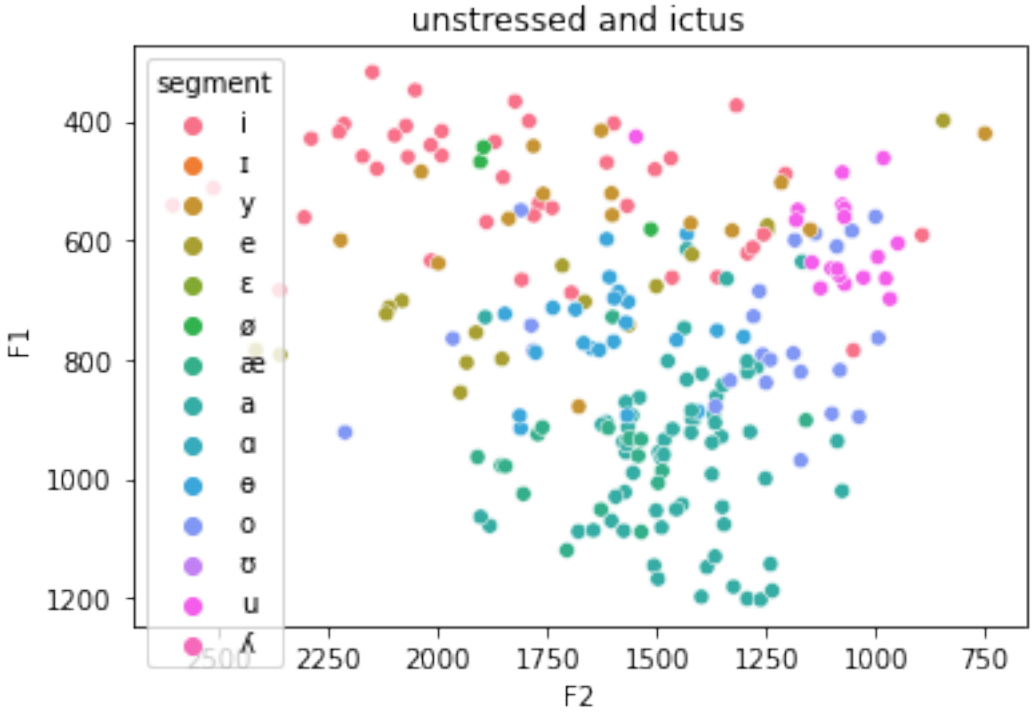

ictus
segment
i
ɪ
y
e
ɛ
ø
æ
a
ɑ
ɐ
o
ʊ
u
ʎ
F1
400
600
800
1000
1200
2500
2250
2000
1750
1500
1250
1000
750
F2

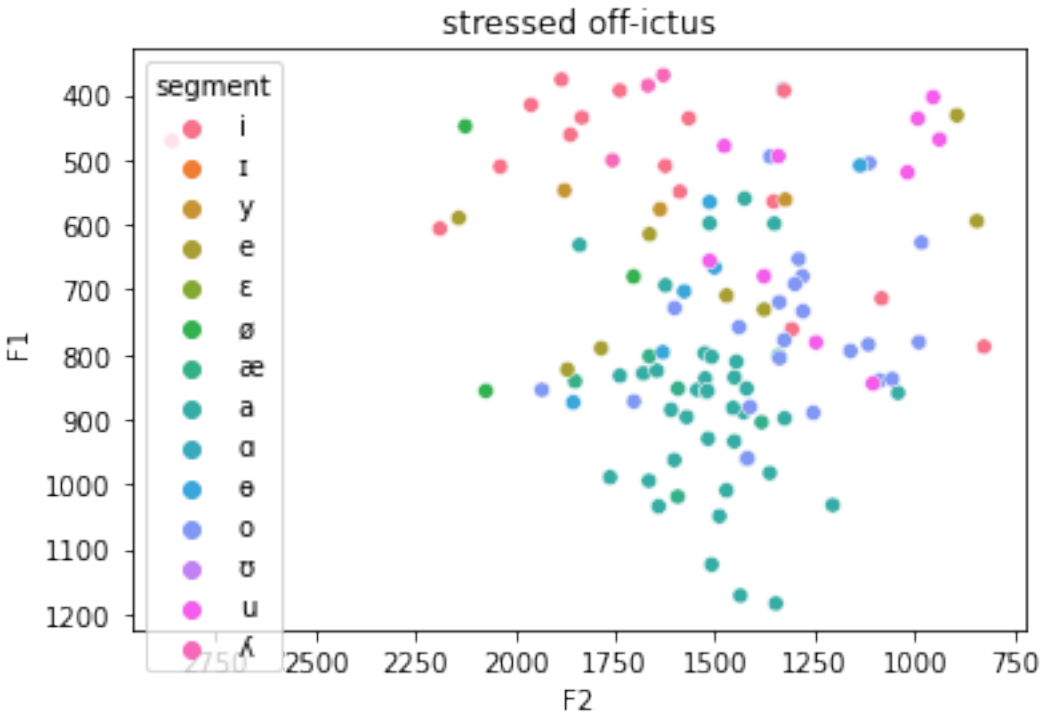

off-ictus
segment
i
ɪ
y
e
ɛ
ø
æ
a
ɑ
ɐ
o
ʊ
u
ʎ
F1
400
600
800
1000
1200
2500
2000
1500
1000
F2

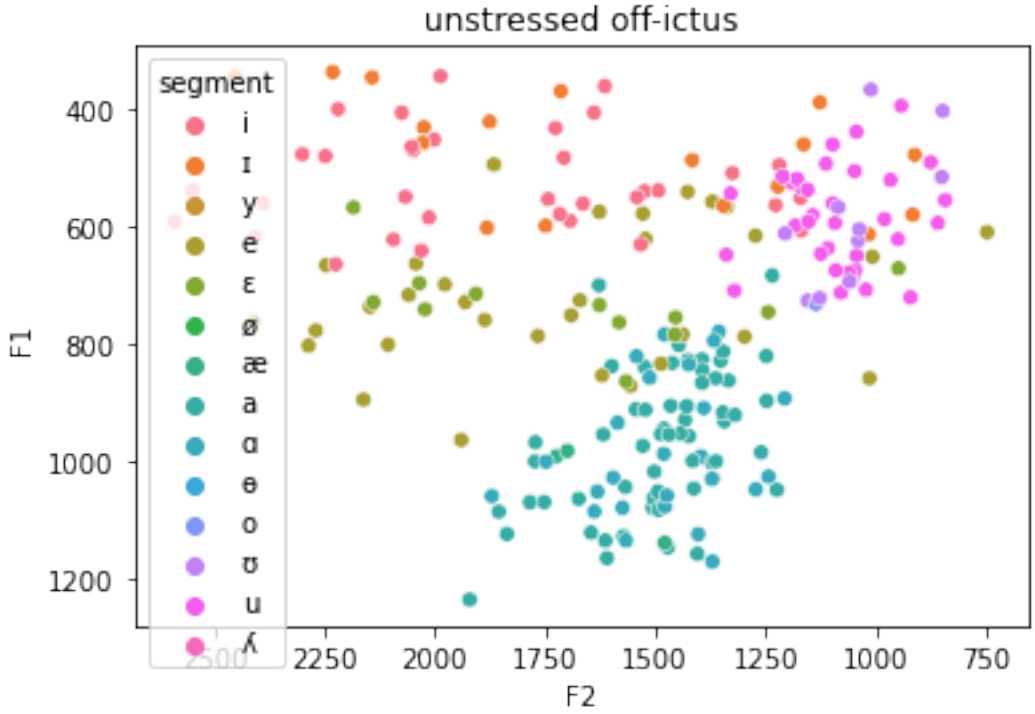

1st (stressed)
segment
i
ɪ
y
e
ɛ
ø
æ
a
ɑ
ɐ
o
ʊ
u
ʎ
F1
400
600
800
1000
1200
2500
2000
1500
1000
F2


2nd (unstressed)
segment
i
ɪ
y
e
ɛ
ø
æ
a
ɑ
ɐ
o
ʊ
u
ʎ
F1
400
600
800
1000
1200
2250
2000
1750
1500
1250
1000
750
F2


stressed and ictus
segment
i
ɪ
y
e
ɛ
ø
æ
a
ɑ
ɐ
o
ʊ
u
ʌ
F1
400
600
800
1000
1200
2500
2250
2000
1750
1500
1250
1000
750
F2


unstressed and ictus
segment
i
ɪ
y
e
ɛ
ø
æ
a
ɑ
ɐ
o
ʊ
u
ʌ
F1
400
600
800
1000
1200
2500
2250
2000
1750
1500
1250
1000
750
F2


stressed off-ictus
segment
i
ɪ
y
e
ɛ
ø
æ
a
ɑ
ɐ
o
ʊ
u
ʏ
F1
400
500
600
700
800
900
1000
1100
1200
2750
2500
2250
2000
1750
1500
1250
1000
750
F2


unstressed off-ictus
segment
i
ɪ
y
e
ɛ
ø
æ
a
ɑ
ɐ
o
ʊ
u
ʏ
F1
400
600
800
1000
1200
2500
2250
2000
1750
1500
1250
1000
750
F2

