In [1]:
```
from google.colab import drive
drive.mount("/content/MyDrive/")
```

```
Drive already mounted at /content/MyDrive/; to attempt to forcibly remount, call drive.mount("/content/MyDrive/", force_remount=True).
```

DESCRIPTION

Problem Statement

Amazon is an online shopping website that now caters to millions of people everywhere. Over 34,000 consumer reviews for Amazon brand products like Kindle, Fire TV Stick and more are provided.

The dataset has attributes like brand, categories, primary categories, reviews.title, reviews.text, and the sentiment. Sentiment is a categorical variable with three levels "Positive", "Negative", and "Neutral". For a given unseen data, the sentiment needs to be predicted.

You are required to predict Sentiment or Satisfaction of a purchase based on multiple features and review text.

In [2]:
```
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
import warnings
warnings.filterwarnings('ignore')
%matplotlib inline
pd.set_option("display.max_rows",None)
pd.set_option("display.max_columns",None)
```

Project Task: Week 1

Class Imbalance Problem:

Perform an EDA on the dataset.

See what a positive, negative, and neutral review looks like

Check the class count for each class. It's a class imbalance problem.

Convert the reviews in Tf-Idf score.

Run multinomial Naive Bayes classifier. Everything will be classified as positive because of the class imbalance.

In [3]:
```
train = pd.read_csv('/content/MyDrive/MyDrive/AI Capstone Proj 1/Project 1-Ecommerce-Datasets/Ecommerce/train_data.csv')
test = pd.read_csv('/content/MyDrive/MyDrive/AI Capstone Proj 1/Project 1-Ecommerce-Datasets/Ecommerce/test_data.csv')
test_hidden = pd.read_csv('/content/MyDrive/MyDrive/AI Capstone Proj 1/Project 1-Ecommerce-Datasets/Ecommerce/test_data_hidden.csv')
```

In [4]:
```
train.head()
```

Out[4]:

	name	brand	categories	primaryCategories	reviews.date	reviews.text	reviews.title	sentin
0	All-New Fire HD 8 Tablet, 8" HD Display, Wi-Fi...	Amazon	Electronics,iPad & Tablets,All Tablets,Fire Ta...	Electronics	2016-12-26T00:00:00.000Z	Purchased on Black FridayPros - Great Price (e...	Powerful tablet	Pos
1	Amazon - Echo Plus w/ Built-In Hub - Silver	Amazon	Amazon Echo,Smart Home,Networking,Home & Tools...	Electronics,Hardware	2018-01-17T00:00:00.000Z	I purchased two Amazon in Echo Plus and two do...	Amazon Echo Plus AWESOME	Pos
2	Amazon Echo Show Alexa-enabled Bluetooth Speak...	Amazon	Amazon Echo,Virtual Assistant Speakers,Electro...	Electronics,Hardware	2017-12-20T00:00:00.000Z	Just an average Alexa option. Does show a few ...	Average	Ne
3	Fire HD 10 Tablet, 10.1 HD Display, Wi-Fi, 16 ...	Amazon	eBook Readers,Fire Tablets,Electronics Feature...	Office Supplies,Electronics	2017-08-04T00:00:00.000Z	very good product. Exactly what I wanted, and ...	Greatttttttt	Pos
4	Brand New Amazon Kindle Fire 16gb 7" Ips Displ...	Amazon	Computers/Tablets & Networking,Tablets & eBook...	Electronics	2017-01-23T00:00:00.000Z	This is the 3rd one I've purchased. I've bough...	Very durable!	Pos

In [5]:
```
test.head()
```

Out[5]:

	name	brand	categories	primaryCategories	reviews.date	reviews.text	reviews.
0	Fire Tablet, 7 Display, Wi-Fi, 16 GB - Include...	Amazon	Fire Tablets,Computers/Tablets & Networking,Ta...	Electronics	2016-05-23T00:00:00.000Z	Amazon kindle fire has a lot of free app and c...	very handy de
1	Amazon Echo Show Alexa-enabled Bluetooth Speak...	Amazon	Computers,Amazon Echo,Virtual Assistant Speake...	Electronics,Hardware	2018-01-02T00:00:00.000Z	The Echo Show is a great addition to the Amazo...	Another winner from Ama
2	All-New Fire HD 8 Tablet, 8" HD Display, Wi-Fi...	Amazon	Electronics,iPad & Tablets,All Tablets,Fire Ta...	Electronics	2017-01-02T00:00:00.000Z	Great value from Best Buy. Bought at Christmas...	simple to use and reliabl
3	Brand New Amazon Kindle Fire 16gb 7" Ips Displ...	Amazon	Computers/Tablets & Networking,Tablets & eBook...	Electronics	2017-03-25T00:00:00.000Z	I use mine for email, Facebook ,games and to g...	Lov
4	Amazon Echo Show Alexa-enabled Bluetooth Speak...	Amazon	Computers,Amazon Echo,Virtual Assistant Speake...	Electronics,Hardware	2017-11-15T00:00:00.000Z	This is a fantastic item & the person I bought...	Fanta

In [6]:
```
train.shape
```

Out[6]:
```
(4000, 8)
```

In [7]:
```
# Keep the Features that we need for further exploring.
df1 = train[['reviews.text','sentiment']]
```

In [8]:
```
df1.head()
```

Out[8]:

	reviews.text	sentiment
0	Purchased on Black FridayPros - Great Price (e...	Positive
1	I purchased two Amazon in Echo Plus and two do...	Positive
2	Just an average Alexa option. Does show a few ...	Neutral
3	very good product. Exactly what I wanted, and ...	Positive
4	This is the 3rd one I've purchased. I've bough...	Positive

In [9]:
```
df1.index = pd.Series(list(range(df1.shape[0])))
```

In [10]:
```
print(df1.shape)
df1.head()
```

```
(4000, 2)
```

Out[10]:

	reviews.text	sentiment
0	Purchased on Black FridayPros - Great Price (e...	Positive
1	I purchased two Amazon in Echo Plus and two do...	Positive
2	Just an average Alexa option. Does show a few ...	Neutral
3	very good product. Exactly what I wanted, and ...	Positive
4	This is the 3rd one I've purchased. I've bough...	Positive

Preprocessing

In [11]:
```
from nltk.tokenize import RegexpTokenizer
from nltk.corpus import stopwords
import nltk
from nltk.corpus import wordnet
from nltk.stem import WordNetLemmatizer
nltk.download('all')
wl = WordNetLemmatizer()
tokenizer = RegexpTokenizer(r'[a-z]+')
stop_words = set(stopwords.words('english'))
```

```
[nltk_data] Downloading collection 'all'
[nltk_data]    |
[nltk_data]    | Downloading package abc to /root/nltk_data...
[nltk_data]    |   Package abc is already up-to-date!
[nltk_data]    | Downloading package alpino to /root/nltk_data...
[nltk_data]    |   Package alpino is already up-to-date!
[nltk_data]    | Downloading package averaged_perceptron_tagger to
[nltk_data]    |     /root/nltk_data...
[nltk_data]    |   Package averaged_perceptron_tagger is already up-
[nltk_data]    |       to-date!
[nltk_data]    | Downloading package averaged_perceptron_tagger_ru to
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[nltk_data]    |   Package averaged_perceptron_tagger_ru is already
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[nltk_data]    | Downloading package cess_esp to /root/nltk_data...
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```

```
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[nltk_data]    | Downloading package stopwords to /root/nltk_data...
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[nltk_data]    |       date!
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[nltk_data]    | Downloading package verbnet3 to /root/nltk_data...
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[nltk_data]    | Downloading package webtext to /root/nltk_data...
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[nltk_data]    | Downloading package word2vec_sample to
```

