Flu Shot Learning - Predict Seasonal Flu Vaccines

August 7, 2020

1 Flu Shot Learning: Predict Seasonal Flu Vaccines

2 Main objective of the analysis that specifies whether your model will be focused on prediction or interpretation

The project is focus solely on prediction of flu vaccines.

3 Brief description of the data set and a summary of its attributes

The data for this competition comes from the National 2009 H1N1 Flu Survey (NHFS).

The National 2009 H1N1 Flu Survey (NHFS) was sponsored by the National Center for Immunization and Respiratory Diseases (NCIRD) and conducted jointly by NCIRD and the National Center for Health Statistics (NCHS), Centers for Disease Control and Prevention (CDC). The NHFS was a list-assisted random-digit-dialing telephone survey of households, designed to monitor influenza immunization coverage in the 2009-10 season.

The target population for the NHFS was all persons 6 months or older living in the United States at the time of the interview. Data from the NHFS were used to produce timely estimates of vaccination coverage rates for both the monovalent pH1N1 and trivalent seasonal influenza vaccines.

The NHFS was conducted between October 2009 and June 2010. It was one-time survey designed specifically to monitor vaccination during the 2009-2010 flu season in response to the 2009 H1N1 pandemic. The CDC has other ongoing programs for annual phone surveys that continue to monitor seasonal flu vaccination.

4 Problem description

Can you predict whether people got seasonal flu vaccines using information they shared about their backgrounds, opinions, and health behaviors?

In this challenge, we will take a look at vaccination, a key public health measure used to fight infectious diseases. Vaccines provide immunization for individuals, and enough immunization in a community can further reduce the spread of diseases through “herd immunity.”

5 The features in this dataset

Your goal is to predict how likely individuals are to receive their seasonal flu vaccines.

Field	Description
seasonal_vaccine	Whether respondent received seasonal flu vaccine
respondent_id	a unique and random identifier
behavioral_antiviral_meds	Has taken antiviral medications. (binary)
behavioral_avoidance	Has avoided close contact with others with flu-like symptoms. (binary)
behavioral_face_mask	Has bought a face mask. (binary)
behavioral_wash_hands	Has frequently washed hands or used hand sanitizer. (binary)
behavioral_large_gatherings	Has reduced time at large gatherings. (binary)
behavioral_outside_home	Has reduced contact with people outside of own household. (binary)
behavioral_touch_face	Has avoided touching eyes, nose, or mouth. (binary)
doctor_recc_seasonal	Seasonal flu vaccine was recommended by doctor. (binary)
chronic_med_condition	Has any of the following chronic medical conditions: asthma or an other lung condition, diabetes, a heart condition, a kidney condition, sickle cell anemia or other anemia, a neurological or neuromuscular condition, a liver condition, or a weakened immune system caused by a chronic illness or by medicines taken for a chronic illness. (binary)
child_under_6_months	Has regular close contact with a child under the age of six months. (binary)
health_worker	Is a healthcare worker. (binary)
health_insurance	Has health insurance. (binary)
opinion_seas_vacc_effective	Respondent's opinion about seasonal flu vaccine effectiveness. 1 = Not at all effective; 2 = Not very effective; 3 = Don't know; 4 = Somewhat effective; 5 = Very effective.
opinion_seas_risk	Respondent's opinion about risk of getting sick with seasonal flu without vaccine. 1 = Very Low; 2 = Somewhat low; 3 = Don't know; 4 = Somewhat high; 5 = Very high.
opinion_seas_sick_from_vacc	Respondent's worry of getting sick from taking seasonal flu vaccine. 1 = Not at all worried; 2 = Not very worried; 3 = Don't know; 4 = Somewhat worried; 5 = Very worried.
age_group	Age group of respondent.
education	Self-reported education level.
race	Race of respondent.
sex	Sex of respondent.
income_poverty	Household annual income of respondent with respect to 2008 Census poverty thresholds.
marital_status	Marital status of respondent.
employment_status	Employment status of respondent.
hhs_geo_region	Respondent's residence using a 10-region geographic classification defined by the U.S. Dept. of Health and Human Services. Values are represented as short random character strings.
census_msa	Respondent's residence within metropolitan statistical areas (MSA) as defined by the U.S. Census.
household_adults	Number of other adults in household, top-coded to 3.
household_children	Number of children in household, top-coded to 3.

Field	Description
employment_industry	Type of industry respondent is employed in. Values are represented as short random character strings.
employment_occupation	Type of occupation of respondent. Values are represented as short random character strings.

6 Brief summary of data exploration and actions taken for data cleaning and feature engineering

Data Exploration includes data summary, statistics, relevant graphs to find any relationships within.

As for data cleaning, we will check for missing values and decide what imputation method. We also check for data duplicates and outliers. Finally perform binary encoding before model training.

6.0.1 Import Libraries

[1]:

```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns
import sklearn

from sklearn.linear_model import LogisticRegression
from sklearn.ensemble import RandomForestClassifier, GradientBoostingClassifier

from sklearn.model_selection import cross_val_score, train_test_split,␣
 ↪GridSearchCV, RandomizedSearchCV
from sklearn.preprocessing import LabelEncoder, StandardScaler, MinMaxScaler,␣
 ↪OneHotEncoder, PolynomialFeatures
from sklearn.metrics import confusion_matrix, classification_report,␣
 ↪mean_absolute_error, mean_squared_error,r2_score
from sklearn.metrics import plot_confusion_matrix, plot_precision_recall_curve,␣
 ↪plot_roc_curve, accuracy_score
from sklearn.metrics import auc, f1_score, precision_score, recall_score,␣
 ↪roc_auc_score


%matplotlib inline
sns.set_style('dark')
sns.set(font_scale=1.2)

import warnings
warnings.filterwarnings('ignore')
import pandas.util.testing as tm
from pycaret.classification import *
```

```
np.random.seed(123)

pd.options.display.max_columns= None
#pd.options.display.max_rows = None
```

```
C:\ProgramData\Anaconda3\lib\site-packages\statsmodels\tools\_testing.py:19:
FutureWarning: pandas.util.testing is deprecated. Use the functions in the
public API at pandas.testing instead.
  import pandas.util.testing as tm
```

[2]:
```
df = pd.read_csv("training_set_features.csv")
```

[3]:
```
df
```

[3]:
```
       respondent_id  behavioral_antiviral_meds  behavioral_avoidance  \
0                  0                        0.0                   0.0
1                  1                        0.0                   1.0
2                  2                        0.0                   1.0
3                  3                        0.0                   1.0
4                  4                        0.0                   1.0
…                …                        …                   …
26702          26702                        0.0                   1.0
26703          26703                        0.0                   1.0
26704          26704                        0.0                   1.0
26705          26705                        0.0                   0.0
26706          26706                        0.0                   1.0

       behavioral_face_mask  behavioral_wash_hands  \
0                       0.0                    0.0
1                       0.0                    1.0
2                       0.0                    0.0
3                       0.0                    1.0
4                       0.0                    1.0
…                    …                    …
26702                   0.0                    0.0
26703                   0.0                    1.0
26704                   1.0                    1.0
26705                   0.0                    0.0
26706                   0.0                    0.0

       behavioral_large_gatherings  behavioral_outside_home  \
0                              0.0                      1.0
1                              0.0                      1.0
2                              0.0                      0.0
3                              1.0                      0.0
4                              1.0                      0.0
…                           …                      …
```

```
26702                          0.0                      1.0
26703                          0.0                      0.0
26704                          1.0                      0.0
26705                          0.0                      0.0
26706                          0.0                      0.0

       behavioral_touch_face  doctor_recc_seasonal  chronic_med_condition  \
0                        1.0                   0.0                    0.0
1                        1.0                   0.0                    0.0
2                        0.0                   NaN                    1.0
3                        0.0                   1.0                    1.0
4                        1.0                   0.0                    0.0
…                      …                   …                    …
26702                    0.0                   0.0                    0.0
26703                    0.0                   1.0                    0.0
26704                    1.0                   0.0                    0.0
26705                    NaN                   0.0                    0.0
26706                    0.0                   0.0                    0.0

       child_under_6_months  health_worker  health_insurance  \
0                       0.0            0.0               1.0
1                       0.0            0.0               1.0
2                       0.0            0.0               NaN
3                       0.0            0.0               NaN
4                       0.0            0.0               NaN
…                     …            …               …
26702                   0.0            0.0               NaN
26703                   0.0            1.0               1.0
26704                   0.0            0.0               NaN
26705                   0.0            0.0               0.0
26706                   0.0            0.0               1.0

       opinion_seas_vacc_effective  opinion_seas_risk  \
0                              2.0                1.0
1                              4.0                2.0
2                              4.0                1.0
3                              5.0                4.0
4                              3.0                1.0
…                            …                …
26702                          5.0                2.0
26703                          5.0                1.0
26704                          5.0                4.0
26705                          2.0                1.0
26706                          5.0                1.0

       opinion_seas_sick_from_vacc      age_group         education      race  \
0                              2.0  55 - 64 Years        < 12 Years     White
```

```
1                              4.0  35 - 44 Years          12 Years     White
2                              2.0  18 - 34 Years  College Graduate     White
3                              1.0      65+ Years          12 Years     White
4                              4.0  45 - 54 Years      Some College     White
…                            …            …               …       …
26702                          2.0      65+ Years      Some College     White
26703                          1.0  18 - 34 Years  College Graduate     White
26704                          2.0  55 - 64 Years      Some College     White
26705                          2.0  18 - 34 Years      Some College  Hispanic
26706                          1.0      65+ Years      Some College     White

          sex             income_poverty marital_status rent_or_own  \
0      Female              Below Poverty    Not Married         Own
1        Male              Below Poverty    Not Married        Rent
2        Male  <= $75,000, Above Poverty    Not Married         Own
3      Female              Below Poverty    Not Married        Rent
4      Female  <= $75,000, Above Poverty        Married         Own
…       …                        …            …         …
26702  Female  <= $75,000, Above Poverty    Not Married         Own
26703    Male  <= $75,000, Above Poverty    Not Married        Rent
26704  Female                        NaN    Not Married         Own
26705  Female  <= $75,000, Above Poverty        Married        Rent
26706    Male  <= $75,000, Above Poverty        Married         Own

        employment_status hhs_geo_region                census_msa  \
0      Not in Labor Force       oxchjgsf                   Non-MSA
1                Employed       bhuqouqj  MSA, Not Principle  City
2                Employed       qufhixun  MSA, Not Principle  City
3      Not in Labor Force       lrircsnp       MSA, Principle City
4                Employed       qufhixun  MSA, Not Principle  City
…                   …            …                       …
26702  Not in Labor Force       qufhixun                   Non-MSA
26703            Employed       lzgpxyit       MSA, Principle City
26704                 NaN       lzgpxyit  MSA, Not Principle  City
26705            Employed       lrircsnp                   Non-MSA
26706  Not in Labor Force       mlyzmhmf       MSA, Principle City

       household_adults  household_children employment_industry  \
0                   0.0                 0.0                 NaN
1                   0.0                 0.0            pxcmvdjn
2                   2.0                 0.0            rucpziij
3                   0.0                 0.0                 NaN
4                   1.0                 0.0            wxleyezf
…                 …                 …                 …
26702               0.0                 0.0                 NaN
26703               1.0                 0.0            fcxhlnwr
26704               0.0                 0.0                 NaN
```

```
26705               1.0                 0.0            fcxhlnwr
26706               1.0                 0.0                 NaN

      employment_occupation  seasonal_vaccine
0                       NaN                 0
1                  xgwztkwe                 1
2                  xtkaffoo                 0
3                       NaN                 1
4                  emcorrxb                 0
…                     …               …
26702                   NaN                 0
26703              cmhcxjea                 0
26704                   NaN                 1
26705              haliazsg                 0
26706                   NaN                 0

[26707 rows x 31 columns]
```

Dataset has 31 categorical features.

[4]:
```
df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 26707 entries, 0 to 26706
Data columns (total 31 columns):
 #   Column                       Non-Null Count  Dtype
---  ------                       --------------  -----
 0   respondent_id                26707 non-null  int64
 1   behavioral_antiviral_meds    26636 non-null  float64
 2   behavioral_avoidance         26499 non-null  float64
 3   behavioral_face_mask         26688 non-null  float64
 4   behavioral_wash_hands        26665 non-null  float64
 5   behavioral_large_gatherings  26620 non-null  float64
 6   behavioral_outside_home      26625 non-null  float64
 7   behavioral_touch_face        26579 non-null  float64
 8   doctor_recc_seasonal         24547 non-null  float64
 9   chronic_med_condition        25736 non-null  float64
 10  child_under_6_months         25887 non-null  float64
 11  health_worker                25903 non-null  float64
 12  health_insurance             14433 non-null  float64
 13  opinion_seas_vacc_effective  26245 non-null  float64
 14  opinion_seas_risk            26193 non-null  float64
 15  opinion_seas_sick_from_vacc  26170 non-null  float64
 16  age_group                    26707 non-null  object
 17  education                    25300 non-null  object
 18  race                         26707 non-null  object
 19  sex                          26707 non-null  object
 20  income_poverty               22284 non-null  object
 21  marital_status               25299 non-null  object
 22  rent_or_own                  24665 non-null  object
 23  employment_status            25244 non-null  object
 24  hhs_geo_region               26707 non-null  object
 25  census_msa                   26707 non-null  object
 26  household_adults             26458 non-null  float64
 27  household_children           26458 non-null  float64
 28  employment_industry          13377 non-null  object
 29  employment_occupation        13237 non-null  object
 30  seasonal_vaccine             26707 non-null  int64
dtypes: float64(17), int64(2), object(12)
memory usage: 6.3+ MB
```