[ ]:
```
from scipy import stats
import statsmodels.formula.api as smf


a_df = formants_df[formants_df.segment==( "a" or " ") ]
i_df = formants_df[formants_df.segment==("i" or " " or "y" ) ]
u_df = formants_df[formants_df.segment==("u"or " ")]
#o_df = formants_df[formants_df.segment==("o"or " ")]



#column: euc distance from mean or mean euc distance of category







#smf.mixedlm("euc ~ position", data = a_df, groups = "performer").fit().
 ↪summary()
#smf.mixedlm("F1 ~ position", data = a_df, groups = "performer").fit().summary()
#smf.mixedlm("F2 ~ position", data = a_df, groups = "performer").fit().summary()
#smf.mixedlm("F3 ~ position", data = a_df, groups = "performer").fit().summary()


#smf.mixedlm("euc ~ stressed", data = a_df, groups = "performer").fit().
 ↪summary()
#smf.mixedlm("F1 ~ stressed", data = a_df, groups = "performer").fit().summary()
#smf.mixedlm("F2 ~ stressed", data = a_df, groups = "performer").fit().summary()
#smf.mixedlm("F3 ~ stressed", data = a_df, groups = "performer").fit().summary()

#smf.mixedlm("euc ~ position + stressed", data = a_df, groups = "performer").
 ↪fit().summary()
#smf.mixedlm("F1 ~ position + stressed", data = a_df, groups = "performer").
 ↪fit().summary()
#smf.mixedlm("F2 ~ position + stressed", data = a_df, groups = "performer").
 ↪fit().summary()
#smf.mixedlm("F3 ~ position + stressed", data = a_df, groups = "performer").
 ↪fit().summary()



def makeTables(data, variable):

    euc = smf.mixedlm("euc ~" + variable, data = data, groups = "performer").
 ↪fit().summary()
```

```
    F1 = smf.mixedlm("F1 ~ "+ variable, data = data, groups = "performer").
 ↪fit().summary()
    F2 = smf.mixedlm("F2 ~ "+ variable, data = data, groups = "performer").
 ↪fit().summary()
    F3 = smf.mixedlm("F3 ~ "+ variable, data = data, groups = "performer").
 ↪fit().summary()
    print( euc, F1, F2, F3)

periph = [a_df,i_df,u_df]
varia = ["position","syllable","position + syllable"]
def allTables():
    labels = ["a","i","u"]
    i = 0
    while i < 3:
        j = 0
        while j < 3:
            print(labels[i] + "," + str(varia[j])+ "\n")
            makeTables(periph[i],varia[j])
            j += 1
        i += 1
print(allTables())
#

#i_df.head()


#smf.mixedlm("euc ~ stressed", data = a_df, groups = "performer").fit().
 ↪summary()
#smf.mixedlm("F1 ~ stressed", data = a_df, groups = "performer").fit().summary()
#smf.mixedlm("F2 ~ stressed", data = a_df, groups = "performer").fit().summary()
#smf.mixedlm("F3 ~ stressed", data = a_df, groups = "performer").fit().summary()

#smf.mixedlm("euc ~ position + stressed", data = a_df, groups = "performer").
 ↪fit().summary()
#smf.mixedlm("F1 ~ position + stressed", data = a_df, groups = "performer").
 ↪fit().summary()
#smf.mixedlm("F2 ~ position + stressed", data = a_df, groups = "performer").
 ↪fit().summary()
#smf.mixedlm("F3 ~ position + stressed", data = a_df, groups = "performer").
 ↪fit().summary()
```

```
#md = smf.mixedlm("Weight ~ Time", data, groups=data["Pig"], re_formula="~Time")
```

```
a,position
```

```
            Mixed Linear Model Regression Results
============================================================
Model:              MixedLM   Dependent Variable:   euc
No. Observations:   226       Method:               REML
No. Groups:         3         Scale:                37715.1840
Min. group size:    8         Log-Likelihood:       -1504.6715
Max. group size:    130       Converged:            Yes
Mean group size:    75.3
------------------------------------------------------------
                 Coef.   Std.Err.   z    P>|z|  [0.025  0.975]
------------------------------------------------------------
Intercept        519.107   51.900 10.002 0.000 417.385 620.828
position[T.off]   76.414   26.376  2.897 0.004  24.719 128.109
performer Var   5451.920   40.155
============================================================
              Mixed Linear Model Regression Results
============================================================
Model:               MixedLM   Dependent Variable:   F1
No. Observations:    226       Method:               REML
No. Groups:          3         Scale:                12890.0084
Min. group size:     8         Log-Likelihood:       -1385.8502
Max. group size:     130       Converged:            Yes
Mean group size:     75.3
------------------------------------------------------------
                 Coef.   Std.Err.   z    P>|z|  [0.025  0.975]
------------------------------------------------------------
Intercept        920.573   58.614 15.706 0.000 805.691 1035.455
position[T.off]  -33.269   15.409 -2.159 0.031 -63.469   -3.069
performer Var   9508.983   88.260
============================================================
              Mixed Linear Model Regression Results
============================================================
Model:               MixedLM   Dependent Variable:   F2
No. Observations:    226       Method:               REML
No. Groups:          3         Scale:                24349.8031
```

```
Min. group size:      8         Log-Likelihood:       -1455.2044
Max. group size:      130       Converged:            Yes
Mean group size:      75.3
-------------------------------------------------------------
                 Coef.   Std.Err.   z    P>|z|  [0.025   0.975]
-------------------------------------------------------------
Intercept       1447.862   31.204 46.400 0.000 1386.704 1509.021
position[T.off]   42.465   21.115  2.011 0.044    1.080   83.851
performer Var   1867.848   14.954
=============================================================
               Mixed Linear Model Regression Results
=============================================================
Model:               MixedLM    Dependent Variable:    F3
No. Observations:    226        Method:                REML
No. Groups:          3          Scale:                 99166.8704
Min. group size:     8          Log-Likelihood:        -1614.4517
Max. group size:     130        Converged:             Yes
Mean group size:     75.3
-------------------------------------------------------------
                  Coef.   Std.Err.   z    P>|z|  [0.025   0.975]
-------------------------------------------------------------
Intercept        2467.357  169.046 14.596 0.000 2136.034 2798.681
position[T.off]  -101.043   42.724 -2.365 0.018 -184.781  -17.305
performer Var   79818.608  259.049
=============================================================

a,syllable

           Mixed Linear Model Regression Results
=========================================================
Model:              MixedLM  Dependent Variable:  euc
No. Observations:   226      Method:              REML
No. Groups:         3        Scale:               38900.3389
Min. group size:    8        Log-Likelihood:      -1508.3589
Max. group size:    130      Converged:           Yes
Mean group size:    75.3
---------------------------------------------------------
               Coef.   Std.Err.   z    P>|z|  [0.025  0.975]
---------------------------------------------------------
Intercept      572.745   58.011  9.873 0.000 459.045 686.444
syllable[T.2]  -25.083   26.399 -0.950 0.342 -76.824  26.658
performer Var 7316.238   51.524
=========================================================
             Mixed Linear Model Regression Results
=========================================================
Model:               MixedLM  Dependent Variable:  F1
No. Observations:    226      Method:              REML
No. Groups:          3        Scale:               13028.3821
```

```
Min. group size:     8        Log-Likelihood:      -1387.0969
Max. group size:     130      Converged:           Yes
Mean group size:     75.3
------------------------------------------------------------
               Coef.   Std.Err.   z    P>|z|  [0.025  0.975]
------------------------------------------------------------
Intercept      891.464   60.036 14.849 0.000 773.795 1009.133
syllable[T.2]   22.451   15.276  1.470 0.142  -7.490   52.392
performer Var 9997.993   92.548
============================================================
             Mixed Linear Model Regression Results
============================================================
Model:              MixedLM   Dependent Variable:   F2
No. Observations:   226       Method:               REML
No. Groups:         3         Scale:                24772.3316
Min. group size:    8         Log-Likelihood:       -1457.2145
Max. group size:    130       Converged:            Yes
Mean group size:    75.3
------------------------------------------------------------
               Coef.   Std.Err.   z    P>|z|  [0.025   0.975]
------------------------------------------------------------
Intercept     1469.280   33.264 44.170 0.000 1404.083 1534.476
syllable[T.2]   -2.116   21.062 -0.100 0.920  -43.397   39.166
performer Var 2112.912   16.948
============================================================
             Mixed Linear Model Regression Results
============================================================
Model:              MixedLM   Dependent Variable:   F3
No. Observations:   226       Method:               REML
No. Groups:         3         Scale:                101070.4550
Min. group size:    8         Log-Likelihood:       -1616.5836
Max. group size:    130       Converged:            Yes
Mean group size:    75.3
------------------------------------------------------------
                Coef.   Std.Err.   z    P>|z|  [0.025   0.975]
------------------------------------------------------------
Intercept      2389.888  169.791 14.075 0.000 2057.103 2722.673
syllable[T.2]    48.360   42.548  1.137 0.256  -35.032  131.752
performer Var 80382.822  259.096
============================================================

a,position + syllable

            Mixed Linear Model Regression Results
============================================================
Model:              MixedLM   Dependent Variable:   euc
No. Observations:   226       Method:               REML
No. Groups:         3         Scale:                37608.5752
```

```
Min. group size:    8         Log-Likelihood:       -1499.6285
Max. group size:    130       Converged:            Yes
Mean group size:    75.3
------------------------------------------------------------
                 Coef.   Std.Err.   z    P>|z|  [0.025  0.975]
------------------------------------------------------------
Intercept        534.925   52.226 10.242 0.000 432.564 637.286
position[T.off]   80.466   26.517  3.035 0.002  28.494 132.439
syllable[T.2]    -34.311   26.137 -1.313 0.189 -85.538  16.916
performer Var   5135.298   38.382
============================================================
             Mixed Linear Model Regression Results
============================================================
Model:               MixedLM   Dependent Variable:   F1
No. Observations:    226       Method:               REML
No. Groups:          3         Scale:                12774.8732
Min. group size:     8         Log-Likelihood:       -1380.6884
Max. group size:     130       Converged:            Yes
Mean group size:     75.3
------------------------------------------------------------
                 Coef.   Std.Err.   z    P>|z|  [0.025  0.975]
------------------------------------------------------------
Intercept        908.065   58.364 15.559 0.000 793.673 1022.457
position[T.off]  -36.378   15.443 -2.356 0.018 -66.644   -6.111
syllable[T.2]     26.589   15.229  1.746 0.081  -3.259   56.437
performer Var   9276.156   86.500
============================================================
             Mixed Linear Model Regression Results
============================================================
Model:               MixedLM   Dependent Variable:   F2
No. Observations:    226       Method:               REML
No. Groups:          3         Scale:                24446.8925
Min. group size:     8         Log-Likelihood:       -1451.1843
Max. group size:     130       Converged:            Yes
Mean group size:     75.3
------------------------------------------------------------
                 Coef.   Std.Err.   z    P>|z|  [0.025   0.975]
------------------------------------------------------------
Intercept       1451.239   32.898 44.113 0.000 1386.759 1515.719
position[T.off]   43.267   21.294  2.032 0.042    1.531   85.002
syllable[T.2]     -6.969   21.060 -0.331 0.741  -48.245   34.307
performer Var   1876.507   14.973
============================================================
              Mixed Linear Model Regression Results
============================================================
Model:               MixedLM    Dependent Variable:    F3
No. Observations:    226        Method:                REML
No. Groups:          3          Scale:                 98710.1980
```

```
Min. group size:     8          Log-Likelihood:        -1608.7626
Max. group size:     130        Converged:             Yes
Mean group size:     75.3
-----------------------------------------------------------------
                  Coef.   Std.Err.    z    P>|z|  [0.025   0.975]
-----------------------------------------------------------------
Intercept        2438.754  169.183 14.415 0.000 2107.161 2770.347
position[T.off]  -108.121   42.911 -2.520 0.012 -192.225  -24.017
syllable[T.2]      60.635   42.330  1.432 0.152  -22.329  143.600
performer Var   78795.664  256.304
=================================================================

i,position

             Mixed Linear Model Regression Results
=================================================================
Model:                MixedLM   Dependent Variable:   euc
No. Observations:     135       Method:               REML
No. Groups:           3         Scale:                193327.5852
Min. group size:      4         Log-Likelihood:       -1003.9136
Max. group size:      70        Converged:            Yes
Mean group size:      45.0
-----------------------------------------------------------------
                  Coef.   Std.Err.    z    P>|z|  [0.025   0.975]
-----------------------------------------------------------------
Intercept        1337.723  130.984 10.213 0.000 1080.998 1594.447
position[T.off]     2.077   79.524  0.026 0.979 -153.787  157.941
performer Var   32583.850  110.217
=================================================================
             Mixed Linear Model Regression Results
=============================================================
Model:              MixedLM   Dependent Variable:   F1
No. Observations:   135       Method:               REML
No. Groups:         3         Scale:                9776.3091
Min. group size:    4         Log-Likelihood:       -806.8837
Max. group size:    70        Converged:            Yes
Mean group size:    45.0
-------------------------------------------------------------
                  Coef.   Std.Err.   z   P>|z|  [0.025  0.975]
-------------------------------------------------------------
Intercept        462.801   59.460 7.783 0.000 346.262 579.341
position[T.off]   11.406   17.899 0.637 0.524 -23.677  46.488
performer Var   9394.023  113.469
=============================================================
              Mixed Linear Model Regression Results
=============================================================
Model:                MixedLM   Dependent Variable:   F2
No. Observations:     135       Method:               REML
```

```
No. Groups:           3         Scale:                159905.8521
Min. group size:      4         Log-Likelihood:       -990.9672
Max. group size:      70        Converged:            Yes
Mean group size:      45.0
-----------------------------------------------------------------
                  Coef.   Std.Err.    z    P>|z|  [0.025   0.975]
-----------------------------------------------------------------
Intercept        1815.278   95.654 18.978 0.000 1627.799 2002.756
position[T.off]    11.121   72.420  0.154 0.878 -130.820  153.062
performer Var   16515.848   56.647
=================================================================
               Mixed Linear Model Regression Results
=================================================================
Model:               MixedLM    Dependent Variable:    F3
No. Observations:    135        Method:                REML
No. Groups:          3          Scale:                 22073.3383
Min. group size:     4          Log-Likelihood:        -861.6128
Max. group size:     70         Converged:             Yes
Mean group size:     45.0
-----------------------------------------------------------------
                  Coef.   Std.Err.    z    P>|z|  [0.025   0.975]
-----------------------------------------------------------------
Intercept        2764.614  117.794 23.470 0.000 2533.743 2995.486
position[T.off]   -83.059   26.906 -3.087 0.002 -135.794  -30.324
performer Var   39062.551  287.092
=================================================================

i,syllable

            Mixed Linear Model Regression Results
============================================================
Model:               MixedLM  Dependent Variable:  euc
No. Observations:    135      Method:              REML
No. Groups:          3        Scale:               192583.2083
Min. group size:     4        Log-Likelihood:      -1003.6855
Max. group size:     70       Converged:           Yes
Mean group size:     45.0
------------------------------------------------------------
                Coef.   Std.Err.   z   P>|z|  [0.025   0.975]
------------------------------------------------------------
Intercept      1304.922  134.523 9.700 0.000 1041.262 1568.581
syllable[T.2]    55.632   76.591 0.726 0.468  -94.484  205.747
performer Var 32164.506  107.586
============================================================
            Mixed Linear Model Regression Results
============================================================
Model:              MixedLM  Dependent Variable:  F1
No. Observations:   135      Method:              REML
```

```
No. Groups:         3        Scale:               9804.7263
Min. group size:    4        Log-Likelihood:      -807.1026
Max. group size:    70       Converged:           Yes
Mean group size:    45.0
------------------------------------------------------------
               Coef.   Std.Err.   z   P>|z|  [0.025  0.975]
------------------------------------------------------------
Intercept      465.503   59.807 7.783 0.000 348.283 582.723
syllable[T.2]    3.397   17.307 0.196 0.844 -30.523  37.318
performer Var 9322.898  112.656
============================================================
              Mixed Linear Model Regression Results
============================================================
Model:              MixedLM   Dependent Variable:   F2
No. Observations:   135       Method:               REML
No. Groups:         3         Scale:                159109.5381
Min. group size:    4         Log-Likelihood:       -990.6740
Max. group size:    70        Converged:            Yes
Mean group size:    45.0
------------------------------------------------------------
                Coef.   Std.Err.   z    P>|z|  [0.025   0.975]
------------------------------------------------------------
Intercept      1785.706  100.263 17.810 0.000 1589.194 1982.218
syllable[T.2]    57.408   69.602  0.825 0.409  -79.010  193.826
performer Var 16553.634   56.193
============================================================
              Mixed Linear Model Regression Results
============================================================
Model:               MixedLM   Dependent Variable:   F3
No. Observations:    135       Method:               REML
No. Groups:          3         Scale:                23709.7408
Min. group size:     4         Log-Likelihood:       -866.2337
Max. group size:     70        Converged:            Yes
Mean group size:     45.0
------------------------------------------------------------
                Coef.   Std.Err.   z    P>|z|  [0.025   0.975]
------------------------------------------------------------
Intercept      2726.315  112.958 24.136 0.000 2504.922 2947.709
syllable[T.2]     3.378   26.913  0.126 0.900  -49.371   56.128
performer Var 35046.398  252.645
============================================================

i,position + syllable

              Mixed Linear Model Regression Results
============================================================
Model:                MixedLM   Dependent Variable:   euc
No. Observations:     135       Method:               REML
```

```
No. Groups:           3         Scale:                 194058.5151
Min. group size:      4         Log-Likelihood:        -998.3716
Max. group size:      70        Converged:             Yes
Mean group size:      45.0
-----------------------------------------------------------------
                  Coef.   Std.Err.    z    P>|z|  [0.025   0.975]
-----------------------------------------------------------------
Intercept        1306.953  136.273  9.591 0.000 1039.862 1574.044
position[T.off]    -8.066   80.879 -0.100 0.921 -166.585  150.454
syllable[T.2]      56.971   78.040  0.730 0.465  -95.985  209.927
performer Var   31926.903  106.955
=================================================================
             Mixed Linear Model Regression Results
=================================================================
Model:              MixedLM   Dependent Variable:   F1
No. Observations:   135       Method:               REML
No. Groups:         3         Scale:                9850.5732
Min. group size:    4         Log-Likelihood:       -803.0952
Max. group size:    70        Converged:            Yes
Mean group size:    45.0
-----------------------------------------------------------------
                 Coef.   Std.Err.   z   P>|z|  [0.025  0.975]
-----------------------------------------------------------------
Intercept        461.981   60.351 7.655 0.000 343.695 580.267
position[T.off]   11.127   18.229 0.610 0.542 -24.602  46.855
syllable[T.2]      1.580   17.600 0.090 0.928 -32.915  36.076
performer Var   9409.610  113.420
=================================================================
               Mixed Linear Model Regression Results
=================================================================
Model:                MixedLM   Dependent Variable:   F2
No. Observations:     135       Method:               REML
No. Groups:           3         Scale:                160319.9746
Min. group size:      4         Log-Likelihood:       -985.4613
Max. group size:      70        Converged:            Yes
Mean group size:      45.0
-----------------------------------------------------------------
                  Coef.   Std.Err.    z    P>|z|  [0.025   0.975]
-----------------------------------------------------------------
Intercept        1785.380  102.649 17.393 0.000 1584.192 1986.568
position[T.off]     0.963   73.599  0.013 0.990 -143.288  145.214
syllable[T.2]      57.245   70.908  0.807 0.419  -81.732  196.221
performer Var   16621.256   56.396
=================================================================
               Mixed Linear Model Regression Results
=================================================================
Model:                MixedLM    Dependent Variable:    F3
No. Observations:     135        Method:                REML
```

```
No. Groups:          3          Scale:                 22175.4297
Min. group size:     4          Log-Likelihood:        -857.2062
Max. group size:     70         Converged:             Yes
Mean group size:     45.0
-----------------------------------------------------------------
                  Coef.   Std.Err.    z    P>|z|  [0.025   0.975]
-----------------------------------------------------------------
Intercept        2754.890  117.761 23.394 0.000 2524.082 2985.698
position[T.off]   -86.081   27.360 -3.146 0.002 -139.705  -32.456
syllable[T.2]      17.322   26.405  0.656 0.512  -34.430   69.074
performer Var   38371.875  281.936
=================================================================

u,position

            Mixed Linear Model Regression Results
=============================================================
Model:              MixedLM   Dependent Variable:   euc
No. Observations:   82        Method:               REML
No. Groups:         3         Scale:                17273.5755
Min. group size:    4         Log-Likelihood:       -511.8639
Max. group size:    44        Converged:            Yes
Mean group size:    27.3
-------------------------------------------------------------
                  Coef.   Std.Err.   z   P>|z|  [0.025  0.975]
-------------------------------------------------------------
Intercept         638.048  177.412 3.596 0.000 290.327 985.769
position[T.off]    40.422   29.823 1.355 0.175 -18.030  98.873
performer Var   91937.555  732.070
=============================================================
             Mixed Linear Model Regression Results
=============================================================
Model:              MixedLM   Dependent Variable:   F1
No. Observations:   82        Method:               REML
No. Groups:         3         Scale:                7730.5233
Min. group size:    4         Log-Likelihood:       -477.6166
Max. group size:    44        Converged:            Yes
Mean group size:    27.3
-------------------------------------------------------------
                  Coef.   Std.Err.   z    P>|z|  [0.025  0.975]
-------------------------------------------------------------
Intercept         567.493   43.574 13.024 0.000 482.089 652.897
position[T.off]  -17.477   19.933 -0.877 0.381 -56.545  21.592
performer Var   4447.651   67.985
=============================================================
              Mixed Linear Model Regression Results
=============================================================
Model:              MixedLM   Dependent Variable:   F2
```

```
No. Observations:    82        Method:               REML
No. Groups:          3         Scale:                13462.7576
Min. group size:     4         Log-Likelihood:       -501.5294
Max. group size:     44        Converged:            Yes
Mean group size:     27.3
------------------------------------------------------------
                  Coef.   Std.Err.   z   P>|z|  [0.025  0.975]
------------------------------------------------------------
Intercept        1196.119  130.778 9.146 0.000 939.799 1452.440
position[T.off]    22.699   26.327 0.862 0.389 -28.901   74.299
performer Var   49357.199  451.501
============================================================
               Mixed Linear Model Regression Results
============================================================
Model:               MixedLM    Dependent Variable:    F3
No. Observations:    82         Method:                REML
No. Groups:          3          Scale:                 70692.7181
Min. group size:     4          Log-Likelihood:        -565.4662
Max. group size:     44         Converged:             Yes
Mean group size:     27.3
------------------------------------------------------------
                  Coef.   Std.Err.   z    P>|z|  [0.025   0.975]
------------------------------------------------------------
Intercept        2252.914   92.661 24.313 0.000 2071.302 2434.527
position[T.off]   116.575   60.453  1.928 0.054   -1.910  235.061
performer Var   17554.011   76.619
============================================================

u,syllable

            Mixed Linear Model Regression Results
============================================================
Model:               MixedLM  Dependent Variable:  euc
No. Observations:    82       Method:              REML
No. Groups:          3        Scale:               17673.2152
Min. group size:     4        Log-Likelihood:      -512.7236
Max. group size:     44       Converged:           Yes
Mean group size:     27.3
------------------------------------------------------------
                Coef.   Std.Err.   z   P>|z|  [0.025  0.975]
------------------------------------------------------------
Intercept       656.214  177.800 3.691 0.000 307.733 1004.695
syllable[T.2]     4.924   31.302 0.157 0.875 -56.427   66.274
performer Var 92217.344  727.337
============================================================
            Mixed Linear Model Regression Results
============================================================
Model:               MixedLM  Dependent Variable:  F1
```