```
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[nltk_data]    |   Package word2vec_sample is already up-to-date!
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[nltk_data]    | Downloading package wordnet_ic to /root/nltk_data...
[nltk_data]    |   Package wordnet_ic is already up-to-date!
[nltk_data]    | Downloading package words to /root/nltk_data...
[nltk_data]    |   Package words is already up-to-date!
[nltk_data]    | Downloading package ycoe to /root/nltk_data...
[nltk_data]    |   Package ycoe is already up-to-date!
[nltk_data]    |
```

In [12]:
```
def preprocess(document):
    document = document.lower() # Convert to Lowercase
    words = tokenizer.tokenize(document) # Tokenize
    words = [w for w in words if not w in stop_words] # Removing stopwords
    # Lemmatizing
    for pos in [wordnet.NOUN, wordnet.VERB, wordnet.ADJ, wordnet.ADV]:
        words = [wl.lemmatize(x, pos) for x in words]
    return " ".join(words)
```

In [13]:
```
df1['Preprocessed_Reviews'] = df1['reviews.text'].apply(preprocess)
df1.head()
```

Out[13]:

	reviews.text	sentiment	Preprocessed_Reviews
0	Purchased on Black FridayPros - Great Price (e...	Positive	purchase black fridaypros great price even sal...
1	I purchased two Amazon in Echo Plus and two do...	Positive	purchase two amazon echo plus two dot plus fou...
2	Just an average Alexa option. Does show a few ...	Neutral	average alexa option show thing screen still l...
3	very good product. Exactly what I wanted, and ...	Positive	good product exactly want good price
4	This is the 3rd one I've purchased. I've bough...	Positive	rd one purchase buy one niece case compare one...

In [14]:
```
df2  = df1[['sentiment','Preprocessed_Reviews']]
df2.head()
```

Out[14]:

	sentiment	Preprocessed_Reviews
0	Positive	purchase black fridaypros great price even sal...
1	Positive	purchase two amazon echo plus two dot plus fou...
2	Neutral	average alexa option show thing screen still l...
3	Positive	good product exactly want good price
4	Positive	rd one purchase buy one niece case compare one...

Creating TF-IDF Matrix & Multinomial Naive Bayes Classifier

In [15]:
```
def textprocess(data):
  import string
  remove_punc = [char for char in data if char not in string.punctuation] #Remove Punctuation Logic
  sent_wout_punc = ''.join(remove_punc) # Join Characters to form sentences
  w = sent_wout_punc.split()
  from nltk.corpus import stopwords
  rem_stopwords = [word for word in w if word.lower() not in stopwords.words('english')]
  return rem_stopwords
```

In [16]:
```
df2.groupby('sentiment').describe()
```

Out[16]:

	Preprocessed_Reviews			
	count	unique	top	freq
sentiment				
Negative	93	78	last model kindle hdx terrible purchase model ...	3
Neutral	158	145	average alexa option show thing screen still l...	2
Positive	3749	3372	buy kindle yr old granddaughter christmas husb...	4

In [17]:
```
df2['Preprocessed_Reviews'].head().apply(textprocess)
```

Out[17]:
```
0    [purchase, black, fridaypros, great, price, ev...
1    [purchase, two, amazon, echo, plus, two, dot, ...
2    [average, alexa, option, show, thing, screen, ...
3          [good, product, exactly, want, good, price]
4    [rd, one, purchase, buy, one, niece, case, com...
Name: Preprocessed_Reviews, dtype: object
```

Sklearn Package CountVectorizer (For creating Bag of Words)

In [18]:
```
from sklearn.feature_extraction.text import CountVectorizer
bag_of_words = CountVectorizer(analyzer=textprocess).fit(df2['Preprocessed_Reviews'])
```

In [19]:
```
len(bag_of_words.vocabulary_)
```

Out[19]:
```
3407
```

In [20]:
```
review_bo_words = bag_of_words.transform(df2['Preprocessed_Reviews'])
```

Tf-Idf

In [21]:
```
from sklearn.feature_extraction.text import TfidfTransformer
```

In [22]:
```
tfidf_data = TfidfTransformer().fit(review_bo_words)
tfidf_final_data = tfidf_data.transform(review_bo_words)
```

In [23]:
```
tfidf_final_data.shape
```

Out[23]:
```
(4000, 3407)
```

The data is all set for Model Building!

- Model Training - NaiveBayes Algorithm
- String Data Handling - MultinomialNB

In [24]:
```
from sklearn.naive_bayes import MultinomialNB
model = MultinomialNB().fit(tfidf_final_data,df2['sentiment'])
```

In [25]:
```
model
```

Out[25]:
```
MultinomialNB()
```

In [26]:
```
df2['Preprocessed_Reviews'][9]
```

Out[26]:
```
'cheap run chrome stuff return store'
```

In [27]:
```
inputData = "cheap run chrome stuff return store"
l1 = textprocess(inputData)
l2 = bag_of_words.transform(l1)
l3 = tfidf_data.transform(l2)
prediction = model.predict(l3[0])
prediction
```

Out[27]:
```
array(['Positive'], dtype='<U8')
```

Insight

After running Multinomial Naive Bayes Classifier Everything is classified as positive because of the class imbalance as seen above.

Tackling Class Imbalance Problem:

In [28]:
```
df2.columns
```

Out[28]:
```
Index(['sentiment', 'Preprocessed_Reviews'], dtype='object')
```

In [29]:
```
X = df2.drop('sentiment',axis=1)
Y = df2['sentiment']
```

In [30]:
```
print(X.shape,Y.shape)
```

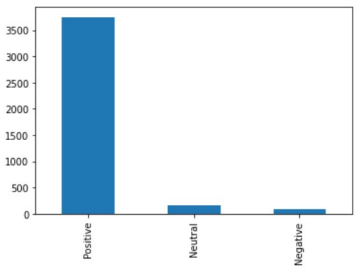
```
(4000, 1) (4000,)
```

In [31]:
```
Y.value_counts()
```

Out[31]:
```
Positive    3749
Neutral      158
Negative      93
Name: sentiment, dtype: int64
```

In [32]:
```
Y.value_counts().plot(kind='bar')
```

Out[32]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x7f7bd1446ad0>
```



Applying Over Sampling

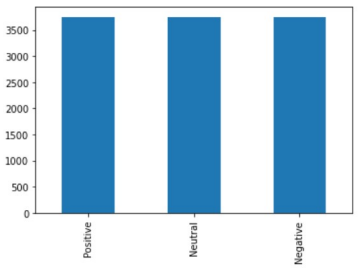
In [33]:
```
# RandomOverSampler to handle imbalanced data
from imblearn.over_sampling import RandomOverSampler
rs = RandomOverSampler(random_state=0)
X_over,Y_over=rs.fit_resample(X,Y)
```

In [34]:
```
Y_over.value_counts()
```

Out[34]:
```
Positive    3749
Neutral     3749
Negative    3749
Name: sentiment, dtype: int64
```

In [35]:
```
Y_over.value_counts().plot(kind='bar')
```

Out[35]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x7f7bd0596510>
```



In [36]:
```
print(X_over.shape,Y_over.shape)
```