Summary of statistics below:

```
[5]: df.describe(include='all').T
```

```
[5]:                             count unique                        top   freq  \
respondent_id                26707    NaN                        NaN    NaN
behavioral_antiviral_meds    26636    NaN                        NaN    NaN
behavioral_avoidance         26499    NaN                        NaN    NaN
behavioral_face_mask         26688    NaN                        NaN    NaN
behavioral_wash_hands        26665    NaN                        NaN    NaN
behavioral_large_gatherings  26620    NaN                        NaN    NaN
behavioral_outside_home      26625    NaN                        NaN    NaN
behavioral_touch_face        26579    NaN                        NaN    NaN
doctor_recc_seasonal         24547    NaN                        NaN    NaN
chronic_med_condition        25736    NaN                        NaN    NaN
child_under_6_months         25887    NaN                        NaN    NaN
health_worker                25903    NaN                        NaN    NaN
health_insurance             14433    NaN                        NaN    NaN
opinion_seas_vacc_effective  26245    NaN                        NaN    NaN
opinion_seas_risk            26193    NaN                        NaN    NaN
opinion_seas_sick_from_vacc  26170    NaN                        NaN    NaN
age_group                    26707      5                  65+ Years   6843
education                    25300      4           College Graduate  10097
race                         26707      4                      White  21222
sex                          26707      2                     Female  15858
income_poverty               22284      3  <= $75,000, Above Poverty  12777
marital_status               25299      2                    Married  13555
rent_or_own                  24665      2                        Own  18736
employment_status            25244      3                   Employed  13560
hhs_geo_region               26707     10                   lzgpxyit   4297
census_msa                   26707      3   MSA, Not Principle  City  11645
household_adults             26458    NaN                        NaN    NaN
household_children           26458    NaN                        NaN    NaN
employment_industry          13377     21                   fcxhlnwr   2468
employment_occupation        13237     23                   xtkaffoo   1778
```

```
seasonal_vaccine             26707    NaN                        NaN    NaN

                                  mean       std  min     25%    50%      75%  \
respondent_id                    13353   7709.79    0  6676.5  13353  20029.5
behavioral_antiviral_meds    0.0488437  0.215545    0       0      0        0
behavioral_avoidance          0.725612  0.446214    0       0      1        1
behavioral_face_mask         0.0689823  0.253429    0       0      0        0
behavioral_wash_hands         0.825614  0.379448    0       1      1        1
behavioral_large_gatherings    0.35864   0.47961    0       0      0        1
behavioral_outside_home       0.337315  0.472802    0       0      0        1
behavioral_touch_face         0.677264  0.467531    0       0      1        1
doctor_recc_seasonal          0.329735  0.470126    0       0      0        1
chronic_med_condition         0.283261  0.450591    0       0      0        1
child_under_6_months         0.0825897  0.275266    0       0      0        0
health_worker                 0.111918  0.315271    0       0      0        0
health_insurance               0.87972    0.3253    0       1      1        1
opinion_seas_vacc_effective    4.02599   1.08656    1       4      4        5
opinion_seas_risk              2.71916   1.38506    1       2      2        4
opinion_seas_sick_from_vacc    2.11811   1.33295    1       1      2        4
age_group                          NaN       NaN  NaN     NaN    NaN      NaN
education                          NaN       NaN  NaN     NaN    NaN      NaN
race                               NaN       NaN  NaN     NaN    NaN      NaN
sex                                NaN       NaN  NaN     NaN    NaN      NaN
income_poverty                     NaN       NaN  NaN     NaN    NaN      NaN
marital_status                     NaN       NaN  NaN     NaN    NaN      NaN
rent_or_own                        NaN       NaN  NaN     NaN    NaN      NaN
employment_status                  NaN       NaN  NaN     NaN    NaN      NaN
hhs_geo_region                     NaN       NaN  NaN     NaN    NaN      NaN
census_msa                         NaN       NaN  NaN     NaN    NaN      NaN
household_adults              0.886499  0.753422    0       0      1        1
household_children            0.534583  0.928173    0       0      0        1
employment_industry                NaN       NaN  NaN     NaN    NaN      NaN
employment_occupation              NaN       NaN  NaN     NaN    NaN      NaN
seasonal_vaccine              0.465608  0.498825    0       0      0        1

                               max
respondent_id                26706
behavioral_antiviral_meds        1
behavioral_avoidance             1
behavioral_face_mask             1
behavioral_wash_hands            1
behavioral_large_gatherings      1
behavioral_outside_home          1
behavioral_touch_face            1
doctor_recc_seasonal             1
chronic_med_condition            1
child_under_6_months             1
```

```
health_worker                  1
health_insurance               1
opinion_seas_vacc_effective    5
opinion_seas_risk              5
opinion_seas_sick_from_vacc    5
age_group                    NaN
education                    NaN
race                         NaN
sex                          NaN
income_poverty               NaN
marital_status               NaN
rent_or_own                  NaN
employment_status            NaN
hhs_geo_region               NaN
census_msa                   NaN
household_adults               3
household_children             3
employment_industry          NaN
employment_occupation        NaN
seasonal_vaccine               1
```

Shape of dataset:

```
[6]: df.shape
```

```
[6]: (26707, 31)
```

```
[7]: df.columns
```

```
[7]: Index(['respondent_id', 'behavioral_antiviral_meds', 'behavioral_avoidance',
            'behavioral_face_mask', 'behavioral_wash_hands',
            'behavioral_large_gatherings', 'behavioral_outside_home',
            'behavioral_touch_face', 'doctor_recc_seasonal',
            'chronic_med_condition', 'child_under_6_months', 'health_worker',
            'health_insurance', 'opinion_seas_vacc_effective', 'opinion_seas_risk',
            'opinion_seas_sick_from_vacc', 'age_group', 'education', 'race', 'sex',
            'income_poverty', 'marital_status', 'rent_or_own', 'employment_status',
            'hhs_geo_region', 'census_msa', 'household_adults',
            'household_children', 'employment_industry', 'employment_occupation',
            'seasonal_vaccine'],
           dtype='object')
```

6.0.2 Data Exploration

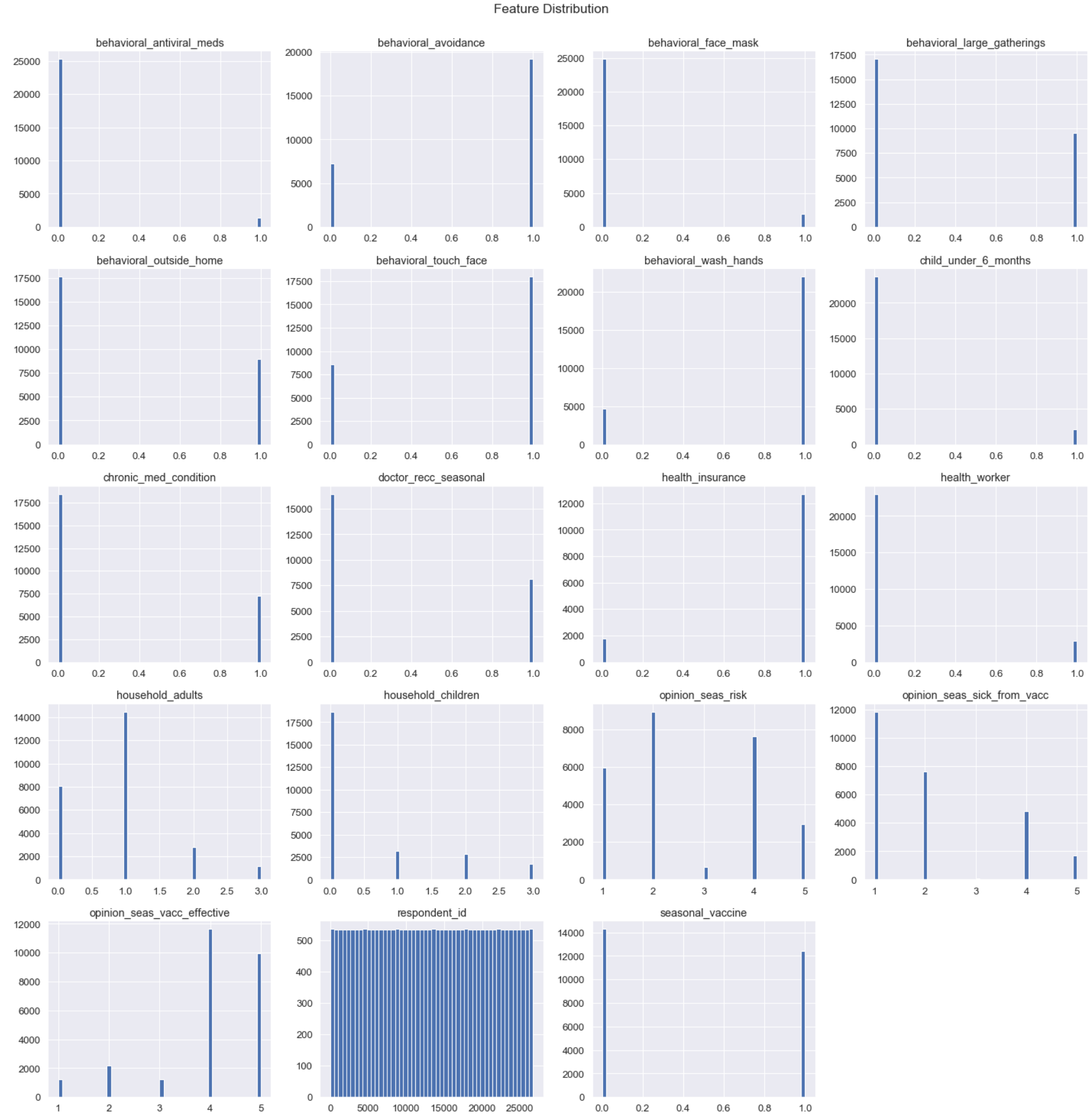
The best way is to create graphs!

6.0.3 Data Visualization

The dataset is mainly discrete/categorical types.

[8]:

```
df.hist(bins=50, figsize=(20,20))

plt.suptitle('Feature Distribution', x=0.5, y=1.02, ha='center',␣
 ↪fontsize='large')

plt.tight_layout()

plt.show();
```

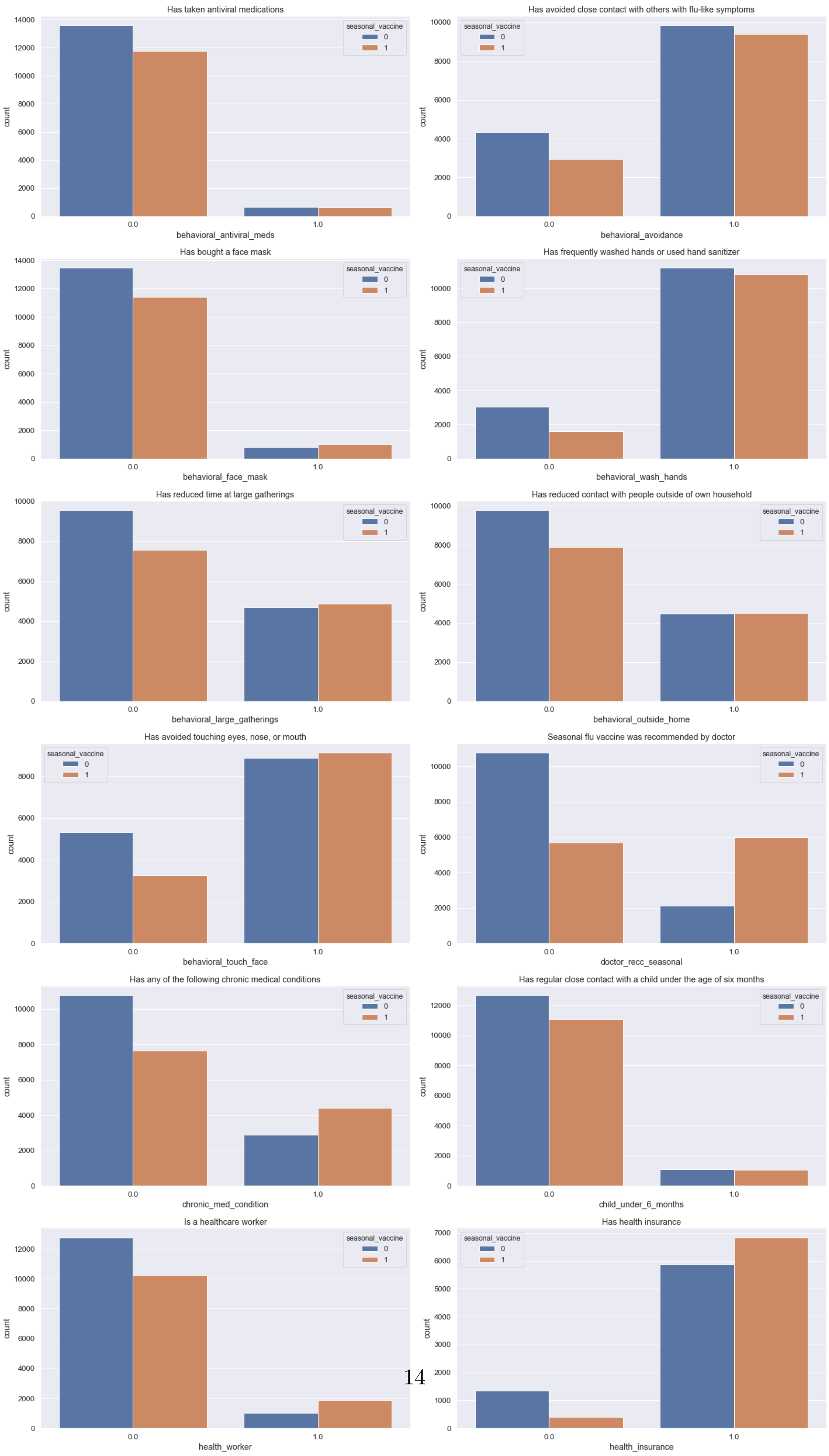


Below are each visuals of the data:

[10]:

```
fig = plt.figure(figsize=(20,40))

plt.subplot(7,2,1)
plt.title("Has taken antiviral medications")
sns.countplot(df.behavioral_antiviral_meds, hue=df.seasonal_vaccine)

plt.subplot(7,2,2)
plt.title("Has avoided close contact with others with flu-like symptoms")
sns.countplot(df.behavioral_avoidance, hue=df.seasonal_vaccine)

plt.subplot(7,2,3)
plt.title("Has bought a face mask")
sns.countplot(df.behavioral_face_mask, hue=df.seasonal_vaccine)

plt.subplot(7,2,4)
plt.title("Has frequently washed hands or used hand sanitizer")
sns.countplot(df.behavioral_wash_hands, hue=df.seasonal_vaccine)

plt.subplot(7,2,5)
plt.title("Has reduced time at large gatherings")
sns.countplot(df.behavioral_large_gatherings, hue=df.seasonal_vaccine)

plt.subplot(7,2,6)
plt.title("Has reduced contact with people outside of own household")
sns.countplot(df.behavioral_outside_home, hue=df.seasonal_vaccine)

plt.subplot(7,2,7)
plt.title("Has avoided touching eyes, nose, or mouth")
sns.countplot(df.behavioral_touch_face, hue=df.seasonal_vaccine)

plt.subplot(7,2,8)
plt.title("Seasonal flu vaccine was recommended by doctor")
sns.countplot(df.doctor_recc_seasonal, hue=df.seasonal_vaccine)

plt.subplot(7,2,9)
plt.title("Has any of the following chronic medical conditions")
sns.countplot(df.chronic_med_condition, hue=df.seasonal_vaccine)

plt.subplot(7,2,10)
plt.title("Has regular close contact with a child under the age of six months")
sns.countplot(df.child_under_6_months, hue=df.seasonal_vaccine)

plt.subplot(7,2,11)
plt.title("Is a healthcare worker")
sns.countplot(df.health_worker, hue=df.seasonal_vaccine)
```

```
plt.subplot(7,2,12)
plt.title("Has health insurance")
sns.countplot(df.health_insurance, hue=df.seasonal_vaccine)


plt.tight_layout()
plt.show()
```


Has taken antiviral medications
count
14000
12000
10000
8000
6000
4000
2000
0
seasonal_vaccine
0
1
0.0
1.0
behavioral_antiviral_meds
Has avoided close contact with others with flu-like symptoms
count
10000
8000
6000
4000
2000
0
seasonal_vaccine
0
1
0.0
1.0
behavioral_avoidance
Has bought a face mask
count
14000
12000
10000
8000
6000
4000
2000
0
seasonal_vaccine
0
1
0.0
1.0
behavioral_face_mask
Has frequently washed hands or used hand sanitizer
count
10000
8000
6000
4000
2000
0
seasonal_vaccine
0
1
0.0
1.0
behavioral_wash_hands
Has reduced time at large gatherings
count
10000
8000
6000
4000
2000
0
seasonal_vaccine
0
1
0.0
1.0
behavioral_large_gatherings
Has reduced contact with people outside of own household
count
10000
8000
6000
4000
2000
0
seasonal_vaccine
0
1
0.0
1.0
behavioral_outside_home
Has avoided touching eyes, nose, or mouth
count
8000
6000
4000
2000
0
seasonal_vaccine
0
1
0.0
1.0
behavioral_touch_face
Seasonal flu vaccine was recommended by doctor
count
10000
8000
6000
4000
2000
0
seasonal_vaccine
0
1
0.0
1.0
doctor_recc_seasonal
Has any of the following chronic medical conditions
count
10000
8000
6000
4000
2000
0
seasonal_vaccine
0
1
0.0
1.0
chronic_med_condition
Has regular close contact with a child under the age of six months
count
12000
10000
8000
6000
4000
2000
0
seasonal_vaccine
0
1
0.0
1.0
child_under_6_months
Is a healthcare worker
count
12000
10000
8000
6000
4000
2000
0
seasonal_vaccine
0
1
0.0
1.0
health_worker
Has health insurance
count
7000
6000
5000
4000
3000
2000
1000
0
seasonal_vaccine
0
1
0.0
1.0
health_insurance

Part 1 of Data Analysis:

Those who had vaccine avoided close contacts which is surprising since vaccines are supposed to protect them. But they didn't avoid large gatherings.

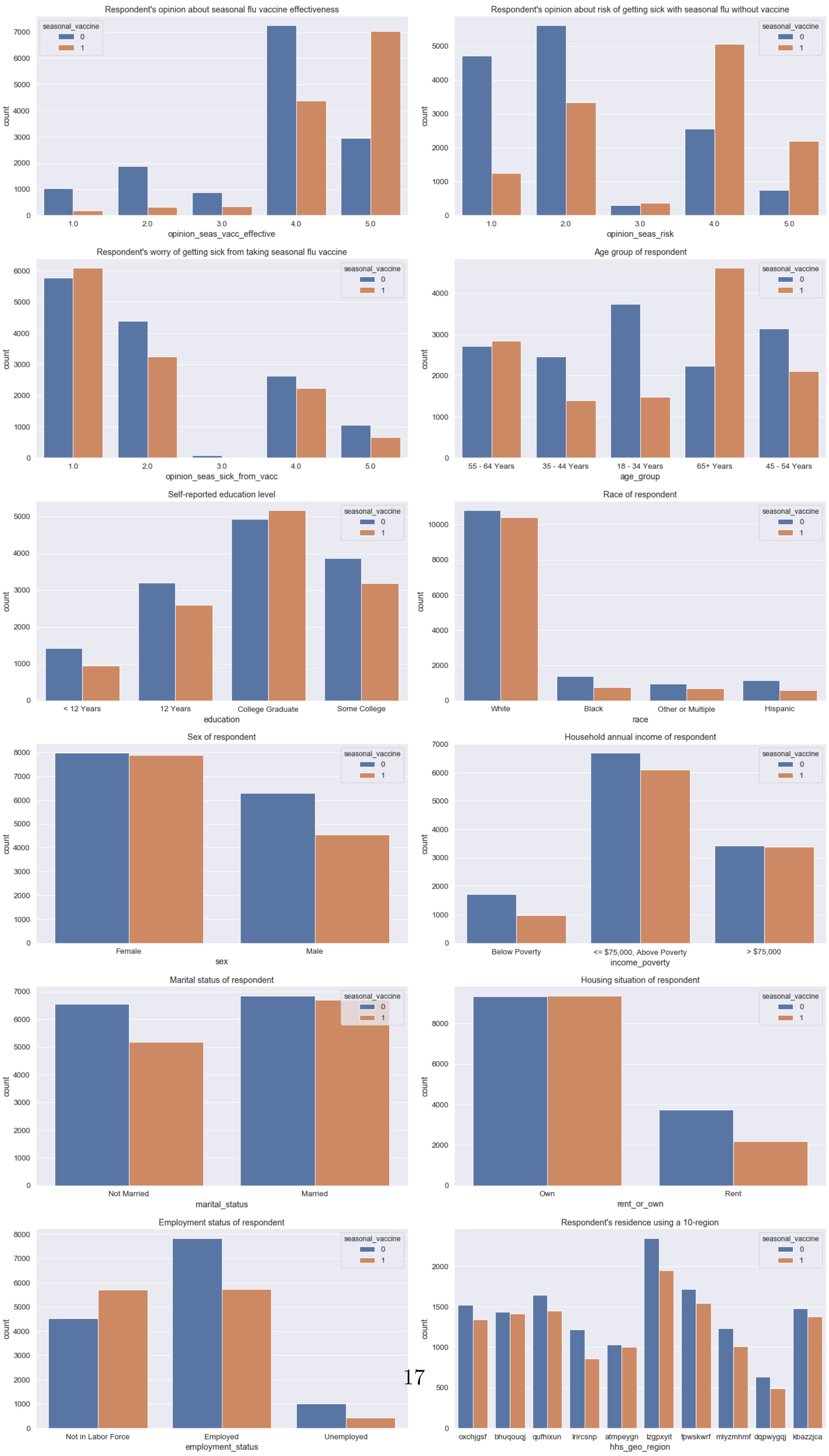
As for flu vaccine which doctor recommended, there is such acceptance among people.

Health Care workers are most vulnerable but majority of them do vaccinate.

[11]:

```
fig = plt.figure(figsize=(20,40))

plt.subplot(7,2,1)
plt.title("Respondent's opinion about seasonal flu vaccine effectiveness")
sns.countplot(df.opinion_seas_vacc_effective, hue=df.seasonal_vaccine)

plt.subplot(7,2,2)
plt.title("Respondent's opinion about risk of getting sick with seasonal flu␣
 ↪without vaccine")
sns.countplot(df.opinion_seas_risk, hue=df.seasonal_vaccine)

plt.subplot(7,2,3)
plt.title("Respondent's worry of getting sick from taking seasonal flu vaccine")
sns.countplot(df.opinion_seas_sick_from_vacc, hue=df.seasonal_vaccine)

plt.subplot(7,2,4)
plt.title("Age group of respondent")
sns.countplot(df.age_group, hue=df.seasonal_vaccine)

plt.subplot(7,2,5)
plt.title("Self-reported education level")
sns.countplot(df.education, hue=df.seasonal_vaccine)

plt.subplot(7,2,6)
plt.title("Race of respondent")
sns.countplot(df.race, hue=df.seasonal_vaccine)

plt.subplot(7,2,7)
plt.title("Sex of respondent")
sns.countplot(df.sex, hue=df.seasonal_vaccine)

plt.subplot(7,2,8)
plt.title("Household annual income of respondent")
sns.countplot(df.income_poverty, hue=df.seasonal_vaccine)

plt.subplot(7,2,9)
plt.title("Marital status of respondent")
```

```
sns.countplot(df.marital_status, hue=df.seasonal_vaccine)

plt.subplot(7,2,10)
plt.title("Housing situation of respondent")
sns.countplot(df.rent_or_own, hue=df.seasonal_vaccine)

plt.subplot(7,2,11)
plt.title("Employment status of respondent")
sns.countplot(df.employment_status, hue=df.seasonal_vaccine)

plt.subplot(7,2,12)
plt.title("Respondent's residence using a 10-region")
sns.countplot(df.hhs_geo_region, hue=df.seasonal_vaccine)



plt.tight_layout()
plt.show()
```


Respondent's opinion about seasonal flu vaccine effectiveness

Respondent's opinion about risk of getting sick with seasonal flu without vaccine

Respondent's worry of getting sick from taking seasonal flu vaccine

Age group of respondent

Self-reported education level

Race of respondent

Sex of respondent

Household annual income of respondent

Marital status of respondent

Housing situation of respondent

Employment status of respondent

Respondent's residence using a 10-region

Part 2 of Data Analysis:

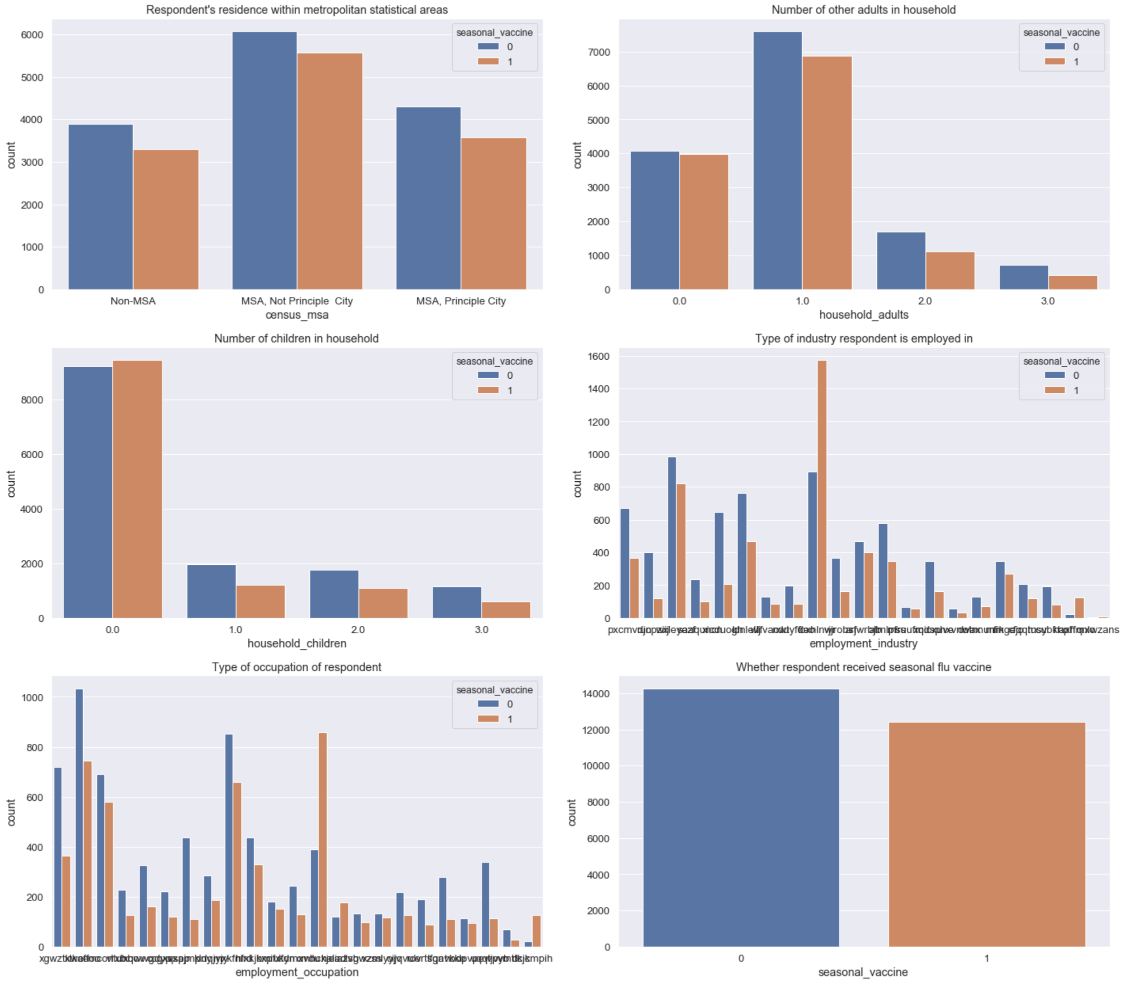
As for respondents opinion, risks and worry, there are no surprises for those who trust flu vaccines.

Respondents more than age 65 and College Educated are vaccinated.

Mainly whites, female, more than 75k income, married, own a house and employed can afford flu vaccines.