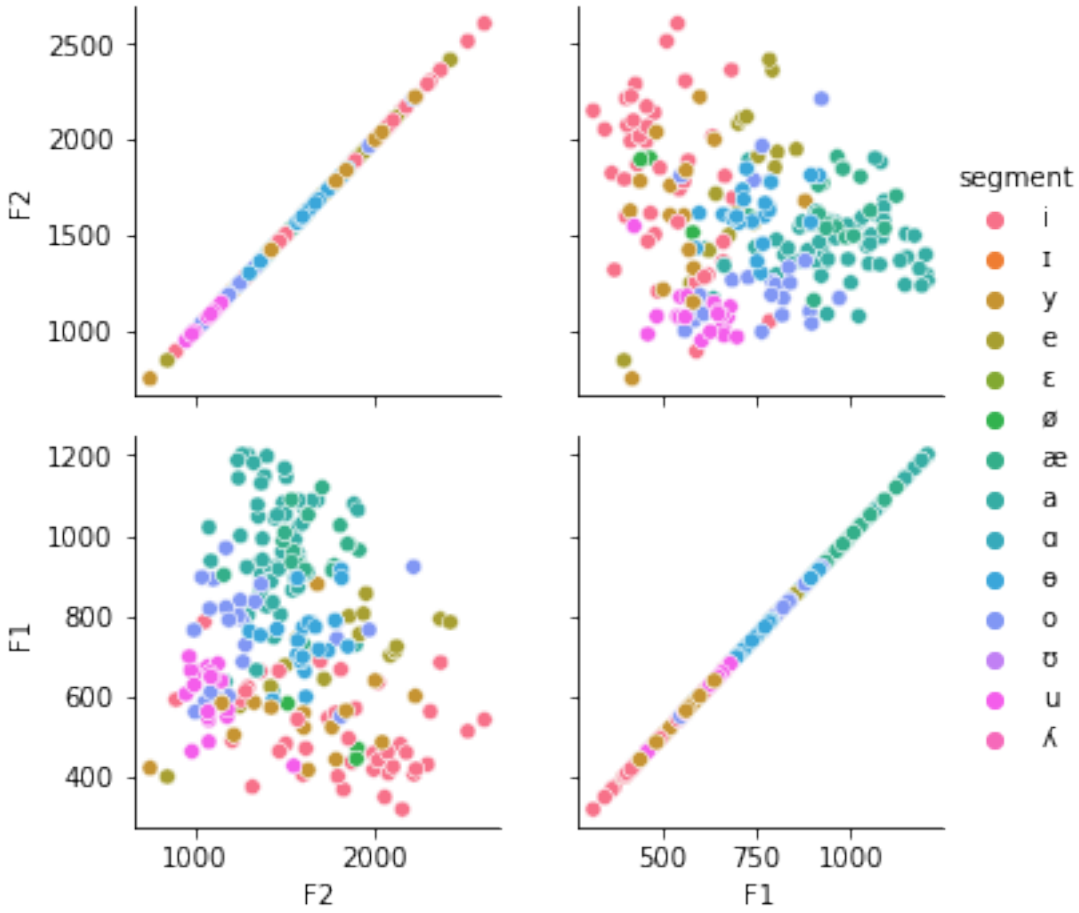
```
No. Observations:    82       Method:              REML
No. Groups:          3        Scale:               7764.6968
Min. group size:     4        Log-Likelihood:      -477.8275
Max. group size:     44       Converged:           Yes
Mean group size:     27.3
------------------------------------------------------------
               Coef.   Std.Err.   z    P>|z|  [0.025  0.975]
------------------------------------------------------------
Intercept      563.966   44.999 12.533 0.000 475.769 652.163
syllable[T.2]  -10.992   20.848 -0.527 0.598 -51.853  29.870
performer Var 4831.306   73.003
============================================================
             Mixed Linear Model Regression Results
============================================================
Model:              MixedLM   Dependent Variable:   F2
No. Observations:   82        Method:               REML
No. Groups:         3         Scale:                13580.3661
Min. group size:    4         Log-Likelihood:       -501.8110
Max. group size:    44        Converged:            Yes
Mean group size:    27.3
------------------------------------------------------------
                Coef.   Std.Err.   z    P>|z|  [0.025  0.975]
------------------------------------------------------------
Intercept      1212.427  129.437  9.367 0.000 958.734 1466.120
syllable[T.2]    -8.918   27.447 -0.325 0.745 -62.714   44.877
performer Var 48238.340  440.837
============================================================
              Mixed Linear Model Regression Results
============================================================
Model:               MixedLM   Dependent Variable:   F3
No. Observations:    82        Method:               REML
No. Groups:          3         Scale:                73517.5481
Min. group size:     4         Log-Likelihood:       -567.1079
Max. group size:     44        Converged:            Yes
Mean group size:     27.3
------------------------------------------------------------
                Coef.   Std.Err.   z    P>|z|  [0.025   0.975]
------------------------------------------------------------
Intercept      2293.083  100.961 22.713 0.000 2095.204 2490.962
syllable[T.2]    34.784   63.384  0.549 0.583  -89.447  159.015
performer Var 21005.736   87.942
============================================================

u,position + syllable

             Mixed Linear Model Regression Results
============================================================
Model:               MixedLM   Dependent Variable:   euc
```