```
(11247, 1) (11247,)
```

In [37]:
```
X_over.head()
```

Out[37]:

	Preprocessed_Reviews
0	purchase black fridaypros great price even sal...
1	purchase two amazon echo plus two dot plus fou...
2	average alexa option show thing screen still l...
3	good product exactly want good price
4	rd one purchase buy one niece case compare one...

In [38]:
```
Y_over.head()
```

Out[38]:
```
0    Positive
1    Positive
2     Neutral
3    Positive
4    Positive
Name: sentiment, dtype: object
```

In [39]:
```
data = pd.concat([X_over,Y_over],axis=1)
data.head()
```

Out[39]:

	Preprocessed_Reviews	sentiment
0	purchase black fridaypros great price even sal...	Positive
1	purchase two amazon echo plus two dot plus fou...	Positive
2	average alexa option show thing screen still l...	Neutral
3	good product exactly want good price	Positive
4	rd one purchase buy one niece case compare one...	Positive

In [40]:
```
data.isnull().sum()
```

Out[40]:
```
Preprocessed_Reviews    0
sentiment               0
dtype: int64
```

In [41]:
```
data.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 11247 entries, 0 to 11246
Data columns (total 2 columns):
 #   Column                Non-Null Count  Dtype 
---  ------                --------------  ----- 
 0   Preprocessed_Reviews  11247 non-null  object
 1   sentiment             11247 non-null  object
dtypes: object(2)
memory usage: 175.9+ KB
```

Train & Test Split Data

In [42]:
```
from sklearn.model_selection import train_test_split
X_train,X_test,Y_train,Y_test = train_test_split(data['Preprocessed_Reviews'],data['sentiment'],test_size=0.1)
```

In [43]:
```
print(X_train.shape,X_test.shape,Y_train.shape,Y_test.shape)
```

```
(10122,) (1125,) (10122,) (1125,)
```

Bag of Words

The aim of this project is to classify the reviews into positive, neutral and negative sentiment.

There are two main steps which are involved:

We need to find word embedding to convert text into a numerical representation.

We fit the numerical representations of text to machine learning algorithms or deep learning architectures.

Text Preprocessing

The following text preprocessing methods are implemented to convert raw reviews to cleaned review making it easier to do feature extraction in the next step.

1. Remove non-character such as digits and symbols.
2. Convert to lower case.
3. Remove stop words such as "the" and "and" if needed.
4. Convert to root words by stemming if needed.

In [44]:
```
from bs4 import BeautifulSoup
import re
import nltk
from nltk.corpus import stopwords
from nltk.stem.porter import PorterStemmer
from nltk.stem import SnowballStemmer, WordNetLemmatizer
from nltk import sent_tokenize, word_tokenize, pos_tag

import logging
from gensim.models import word2vec
from gensim.models.keyedvectors import KeyedVectors
def cleanText(raw_text, remove_stopwords=False, stemming=False, split_text=False, \
              ):
    '''
    Convert a raw review to a cleaned review
    '''
    text = BeautifulSoup(raw_text, 'lxml').get_text()  #remove html
    letters_only = re.sub("[^a-zA-Z]", " ", text)  # remove non-character
    words = letters_only.lower().split() # convert to lower case

    if remove_stopwords: # remove stopword
        stops = set(stopwords.words("english"))
        words = [w for w in words if not w in stops]

    if stemming==True: # stemming
#         stemmer = PorterStemmer()
        stemmer = SnowballStemmer('english')
        words = [stemmer.stem(w) for w in words]

    if split_text==True:  # split text
        return (words)

    return( " ".join(words))
```

In [45]:
```
# Preprocess text data in training set and validation set
X_train_cleaned = []
X_test_cleaned = []

for d in X_train:
    X_train_cleaned.append(cleanText(d))
print('Show a cleaned review in the training set : \n',  X_train_cleaned[10])

for d in X_test:
    X_test_cleaned.append(cleanText(d))
```

```
Show a cleaned review in the training set :
 opinion model small feel cheap sd card slot
```

CountVectorizer with Multinomial Naive Bayes (Benchmark Model)

- Now as we have cleaned all reviews the next step is converting the reviews into numerical representations for a machine learning algorithm.
- We will use CountVectorizer which implements both tokenization and occurrence counting in a single class provided by the Sklearn library. The output is a sparse matrix representation of the document.

In [46]:
```
# Fit and transform the training data to a document-term matrix using CountVectorizer
CVec = CountVectorizer()
X_train_CVec = CVec.fit_transform(X_train_cleaned)
print("Number of features : %d \n" %len(CVec.get_feature_names())) #6378
print("Show some feature names : \n", CVec.get_feature_names()[::1000])


# Train MultinomialNB classifier
mnb = MultinomialNB()
mnb.fit(X_train_CVec, Y_train)
```

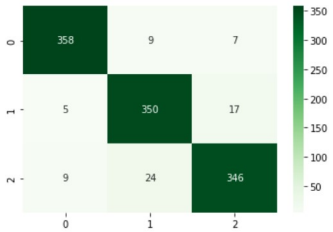
```
Number of features : 3285

Show some feature names :
 ['abc', 'eve', 'orginal', 'trek']
```

Out[46]:
```
MultinomialNB()
```

In [47]:
```
from sklearn.metrics import classification_report,accuracy_score,confusion_matrix

def metrics(preds):
  print("Accuracy on validation set: ",accuracy_score(Y_test,preds))
  print(classification_report(Y_test,preds))
  print(confusion_matrix(Y_test,preds))
  sns.heatmap(confusion_matrix(Y_test,preds),cmap="Greens",annot=True,fmt='d')
```

In [48]:
```
# Evaluate the model on validaton set
preds = mnb.predict(CVec.transform(X_test_cleaned))
metrics(preds)
```

```
Accuracy on validation set:  0.9368888888888889
              precision    recall  f1-score   support

    Negative       0.96      0.96      0.96       374
     Neutral       0.91      0.94      0.93       372
    Positive       0.94      0.91      0.92       379

    accuracy                           0.94      1125
   macro avg       0.94      0.94      0.94      1125
weighted avg       0.94      0.94      0.94      1125

[[358   9   7]
 [  5 350  17]
 [  9  24 346]]
```



TfidfVectorizer with Logistic Regression

- Some words might appear quite frequently but have a very less or negligible meaningful information about the sentiment for a particular review. Instead of using occurance counting we will use tf-idf transform to scale down the impact of frequently appearing words in a given corpus.
- In sklearn library we will use TfidfVectorizer which implements both tokenization and tf-idf weighted counting in a single class.

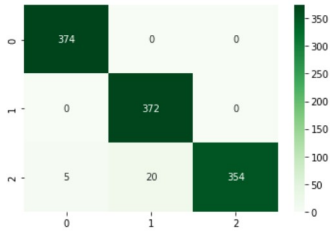
In [49]:
```
# Fitting and transforming the training data to a document-term matrix using TfidfVectorizer
from sklearn.feature_extraction.text import TfidfVectorizer
from sklearn.linear_model import LogisticRegression
tfidf = TfidfVectorizer(min_df=5) #minimum document frequency of 5
X_train_tfidf = tfidf.fit_transform(X_train)
print("Number of features : %d \n" %len(tfidf.get_feature_names())) #1722
print("Show some feature names : \n", tfidf.get_feature_names()[::1000])

# Logistic Regression
lr = LogisticRegression()
lr.fit(X_train_tfidf, Y_train)
```

```
Number of features : 1439

Show some feature names :
 ['ability', 'qc']
```

Out[49]:
```
LogisticRegression()
```

In [50]:
```
# Evaluating on the validaton set
predict = lr.predict(tfidf.transform(X_test_cleaned))
metrics(predict)
```

```
Accuracy on validation set:  0.9777777777777777
              precision    recall  f1-score   support