[12]:

```
fig = plt.figure(figsize=(20,40))

plt.subplot(7,2,1)
plt.title("Respondent's residence within metropolitan statistical areas")
sns.countplot(df.census_msa, hue=df.seasonal_vaccine)

plt.subplot(7,2,2)
plt.title("Number of other adults in household")
sns.countplot(df.household_adults, hue=df.seasonal_vaccine)

plt.subplot(7,2,3)
plt.title("Number of children in household")
sns.countplot(df.household_children, hue=df.seasonal_vaccine)

plt.subplot(7,2,4)
plt.title("Type of industry respondent is employed in")
sns.countplot(df.employment_industry, hue=df.seasonal_vaccine)

plt.subplot(7,2,5)
plt.title("Type of occupation of respondent")
sns.countplot(df.employment_occupation, hue=df.seasonal_vaccine)

plt.subplot(7,2,6)
plt.title("Whether respondent received seasonal flu vaccine")
sns.countplot(df.seasonal_vaccine)


plt.tight_layout()
plt.show()
```



Part 3 of Data Analysis:

City dwellers, one household adults and no children mainly are vaccinated.

Unknown employment industry and occupation type is masked/not revealed to us.

As for seasonal vaccine, both are more or less equal quantity.

```
[13]: df['seasonal_vaccine'].value_counts()
```

```
[13]: 0    14272
      1    12435
      Name: seasonal_vaccine, dtype: int64
```

Now we check any correlation between features:

```
[14]: df.corr()
```

```
[14]:                        respondent_id  behavioral_antiviral_meds  \
respondent_id                     1.000000                  -0.008475
behavioral_antiviral_meds        -0.008475                   1.000000
behavioral_avoidance              0.009638                   0.049247
behavioral_face_mask             -0.006644                   0.146261
behavioral_wash_hands             0.011105                   0.064119
behavioral_large_gatherings       0.004539                   0.106287
behavioral_outside_home           0.009011                   0.127679
behavioral_touch_face             0.007575                   0.070868
doctor_recc_seasonal              0.001500                   0.030909
chronic_med_condition             0.005797                   0.008465
child_under_6_months             -0.004839                   0.028788
health_worker                    -0.003149                   0.009465
health_insurance                 -0.012603                  -0.063988
opinion_seas_vacc_effective       0.005935                   0.015003
opinion_seas_risk                -0.005291                   0.085315
opinion_seas_sick_from_vacc       0.009563                   0.084305
household_adults                  0.000187                   0.044900
household_children               -0.003726                   0.084822
seasonal_vaccine                 -0.004652                   0.006277

                             behavioral_avoidance  behavioral_face_mask  \
respondent_id                            0.009638             -0.006644
behavioral_antiviral_meds                0.049247              0.146261
behavioral_avoidance                     1.000000              0.064946
behavioral_face_mask                     0.064946              1.000000
behavioral_wash_hands                    0.338130              0.083363
behavioral_large_gatherings              0.227675              0.180907
behavioral_outside_home                  0.220348              0.163382
behavioral_touch_face                    0.335335              0.104335
doctor_recc_seasonal                     0.074088              0.069481
chronic_med_condition                    0.039435              0.068113
child_under_6_months                    -0.000414              0.039726
health_worker                            0.001180              0.069992
health_insurance                         0.032662             -0.040257
opinion_seas_vacc_effective              0.119554              0.041556
opinion_seas_risk                        0.129504              0.110161
opinion_seas_sick_from_vacc              0.082942              0.090009
household_adults                         0.019122              0.013991
household_children                       0.040328              0.005826
seasonal_vaccine                         0.076395              0.050083

                             behavioral_wash_hands  \
respondent_id                             0.011105
behavioral_antiviral_meds                 0.064119
behavioral_avoidance                      0.338130
behavioral_face_mask                      0.083363
```

```
behavioral_wash_hands                        1.000000
behavioral_large_gatherings                  0.195364
behavioral_outside_home                      0.192619
behavioral_touch_face                        0.365064
doctor_recc_seasonal                         0.102044
chronic_med_condition                        0.030260
child_under_6_months                         0.036188
health_worker                                0.053761
health_insurance                             0.031919
opinion_seas_vacc_effective                  0.138517
opinion_seas_risk                            0.172464
opinion_seas_sick_from_vacc                  0.088029
household_adults                             0.009669
household_children                           0.047764
seasonal_vaccine                             0.112414

                             behavioral_large_gatherings  \
respondent_id                                   0.004539
behavioral_antiviral_meds                       0.106287
behavioral_avoidance                            0.227675
behavioral_face_mask                            0.180907
behavioral_wash_hands                           0.195364
behavioral_large_gatherings                     1.000000
behavioral_outside_home                         0.584085
behavioral_touch_face                           0.253683
doctor_recc_seasonal                            0.093557
chronic_med_condition                           0.104721
child_under_6_months                            0.021168
health_worker                                  -0.032319
health_insurance                               -0.059000
opinion_seas_vacc_effective                     0.078491
opinion_seas_risk                               0.132865
opinion_seas_sick_from_vacc                     0.135446
household_adults                               -0.031938
household_children                             -0.009449
seasonal_vaccine                                0.064025

                             behavioral_outside_home  behavioral_touch_face  \
respondent_id                               0.009011               0.007575
behavioral_antiviral_meds                   0.127679               0.070868
behavioral_avoidance                        0.220348               0.335335
behavioral_face_mask                        0.163382               0.104335
behavioral_wash_hands                       0.192619               0.365064
behavioral_large_gatherings                 0.584085               0.253683
behavioral_outside_home                     1.000000               0.267719
behavioral_touch_face                       0.267719               1.000000
doctor_recc_seasonal                        0.085622               0.100808
```

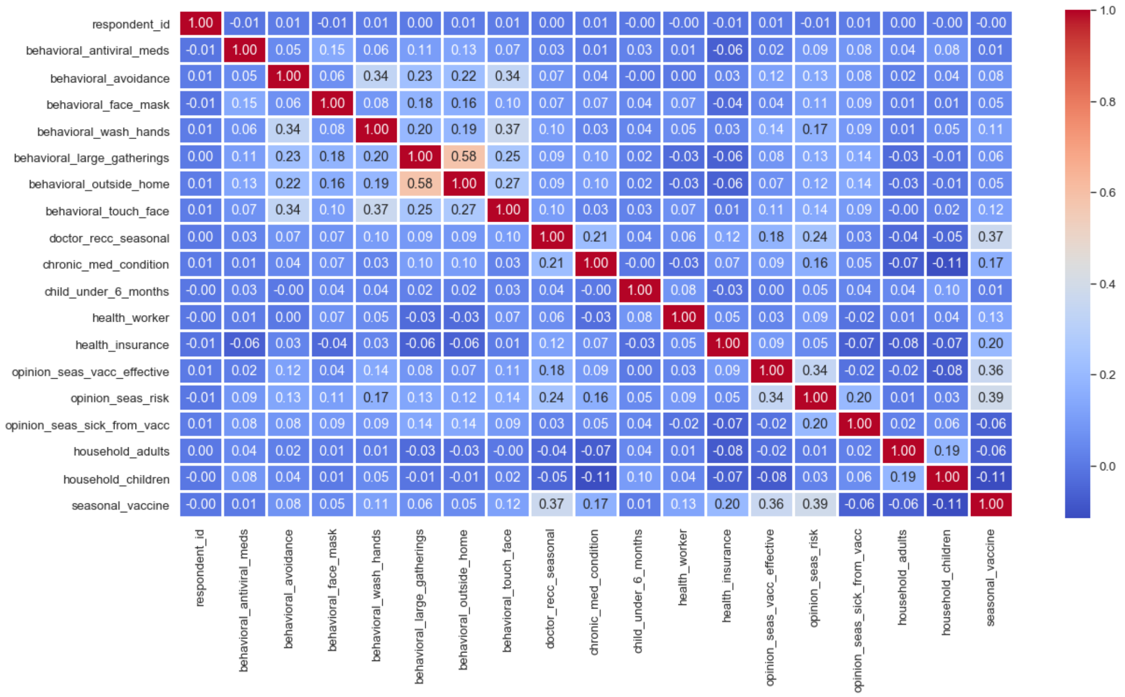
```
chronic_med_condition                       0.098858               0.028876
child_under_6_months                        0.018195               0.026640
health_worker                              -0.034619               0.067648
health_insurance                           -0.061381               0.011024
opinion_seas_vacc_effective                 0.067469               0.105798
opinion_seas_risk                           0.120237               0.143735
opinion_seas_sick_from_vacc                 0.138133               0.090097
household_adults                           -0.027527              -0.000553
household_children                         -0.009558               0.023606
seasonal_vaccine                            0.053509               0.120228

                             doctor_recc_seasonal  chronic_med_condition  \
respondent_id                            0.001500               0.005797
behavioral_antiviral_meds                0.030909               0.008465
behavioral_avoidance                     0.074088               0.039435
behavioral_face_mask                     0.069481               0.068113
behavioral_wash_hands                    0.102044               0.030260
behavioral_large_gatherings              0.093557               0.104721
behavioral_outside_home                  0.085622               0.098858
behavioral_touch_face                    0.100808               0.028876
doctor_recc_seasonal                     1.000000               0.213806
chronic_med_condition                    0.213806               1.000000
child_under_6_months                     0.036832              -0.001349
health_worker                            0.059402              -0.026481
health_insurance                         0.117195               0.066088
opinion_seas_vacc_effective              0.180902               0.091737
opinion_seas_risk                        0.240087               0.162061
opinion_seas_sick_from_vacc              0.025356               0.052587
household_adults                        -0.040769              -0.071346
household_children                      -0.048380              -0.108237
seasonal_vaccine                         0.369190               0.170174

                             child_under_6_months  health_worker  \
respondent_id                           -0.004839      -0.003149
behavioral_antiviral_meds                0.028788       0.009465
behavioral_avoidance                    -0.000414       0.001180
behavioral_face_mask                     0.039726       0.069992
behavioral_wash_hands                    0.036188       0.053761
behavioral_large_gatherings              0.021168      -0.032319
behavioral_outside_home                  0.018195      -0.034619
behavioral_touch_face                    0.026640       0.067648
doctor_recc_seasonal                     0.036832       0.059402
chronic_med_condition                   -0.001349      -0.026481
child_under_6_months                     1.000000       0.079078
health_worker                            0.079078       1.000000
health_insurance                        -0.026836       0.046680
opinion_seas_vacc_effective              0.003653       0.030395
```

```
opinion_seas_risk                        0.050267       0.089142
opinion_seas_sick_from_vacc              0.037582      -0.017893
household_adults                         0.044828       0.013380
household_children                       0.099562       0.037698
seasonal_vaccine                         0.012097       0.127311

                             health_insurance  opinion_seas_vacc_effective  \
respondent_id                       -0.012603                     0.005935
behavioral_antiviral_meds           -0.063988                     0.015003
behavioral_avoidance                 0.032662                     0.119554
behavioral_face_mask                -0.040257                     0.041556
behavioral_wash_hands                0.031919                     0.138517
behavioral_large_gatherings         -0.059000                     0.078491
behavioral_outside_home             -0.061381                     0.067469
behavioral_touch_face                0.011024                     0.105798
doctor_recc_seasonal                 0.117195                     0.180902
chronic_med_condition                0.066088                     0.091737
child_under_6_months                -0.026836                     0.003653
health_worker                        0.046680                     0.030395
health_insurance                     1.000000                     0.091247
opinion_seas_vacc_effective          0.091247                     1.000000
opinion_seas_risk                    0.050232                     0.344800
opinion_seas_sick_from_vacc         -0.065886                    -0.017340
household_adults                    -0.078697                    -0.022579
household_children                  -0.069402                    -0.076503
seasonal_vaccine                     0.200858                     0.361875

                             opinion_seas_risk  opinion_seas_sick_from_vacc  \
respondent_id                        -0.005291                     0.009563
behavioral_antiviral_meds             0.085315                     0.084305
behavioral_avoidance                  0.129504                     0.082942
behavioral_face_mask                  0.110161                     0.090009
behavioral_wash_hands                 0.172464                     0.088029
behavioral_large_gatherings           0.132865                     0.135446
behavioral_outside_home               0.120237                     0.138133
behavioral_touch_face                 0.143735                     0.090097
doctor_recc_seasonal                  0.240087                     0.025356
chronic_med_condition                 0.162061                     0.052587
child_under_6_months                  0.050267                     0.037582
health_worker                         0.089142                    -0.017893
health_insurance                      0.050232                    -0.065886
opinion_seas_vacc_effective           0.344800                    -0.017340
opinion_seas_risk                     1.000000                     0.200379
opinion_seas_sick_from_vacc           0.200379                     1.000000
household_adults                      0.006111                     0.022925
household_children                    0.025898                     0.057286
seasonal_vaccine                      0.390106                    -0.061510
```

```
                             household_adults  household_children  \
respondent_id                        0.000187           -0.003726
behavioral_antiviral_meds            0.044900            0.084822
behavioral_avoidance                 0.019122            0.040328
behavioral_face_mask                 0.013991            0.005826
behavioral_wash_hands                0.009669            0.047764
behavioral_large_gatherings         -0.031938           -0.009449
behavioral_outside_home             -0.027527           -0.009558
behavioral_touch_face               -0.000553            0.023606
doctor_recc_seasonal                -0.040769           -0.048380
chronic_med_condition               -0.071346           -0.108237
child_under_6_months                 0.044828            0.099562
health_worker                        0.013380            0.037698
health_insurance                    -0.078697           -0.069402
opinion_seas_vacc_effective         -0.022579           -0.076503
opinion_seas_risk                    0.006111            0.025898
opinion_seas_sick_from_vacc          0.022925            0.057286
household_adults                     1.000000            0.189571
household_children                   0.189571            1.000000
seasonal_vaccine                    -0.064840           -0.114614

                             seasonal_vaccine
respondent_id                       -0.004652
behavioral_antiviral_meds            0.006277
behavioral_avoidance                 0.076395
behavioral_face_mask                 0.050083
behavioral_wash_hands                0.112414
behavioral_large_gatherings          0.064025
behavioral_outside_home              0.053509
behavioral_touch_face                0.120228
doctor_recc_seasonal                 0.369190
chronic_med_condition                0.170174
child_under_6_months                 0.012097
health_worker                        0.127311
health_insurance                     0.200858
opinion_seas_vacc_effective          0.361875
opinion_seas_risk                    0.390106
opinion_seas_sick_from_vacc         -0.061510
household_adults                    -0.064840
household_children                  -0.114614
seasonal_vaccine                     1.000000
```

[15]:

```
plt.figure(figsize=(20,10))
sns.heatmap(df.corr(),cmap="coolwarm",annot=True,fmt='.2f',linewidths=2)
plt.show()
```



Quote:

“Factors that may bias the results of observational studies can be broadly categorized as: selection bias resulting from the way study subjects are recruited or from differing rates of study participation depending on the subjects’ cultural background, age, or socioeconomic status, information bias, measurement error, confounders, and further factors.”