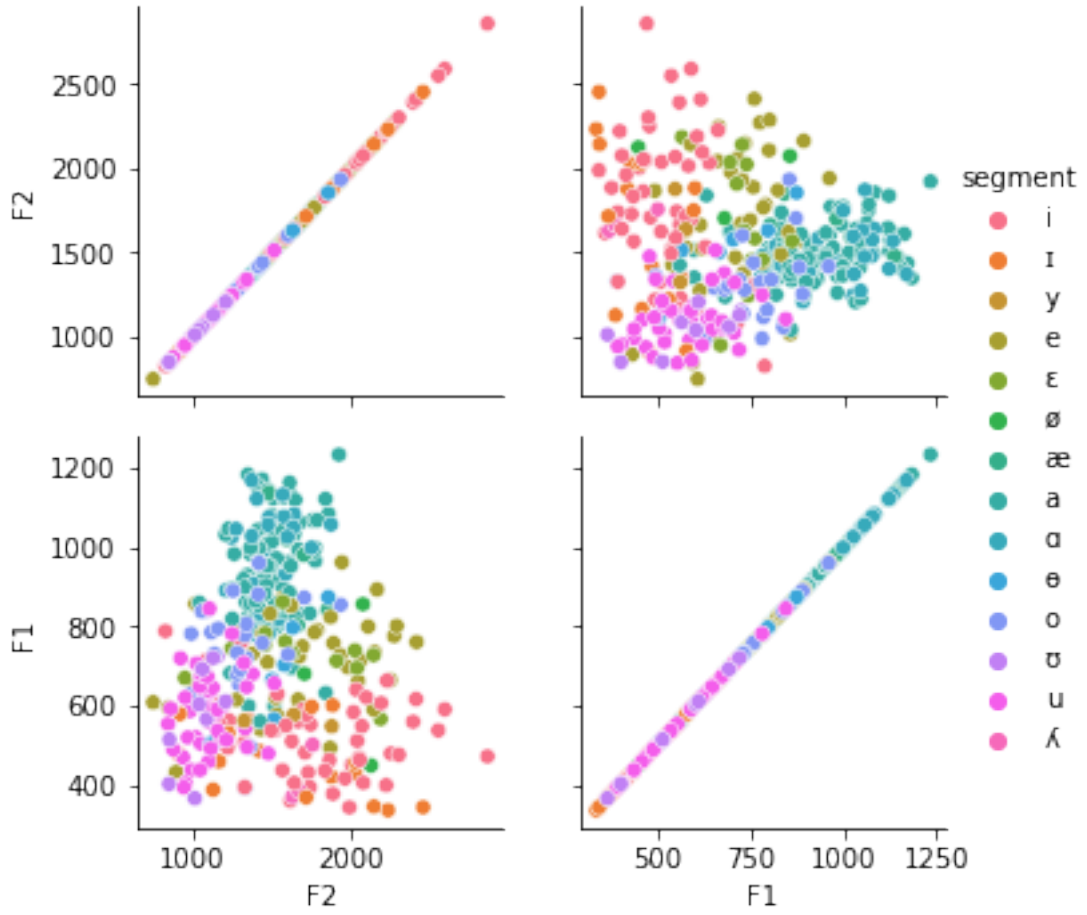
```
No. Observations:    82        Method:               REML
No. Groups:          3         Scale:                17490.5467
Min. group size:     4         Log-Likelihood:       -507.4403
Max. group size:     44        Converged:            Yes
Mean group size:     27.3
------------------------------------------------------------
                  Coef.   Std.Err.   z    P>|z|  [0.025  0.975]
------------------------------------------------------------
Intercept         640.908  176.828  3.624 0.000 294.332 987.485
position[T.off]    42.534   31.316  1.358 0.174 -18.843 103.911
syllable[T.2]      -7.674   32.495 -0.236 0.813 -71.364  56.016
performer Var   90827.199  720.369
============================================================
             Mixed Linear Model Regression Results
============================================================
Model:               MixedLM   Dependent Variable:   F1
No. Observations:    82        Method:               REML
No. Groups:          3         Scale:                7812.7862
Min. group size:     4         Log-Likelihood:       -473.5855
Max. group size:     44        Converged:            Yes
Mean group size:     27.3
------------------------------------------------------------
                 Coef.   Std.Err.   z    P>|z|  [0.025  0.975]
------------------------------------------------------------
Intercept        569.765   45.183 12.610 0.000 481.208 658.322
position[T.off]  -15.756   20.913 -0.753 0.451 -56.744  25.233
syllable[T.2]     -6.274   21.828 -0.287 0.774 -49.056  36.507
performer Var   4695.260   71.314
============================================================
              Mixed Linear Model Regression Results
============================================================
Model:               MixedLM   Dependent Variable:   F2
No. Observations:    82        Method:               REML
No. Groups:          3         Scale:                13587.8392
Min. group size:     4         Log-Likelihood:       -497.0818
Max. group size:     44        Converged:            Yes
Mean group size:     27.3
------------------------------------------------------------
                  Coef.   Std.Err.   z    P>|z|  [0.025  0.975]
------------------------------------------------------------
Intercept        1202.529  128.936  9.327 0.000 949.818 1455.239
position[T.off]    27.393   27.600  0.992 0.321 -26.703   81.489
syllable[T.2]     -17.047   28.651 -0.595 0.552 -73.201   39.108
performer Var   47549.967  434.875
============================================================
               Mixed Linear Model Regression Results
============================================================
Model:               MixedLM    Dependent Variable:    F3
```

```
No. Observations:    82          Method:                REML
No. Groups:          3           Scale:                 71596.0699
Min. group size:     4           Log-Likelihood:        -560.3731
Max. group size:     44          Converged:             Yes
Mean group size:     27.3
------------------------------------------------------------------
                   Coef.   Std.Err.    z    P>|z|   [0.025   0.975]
------------------------------------------------------------------
Intercept         2252.559   97.197 23.175 0.000 2062.057 2443.062
position[T.off]    116.374   63.431  1.835 0.067   -7.948  240.696
syllable[T.2]        0.843   65.186  0.013 0.990 -126.919  128.605
performer Var    17663.301   76.820
==================================================================

None
```