    Negative       0.99      1.00      0.99       374
     Neutral       0.95      1.00      0.97       372
    Positive       1.00      0.93      0.97       379

    accuracy                           0.98      1125
   macro avg       0.98      0.98      0.98      1125
weighted avg       0.98      0.98      0.98      1125

[[374   0   0]
 [  0 372   0]
 [  5  20 354]]
```



TfidfVectorizer with Linear SVM by using SGD

Some words might appear quite frequently but have a very less or negligible meaningful information about the sentiment for a particular review. Instead of using occurance counting we will use tf-idf transform to scale down the impact of frequently appearing words in a given corpus.

In sklearn library we will use TfidfVectorizer which implements both tokenization and tf-idf weighted counting in a single class.

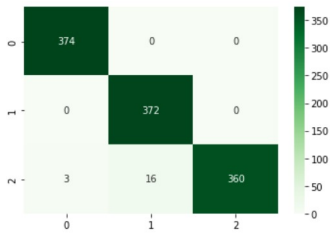
In [51]:
```
# Fitting and transforming the training data to a document-term matrix using TfidfVectorizer
tfidf = TfidfVectorizer(min_df=5) #minimum document frequency of 5
X_train_tfidf = tfidf.fit_transform(X_train)
print("Number of features : %d \n" %len(tfidf.get_feature_names())) #1722
print("Show some feature names : \n", tfidf.get_feature_names()[::1000])

# SVM
from sklearn.linear_model import SGDClassifier
clf = SGDClassifier(loss="hinge", penalty="l2")
clf.fit(X_train_tfidf, Y_train)
```

```
Number of features : 1439

Show some feature names :
 ['ability', 'qc']
```

Out[51]:
```
SGDClassifier()
```

In [52]:
```
# Evaluating on the validaton set
predictions = clf.predict(tfidf.transform(X_test_cleaned))
metrics(predictions)
```

```
Accuracy on validation set:  0.9831111111111112
              precision    recall  f1-score   support

    Negative       0.99      1.00      1.00       374
     Neutral       0.96      1.00      0.98       372
    Positive       1.00      0.95      0.97       379

    accuracy                           0.98      1125
   macro avg       0.98      0.98      0.98      1125
weighted avg       0.98      0.98      0.98      1125

[[374   0   0]
 [  0 372   0]
 [  3  16 360]]
```



Using XGBoost Classifier

Some words might appear quite frequently but have a very less or negligible meaningful information about the sentiment for a particular review. Instead of using occurance counting we will use tf-idf transform to scale down the impact of frequently appearing words in a given corpus.

In sklearn library we will use TfidfVectorizer which implements both tokenization and tf-idf weighted counting in a single class.

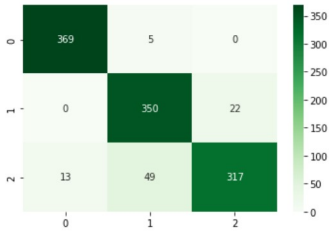
In [53]:
```
from xgboost import XGBClassifier
# Fitting and transforming the training data to a document-term matrix using TfidfVectorizer
tfidf = TfidfVectorizer(min_df=5) #minimum document frequency of 5
X_train_tfidf = tfidf.fit_transform(X_train)
print("Number of features : %d \n" %len(tfidf.get_feature_names())) #1722
print("Show some feature names : \n", tfidf.get_feature_names()[::1000])

# XGBoost Classifier
xgb = XGBClassifier()
xgb.fit(X_train_tfidf, Y_train)
```

```
Number of features : 1439

Show some feature names :
 ['ability', 'qc']
```

Out[53]:
```
XGBClassifier(objective='multi:softprob')
```

In [54]:
```
# Evaluating on the validaton set
predict_xg = xgb.predict(tfidf.transform(X_test_cleaned))
metrics(predict_xg)
```

```
Accuracy on validation set:  0.9208888888888889
              precision    recall  f1-score   support

    Negative       0.97      0.99      0.98       374
     Neutral       0.87      0.94      0.90       372
    Positive       0.94      0.84      0.88       379

    accuracy                           0.92      1125
   macro avg       0.92      0.92      0.92      1125
weighted avg       0.92      0.92      0.92      1125

[[369   5   0]
 [  0 350  22]
 [ 13  49 317]]
```

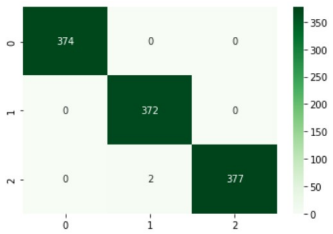


Pipeline and GridSearch

We will build a pipeline in the Sklearn library to streamline the workflow and use GridSearch on the pipeline model to implement hyperparameter tuning for both the vectorizer and classifier at once.

In [55]:
```
# Building a pipeline
from sklearn.model_selection import GridSearchCV
from sklearn.pipeline import Pipeline
estimators = [("tfidf", TfidfVectorizer()), ("lr", LogisticRegression())]
model = Pipeline(estimators)


# Grid search
params = {"lr__C":[0.1, 1, 10], #regularization param of logistic regression
          "tfidf__min_df": [1, 3], #min count of words
          "tfidf__max_features": [1000, None], #max features
          "tfidf__ngram_range": [(1,1), (1,2)], #1-grams or 2-grams
          "tfidf__stop_words": [None, "english"]} #use stopwords or don't

grid = GridSearchCV(estimator=model, param_grid=params, scoring="accuracy", n_jobs=-1)
grid.fit(X_train_cleaned, Y_train)
print("The best paramenter set is : \n", grid.best_params_)


# Evaluate on the validaton set
pred = grid.predict(X_test_cleaned)
metrics(pred)
```

```
The best paramenter set is :
 {'lr__C': 10, 'tfidf__max_features': None, 'tfidf__min_df': 3, 'tfidf__ngram_range': (1, 2), 'tfidf__stop_words': None}
Accuracy on validation set:  0.9982222222222222
              precision    recall  f1-score   support

    Negative       1.00      1.00      1.00       374
     Neutral       0.99      1.00      1.00       372
    Positive       1.00      0.99      1.00       379

    accuracy                           1.00      1125
   macro avg       1.00      1.00      1.00      1125
weighted avg       1.00      1.00      1.00      1125

[[374   0   0]
 [  0 372   0]
 [  0   2 377]]
```



Word2Vec

Another common approach of word embedding is the prediction based embedding like Word2Vec model. Briefly, Word2Vec is a combination of two techniques: Continuous Bag of Words (CBoW) and Skip-Gram model. Both are Shallow Neural Networks which learn weights for the word vector representations.

Here, we will train Word2Vec model to create our own word vector representation using gensim library. Then we will fit the feature vectors of the reviews to the Random Forest Classifier. Here's the workflow of this part: -

- Parse review text to sentences (Word2Vec model takes a list of sentences as inputs).
- Create vocabulary list using Word2Vec model.
- Transform each review into numerical representation by computing average feature vectors of words therein
- Fit the average feature vectors to Random Forest Classifier

Parsing Review into Sentences

Word2Vec model takes a list of sentences as inputs and outputs word vector representations for words in the vocabulary list created. Before we train the Word2Vec model, we have to parse reviews in the training set into sentences.

In [56]:
```
# Splitting review text into parsed sentences using NLTK's punkt tokenizer

tokenizer = nltk.data.load('tokenizers/punkt/english.pickle')

def parseSent(review, tokenizer, remove_stopwords=False):
    '''
    Parse text into sentences
    '''
    raw_sentences = tokenizer.tokenize(review.strip())
    sentences = []
    for raw_sentence in raw_sentences:
        if len(raw_sentence) > 0:
            sentences.append(cleanText(raw_sentence, remove_stopwords, split_text=True))
    return sentences