We will drop a number of features which we think that will make the model biased to a certain group/gender/income/social.

6.0.4 Drop unwanted features

[16]:
```
df.columns
```

[16]:
```
Index(['respondent_id', 'behavioral_antiviral_meds', 'behavioral_avoidance',
       'behavioral_face_mask', 'behavioral_wash_hands',
       'behavioral_large_gatherings', 'behavioral_outside_home',
       'behavioral_touch_face', 'doctor_recc_seasonal',
       'chronic_med_condition', 'child_under_6_months', 'health_worker',
       'health_insurance', 'opinion_seas_vacc_effective', 'opinion_seas_risk',
       'opinion_seas_sick_from_vacc', 'age_group', 'education', 'race', 'sex',
       'income_poverty', 'marital_status', 'rent_or_own', 'employment_status',
       'hhs_geo_region', 'census_msa', 'household_adults',
       'household_children', 'employment_industry', 'employment_occupation',
       'seasonal_vaccine'],
      dtype='object')
```

[17]:

```
df.drop(['respondent_id','health_insurance','age_group', 'education', 'race',␣
↪'sex', 'income_poverty', 'marital_status', 'rent_or_own',
        'employment_status','hhs_geo_region', 'census_msa',␣
↪'household_adults', 'household_children', 'employment_industry',
         'employment_occupation'],axis=1,inplace=True)
```

[18]:

```
df
```

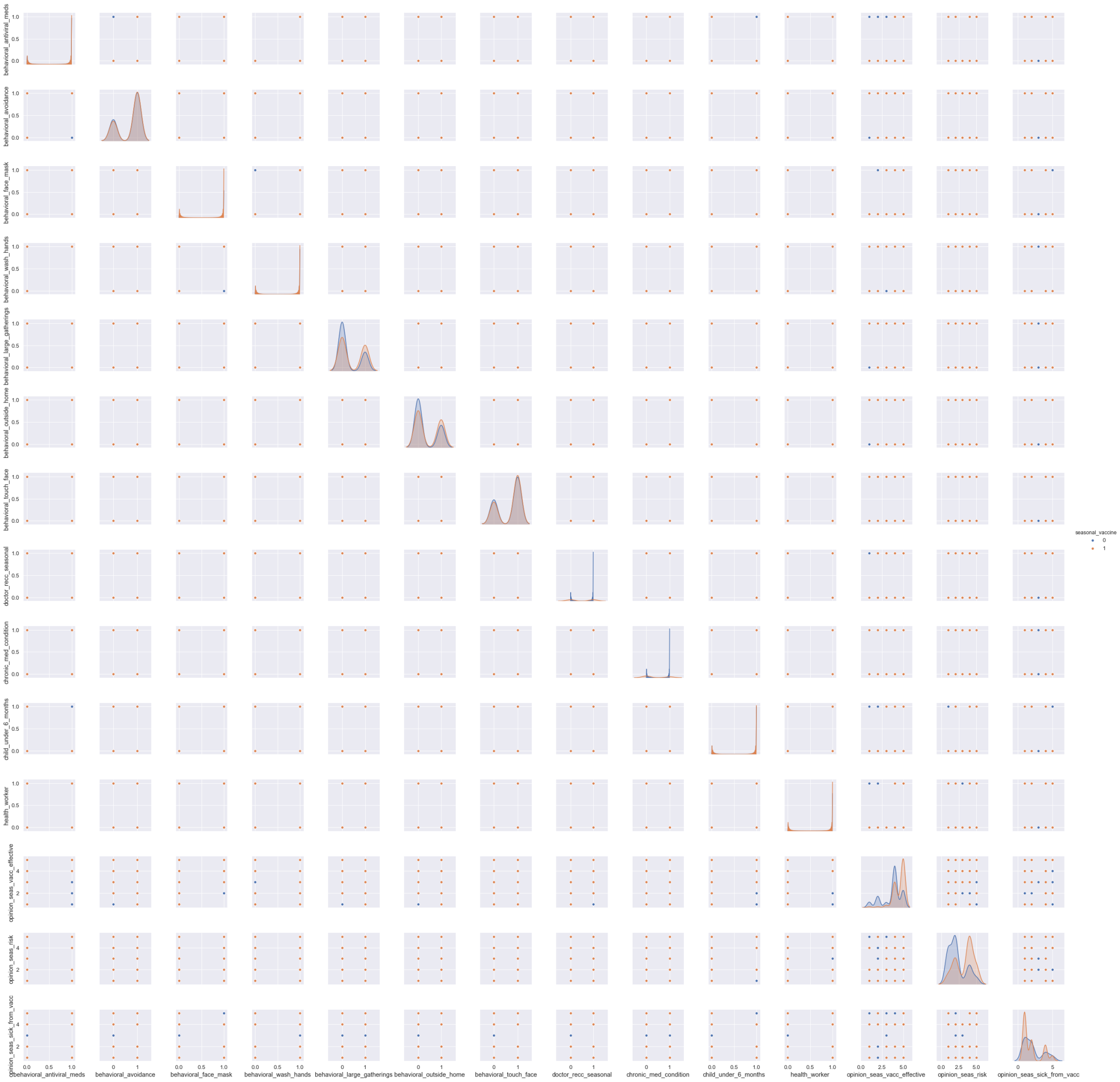
[18]:

```
       behavioral_antiviral_meds  behavioral_avoidance  behavioral_face_mask  \
0                            0.0                   0.0                   0.0
1                            0.0                   1.0                   0.0
2                            0.0                   1.0                   0.0
3                            0.0                   1.0                   0.0
4                            0.0                   1.0                   0.0
…                            …                     …                     …
26702                        0.0                   1.0                   0.0
26703                        0.0                   1.0                   0.0
26704                        0.0                   1.0                   1.0
26705                        0.0                   0.0                   0.0
26706                        0.0                   1.0                   0.0

       behavioral_wash_hands  behavioral_large_gatherings  \
0                        0.0                          0.0
1                        1.0                          0.0
2                        0.0                          0.0
3                        1.0                          1.0
4                        1.0                          1.0
…                        …                            …
26702                    0.0                          0.0
26703                    1.0                          0.0
26704                    1.0                          1.0
26705                    0.0                          0.0
26706                    0.0                          0.0

       behavioral_outside_home  behavioral_touch_face  doctor_recc_seasonal  \
0                          1.0                    1.0                   0.0
1                          1.0                    1.0                   0.0
2                          0.0                    0.0                   NaN
3                          0.0                    0.0                   1.0
4                          0.0                    1.0                   0.0
…                          …                      …                     …
26702                      1.0                    0.0                   0.0
26703                      0.0                    0.0                   1.0
26704                      0.0                    1.0                   0.0
26705                      0.0                    NaN                   0.0
26706                      0.0                    0.0                   0.0
```

```
       chronic_med_condition  child_under_6_months  health_worker  \
0                        0.0                   0.0            0.0
1                        0.0                   0.0            0.0
2                        1.0                   0.0            0.0
3                        1.0                   0.0            0.0
4                        0.0                   0.0            0.0
…                       …                   …            …
26702                    0.0                   0.0            0.0
26703                    0.0                   0.0            1.0
26704                    0.0                   0.0            0.0
26705                    0.0                   0.0            0.0
26706                    0.0                   0.0            0.0

       opinion_seas_vacc_effective  opinion_seas_risk  \
0                              2.0                1.0
1                              4.0                2.0
2                              4.0                1.0
3                              5.0                4.0
4                              3.0                1.0
…                             …                …
26702                          5.0                2.0
26703                          5.0                1.0
26704                          5.0                4.0
26705                          2.0                1.0
26706                          5.0                1.0

       opinion_seas_sick_from_vacc  seasonal_vaccine
0                              2.0                 0
1                              4.0                 1
2                              2.0                 0
3                              1.0                 1
4                              4.0                 0
…                             …               …
26702                          2.0                 0
26703                          1.0                 0
26704                          2.0                 1
26705                          2.0                 0
26706                          1.0                 0

[26707 rows x 15 columns]
```

[19]:

```python
sns.pairplot(df.sample(500), hue='seasonal_vaccine')
plt.show()
```



6.0.5 Treat Missing Values

[20]:
```
df.isnull().sum()
```

[20]:
```
behavioral_antiviral_meds        71
behavioral_avoidance            208
behavioral_face_mask             19
behavioral_wash_hands            42
behavioral_large_gatherings      87
behavioral_outside_home          82
behavioral_touch_face           128
doctor_recc_seasonal           2160
chronic_med_condition           971
child_under_6_months            820
```

```
health_worker                  804
opinion_seas_vacc_effective    462
opinion_seas_risk              514
opinion_seas_sick_from_vacc    537
seasonal_vaccine                 0
dtype: int64
```

```
[21]: df.dropna(inplace=True)
```

```
[22]: df.isnull().sum()
```

```
[22]: behavioral_antiviral_meds      0
      behavioral_avoidance           0
      behavioral_face_mask           0
      behavioral_wash_hands          0
      behavioral_large_gatherings    0
      behavioral_outside_home        0
      behavioral_touch_face          0
      doctor_recc_seasonal           0
      chronic_med_condition          0
      child_under_6_months           0
      health_worker                  0
      opinion_seas_vacc_effective    0
      opinion_seas_risk              0
      opinion_seas_sick_from_vacc    0
      seasonal_vaccine               0
      dtype: int64
```

```
[23]: df.reset_index(drop=True,inplace=True)
```

```
[24]: df
```

```
[24]:        behavioral_antiviral_meds  behavioral_avoidance  behavioral_face_mask  \
      0                            0.0                   0.0                   0.0
      1                            0.0                   1.0                   0.0
      2                            0.0                   1.0                   0.0
      3                            0.0                   1.0                   0.0
      4                            0.0                   1.0                   0.0
      …                          …                   …                   …
      23183                        0.0                   0.0                   0.0
      23184                        0.0                   1.0                   0.0
      23185                        0.0                   1.0                   0.0
      23186                        0.0                   1.0                   1.0
      23187                        0.0                   1.0                   0.0

             behavioral_wash_hands  behavioral_large_gatherings  \
      0                        0.0                          0.0
```

```
1                        1.0                          0.0
2                        1.0                          1.0
3                        1.0                          1.0
4                        1.0                          0.0
…                      …                          …
23183                    1.0                          0.0
23184                    0.0                          0.0
23185                    1.0                          0.0
23186                    1.0                          1.0
23187                    0.0                          0.0

       behavioral_outside_home  behavioral_touch_face  doctor_recc_seasonal  \
0                          1.0                    1.0                   0.0
1                          1.0                    1.0                   0.0
2                          0.0                    0.0                   1.0
3                          0.0                    1.0                   0.0
4                          0.0                    1.0                   1.0
…                        …                    …                   …
23183                      0.0                    1.0                   0.0
23184                      1.0                    0.0                   0.0
23185                      0.0                    0.0                   1.0
23186                      0.0                    1.0                   0.0
23187                      0.0                    0.0                   0.0

       chronic_med_condition  child_under_6_months  health_worker  \
0                        0.0                   0.0            0.0
1                        0.0                   0.0            0.0
2                        1.0                   0.0            0.0
3                        0.0                   0.0            0.0
4                        0.0                   0.0            0.0
…                      …                   …            …
23183                    0.0                   1.0            0.0
23184                    0.0                   0.0            0.0
23185                    0.0                   0.0            1.0
23186                    0.0                   0.0            0.0
23187                    0.0                   0.0            0.0

       opinion_seas_vacc_effective  opinion_seas_risk  \
0                              2.0                1.0
1                              4.0                2.0
2                              5.0                4.0
3                              3.0                1.0
4                              5.0                4.0
…                            …                …
23183                          4.0                2.0
23184                          5.0                2.0
23185                          5.0                1.0
```

```
23186                         5.0               4.0
23187                         5.0               1.0

       opinion_seas_sick_from_vacc  seasonal_vaccine
0                             2.0                 0
1                             4.0                 1
2                             1.0                 1
3                             4.0                 0
4                             4.0                 0
…                               …                 …
23183                         4.0                 0
23184                         2.0                 0
23185                         1.0                 0
23186                         2.0                 1
23187                         1.0                 0

[23188 rows x 15 columns]
```