[ ]:
```
seg_order = ["i"," ","y","e"," ","ø","æ","a"," "," ","o"," ","u"," " ]
eesti_colors = ['#f77189', '#ef7d32', '#c69432', '#a79f31', '#82a931',␣
 ↪'#32b24e', '#34af8a', '#36ada4', '#37aabb', '#3aa6da', '#8197f4', '#c180f4',␣
 ↪'#f45deb', '#f669ba']
seg_colors = {}
for index,item in enumerate(seg_order):
    seg_colors[item] = eesti_colors
variables = ["F1","F2","performer"]
# def vowelCharter(data,colorby):
#     fig, ax = plt.subplots()
#     #ax = sns.kdeplot(data = data, x="F1",y="F2",hue=colorby)
#     #ax.set_title(label)

# vowelCharter(formants_df,"segment")
positions = ["position","syllable"]
measurements = ["F2","F1"]
variables = ["F1","F2","F3","euc","position","syllable"]
#ax = sns.pairplot(data=formants_df,hue="segment")

def pairVowels(data):
    g = sns.PairGrid(data=data,hue="segment",hue_order = seg_order,␣
 ↪vars=measurements)

    g.map(sns.scatterplot)




   # g.map_diag(sns.boxplot)
    # g.map_lower(sns.kdeplot)
    g.add_legend()
```

```
for item in twoWay:
    pairVowels(item)
```