# Parsing each review in the training set into sentences
sentences = []
for review in X_train_cleaned:
    sentences += parseSent(review, tokenizer)

print('%d parsed sentence in the training set\n'  %len(sentences))
print('Show a parsed sentence in the training set : \n',  sentences[10])
```

```
10122 parsed sentence in the training set

Show a parsed sentence in the training set :
 ['opinion', 'model', 'small', 'feel', 'cheap', 'sd', 'card', 'slot']
```

In [57]:
```
from gensim.models import Word2Vec
w2v = Word2Vec()
```

Creating Vocabulary List using Word2Vec Model

As we have a set of cleaned and parsed sentences from the training data, we will train our own word vector representations by specifying the embedding dimension (= length of feature vector).

In [58]:
```
# Fitting parsed sentences to Word2Vec model

num_features = 300  #embedding dimension
min_word_count = 10
num_workers = 4
context = 10
downsampling = 1e-3

print("Training Word2Vec model ...\n")
w2v = Word2Vec(sentences, workers=num_workers, size=num_features, min_count = min_word_count,\
               window = context, sample = downsampling)
w2v.init_sims(replace=True)
w2v.save("w2v_300features_10minwordcounts_10context") #save trained word2vec model

print("Number of words in the vocabulary list : %d \n" %len(w2v.wv.index2word)) #4016
print("Show first 10 words in the vocabulary list  vocabulary list: \n", w2v.wv.index2word[0:10])
```

```
Training Word2Vec model ...

Number of words in the vocabulary list : 1235

Show first 10 words in the vocabulary list  vocabulary list:
 ['tablet', 'buy', 'use', 'good', 'get', 'amazon', 'great', 'work', 'one', 'kindle']
```

Averaging Feature Vectors

Now we have created a vocabulary list of words with each word having a word representation(ie. feature vector of dim 300).

To find a numerical representation for a review, we run through each word in a review text. For words appear in the vocabulary list, we compute the average feature vectors of all those words. The average feature vector is the numerical represenation of the review.

In [59]:
```
# Transfroming the training data into feature vectors

def makeFeatureVec(review, model, num_features):
    '''
    Transform a review to a feature vector by averaging feature vectors of words
    appeared in that review and in the vocabulary list created
    '''
    featureVec = np.zeros((num_features,),dtype="float32")
    nwords = 0.
    index2word_set = set(model.wv.index2word) #index2word is the vocabulary list of the Word2Vec model
    isZeroVec = True
    for word in review:
        if word in index2word_set:
            nwords = nwords + 1.
            featureVec = np.add(featureVec, model[word])
            isZeroVec = False
    if isZeroVec == False:
        featureVec = np.divide(featureVec, nwords)
    return featureVec


def getAvgFeatureVecs(reviews, model, num_features):
    '''
    Transform all reviews to feature vectors using makeFeatureVec()
    '''
    counter = 0
    reviewFeatureVecs = np.zeros((len(reviews),num_features),dtype="float32")
    for review in reviews:
        reviewFeatureVecs[counter] = makeFeatureVec(review, model,num_features)
        counter = counter + 1
    return reviewFeatureVecs
```

In [60]:
```
# Getting feature vectors for training set
X_train_cleaned = []
for review in X_train:
    X_train_cleaned.append(cleanText(review, remove_stopwords=True, split_text=True))
trainVector = getAvgFeatureVecs(X_train_cleaned, w2v, num_features)
print("Training set : %d feature vectors with %d dimensions" %trainVector.shape)


# Getting feature vectors for validation set
X_test_cleaned = []
for review in X_test:
    X_test_cleaned.append(cleanText(review, remove_stopwords=True, split_text=True))
testVector = getAvgFeatureVecs(X_test_cleaned, w2v, num_features)
print("Validation set : %d feature vectors with %d dimensions" %testVector.shape)
```

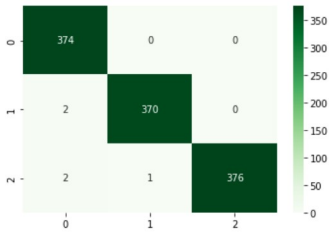
```
Training set : 10122 feature vectors with 300 dimensions
Validation set : 1125 feature vectors with 300 dimensions
```

In [61]:
```
# Getting feature vectors for training set
trainVector = getAvgFeatureVecs(X_train, w2v, num_features)
print("Training set : %d feature vectors with %d dimensions" %trainVector.shape)

# Getting feature vectors for validation set
testVector = getAvgFeatureVecs(X_test, w2v, num_features)
print("Validation set : %d feature vectors with %d dimensions" %testVector.shape)
```

```
Training set : 10122 feature vectors with 300 dimensions
Validation set : 1125 feature vectors with 300 dimensions
```

In [62]:
```
# Random Forest Classifier
from sklearn.ensemble import RandomForestClassifier
rf = RandomForestClassifier(n_estimators=100)
rf.fit(trainVector, Y_train)
predict_rf = rf.predict(testVector)
metrics(predict_rf)
```

```
Accuracy on validation set:  0.9955555555555555
              precision    recall  f1-score   support

    Negative       0.99      1.00      0.99       374
     Neutral       1.00      0.99      1.00       372
    Positive       1.00      0.99      1.00       379

    accuracy                           1.00      1125
   macro avg       1.00      1.00      1.00      1125
weighted avg       1.00      1.00      1.00      1125

[[374   0   0]
 [  2 370   0]
 [  2   1 376]]
```



Applying LSTM

Long Short Term Memory(LSTM) Networks are a special kind of the Recurrent Neural Networks(RNN) capable of learning long-term dependencies. LSTM can be very useful in text mining problems as it involves dependencies in the sentences which can be caught in the "memory" of the LSTM. Here, we will train a simple LSTM and LSTM with Word2Vec embedding for classifying the reviews into positive and negative sentiments using Keras library.

Simple LSTM

We need to preprocess the text data to 2D tensor before we begin fitting it into a simple LSTM. Firstly we will tokenize the corpus by considering only top words (top_words = 20000) and transforming reviews to numerical sequences using the trained tokenizer. Lastly we will make it sure that all the numerical sequences have the same length (maxlen=100) for modelling by truncating the long reviews and padding shorter reviews having zero values.

For constructing a simple LSTM, we will use embedding class in Keras to building up the first layer. This embedding layer converts numerical sequence of words into a word embedding. We should also note that the embedding class provides a convenient way to map discrete words into a continuous vector space but it doesn't take the semantic similarity of the words into account. The next layer is the LSTM layer with 128 memory units. Finally, we will use a dense output layer with a single neuron and a sigmoid activation function to make 0 or 1 prediction for the two classes (positive sentiment and negative sentiment). As it is a binary classification problem log loss is used as the loss function(binary_crossentropy in Keras). ADAM optimization algorithm will be used.

Here's the workflow in this part: -

- Prepare X_train and X_test to 2D tensor.
- Train a simple LSTM (embedding layer => LSTM layer => dense layer).
- Compile and fit the model using log loss function and ADAM optimizer.

In [63]:
```
data2 = data
```

In [65]:
```
data2['sentiment'].value_counts()
```

Out[65]:
```
Positive    3749
Neutral     3749
Negative    3749
Name: sentiment, dtype: int64
```

In [66]:
```
data2['sentiment'] = data2['sentiment'].replace({'Negative':0,'Positive':1,'Neutral':2})
```

In [67]:
```
data2['sentiment'].value_counts()
```

Out[67]:
```
1    3749
2    3749
0    3749
Name: sentiment, dtype: int64
```

In [68]:
```
data2.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 11247 entries, 0 to 11246
Data columns (total 2 columns):
 #   Column               Non-Null Count  Dtype 
---  ------               --------------  ----- 
 0   Preprocessed_Reviews  11247 non-null  object
 1   sentiment            11247 non-null  int64 
dtypes: int64(1), object(1)
memory usage: 175.9+ KB
```

In [69]:
```
X_train,X_test,y_train,y_test = train_test_split(data2['Preprocessed_Reviews'],data2['sentiment'],test_size=0.1)
```

In [70]:
```
print(X_train.shape,X_test.shape,y_train.shape,y_test.shape)
```