[25]:
```
df['seasonal_vaccine'].value_counts()
```

[25]:
```
0    12111
1    11077
Name: seasonal_vaccine, dtype: int64
```

[26]:
```
df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 23188 entries, 0 to 23187
Data columns (total 15 columns):
 #   Column                       Non-Null Count  Dtype
---  ------                       --------------  -----
 0   behavioral_antiviral_meds    23188 non-null  float64
 1   behavioral_avoidance         23188 non-null  float64
 2   behavioral_face_mask         23188 non-null  float64
 3   behavioral_wash_hands        23188 non-null  float64
 4   behavioral_large_gatherings  23188 non-null  float64
 5   behavioral_outside_home      23188 non-null  float64
 6   behavioral_touch_face        23188 non-null  float64
 7   doctor_recc_seasonal         23188 non-null  float64
 8   chronic_med_condition        23188 non-null  float64
 9   child_under_6_months         23188 non-null  float64
 10  health_worker                23188 non-null  float64
 11  opinion_seas_vacc_effective  23188 non-null  float64
 12  opinion_seas_risk            23188 non-null  float64
 13  opinion_seas_sick_from_vacc  23188 non-null  float64
 14  seasonal_vaccine             23188 non-null  int64
dtypes: float64(14), int64(1)
```

```
memory usage: 2.7 MB
```

```
[27]: df = df.astype('int8')  #Change to integer type
```

```
[28]: df.dtypes
```

```
[28]: behavioral_antiviral_meds      int8
      behavioral_avoidance           int8
      behavioral_face_mask           int8
      behavioral_wash_hands          int8
      behavioral_large_gatherings    int8
      behavioral_outside_home        int8
      behavioral_touch_face          int8
      doctor_recc_seasonal           int8
      chronic_med_condition          int8
      child_under_6_months           int8
      health_worker                  int8
      opinion_seas_vacc_effective    int8
      opinion_seas_risk              int8
      opinion_seas_sick_from_vacc    int8
      seasonal_vaccine               int8
      dtype: object
```

```
[29]: df
```

```
[29]:        behavioral_antiviral_meds  behavioral_avoidance  behavioral_face_mask  \
      0                              0                     0                     0
      1                              0                     1                     0
      2                              0                     1                     0
      3                              0                     1                     0
      4                              0                     1                     0
      …                            …                   …                   …
      23183                          0                     0                     0
      23184                          0                     1                     0
      23185                          0                     1                     0
      23186                          0                     1                     1
      23187                          0                     1                     0

             behavioral_wash_hands  behavioral_large_gatherings  \
      0                          0                            0
      1                          1                            0
      2                          1                            1
      3                          1                            1
      4                          1                            0
      …                        …                          …
      23183                      1                            0
      23184                      0                            0
```

```
23185                      1                            0
23186                      1                            1
23187                      0                            0

       behavioral_outside_home  behavioral_touch_face  doctor_recc_seasonal  \
0                            1                      1                     0
1                            1                      1                     0
2                            0                      0                     1
3                            0                      1                     0
4                            0                      1                     1
…                        …                    …                   …
23183                        0                      1                     0
23184                        1                      0                     0
23185                        0                      0                     1
23186                        0                      1                     0
23187                        0                      0                     0

       chronic_med_condition  child_under_6_months  health_worker  \
0                          0                     0              0
1                          0                     0              0
2                          1                     0              0
3                          0                     0              0
4                          0                     0              0
…                      …                   …            …
23183                      0                     1              0
23184                      0                     0              0
23185                      0                     0              1
23186                      0                     0              0
23187                      0                     0              0

       opinion_seas_vacc_effective  opinion_seas_risk  \
0                                2                  1
1                                4                  2
2                                5                  4
3                                3                  1
4                                5                  4
…                            …                …
23183                            4                  2
23184                            5                  2
23185                            5                  1
23186                            5                  4
23187                            5                  1

       opinion_seas_sick_from_vacc  seasonal_vaccine
0                                2                 0
1                                4                 1
2                                1                 1
```

```
3                                4                 0
4                                4                 0
…                            …               …
23183                            4                 0
23184                            2                 0
23185                            1                 0
23186                            2                 1
23187                            1                 0

[23188 rows x 15 columns]
```

[30]:

```
df.describe()
```

[30]:

```
       behavioral_antiviral_meds  behavioral_avoidance  behavioral_face_mask  \
count               23188.000000          23188.000000          23188.000000   
mean                    0.049336              0.731197              0.068139   
std                     0.216573              0.443347              0.251989   
min                     0.000000              0.000000              0.000000   
25%                     0.000000              0.000000              0.000000   
50%                     0.000000              1.000000              0.000000   
75%                     0.000000              1.000000              0.000000   
max                     1.000000              1.000000              1.000000   

       behavioral_wash_hands  behavioral_large_gatherings  \
count           23188.000000                 23188.000000   
mean                0.829481                     0.358289   
std                 0.376096                     0.479508   
min                 0.000000                     0.000000   
25%                 1.000000                     0.000000   
50%                 1.000000                     0.000000   
75%                 1.000000                     1.000000   
max                 1.000000                     1.000000   

       behavioral_outside_home  behavioral_touch_face  doctor_recc_seasonal  \
count             23188.000000           23188.000000          23188.000000   
mean                  0.336855               0.684319              0.331335   
std                   0.472645               0.464796              0.470703   
min                   0.000000               0.000000              0.000000   
25%                   0.000000               0.000000              0.000000   
50%                   0.000000               1.000000              0.000000   
75%                   1.000000               1.000000              1.000000   
max                   1.000000               1.000000              1.000000   

       chronic_med_condition  child_under_6_months  health_worker  \
count           23188.000000          23188.000000   23188.000000   
mean                0.284199              0.084009       0.113723   
std                 0.451042              0.277407       0.317481   
```

```
min                 0.000000              0.000000       0.000000
25%                 0.000000              0.000000       0.000000
50%                 0.000000              0.000000       0.000000
75%                 1.000000              0.000000       0.000000
max                 1.000000              1.000000       1.000000

       opinion_seas_vacc_effective  opinion_seas_risk  \
count                 23188.000000       23188.000000
mean                      4.038166           2.730680
std                       1.078839           1.388191
min                       1.000000           1.000000
25%                       4.000000           2.000000
50%                       4.000000           2.000000
75%                       5.000000           4.000000
max                       5.000000           5.000000

       opinion_seas_sick_from_vacc  seasonal_vaccine
count                 23188.000000      23188.000000
mean                      2.115577          0.477704
std                       1.332636          0.499513
min                       1.000000          0.000000
25%                       1.000000          0.000000
50%                       2.000000          0.000000
75%                       4.000000          1.000000
max                       5.000000          1.000000
```

[31]:
```python
df['opinion_seas_vacc_effective'] = df['opinion_seas_vacc_effective'].
 ↪astype('object')
```

[32]:
```python
df['opinion_seas_risk'] = df['opinion_seas_risk'].astype('object')
```

[33]:
```python
df['opinion_seas_sick_from_vacc'] = df['opinion_seas_sick_from_vacc'].
 ↪astype('object')
```

[34]:
```python
df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 23188 entries, 0 to 23187
Data columns (total 15 columns):
 #   Column                       Non-Null Count  Dtype
---  ------                       --------------  -----
 0   behavioral_antiviral_meds    23188 non-null  int8
 1   behavioral_avoidance         23188 non-null  int8
 2   behavioral_face_mask         23188 non-null  int8
 3   behavioral_wash_hands        23188 non-null  int8
 4   behavioral_large_gatherings  23188 non-null  int8
 5   behavioral_outside_home      23188 non-null  int8
 6   behavioral_touch_face        23188 non-null  int8
 7   doctor_recc_seasonal         23188 non-null  int8
 8   chronic_med_condition        23188 non-null  int8
 9   child_under_6_months         23188 non-null  int8
 10  health_worker                23188 non-null  int8
 11  opinion_seas_vacc_effective  23188 non-null  object
 12  opinion_seas_risk            23188 non-null  object
 13  opinion_seas_sick_from_vacc  23188 non-null  object
 14  seasonal_vaccine             23188 non-null  int8
dtypes: int8(12), object(3)
memory usage: 815.3+ KB
```

6.0.6 Create dummy variables

[35]:
```
df2 = pd.get_dummies(data=df, drop_first=True)
```

[36]:
```
df2
```

[36]:
```
       behavioral_antiviral_meds  behavioral_avoidance  behavioral_face_mask  \
0                              0                     0                     0
1                              0                     1                     0
2                              0                     1                     0
3                              0                     1                     0
4                              0                     1                     0
…                            …                     …                     …
23183                          0                     0                     0
23184                          0                     1                     0
23185                          0                     1                     0
23186                          0                     1                     1
23187                          0                     1                     0

       behavioral_wash_hands  behavioral_large_gatherings  \
0                          0                            0
1                          1                            0
2                          1                            1
3                          1                            1
4                          1                            0
…                        …                          …
23183                      1                            0
23184                      0                            0
23185                      1                            0
23186                      1                            1
23187                      0                            0

       behavioral_outside_home  behavioral_touch_face  doctor_recc_seasonal  \
0                            1                      1                     0
1                            1                      1                     0
```

```
2                            0                      0                    1
3                            0                      1                    0
4                            0                      1                    1
…                        …                    …                  …
23183                        0                      1                    0
23184                        1                      0                    0
23185                        0                      0                    1
23186                        0                      1                    0
23187                        0                      0                    0

       chronic_med_condition  child_under_6_months  health_worker  \
0                          0                     0              0
1                          0                     0              0
2                          1                     0              0
3                          0                     0              0
4                          0                     0              0
…                      …                   …            …
23183                      0                     1              0
23184                      0                     0              0
23185                      0                     0              1
23186                      0                     0              0
23187                      0                     0              0

       seasonal_vaccine  opinion_seas_vacc_effective_2  \
0                     0                              1
1                     1                              0
2                     1                              0
3                     0                              0
4                     0                              0
…                 …                            …
23183                 0                              0
23184                 0                              0
23185                 0                              0
23186                 1                              0
23187                 0                              0

       opinion_seas_vacc_effective_3  opinion_seas_vacc_effective_4  \
0                                  0                              0
1                                  0                              1
2                                  0                              0
3                                  1                              0
4                                  0                              0
…                              …                            …
23183                              0                              1
23184                              0                              0
23185                              0                              0
23186                              0                              0
```

```
23187                              0                              0

       opinion_seas_vacc_effective_5  opinion_seas_risk_2  \
0                                  0                    0   
1                                  0                    1   
2                                  1                    0   
3                                  0                    0   
4                                  1                    0   
…                              …                   …
23183                              0                    1   
23184                              1                    1   
23185                              1                    0   
23186                              1                    0   
23187                              1                    0   

       opinion_seas_risk_3  opinion_seas_risk_4  opinion_seas_risk_5  \
0                        0                    0                    0   
1                        0                    0                    0   
2                        0                    1                    0   
3                        0                    0                    0   
4                        0                    1                    0   
…                     …                  …                  …
23183                    0                    0                    0   
23184                    0                    0                    0   
23185                    0                    0                    0   
23186                    0                    1                    0   
23187                    0                    0                    0   

       opinion_seas_sick_from_vacc_2  opinion_seas_sick_from_vacc_3  \
0                                  1                              0   
1                                  0                              0   
2                                  0                              0   
3                                  0                              0   
4                                  0                              0   
…                              …                             …
23183                              0                              0   
23184                              1                              0   
23185                              0                              0   
23186                              1                              0   
23187                              0                              0   

       opinion_seas_sick_from_vacc_4  opinion_seas_sick_from_vacc_5  
0                                  0                              0  
1                                  1                              0  
2                                  0                              0  
3                                  1                              0  
4                                  1                              0  
```

```
…                              …                            …
23183                              1                             0
23184                              0                             0
23185                              0                             0
23186                              0                             0
23187                              0                             0

[23188 rows x 24 columns]
```

[37]:
```
df2.columns
```

[37]:
```
Index(['behavioral_antiviral_meds', 'behavioral_avoidance',
       'behavioral_face_mask', 'behavioral_wash_hands',
       'behavioral_large_gatherings', 'behavioral_outside_home',
       'behavioral_touch_face', 'doctor_recc_seasonal',
       'chronic_med_condition', 'child_under_6_months', 'health_worker',
       'seasonal_vaccine', 'opinion_seas_vacc_effective_2',
       'opinion_seas_vacc_effective_3', 'opinion_seas_vacc_effective_4',
       'opinion_seas_vacc_effective_5', 'opinion_seas_risk_2',
       'opinion_seas_risk_3', 'opinion_seas_risk_4', 'opinion_seas_risk_5',
       'opinion_seas_sick_from_vacc_2', 'opinion_seas_sick_from_vacc_3',
       'opinion_seas_sick_from_vacc_4', 'opinion_seas_sick_from_vacc_5'],
      dtype='object')
```

[38]:
```
df2 = df2[['behavioral_antiviral_meds', 'behavioral_avoidance',
       'behavioral_face_mask', 'behavioral_wash_hands',
       'behavioral_large_gatherings', 'behavioral_outside_home',
       'behavioral_touch_face', 'doctor_recc_seasonal',
       'chronic_med_condition', 'child_under_6_months', 'health_worker',
       'opinion_seas_vacc_effective_2',
       'opinion_seas_vacc_effective_3', 'opinion_seas_vacc_effective_4',
       'opinion_seas_vacc_effective_5', 'opinion_seas_risk_2',
       'opinion_seas_risk_3', 'opinion_seas_risk_4', 'opinion_seas_risk_5',
       'opinion_seas_sick_from_vacc_2', 'opinion_seas_sick_from_vacc_3',
       'opinion_seas_sick_from_vacc_4',␣
 ↪'opinion_seas_sick_from_vacc_5','seasonal_vaccine' ]]
```

[39]:
```
df2
```

[39]:
```
       behavioral_antiviral_meds  behavioral_avoidance  behavioral_face_mask  \
0                              0                     0                     0
1                              0                     1                     0
2                              0                     1                     0
3                              0                     1                     0
4                              0                     1                     0
…                          …                   …                  …
23183                          0                     0                     0
```

```
23184                          0                     1                     0
23185                          0                     1                     0
23186                          0                     1                     1
23187                          0                     1                     0

       behavioral_wash_hands  behavioral_large_gatherings  \
0                          0                            0
1                          1                            0
2                          1                            1
3                          1                            1
4                          1                            0
…                      …                          …
23183                      1                            0
23184                      0                            0
23185                      1                            0
23186                      1                            1
23187                      0                            0

       behavioral_outside_home  behavioral_touch_face  doctor_recc_seasonal  \
0                            1                      1                     0
1                            1                      1                     0
2                            0                      0                     1
3                            0                      1                     0
4                            0                      1                     1
…                        …                    …                   …
23183                        0                      1                     0
23184                        1                      0                     0
23185                        0                      0                     1
23186                        0                      1                     0
23187                        0                      0                     0

       chronic_med_condition  child_under_6_months  health_worker  \
0                          0                     0              0
1                          0                     0              0
2                          1                     0              0
3                          0                     0              0
4                          0                     0              0
…                      …                   …            …
23183                      0                     1              0
23184                      0                     0              0
23185                      0                     0              1
23186                      0                     0              0
23187                      0                     0              0

       opinion_seas_vacc_effective_2  opinion_seas_vacc_effective_3  \
0                                  1                              0
1                                  0                              0
```

```
2                                  0                              0
3                                  0                              1
4                                  0                              0
…                              …                            …
23183                              0                              0
23184                              0                              0
23185                              0                              0
23186                              0                              0
23187                              0                              0

       opinion_seas_vacc_effective_4  opinion_seas_vacc_effective_5  \
0                                  0                              0
1                                  1                              0
2                                  0                              1
3                                  0                              0
4                                  0                              1
…                              …                            …
23183                              1                              0
23184                              0                              1
23185                              0                              1
23186                              0                              1
23187                              0                              1

       opinion_seas_risk_2  opinion_seas_risk_3  opinion_seas_risk_4  \
0                        0                    0                    0
1                        1                    0                    0
2                        0                    0                    1
3                        0                    0                    0
4                        0                    0                    1
…                    …                  …                  …
23183                    1                    0                    0
23184                    1                    0                    0
23185                    0                    0                    0
23186                    0                    0                    1
23187                    0                    0                    0

       opinion_seas_risk_5  opinion_seas_sick_from_vacc_2  \
0                        0                              1
1                        0                              0
2                        0                              0
3                        0                              0
4                        0                              0
…                    …                            …
23183                    0                              0
23184                    0                              1
23185                    0                              0
23186                    0                              1
```

```
23187                    0                              0

       opinion_seas_sick_from_vacc_3  opinion_seas_sick_from_vacc_4  \
0                                  0                              0
1                                  0                              1
2                                  0                              0
3                                  0                              1
4                                  0                              1
…                              …                            …
23183                              0                              1
23184                              0                              0
23185                              0                              0
23186                              0                              0
23187                              0                              0

       opinion_seas_sick_from_vacc_5  seasonal_vaccine
0                                  0                 0
1                                  0                 1
2                                  0                 1
3                                  0                 0
4                                  0                 0
…                              …               …
23183                              0                 0
23184                              0                 0
23185                              0                 0
23186                              0                 1
23187                              0                 0

[23188 rows x 24 columns]
```

6.0.7 Create and save processed dataset

```
[40]: df2.to_csv("train.csv",index=False)
```

```
[ ]:
```

```
[41]: df = pd.read_csv("train.csv")
```

```
[42]: df
```

```
[42]:
       behavioral_antiviral_meds  behavioral_avoidance  behavioral_face_mask  \
0                              0                     0                     0
1                              0                     1                     0
2                              0                     1                     0
3                              0                     1                     0
4                              0                     1                     0
…                          …                   …                   …
```

```
23183                          0                     0                     0
23184                          0                     1                     0
23185                          0                     1                     0
23186                          0                     1                     1
23187                          0                     1                     0

       behavioral_wash_hands  behavioral_large_gatherings  \
0                          0                            0
1                          1                            0
2                          1                            1
3                          1                            1
4                          1                            0
…                      …                          …
23183                      1                            0
23184                      0                            0
23185                      1                            0
23186                      1                            1
23187                      0                            0

       behavioral_outside_home  behavioral_touch_face  doctor_recc_seasonal  \
0                            1                      1                     0
1                            1                      1                     0
2                            0                      0                     1
3                            0                      1                     0
4                            0                      1                     1
…                        …                    …                   …
23183                        0                      1                     0
23184                        1                      0                     0
23185                        0                      0                     1
23186                        0                      1                     0
23187                        0                      0                     0

       chronic_med_condition  child_under_6_months  health_worker  \
0                          0                     0              0
1                          0                     0              0
2                          1                     0              0
3                          0                     0              0
4                          0                     0              0
…                      …                   …            …
23183                      0                     1              0
23184                      0                     0              0
23185                      0                     0              1
23186                      0                     0              0
23187                      0                     0              0

       opinion_seas_vacc_effective_2  opinion_seas_vacc_effective_3  \
0                                  1                              0
```

```
1                                  0                              0
2                                  0                              0
3                                  0                              1
4                                  0                              0
…                              …                            …
23183                              0                              0
23184                              0                              0
23185                              0                              0
23186                              0                              0
23187                              0                              0

       opinion_seas_vacc_effective_4  opinion_seas_vacc_effective_5  \
0                                  0                              0
1                                  1                              0
2                                  0                              1
3                                  0                              0
4                                  0                              1
…                              …                            …
23183                              1                              0
23184                              0                              1
23185                              0                              1
23186                              0                              1
23187                              0                              1

       opinion_seas_risk_2  opinion_seas_risk_3  opinion_seas_risk_4  \
0                        0                    0                    0
1                        1                    0                    0
2                        0                    0                    1
3                        0                    0                    0
4                        0                    0                    1
…                    …                  …                  …
23183                    1                    0                    0
23184                    1                    0                    0
23185                    0                    0                    0
23186                    0                    0                    1
23187                    0                    0                    0

       opinion_seas_risk_5  opinion_seas_sick_from_vacc_2  \
0                        0                              1
1                        0                              0
2                        0                              0
3                        0                              0
4                        0                              0
…                    …                            …
23183                    0                              0
23184                    0                              1
23185                    0                              0
```

```
23186                    0                              1
23187                    0                              0

       opinion_seas_sick_from_vacc_3  opinion_seas_sick_from_vacc_4  \
0                                  0                              0
1                                  0                              1
2                                  0                              0
3                                  0                              1
4                                  0                              1
…                              …                            …
23183                              0                              1
23184                              0                              0
23185                              0                              0
23186                              0                              0
23187                              0                              0

       opinion_seas_sick_from_vacc_5  seasonal_vaccine
0                                  0                 0
1                                  0                 1
2                                  0                 1
3                                  0                 0
4                                  0                 0
…                              …               …
23183                              0                 0
23184                              0                 0
23185                              0                 0
23186                              0                 1
23187                              0                 0

[23188 rows x 24 columns]
```

[43]:
```
df.shape
```

[43]:
```
(23188, 24)
```

7 Summary of training at least three different classifier models, preferably of different nature in explainability and predictability. For example, you can start with a simple logistic regression as a baseline, adding other models or ensemble models. Preferably, all your models use the same training and test splits, or the same cross-validation method.

7.0.1 Train Test Split

[44]:

```
X = df.iloc[:,0:23]
y = df.iloc[:,23]
```

[45]:

```
X.values
```

[45]:

```
array([[0, 0, 0, …, 0, 0, 0],
       [0, 1, 0, …, 0, 1, 0],
       [0, 1, 0, …, 0, 0, 0],
       …,
       [0, 1, 0, …, 0, 0, 0],
       [0, 1, 1, …, 0, 0, 0],
       [0, 1, 0, …, 0, 0, 0]], dtype=int64)
```

[46]:

```
y.values
```

[46]:

```
array([0, 1, 1, …, 0, 1, 0], dtype=int64)
```

[47]:

```
X_train, X_test, y_train, y_test = train_test_split(X.values, y.values,␣
 ↪test_size=0.2, random_state=123, stratify=y)
```

[48]:

```
X_train
```

[48]:

```
array([[0, 1, 0, …, 0, 0, 0],
       [0, 1, 0, …, 0, 0, 0],
       [0, 1, 0, …, 0, 0, 0],
       …,
       [0, 1, 1, …, 0, 0, 0],
       [0, 0, 0, …, 0, 0, 0],
       [0, 1, 0, …, 0, 0, 0]], dtype=int64)
```

[49]:

```
X_test
```

[49]:

```
array([[0, 1, 0, …, 0, 0, 0],
       [0, 1, 0, …, 0, 0, 0],
       [0, 0, 0, …, 0, 0, 0],
       …,
       [0, 0, 0, …, 0, 0, 0],
       [1, 0, 0, …, 0, 0, 0],
       [0, 1, 0, …, 0, 0, 0]], dtype=int64)
```

```
[50]: y_train
```

```
[50]: array([1, 0, 1, …, 1, 1, 1], dtype=int64)
```

7.0.2 Logistic Regression

```
[51]: lr = LogisticRegression(random_state=123)
```

```
[52]: lr.fit(X_train, y_train)
```

```
[52]: LogisticRegression(C=1.0, class_weight=None, dual=False, fit_intercept=True,
                         intercept_scaling=1, l1_ratio=None, max_iter=100,
                         multi_class='auto', n_jobs=None, penalty='l2',
                         random_state=123, solver='lbfgs', tol=0.0001, verbose=0,
                         warm_start=False)
```

```
[53]: lr.coef_
```

```
[53]: array([[-0.23062336, -0.07794305, -0.00527337,  0.09815467,  0.00333909,
              -0.07933634,  0.27948713,  1.36430408,  0.35155097, -0.16748045,
               0.79348647, -0.29698112,  0.6244859 ,  0.75495696,  1.77721418,
               0.80614637,  1.6792209 ,  1.70246871,  2.0063813 , -0.44950573,
              -1.62206222, -0.67756796, -1.24302248]])
```

```
[54]: lr.intercept_
```

```
[54]: array([-2.63615376])
```

```
[55]: ypred_lr = lr.predict(X_test)
```

```
[56]: y_test[:10]
```

```
[56]: array([1, 0, 1, 0, 1, 1, 1, 0, 1, 1], dtype=int64)
```

```
[57]: ypred_lr[:10]
```

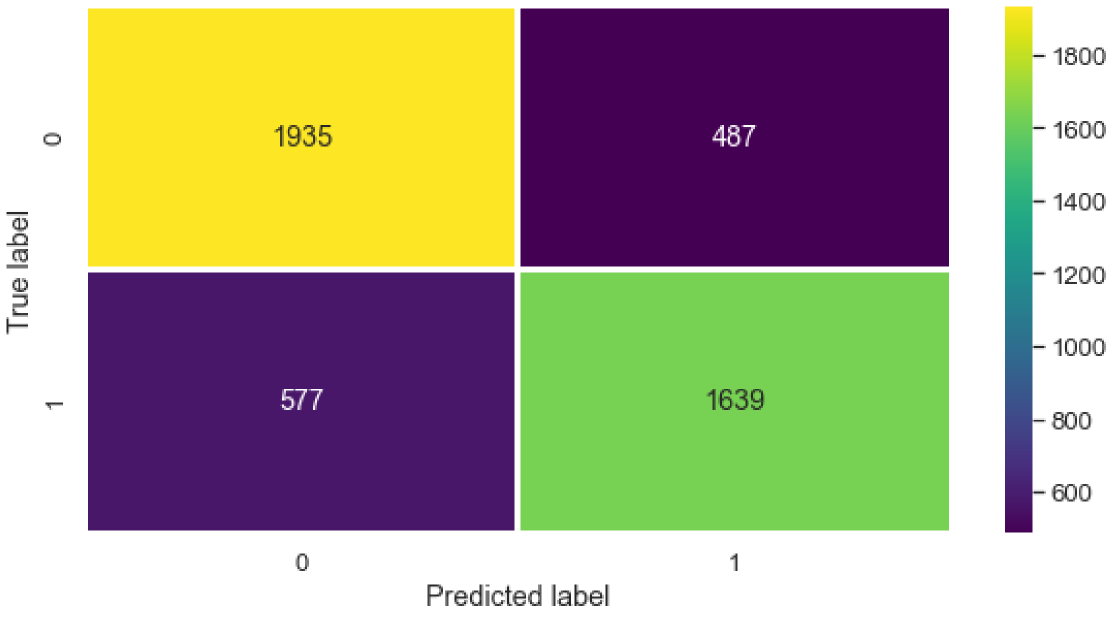
```
[57]: array([1, 0, 0, 0, 1, 1, 1, 0, 0, 1], dtype=int64)
```

7.0.3 Logistic Regression Model Evaluation

```
[58]: cm = confusion_matrix(y_test,ypred_lr)
      cm
```

[58]:
```
array([[1935,  487],
       [ 577, 1639]], dtype=int64)
```

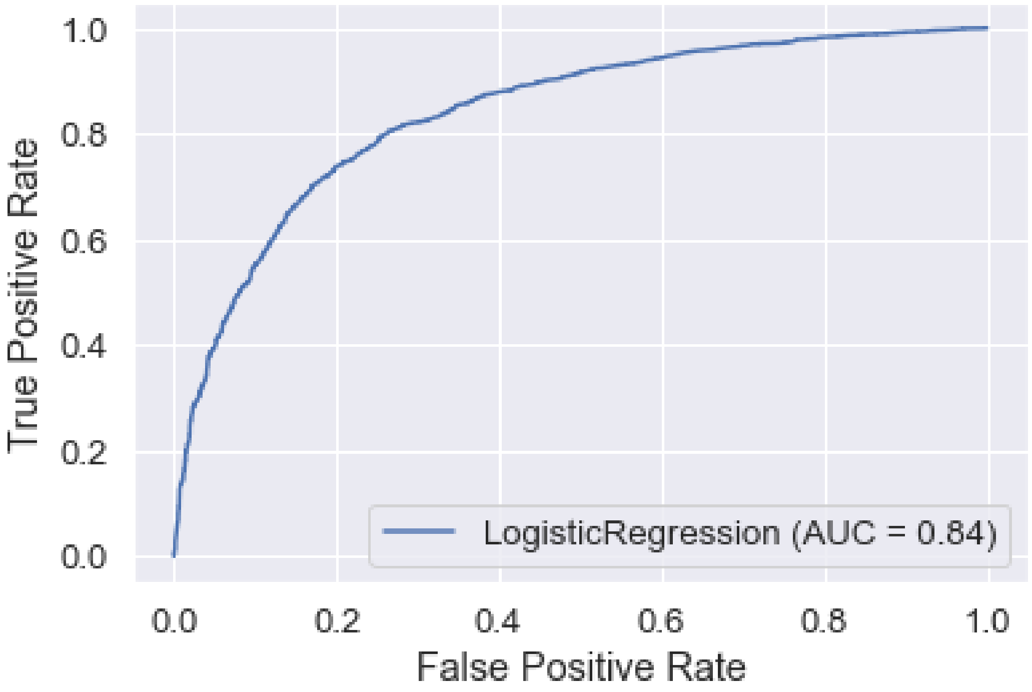
[59]:
```
fig , ax = plt.subplots(figsize=(10,5))
sns.heatmap(cm, annot=True,fmt='.4g',linewidths=2, cmap='viridis')
plt.ylabel('True label')
plt.xlabel('Predicted label')
plt.show()
```



[60]:
```
print(classification_report(y_test,ypred_lr))
```

```
              precision    recall  f1-score   support

           0       0.77      0.80      0.78      2422
           1       0.77      0.74      0.75      2216

    accuracy                           0.77      4638
   macro avg       0.77      0.77      0.77      4638
weighted avg       0.77      0.77      0.77      4638
```

[61]:
```
plot_roc_curve(lr,X_test,y_test)
plt.show()
```



```
[62]: accuracy_score(y_test,ypred_lr)
```

```
[62]: 0.7705907718844329
```

7.0.4 Random Forest Classifier

```
[63]: rf = RandomForestClassifier(random_state=123)
```

```
[64]: rf.fit(X_train, y_train)
```

```
[64]: RandomForestClassifier(bootstrap=True, ccp_alpha=0.0, class_weight=None,
                             criterion='gini', max_depth=None, max_features='auto',
                             max_leaf_nodes=None, max_samples=None,
                             min_impurity_decrease=0.0, min_impurity_split=None,
                             min_samples_leaf=1, min_samples_split=2,
                             min_weight_fraction_leaf=0.0, n_estimators=100,
                             n_jobs=None, oob_score=False, random_state=123,
                             verbose=0, warm_start=False)
```

```
[65]: ypred_rf = rf.predict(X_test)
```

```
[66]: y_test[:10]
```

```
[66]: array([1, 0, 1, 0, 1, 1, 1, 0, 1, 1], dtype=int64)
```

[67]:
```
ypred_rf[:10]
```

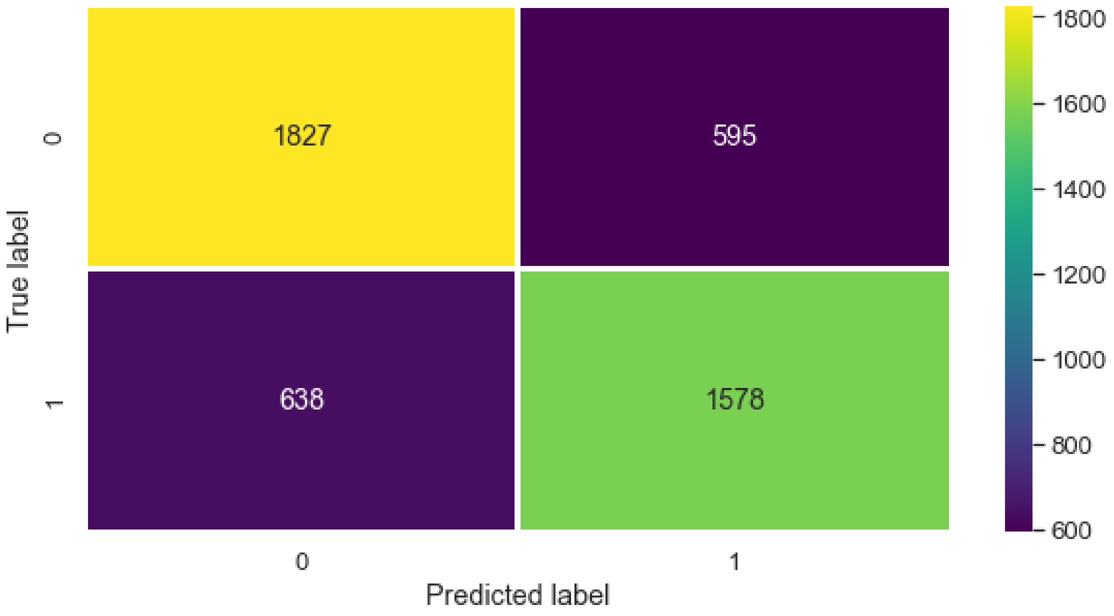
[67]:
```
array([1, 0, 0, 0, 1, 1, 1, 1, 0, 1], dtype=int64)
```

7.0.5 Random Forest Model Evaluation

[68]:
```
cm = confusion_matrix(y_test,ypred_rf)
cm
```

[68]:
```
array([[1827,  595],
       [ 638, 1578]], dtype=int64)
```

[69]:
```
fig , ax = plt.subplots(figsize=(10,5))
sns.heatmap(cm, annot=True,fmt='.4g',linewidths=2, cmap='viridis')
plt.ylabel('True label')
plt.xlabel('Predicted label')
plt.show()
```

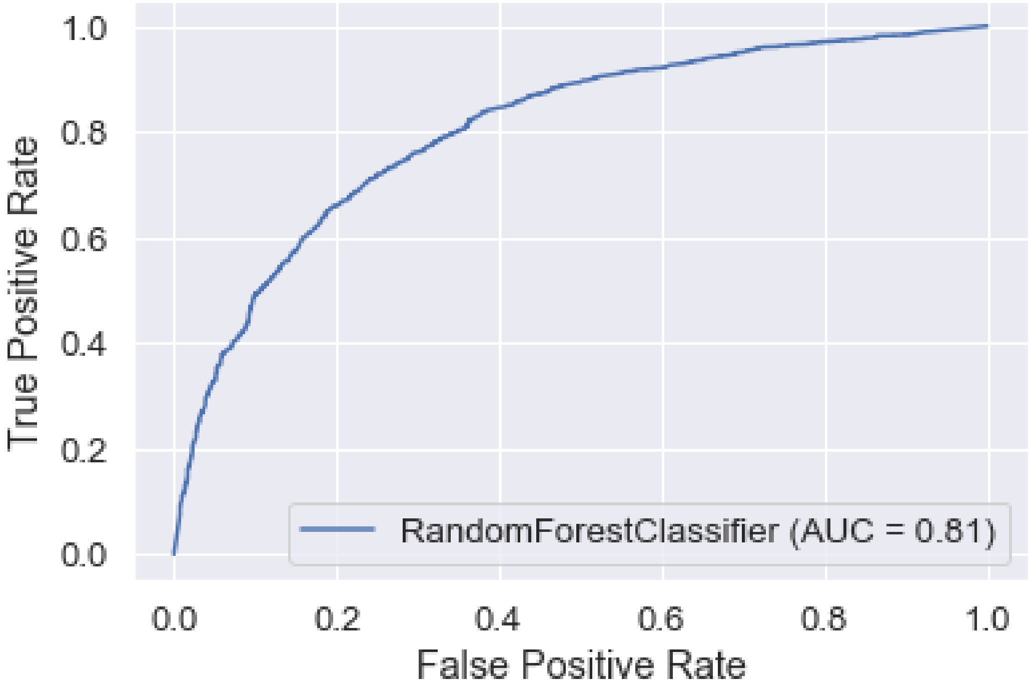


[70]:
```
print(classification_report(y_test,ypred_rf))
```

```
              precision    recall  f1-score   support

           0       0.74      0.75      0.75      2422
           1       0.73      0.71      0.72      2216

    accuracy                           0.73      4638
   macro avg       0.73      0.73      0.73      4638
```

```
weighted avg       0.73      0.73      0.73      4638
```

[71]:
```
plot_roc_curve(rf,X_test,y_test)
plt.show()
```



[72]:
```
accuracy_score(y_test,ypred_rf)
```

[72]:
```
0.7341526520051747
```

7.0.6 Gradient Boosting Classifer

[73]:
```
gbc = GradientBoostingClassifier(random_state=123)
```

[74]:
```
gbc.fit(X_train,y_train)
```

[74]:
```
GradientBoostingClassifier(ccp_alpha=0.0, criterion='friedman_mse', init=None,
                           learning_rate=0.1, loss='deviance', max_depth=3,
                           max_features=None, max_leaf_nodes=None,
                           min_impurity_decrease=0.0, min_impurity_split=None,
                           min_samples_leaf=1, min_samples_split=2,
                           min_weight_fraction_leaf=0.0, n_estimators=100,
                           n_iter_no_change=None, presort='deprecated',
                           random_state=123, subsample=1.0, tol=0.0001,
                           validation_fraction=0.1, verbose=0,
                           warm_start=False)
```

```
[75]: ypredgbc = gbc.predict(X_test)
```

```
[76]: y_test[:10]
```

```
[76]: array([1, 0, 1, 0, 1, 1, 1, 0, 1, 1], dtype=int64)
```

```
[77]: ypredgbc[:10]
```

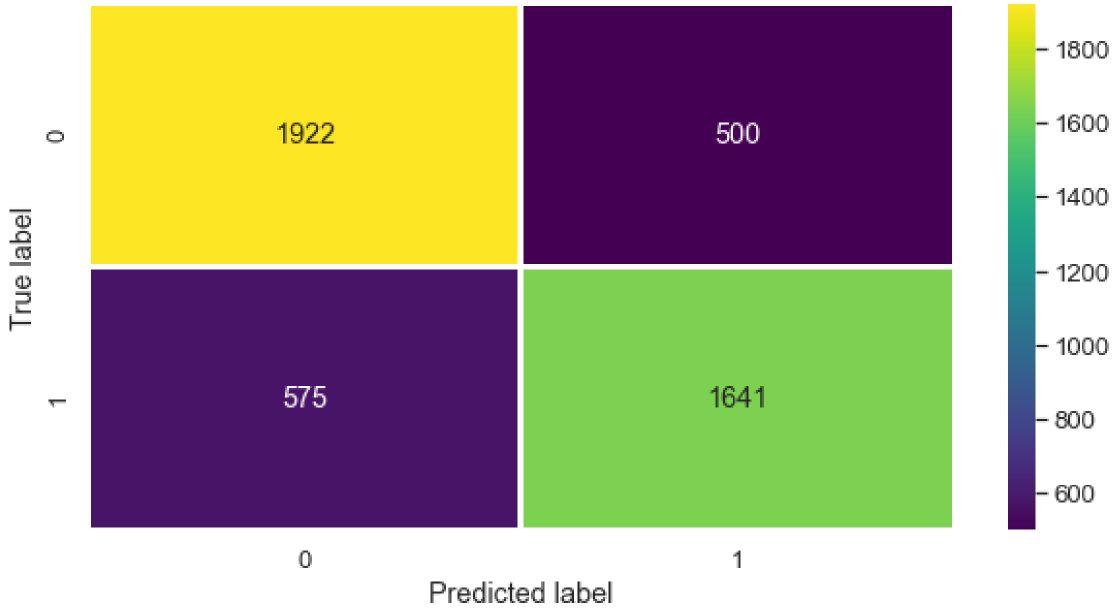
```
[77]: array([1, 0, 0, 0, 1, 1, 1, 1, 0, 1], dtype=int64)
```

7.0.7 Gradient Boosting Model Evaluation

```
[78]: cm = confusion_matrix(y_test,ypredgbc)
      cm
```

```
[78]: array([[1922,  500],
             [ 575, 1641]], dtype=int64)
```

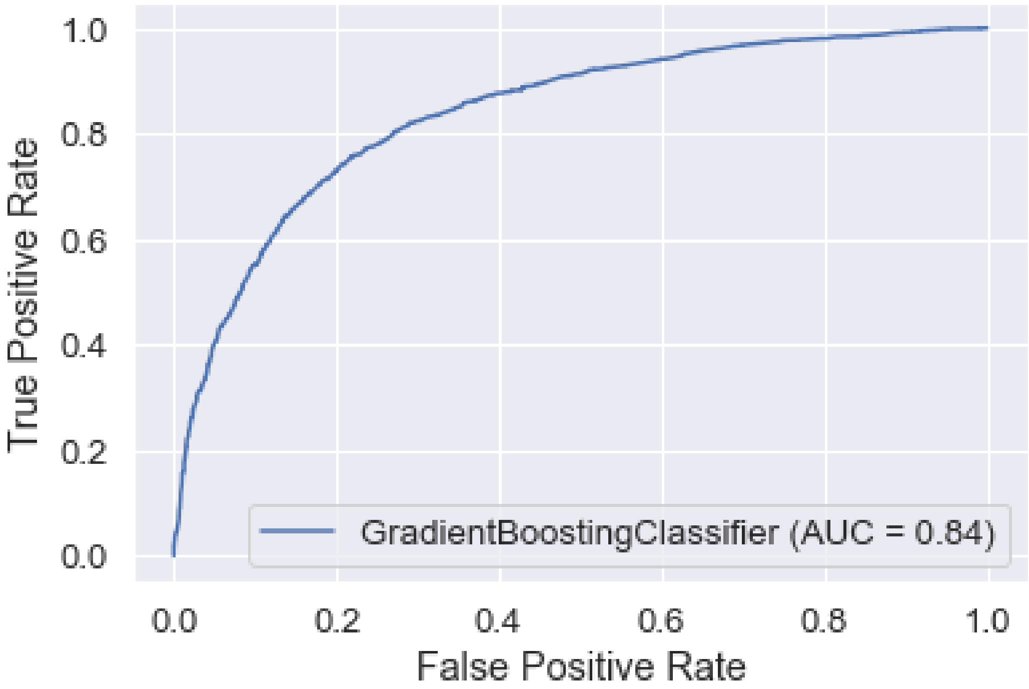
```
[79]: fig , ax = plt.subplots(figsize=(10,5))
      sns.heatmap(cm, annot=True,fmt='.4g',linewidths=2, cmap='viridis')
      plt.ylabel('True label')
      plt.xlabel('Predicted label')
      plt.show()
```



[80]:
```
print(classification_report(y_test,ypredgbc))
```

```
              precision    recall  f1-score   support

           0       0.77      0.79      0.78      2422
           1       0.77      0.74      0.75      2216

    accuracy                           0.77      4638
   macro avg       0.77      0.77      0.77      4638
weighted avg       0.77      0.77      0.77      4638
```

[81]:
```
plot_roc_curve(gbc,X_test,y_test)
plt.show()
```



[82]:
```
accuracy_score(y_test,ypredgbc)
```

[82]:
```
0.7682190599396291
```

8 A paragraph explaining which of your classifier models you recommend as a final model that best fits your needs in terms of accuracy and explainability.

Logistic Regression gives us the best accuracy and F1 score. Therefore it is recommended.

9 Summary Key Findings and Insights, which walks your reader through the main drivers of your model and insights from your data derived from your classifier model.

The features we selected gave us a decent accuracy and good result. The result differences are small and we select Logistic Regression because it's a simple model.

10 Suggestions for next steps in analyzing this data, which may include suggesting revisiting this model adding specific data features to achieve a better explanation or a better prediction.

For features that are biased, we need to gather more data and made equal values for race, sex, income etc. We have to ensure the model we developed stays bias free.

We can also explore other models like decision tree, support vector machine, KNN classifiers model to see if they can able to analyse the data patterns to give better predictions. We also can adjust hyperparameters for each model to get better results.