Error in callback <function flush_figures at 0x7fa3c9c6a700> (for post_execute):

```
---------------------------------------------------------------------------
KeyboardInterrupt                         Traceback (most recent call last)
~/miniconda3/envs/soundmines/lib/python3.9/site-packages/matplotlib_inline/
 ↪backend_inline.py in flush_figures()
    119         # ignore the tracking, just draw and close all figures
    120         try:
--> 121             return show(True)
    122         except Exception as e:
    123             # safely show traceback if in IPython, else raise

~/miniconda3/envs/soundmines/lib/python3.9/site-packages/matplotlib_inline/
 ↪backend_inline.py in show(close, block)
     39     try:
     40         for figure_manager in Gcf.get_all_fig_managers():
---> 41             display(

     42                 figure_manager.canvas.figure,
```

```
     43                 metadata=_fetch_figure_metadata(figure_manager.canvas.
 ↪figure)

~/miniconda3/envs/soundmines/lib/python3.9/site-packages/IPython/core/display.p␣
 ↪in display(include, exclude, metadata, transient, display_id, *objs, **kwargs
    318             publish_display_data(data=obj, metadata=metadata, **kwargs)
    319         else:
--> 320             format_dict, md_dict = format(obj, include=include,␣
 ↪exclude=exclude)
    321             if not format_dict:
    322                 # nothing to display (e.g. _ipython_display_ took over)

~/miniconda3/envs/soundmines/lib/python3.9/site-packages/IPython/core/formatter.
 ↪py in format(self, obj, include, exclude)
    178             md = None
    179             try:
--> 180                 data = formatter(obj)
    181             except:
    182                 # FIXME: log the exception

~/miniconda3/envs/soundmines/lib/python3.9/site-packages/decorator.py in␣
 ↪fun(*args, **kw)
    230             if not kwsyntax:
    231                 args, kw = fix(args, kw, sig)
--> 232             return caller(func, *(extras + args), **kw)
    233     fun.__name__ = func.__name__
    234     fun.__doc__ = func.__doc__

~/miniconda3/envs/soundmines/lib/python3.9/site-packages/IPython/core/formatter.
 ↪py in catch_format_error(method, self, *args, **kwargs)
    222     """show traceback on failed format call"""
    223     try:
--> 224         r = method(self, *args, **kwargs)
    225     except NotImplementedError:
    226         # don't warn on NotImplementedErrors

~/miniconda3/envs/soundmines/lib/python3.9/site-packages/IPython/core/formatter.
 ↪py in __call__(self, obj)
    339                 pass
    340             else:
--> 341                 return printer(obj)
    342             # Finally look for special method names
    343             method = get_real_method(obj, self.print_method)

~/miniconda3/envs/soundmines/lib/python3.9/site-packages/IPython/core/pylabtools.
 ↪py in print_figure(fig, fmt, bbox_inches, base64, **kwargs)
    149         FigureCanvasBase(fig)
    150
```

```
--> 151     fig.canvas.print_figure(bytes_io, **kw)
    152     data = bytes_io.getvalue()
    153     if fmt == 'svg':

~/miniconda3/envs/soundmines/lib/python3.9/site-packages/matplotlib/
 ↪backend_bases.py in print_figure(self, filename, dpi, facecolor, edgecolor,␣
 ↪orientation, format, bbox_inches, pad_inches, bbox_extra_artists, backend,␣
 ↪**kwargs)
   2312                 # force the figure dpi to 72), so we need to set it␣
 ↪again here.
   2313                 with cbook._setattr_cm(self.figure, dpi=dpi):
-> 2314                     result = print_method(
   2315                         filename,
   2316                         facecolor=facecolor,

~/miniconda3/envs/soundmines/lib/python3.9/site-packages/matplotlib/
 ↪backend_bases.py in wrapper(*args, **kwargs)
   1641             kwargs.pop(arg)
   1642
-> 1643         return func(*args, **kwargs)
   1644
   1645     return wrapper

~/miniconda3/envs/soundmines/lib/python3.9/site-packages/matplotlib/_api/
 ↪deprecation.py in wrapper(*inner_args, **inner_kwargs)
    410                             else deprecation_addendum,
    411                 **kwargs)
--> 412         return func(*inner_args, **inner_kwargs)
    413
    414     DECORATORS[wrapper] = decorator

~/miniconda3/envs/soundmines/lib/python3.9/site-packages/matplotlib/backends/
 ↪backend_agg.py in print_png(self, filename_or_obj, metadata, pil_kwargs, *arg
    538             *metadata*, including the default 'Software' key.
    539         """
--> 540         FigureCanvasAgg.draw(self)
    541         mpl.image.imsave(
    542             filename_or_obj, self.buffer_rgba(), format="png",␣
 ↪origin="upper",

~/miniconda3/envs/soundmines/lib/python3.9/site-packages/matplotlib/backends/
 ↪backend_agg.py in draw(self)
    434              (self.toolbar._wait_cursor_for_draw_cm() if self.toolbar
    435               else nullcontext()):
--> 436             self.figure.draw(self.renderer)
    437             # A GUI class may be need to update a window using this␣
 ↪draw, so
    438             # don't forget to call the superclass.
```

```
~/miniconda3/envs/soundmines/lib/python3.9/site-packages/matplotlib/artist.py in
↪draw_wrapper(artist, renderer, *args, **kwargs)
     71     @wraps(draw)
     72     def draw_wrapper(artist, renderer, *args, **kwargs):
---> 73         result = draw(artist, renderer, *args, **kwargs)
     74         if renderer._rasterizing:
     75             renderer.stop_rasterizing()

~/miniconda3/envs/soundmines/lib/python3.9/site-packages/matplotlib/artist.py in
↪draw_wrapper(artist, renderer)
     48                 renderer.start_filter()
     49
---> 50             return draw(artist, renderer)
     51         finally:
     52             if artist.get_agg_filter() is not None:

~/miniconda3/envs/soundmines/lib/python3.9/site-packages/matplotlib/figure.py in
↪draw(self, renderer)
   2801
   2802             self.patch.draw(renderer)
-> 2803             mimage._draw_list_compositing_images(
   2804                 renderer, self, artists, self.suppressComposite)
   2805

~/miniconda3/envs/soundmines/lib/python3.9/site-packages/matplotlib/image.py in
↪_draw_list_compositing_images(renderer, parent, artists, suppress_composite)
    130     if not_composite or not has_images:
    131         for a in artists:
--> 132             a.draw(renderer)
    133     else:
    134         # Composite any adjacent images together

~/miniconda3/envs/soundmines/lib/python3.9/site-packages/matplotlib/artist.py in
↪draw_wrapper(artist, renderer)
     48                 renderer.start_filter()
     49
---> 50             return draw(artist, renderer)
     51         finally:
     52             if artist.get_agg_filter() is not None:

~/miniconda3/envs/soundmines/lib/python3.9/site-packages/matplotlib/axes/_base.
↪py in draw(self, renderer)
   3044                 artists.remove(spine)
   3045
-> 3046         self._update_title_position(renderer)
   3047
```

```
   3048         if not self.axison:

~/miniconda3/envs/soundmines/lib/python3.9/site-packages/matplotlib/axes/_base.
 ↪py in _update_title_position(self, renderer)
   2984                 if (ax.xaxis.get_ticks_position() in ['top', 'unknown']
   2985                         or ax.xaxis.get_label_position() == 'top'):
-> 2986                     bb = ax.xaxis.get_tightbbox(renderer)
   2987                 else:
   2988                     bb = ax.get_window_extent(renderer)

~/miniconda3/envs/soundmines/lib/python3.9/site-packages/matplotlib/axis.py in␣
 ↪get_tightbbox(self, renderer, for_layout_only)
   1101             return
   1102
-> 1103         ticks_to_draw = self._update_ticks()
   1104
   1105         self._update_label_position(renderer)

~/miniconda3/envs/soundmines/lib/python3.9/site-packages/matplotlib/axis.py in␣
 ↪_update_ticks(self)
   1044         """
   1045         major_locs = self.get_majorticklocs()
-> 1046         major_labels = self.major.formatter.format_ticks(major_locs)
   1047         major_ticks = self.get_major_ticks(len(major_locs))
   1048         self.major.formatter.set_locs(major_locs)

~/miniconda3/envs/soundmines/lib/python3.9/site-packages/matplotlib/ticker.py i␣
 ↪format_ticks(self, values)
    221     def format_ticks(self, values):
    222         """Return the tick labels for all the ticks at once."""
--> 223         self.set_locs(values)
    224         return [self(value, i) for i, value in enumerate(values)]
    225

~/miniconda3/envs/soundmines/lib/python3.9/site-packages/matplotlib/ticker.py i␣
 ↪set_locs(self, locs)
    710                 self._compute_offset()
    711             self._set_order_of_magnitude()
--> 712             self._set_format()
    713
    714     def _compute_offset(self):

~/miniconda3/envs/soundmines/lib/python3.9/site-packages/matplotlib/ticker.py i␣
 ↪_set_format(self)
    793             _locs = self.locs
    794         locs = (np.asarray(_locs) - self.offset) / 10. ** self.
 ↪orderOfMagnitude
--> 795         loc_range = np.ptp(locs)
```

```
    796         # Curvilinear coordinates can yield two identical points.
    797         if loc_range == 0:

KeyboardInterrupt:
```