```
(10122,) (1125,) (10122,) (1125,)
```

In [74]:
```
from tensorflow.keras.preprocessing import sequence
from keras.utils import np_utils
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Embedding
from keras.layers.core import Dense, Dropout, Activation, Lambda
from tensorflow.keras.layers import LSTM, SimpleRNN, GRU
from keras.preprocessing.text import Tokenizer
from collections import defaultdict
from keras.layers.convolutional import Convolution1D
from keras import backend as K
from keras.callbacks import EarlyStopping
```

In [75]:
```
top_words = 20000
maxlen = 100
batch_size = 32
nb_classes = 3
nb_epoch = 3


# Vectorize X_train and X_test to 2D tensor
tokenizer = Tokenizer(nb_words=top_words) #Considering only top 20000 words in the corpus
tokenizer.fit_on_texts(X_train)
# tokenizer.word_index #access word-to-index dictionary of trained tokenizer

sequences_train = tokenizer.texts_to_sequences(X_train)
sequences_test = tokenizer.texts_to_sequences(X_test)

X_train_seq = sequence.pad_sequences(sequences_train, maxlen=maxlen)
X_test_seq = sequence.pad_sequences(sequences_test, maxlen=maxlen)


# One-Hot Encoding of y_train and y_test
y_train_seq = np_utils.to_categorical(y_train, nb_classes)
y_test_seq = np_utils.to_categorical(y_test, nb_classes)

print('X_train shape:', X_train_seq.shape)
print('X_test shape:', X_test_seq.shape)
print('y_train shape:', y_train_seq.shape)
print('y_test shape:', y_test_seq.shape)
```

```
X_train shape: (10122, 100)
X_test shape: (1125, 100)
y_train shape: (10122, 3)
y_test shape: (1125, 3)
```

In [80]:
```
# Constructing a Simple LSTM
model1 = Sequential()
model1.add(Embedding(top_words, 128))
model1.add(Dropout(0.2))
model1.add(LSTM(128, dropout=0.2, recurrent_dropout=0.2))
model1.add(Dense(nb_classes))
model1.add(Activation('softmax'))
model1.summary()

# Compiling LSTM
model1.compile(loss='binary_crossentropy',
              optimizer='adam',
              metrics=['accuracy'])

model1.fit(X_train_seq, y_train_seq, batch_size=batch_size, epochs=nb_epoch, verbose=1)

# Model Evaluation
score = model1.evaluate(X_test_seq, y_test_seq, batch_size=batch_size)
print("Test loss: ",score[0])
print('Test accuracy: ',score[1])
```

```
Model: "sequential_4"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 embedding_3 (Embedding)     (None, None, 128)         2560000

 dropout_3 (Dropout)         (None, None, 128)         0

 lstm_2 (LSTM)               (None, 128)               131584

 dense_2 (Dense)             (None, 3)                 387

 activation_2 (Activation)   (None, 3)                 0

=================================================================
Total params: 2,691,971
Trainable params: 2,691,971
Non-trainable params: 0
_________________________________________________________________
Epoch 1/3
317/317 [==============================] - 119s 357ms/step - loss: 0.2637 - accuracy: 0.8243
Epoch 2/3
317/317 [==============================] - 112s 352ms/step - loss: 0.0323 - accuracy: 0.9874
Epoch 3/3
317/317 [==============================] - 110s 347ms/step - loss: 0.0174 - accuracy: 0.9933
36/36 [==============================] - 2s 41ms/step - loss: 0.0204 - accuracy: 0.9938
Test loss:  0.020434588193893433
Test accuracy:  0.9937777519226074
```

In [89]:
```
# Getting weight matrix of the embedding layer
model1.layers[0].get_weights()[0] # weight matrix of the embedding layer, word-by-dim matrix
print(model1.layers[0].get_weights()[0].shape)
```

```
(20000, 128)
```

LSTM with Word2Vec Embedding

In the simple LSTM model constructed above, the embedding class in Keras comes in handy for converting the numerical sequence of words into a word embedding but it doesn't take the semantic similarity of the words into account. The model assigns random weights to the embedding layer and learn the embeddings by minimizing the global error of the network.

Instead of using random weights we will use pretrained word embeddings for initializing the weight of an embedding layer. Here, we will use the Word2Vec embedding trained in Part 4 for intializing the weights of embedding layer in LSTM.

1. Load pretrained word embedding model.
2. Construct embedding layer using embedding matrix as weights.
3. Train a LSTM with Word2Vec embedding (embedding layer => LSTM layer => dense layer).
4. Compile and fit the model using log loss function and ADAM optimizer.

In [90]:
```
# Loading pretrained Word2Vec model
w2v = Word2Vec.load("w2v_300features_10minwordcounts_10context")


# Getting Word2Vec embedding matrix
embedding_matrix = w2v.wv.syn0  # embedding matrix, type = numpy.ndarray
print("Shape of embedding matrix : ", embedding_matrix.shape)
```

```
Shape of embedding matrix :  (1235, 300)
```

In [91]:
```
top_words = embedding_matrix.shape[0] #4016
maxlen = 100
batch_size = 32
nb_classes = 3
nb_epoch = 3


# Vectorizing X_train and X_test to 2D tensor
tokenizer = Tokenizer(nb_words=top_words) #Considering only top 20000 words in the corpus
tokenizer.fit_on_texts(X_train)
# tokenizer.word_index #access word-to-index dictionary of trained tokenizer

sequences_train = tokenizer.texts_to_sequences(X_train)
sequences_test = tokenizer.texts_to_sequences(X_test)

X_train_seq = sequence.pad_sequences(sequences_train, maxlen=maxlen)
X_test_seq = sequence.pad_sequences(sequences_test, maxlen=maxlen)


# One-Hot Encoding of y_train and y_test
y_train_seq = np_utils.to_categorical(y_train, nb_classes)
y_test_seq = np_utils.to_categorical(y_test, nb_classes)

print('X_train shape:', X_train_seq.shape) #(27799, 100)
print('X_test shape:', X_test_seq.shape) #(3089, 100)
print('y_train shape:', y_train_seq.shape) #(27799, 2)
print('y_test shape:', y_test_seq.shape) #(3089, 2)
```

```
X_train shape: (10122, 100)
X_test shape: (1125, 100)
y_train shape: (10122, 3)
y_test shape: (1125, 3)
```

In [92]:
```
# Constructing Word2Vec embedding layer
embedding_layer = Embedding(embedding_matrix.shape[0], #4016
                            embedding_matrix.shape[1], #300
                            weights=[embedding_matrix])


# Constructing LSTM with Word2Vec embedding
model2 = Sequential()
model2.add(embedding_layer)
model2.add(LSTM(128, dropout=0.2, recurrent_dropout=0.2))
model2.add(Dense(nb_classes))
model2.add(Activation('softmax'))
model2.summary()