[ ]:
```
help(dict)
```

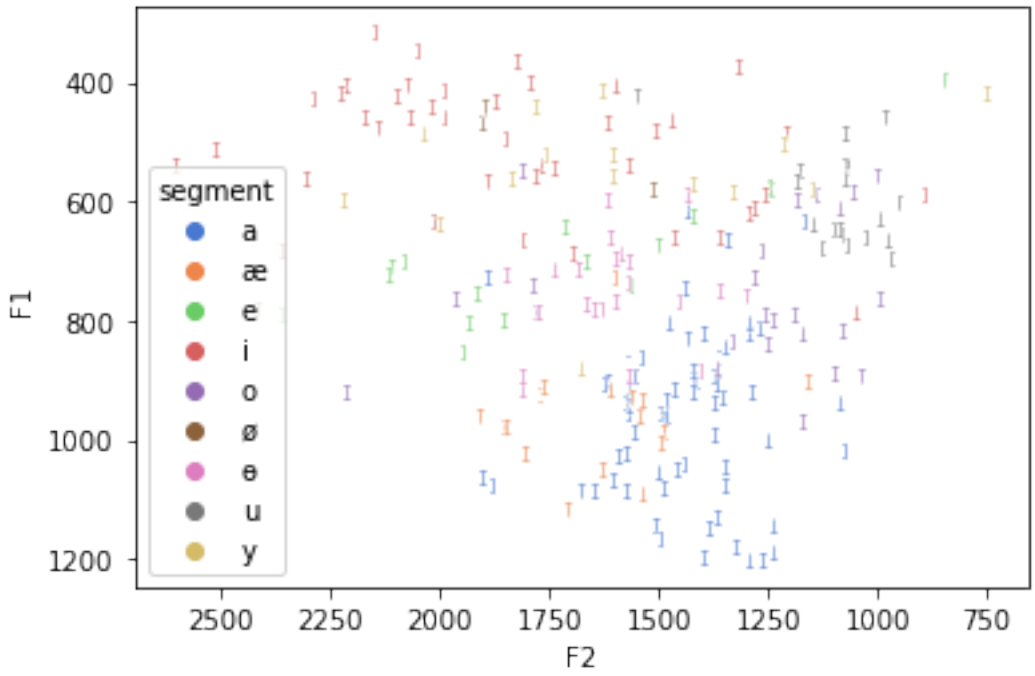
```
Help on class dict in module builtins:

class dict(object)
 |  dict() -> new empty dictionary
 |  dict(mapping) -> new dictionary initialized from a mapping object's
 |      (key, value) pairs
 |  dict(iterable) -> new dictionary initialized as if via:
 |      d = {}
 |      for k, v in iterable:
 |          d[k] = v
 |  dict(**kwargs) -> new dictionary initialized with the name=value pairs
 |      in the keyword argument list.  For example:  dict(one=1, two=2)
 |
 |  Built-in subclasses:
 |      StgDict
 |
 |  Methods defined here:
 |
 |  __contains__(self, key, /)
 |      True if the dictionary has the specified key, else False.
 |
 |  __delitem__(self, key, /)
 |      Delete self[key].
 |
 |  __eq__(self, value, /)
 |      Return self==value.
 |
 |  __ge__(self, value, /)
 |      Return self>=value.
 |
 |  __getattribute__(self, name, /)
 |      Return getattr(self, name).
 |
 |  __getitem__(…)
 |      x.__getitem__(y) <==> x[y]
 |
 |  __gt__(self, value, /)
 |      Return self>value.
 |
 |  __init__(self, /, *args, **kwargs)
```

```
|      Initialize self.  See help(type(self)) for accurate signature.
|
|  __ior__(self, value, /)
|      Return self|=value.
|
|  __iter__(self, /)
|      Implement iter(self).
|
|  __le__(self, value, /)
|      Return self<=value.
|
|  __len__(self, /)
|      Return len(self).
|
|  __lt__(self, value, /)
|      Return self<value.
|
|  __ne__(self, value, /)
|      Return self!=value.
|
|  __or__(self, value, /)
|      Return self|value.
|
|  __repr__(self, /)
|      Return repr(self).
|
|  __reversed__(self, /)
|      Return a reverse iterator over the dict keys.
|
|  __ror__(self, value, /)
|      Return value|self.
|
|  __setitem__(self, key, value, /)
|      Set self[key] to value.
|
|  __sizeof__(…)
|      D.__sizeof__() -> size of D in memory, in bytes
|
|  clear(…)
|      D.clear() -> None.  Remove all items from D.
|
|  copy(…)
|      D.copy() -> a shallow copy of D
|
|  get(self, key, default=None, /)
|      Return the value for key if key is in the dictionary, else default.
|
|  items(…)
```

```
 |      D.items() -> a set-like object providing a view on D's items
 |
 |  keys(…)
 |      D.keys() -> a set-like object providing a view on D's keys
 |
 |  pop(…)
 |      D.pop(k[,d]) -> v, remove specified key and return the corresponding
value.
 |
 |      If key is not found, default is returned if given, otherwise KeyError is
raised
 |
 |  popitem(self, /)
 |      Remove and return a (key, value) pair as a 2-tuple.
 |
 |      Pairs are returned in LIFO (last-in, first-out) order.
 |      Raises KeyError if the dict is empty.
 |
 |  setdefault(self, key, default=None, /)
 |      Insert key with a value of default if key is not in the dictionary.
 |
 |      Return the value for key if key is in the dictionary, else default.
 |
 |  update(…)
 |      D.update([E, ]**F) -> None.  Update D from dict/iterable E and F.
 |      If E is present and has a .keys() method, then does:  for k in E: D[k] =
E[k]
 |      If E is present and lacks a .keys() method, then does:  for k, v in E:
D[k] = v
 |      In either case, this is followed by: for k in F:  D[k] = F[k]
 |
 |  values(…)
 |      D.values() -> an object providing a view on D's values
 |
 |  ----------------------------------------------------------------------
 |  Class methods defined here:
 |
 |  __class_getitem__(…) from builtins.type
 |      See PEP 585
 |
 |  fromkeys(iterable, value=None, /) from builtins.type
 |      Create a new dictionary with keys from iterable and values set to value.
 |
 |  ----------------------------------------------------------------------
 |  Static methods defined here:
 |
 |  __new__(*args, **kwargs) from builtins.type
 |      Create and return a new object.  See help(type) for accurate signature.
```

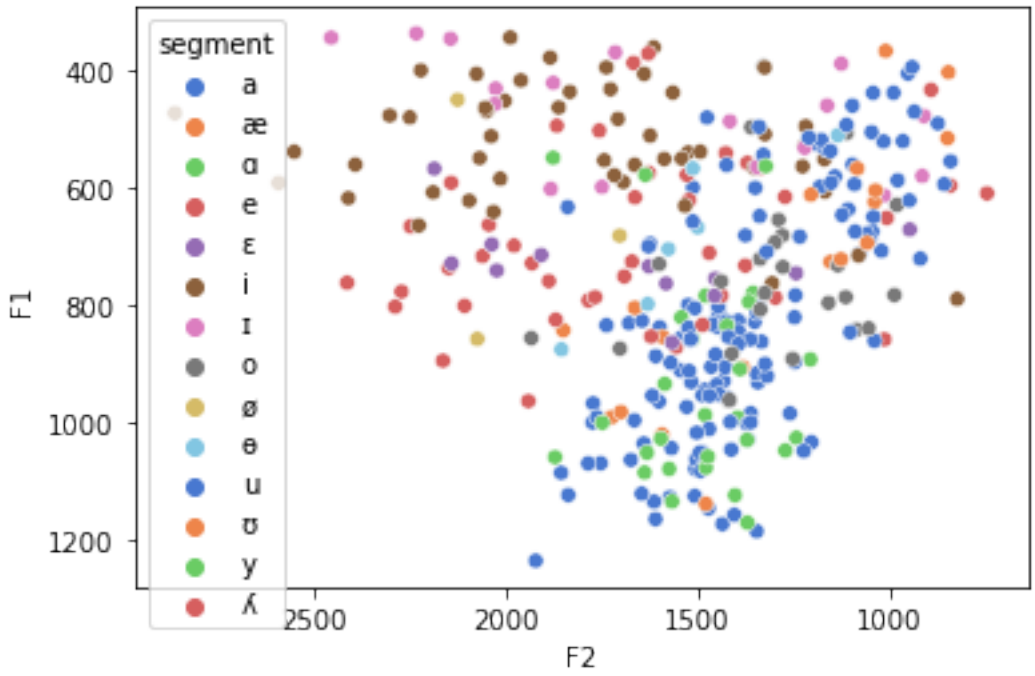
```
|
|  ----------------------------------------------------------------------
|  Data and other attributes defined here:
|
|  __hash__ = None
```

[ ]:
```
import numpy as np
import matplotlib.pyplot as plt
import matplotlib as mpl
import pandas as pd
import seaborn as sns
# plt.style.use('ggplot')


ictus_df = formants_df[formants_df.position=="ictus"]

chart = sns.scatterplot(x="F2",y="F1",data=ictus_df,marker = r'$\mathrm{ }$',␣
↪hue="segment",palette="muted",markers="$\alpha$")
chart.invert_xaxis()
chart.invert_yaxis()
```

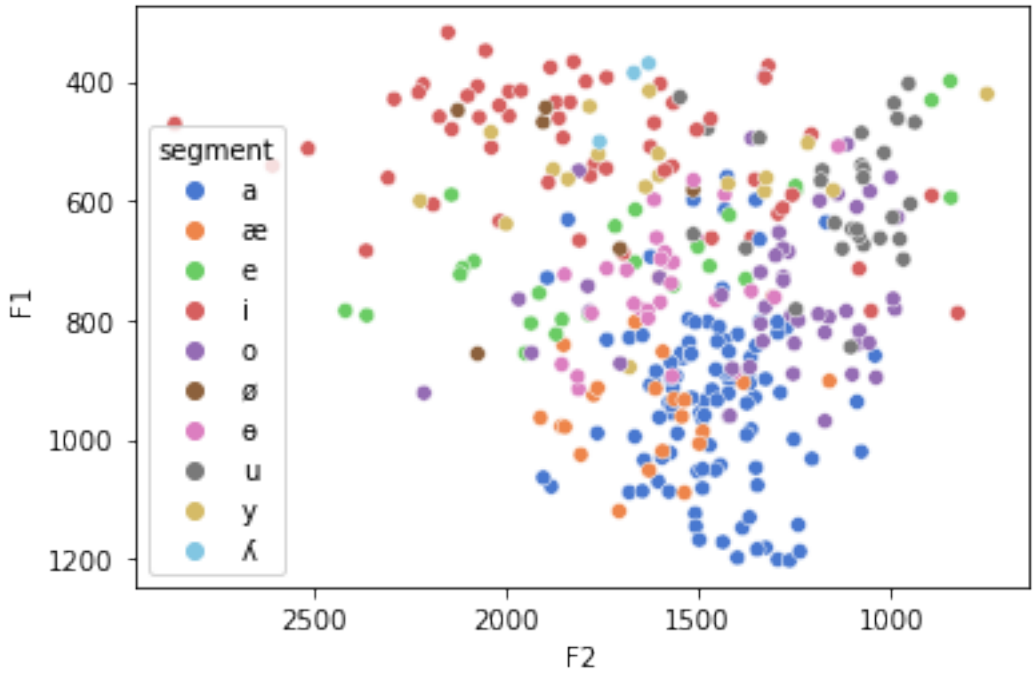



[ ]:
```
import pandas as pd
import seaborn as sns
off_ictus_df = formants_df[formants_df.position=="off"]
```

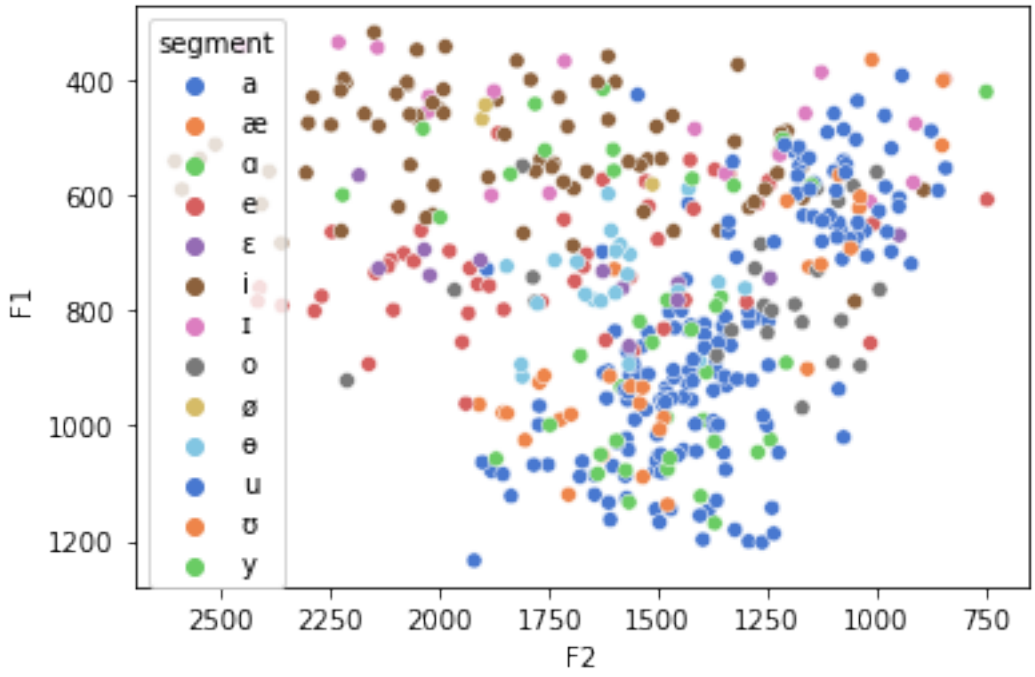
```
chart = sns.
 ↪scatterplot(x="F2",y="F1",data=off_ictus_df,hue="segment",palette="muted")
chart.invert_xaxis()
chart.invert_yaxis()
```



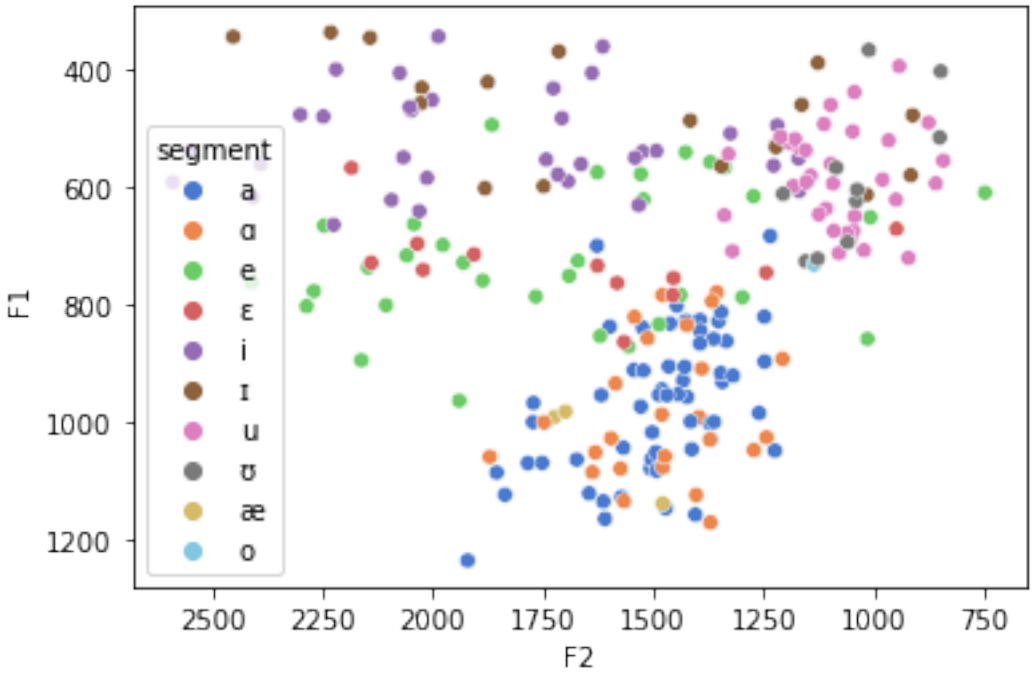

[ ]:
```
import pandas as pd
import seaborn as sns
first_df = formants_df[formants_df.syllable==1]

chart = sns.
 ↪scatterplot(x="F2",y="F1",data=first_df,hue="segment",palette="muted")
chart.invert_xaxis()
chart.invert_yaxis()
# first_df.head()
```




[ ]:
```
import pandas as pd
import seaborn as sns
second_df = formants_df[formants_df.syllable==2]

chart = sns.
 ↪scatterplot(x="F2",y="F1",data=second_df,hue="segment",palette="muted")
chart.invert_xaxis()
chart.invert_yaxis()
```




[ ]:
```
first_ictus_df = formants_df[(formants_df.syllable==1)& (formants_df.
 ↪position=="ictus")]
second_ictus_df = formants_df[(formants_df.syllable==2)& (formants_df.
 ↪position=="ictus")]
first_off_df = formants_df[(formants_df.syllable==1)& (formants_df.
 ↪position=="off")]
second_off_df = formants_df[(formants_df.syllable==2)& (formants_df.
 ↪position=="off")]

chart = sns.
 ↪scatterplot(x="F2",y="F1",data=second_off_df,hue="segment",palette="muted")
chart.invert_xaxis()
chart.invert_yaxis()
```


segment
a
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æ
o
F1
400
600
800
1000
1200
F2
2500
2250
2000
1750
1500
1250
1000
750