# Compiling model
model2.compile(loss='binary_crossentropy',
               optimizer='adam',
               metrics=['accuracy'])

model2.fit(X_train_seq, y_train_seq, batch_size=batch_size, epochs=nb_epoch, verbose=1)


# Model evaluation
score = model2.evaluate(X_test_seq, y_test_seq, batch_size=batch_size)
print('Test loss:',score[0])
print('Test accuracy:',score[1])
```

```
Model: "sequential_5"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 embedding_4 (Embedding)     (None, None, 300)         370500

 lstm_3 (LSTM)               (None, 128)               219648

 dense_3 (Dense)             (None, 3)                 387

 activation_3 (Activation)   (None, 3)                 0

=================================================================
Total params: 590,535
Trainable params: 590,535
Non-trainable params: 0
_________________________________________________________________
Epoch 1/3
317/317 [==============================] - 145s 440ms/step - loss: 0.2091 - accuracy: 0.8612
Epoch 2/3
317/317 [==============================] - 137s 433ms/step - loss: 0.0285 - accuracy: 0.9884
Epoch 3/3
317/317 [==============================] - 138s 437ms/step - loss: 0.0106 - accuracy: 0.9961
36/36 [==============================] - 2s 55ms/step - loss: 0.0151 - accuracy: 0.9956
Test loss: 0.015092512592673302
Test accuracy: 0.995555579662323
```

Optional Tasks: Topic Modelling

Latent Dirichlet Allocation(LDA)

In [94]:
```
doc_complete = data2["Preprocessed_Reviews"].tolist()
doc_clean = [cleanText(doc).split() for doc in doc_complete]
```

In [95]:
```
import gensim
from gensim import corpora
```

In [96]:
```
dictionary = corpora.Dictionary(doc_clean)
print(dictionary)
```

```
Dictionary(3415 unique tokens: ['able', 'access', 'accomplish', 'ad', 'add']...)
```

In [97]:
```
doc_term_matrix = [dictionary.doc2bow(doc) for doc in doc_clean]
doc_term_matrix
```

Out[97]:
```
[[(0, 1),
  (1, 1),
  (2, 1),
  (3, 1),
  (4, 2),
  (5, 1),
  (6, 3),
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```

In [98]:
```
from gensim.models import LdaModel
```

In [99]:
```
NUM_TOPICS = 9
ldamodel = LdaModel(doc_term_matrix, num_topics=NUM_TOPICS, id2word=dictionary, passes=30)
```

In [100]:
```
topics = ldamodel.show_topics()
for topic in topics:
    print(topic)
    print()
```

```
(0, '0.028*"use" + 0.028*"work" + 0.026*"buy" + 0.023*"week" + 0.018*"junk" + 0.017*"turn" + 0.016*"try" + 0.015*"last" + 0.015*"long" + 0.014*"back"')

(1, '0.024*"use" + 0.024*"good" + 0.020*"amazon" + 0.019*"generation" + 0.019*"th" + 0.019*"much" + 0.017*"youtube" + 0.017*"video" + 0.017*"echo" + 0.015*"would"')

(2, '0.035*"read" + 0.025*"book" + 0.025*"device" + 0.019*"light" + 0.016*"kindle" + 0.014*"would" + 0.013*"buy" + 0.013*"good" + 0.012*"purchase" + 0.012*"fire"')

(3, '0.031*"like" + 0.029*"apps" + 0.022*"return" + 0.022*"lot" + 0.017*"slow" + 0.017*"find" + 0.014*"game" + 0.014*"screen" + 0.013*"nothing" + 0.013*"kid"')

(4, '0.043*"use" + 0.026*"good" + 0.026*"great" + 0.024*"echo" + 0.022*"screen" + 0.019*"sound" + 0.017*"easy" + 0.015*"love" + 0.015*"like" + 0.015*"thing"')

(5, '0.048*"buy" + 0.031*"one" + 0.029*"kindle" + 0.028*"year" + 0.024*"charge" + 0.021*"get" + 0.020*"model" + 0.019*"go" + 0.017*"last" + 0.016*"replace"')

(6, '0.074*"tablet" + 0.043*"good" + 0.028*"kid" + 0.025*"price" + 0.018*"apps" + 0.017*"game" + 0.017*"buy" + 0.016*"amazon" + 0.016*"play" + 0.016*"work"')

(7, '0.037*"echo" + 0.030*"alexa" + 0.029*"show" + 0.026*"work" + 0.025*"get" + 0.020*"first" + 0.017*"useless" + 0.016*"make" + 0.015*"update" + 0.014*"sure"')

(8, '0.043*"amazon" + 0.037*"one" + 0.032*"get" + 0.029*"device" + 0.026*"register" + 0.022*"code" + 0.018*"tablet" + 0.018*"software" + 0.017*"like" + 0.016*"easy"')
```

In [101]:
```
word_dict = {}
for i in range(NUM_TOPICS):
    words = ldamodel.show_topic(i, topn = 20)
    word_dict["Topic # " + "{}".format(i)] = [i[0] for i in words]
```

In [102]:
```
pd.DataFrame(word_dict)
```

Out[102]:

	Topic # 0	Topic # 1	Topic # 2	Topic # 3	Topic # 4	Topic # 5	Topic # 6	Topic # 7	Topic # 8
0	use	use	read	like	use	buy	tablet	echo	amazon
1	work	good	book	apps	good	one	good	alexa	one
2	buy	amazon	device	return	great	kindle	kid	show	get
3	week	generation	light	lot	echo	year	price	work	device
4	junk	th	kindle	slow	screen	charge	apps	get	register
5	turn	much	would	find	sound	get	game	first	code
6	try	youtube	buy	game	easy	model	buy	useless	tablet
7	last	video	good	screen	love	go	amazon	make	software
8	long	echo	purchase	nothing	like	last	play	update	like
9	back	would	fire	kid	thing	replace	work	sure	easy
10	would	device	able	also	buy	time	great	great	nothing
11	phone	show	great	want	quality	problem	ok	amazon	little
12	go	love	gig	new	play	charger	google	light	start
13	since	speaker	screen	old	tablet	old	product	tell	still
14	get	buy	internet	use	music	first	get	answer	also
15	apps	one	amazon	seem	tap	purchase	love	could	would
16	kindle	work	o	pay	look	shut	child	plus	bite
17	fire	sound	bright	lock	would	back	like	home	say
18	store	dot	love	ad	really	product	old	ask	feel
19	time	music	wish	ipad	set	come	little	buy	time

In [103]:
```
ldamodel.show_topic(0, topn = 20)
```

Out[103]:
```
[('use', 0.028106203),
 ('work', 0.027848706),
 ('buy', 0.025598476),
 ('week', 0.022567693),
 ('junk', 0.017699609),
 ('turn', 0.016971692),
 ('try', 0.015664443),
 ('last', 0.015461913),
 ('long', 0.015151899),
 ('back', 0.014390383),
 ('would', 0.01158516),
 ('phone', 0.0115663875),
 ('go', 0.01137696),
 ('since', 0.010680993),
 ('get', 0.01067237),
 ('apps', 0.010472597),
 ('kindle', 0.0103090545),
 ('fire', 0.009739046),
 ('store', 0.009438848),
 ('time', 0.009307361)]
```

In [104]:
```
!pip install pyLDAvis
```

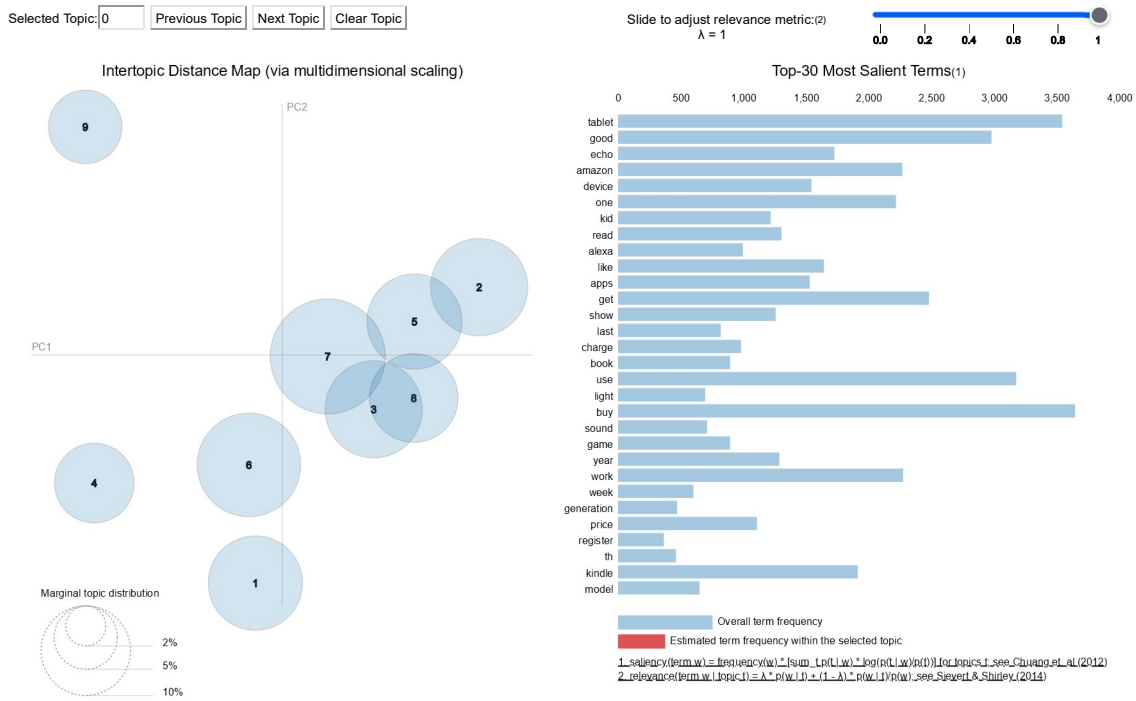
```
Looking in indexes: https://pypi.org/simple, https://us-python.pkg.dev/colab-wheels/public/simple/
Collecting pyLDAvis
  Downloading pyLDAvis-3.3.1.tar.gz (1.7 MB)
     |████████████████████████████████| 1.7 MB 5.5 MB/s
  Installing build dependencies ... done
  Getting requirements to build wheel ... done
  Installing backend dependencies ... done
    Preparing wheel metadata ... done
Requirement already satisfied: setuptools in /usr/local/lib/python3.7/dist-packages (from pyLDAvis) (57.4.0)
Requirement already satisfied: jinja2 in /usr/local/lib/python3.7/dist-packages (from pyLDAvis) (2.11.3)
Collecting sklearn
  Downloading sklearn-0.0.post1.tar.gz (3.6 kB)
Requirement already satisfied: numpy>=1.20.0 in /usr/local/lib/python3.7/dist-packages (from pyLDAvis) (1.21.6)
Requirement already satisfied: gensim in /usr/local/lib/python3.7/dist-packages (from pyLDAvis) (3.6.0)
Collecting funcy
  Downloading funcy-1.17-py2.py3-none-any.whl (33 kB)
Requirement already satisfied: future in /usr/local/lib/python3.7/dist-packages (from pyLDAvis) (0.16.0)
Requirement already satisfied: numexpr in /usr/local/lib/python3.7/dist-packages (from pyLDAvis) (2.8.4)
Requirement already satisfied: scipy in /usr/local/lib/python3.7/dist-packages (from pyLDAvis) (1.7.3)
Requirement already satisfied: scikit-learn in /usr/local/lib/python3.7/dist-packages (from pyLDAvis) (1.0.2)
Requirement already satisfied: joblib in /usr/local/lib/python3.7/dist-packages (from pyLDAvis) (1.2.0)
Requirement already satisfied: pandas>=1.2.0 in /usr/local/lib/python3.7/dist-packages (from pyLDAvis) (1.3.5)
Requirement already satisfied: python-dateutil>=2.7.3 in /usr/local/lib/python3.7/dist-packages (from pandas>=1.2.0->pyLDAvis) (2.8.2)
Requirement already satisfied: pytz>=2017.3 in /usr/local/lib/python3.7/dist-packages (from pandas>=1.2.0->pyLDAvis) (2022.6)
Requirement already satisfied: six>=1.5 in /usr/local/lib/python3.7/dist-packages (from python-dateutil>=2.7.3->pandas>=1.2.0->pyLDAvis) (1.15.0)
Requirement already satisfied: smart-open>=1.2.1 in /usr/local/lib/python3.7/dist-packages (from gensim->pyLDAvis) (5.2.1)
Requirement already satisfied: MarkupSafe>=0.23 in /usr/local/lib/python3.7/dist-packages (from jinja2->pyLDAvis) (2.0.1)
Requirement already satisfied: threadpoolctl>=2.0.0 in /usr/local/lib/python3.7/dist-packages (from scikit-learn->pyLDAvis) (3.1.0)
Building wheels for collected packages: pyLDAvis, sklearn
  Building wheel for pyLDAvis (PEP 517) ... done
  Created wheel for pyLDAvis: filename=pyLDAvis-3.3.1-py2.py3-none-any.whl size=136898 sha256=086e7efc19bc08031bed2f01d4460971aad5d5fb157bddb3eea841247b8dc4fe
  Stored in directory: /root/.cache/pip/wheels/c9/21/f6/17bcf2667e8a68532ba2fbf6d5c72fdf4c7f7d9abfa4852d2f
  Building wheel for sklearn (setup.py) ... done
  Created wheel for sklearn: filename=sklearn-0.0.post1-py3-none-any.whl size=2344 sha256=cc1679a1f5138e82b0e7a314902b0c9291c916ce15ea8f8e5fa33ec41f4fac26
  Stored in directory: /root/.cache/pip/wheels/42/56/cc/4a8bf86613aafd5b7f1b310477667c1fca5c51c3ae4124a003
Successfully built pyLDAvis sklearn
Installing collected packages: sklearn, funcy, pyLDAvis
Successfully installed funcy-1.17 pyLDAvis-3.3.1 sklearn-0.0.post1
```

In [107]:
```
import pyLDAvis
from pyLDAvis import gensim_models as gensim
```

Displaying Results & Getting Insights

In [109]:
```
Lda_display = gensim.prepare(ldamodel, doc_term_matrix, dictionary, sort_topics=False)
pyLDAvis.display(Lda_display)
```

Out[109]:



Creating a Wordcloud

In [111]:
```
from wordcloud import WordCloud, STOPWORDS
txt = data2["Preprocessed_Reviews"].values
wc = WordCloud(width=200, height=100, background_color="white", stopwords=STOPWORDS).generate(str(txt))
fig = plt.figure(figsize=(20,20), facecolor='k', edgecolor='w')
plt.imshow(wc, interpolation="bilinear")
plt.axis("off")
plt.tight_layout()
plt.show()
```

In [ ]: