In [ ]:
```
# import pandas as pd
# from ast import literal_eval

# if not isinstance(df_reviews['category'].iloc[0], list):
#     df_reviews['category'] = df_reviews['category'].apply(lambda x: literal_e

# pharmacy_rows = df_reviews[df_reviews['category'].apply(lambda x: 'Hotel' in
```

In [1]:
```
import pandas as pd
import numpy as np
import math
```

In [2]:
```
from google.colab import auth
auth.authenticate_user()
```

In [3]:
```
from google.cloud import storage

project_id = "sharp-matter-449521-u2"
!gcloud config set project {project_id}
```

```
Updated property [core/project].
```

In [4]:
```
!pip install pyspark py4j
!wget -P /usr/lib/spark/jars/ https://storage.googleapis.com/hadoop-lib/gcs/gcs
```

```
Requirement already satisfied: pyspark in /usr/local/lib/python3.11/dist-packa
ges (3.5.5)
Requirement already satisfied: py4j in /usr/local/lib/python3.11/dist-packages
(0.10.9.7)
--2025-04-22 16:57:13--  https://storage.googleapis.com/hadoop-lib/gcs/gcs-con
nector-hadoop3-latest.jar
Resolving storage.googleapis.com (storage.googleapis.com)... 64.233.188.207, 6
4.233.189.207, 108.177.97.207, ...
Connecting to storage.googleapis.com (storage.googleapis.com)|64.233.188.207|:
443... connected.
HTTP request sent, awaiting response... 200 OK
Length: 40713341 (39M) [application/java-archive]
Saving to: ‘/usr/lib/spark/jars/gcs-connector-hadoop3-latest.jar’

gcs-connector-hadoo 100%[===================>]  38.83M  18.4MB/s    in 2.1s

2025-04-22 16:57:15 (18.4 MB/s) - ‘/usr/lib/spark/jars/gcs-connector-hadoop3-l
atest.jar’ saved [40713341/40713341]
```

In [5]:
```
from pyspark.sql import SparkSession
```

In [6]:
```
spark = SparkSession.builder \
    .appName("BigDataProcessing") \
    .config("spark.jars", "/usr/lib/spark/jars/gcs-connector-hadoop3-latest.ja
    .config("spark.hadoop.fs.gs.impl", "com.google.cloud.hadoop.fs.gcs.GoogleHa
    .config("spark.hadoop.fs.gs.auth.service.account.enable", "true") \
    .getOrCreate()
```

In [ ]:
```
import pandas as pd
df_sample_pd = pd.read_parquet("gs://final_dataset_dat490/sample_reviews_strat
df_sample_pd = df_sample_pd.sort_values(["gmap_id", "timestamp"]).reset_index(
df_sample_pd.columns
```

Out[ ]:
```
Index(['gmap_id', 'customer_name', 'rating', 'reviews', 'time', 'avg_rating',
       'category', 'latitude', 'longitude', 'business_name', 'num_of_reviews',
       'state', 'standard_category', 'Monday', 'Tuesday', 'Wednesday',
       'Thursday', 'Friday', 'Saturday', 'Sunday', 'timestamp', 'week',
       'month', 'year', 'time_seconds', 'review_length', 'length_bucket'],
      dtype='object')
```

In [ ]:
```
df_sample_pd['year'].unique()
```

Out[ ]:
```
array([2021, 2020, 2016, 2019, 2018, 2017, 2015, 2013, 2012, 2014, 2011],
      dtype=int32)
```

In [ ]:
```
df_sample_pd.groupby('year')['gmap_id'].count()
```

Out[ ]:

	gmap_id
year	
2011	1
2012	5
2013	5
2014	4
2015	10
2016	92
2017	275
2018	586
2019	1190
2020	2099
2021	5734

dtype: int64

In [ ]:
```
df_sample_pd.groupby('standard_category')['gmap_id'].count()
```

Out[ ]:

	gmap_id
standard_category	
Automotive	553
Bakery	108
Bar	199
Beauty & Wellness	575
Business Services	355
Cafe	150
Construction	14
Consulting	37
Education	52
Entertainment	24
Event Venue	181
Finance	29
Fitness	241
Grocery Store	343
Healthcare	344
Hotel	158
Insurance	15
Laundry Services	43
Legal Services	30
Non-Profit	87
Other	523
Pet Services	54
Public Services	182
Real Estate	90
Religious Institution	167
Restaurant	2408
Retail	2650
Storage Services	25
Tourism & Attractions	310
Transportation	54

dtype: int64

In [ ]:

```
import torch
print(torch.cuda.is_available())
```

```
True
```

In [ ]:

```
from transformers import pipeline
from tqdm import tqdm

tqdm.pandas()

# Zero-shot classification pipeline with BART
zero_shot_classifier = pipeline("zero-shot-classification", model="facebook/ba
```

```
/usr/local/lib/python3.11/dist-packages/huggingface_hub/utils/_auth.py:94: Use
rWarning:
The secret `HF_TOKEN` does not exist in your Colab secrets.
To authenticate with the Hugging Face Hub, create a token in your settings tab
(https://huggingface.co/settings/tokens), set it as secret in your Google Cola
b and restart your session.
You will be able to reuse this secret in all of your notebooks.
Please note that authentication is recommended but still optional to access pu
blic models or datasets.
  warnings.warn(
config.json:   0%|          | 0.00/1.15k [00:00<?, ?B/s]
Xet Storage is enabled for this repo, but the 'hf_xet' package is not installe
d. Falling back to regular HTTP download. For better performance, install the
package with: `pip install huggingface_hub[hf_xet]` or `pip install hf_xet`
WARNING:huggingface_hub.file_download:Xet Storage is enabled for this repo, bu
t the 'hf_xet' package is not installed. Falling back to regular HTTP downloa
d. For better performance, install the package with: `pip install huggingface_
hub[hf_xet]` or `pip install hf_xet`
model.safetensors:   0%|          | 0.00/1.63G [00:00<?, ?B/s]
tokenizer_config.json:   0%|          | 0.00/26.0 [00:00<?, ?B/s]
vocab.json:   0%|          | 0.00/899k [00:00<?, ?B/s]
merges.txt:   0%|          | 0.00/456k [00:00<?, ?B/s]
tokenizer.json:   0%|          | 0.00/1.36M [00:00<?, ?B/s]
Device set to use cpu
```

In [ ]:

```
df_sample_pd.head()
```

In [ ]:

```
df_sample_pd.columns
```

Out[ ]:

```
Index(['gmap_id', 'customer_name', 'rating', 'reviews', 'time', 'avg_rating',
       'category', 'latitude', 'longitude', 'business_name', 'num_of_reviews',
       'state', 'standard_category', 'Monday', 'Tuesday', 'Wednesday',
       'Thursday', 'Friday', 'Saturday', 'Sunday', 'timestamp', 'week',
       'month', 'year', 'time_seconds', 'review_length', 'length_bucket',
       'bart_label'],
      dtype='object')
```

In [ ]:

```
!pip install --upgrade openai
```

```
Requirement already satisfied: openai in /usr/local/lib/python3.11/dist-packag
es (1.70.0)
Collecting openai
  Downloading openai-1.73.0-py3-none-any.whl.metadata (25 kB)
Requirement already satisfied: anyio<5,>=3.5.0 in /usr/local/lib/python3.11/di
st-packages (from openai) (4.9.0)
Requirement already satisfied: distro<2,>=1.7.0 in /usr/local/lib/python3.11/d
ist-packages (from openai) (1.9.0)
Requirement already satisfied: httpx<1,>=0.23.0 in /usr/local/lib/python3.11/d
ist-packages (from openai) (0.28.1)
Requirement already satisfied: jiter<1,>=0.4.0 in /usr/local/lib/python3.11/di
st-packages (from openai) (0.9.0)
Requirement already satisfied: pydantic<3,>=1.9.0 in /usr/local/lib/python3.1
1/dist-packages (from openai) (2.11.2)
Requirement already satisfied: sniffio in /usr/local/lib/python3.11/dist-packa
ges (from openai) (1.3.1)
Requirement already satisfied: tqdm>4 in /usr/local/lib/python3.11/dist-packag
es (from openai) (4.67.1)
Requirement already satisfied: typing-extensions<5,>=4.11 in /usr/local/lib/py
thon3.11/dist-packages (from openai) (4.13.1)
Requirement already satisfied: idna>=2.8 in /usr/local/lib/python3.11/dist-pac
kages (from anyio<5,>=3.5.0->openai) (3.10)
Requirement already satisfied: certifi in /usr/local/lib/python3.11/dist-packa
ges (from httpx<1,>=0.23.0->openai) (2025.1.31)
Requirement already satisfied: httpcore==1.* in /usr/local/lib/python3.11/dist
-packages (from httpx<1,>=0.23.0->openai) (1.0.7)
Requirement already satisfied: h11<0.15,>=0.13 in /usr/local/lib/python3.11/di
st-packages (from httpcore==1.*->httpx<1,>=0.23.0->openai) (0.14.0)
Requirement already satisfied: annotated-types>=0.6.0 in /usr/local/lib/python
3.11/dist-packages (from pydantic<3,>=1.9.0->openai) (0.7.0)
Requirement already satisfied: pydantic-core==2.33.1 in /usr/local/lib/python
3.11/dist-packages (from pydantic<3,>=1.9.0->openai) (2.33.1)
Requirement already satisfied: typing-inspection>=0.4.0 in /usr/local/lib/pyth
on3.11/dist-packages (from pydantic<3,>=1.9.0->openai) (0.4.0)
Downloading openai-1.73.0-py3-none-any.whl (644 kB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 644.4/644.4 kB 9.9 MB/s eta 0:00:0
0
Installing collected packages: openai
  Attempting uninstall: openai
    Found existing installation: openai 1.70.0
    Uninstalling openai-1.70.0:
      Successfully uninstalled openai-1.70.0
Successfully installed openai-1.73.0
```

In [ ]:
```
from openai import OpenAI
from google.colab import userdata

client = OpenAI(api_key=userdata.get("openai_api_key"))
```

In [ ]:
```
from openai import OpenAI
from google.colab import userdata

client = OpenAI(api_key=userdata.get("openai_api_key"))

models = client.models.list()

for model in models.data:
    print(model.id)
```

```
gpt-4o-audio-preview-2024-12-17
dall-e-3
dall-e-2
gpt-4o-audio-preview-2024-10-01
gpt-4o-realtime-preview-2024-10-01
gpt-4o-realtime-preview
babbage-002
tts-1-hd-1106
text-embedding-3-large
gpt-4
text-embedding-ada-002
tts-1-hd
gpt-4o-mini-audio-preview
gpt-4-0125-preview
gpt-4o-audio-preview
gpt-4-turbo-preview
o1-preview-2024-09-12
gpt-4o-mini-realtime-preview
gpt-4o-mini-realtime-preview-2024-12-17
gpt-3.5-turbo-instruct-0914
gpt-4o-mini-search-preview
tts-1-1106
davinci-002
gpt-3.5-turbo-1106
gpt-4-turbo
gpt-4o-realtime-preview-2024-12-17
gpt-3.5-turbo-instruct
gpt-3.5-turbo
chatgpt-4o-latest
gpt-4o-mini-search-preview-2025-03-11
gpt-4o-2024-11-20
whisper-1
gpt-4o-2024-05-13
gpt-3.5-turbo-16k
gpt-4-turbo-2024-04-09
gpt-4-1106-preview
o1-preview
gpt-4-0613
gpt-4o-search-preview
gpt-4.5-preview
gpt-4.5-preview-2025-02-27
gpt-4o-search-preview-2025-03-11
tts-1
omni-moderation-2024-09-26
text-embedding-3-small
gpt-4o-mini-tts
gpt-4o
gpt-4o-mini
gpt-4o-2024-08-06
gpt-4o-transcribe
gpt-4o-mini-2024-07-18
gpt-4o-mini-transcribe
o1-mini
gpt-4o-mini-audio-preview-2024-12-17
gpt-3.5-turbo-0125
o1-mini-2024-09-12
omni-moderation-latest
```

In [ ]:
```
from openai import OpenAI
from google.colab import userdata
from tqdm import tqdm
import json
import re
import time

# Set up client
client = OpenAI(api_key=userdata.get("openai_api_key"))

def extract_json_list(reply):
    reply = reply.strip().strip("```json").strip("```").strip()
    match = re.search(r'\[.*?\]', reply, re.DOTALL)
    if match:
        return json.loads(match.group())
    else:
        raise ValueError("No JSON list found in GPT reply")

# Input reviews
review_texts = df_sample_pd["reviews"].tolist()
batch_size = 5
all_labels = []

for i in tqdm(range(0, len(review_texts), batch_size)):
    batch = review_texts[i:i+batch_size]

    reviews_block = "\n".join([f"{j+1}. {text}" for j, text in enumerate(batch

    try:
        response = client.chat.completions.create(
            model="gpt-4o",
            messages=[
                {
                    "role": "system",
                    "content": (
                        "You are a helpful assistant that classifies customer
                        "Only respond with a JSON list of labels."
                    )
                },
                {
                    "role": "user",
                    "content": (
                        f"Please classify the following customer reviews:\n\n{
                        "Respond with a JSON list like this: [\"Positive\", \"
                    )
                }
            ],
            temperature=0,
            max_tokens=100
        )
        reply = response.choices[0].message.content.strip()
        labels = extract_json_list(reply)
        all_labels.extend(labels)

    except Exception as e:
        print(f"Error on batch {i//batch_size}: {e}")
        all_labels.extend([None] * len(batch))

    time.sleep(0.5)
```

```
100%|██████████| 2001/2001 [40:11<00:00,  1.21s/it]
```

In [ ]:
```python
from openai import OpenAI
from google.colab import userdata
from google.colab import drive
import pandas as pd
from tqdm import tqdm
import json
import re
import time

drive.mount('/content/drive')

client = OpenAI(api_key=userdata.get("openai_api_key"))

def extract_json_list(reply):
    reply = reply.strip().strip("```json").strip("```").strip()
    match = re.search(r'\[.*?\]', reply, re.DOTALL)
    if match:
        return json.loads(match.group())
    else:
        raise ValueError("No JSON list found in GPT reply")

# Loading the Excel file from Google Drive
file_path = "/content/drive/MyDrive/Reviews std DAT490 labelled.xlsx"
df = pd.read_excel(file_path)

review_texts = df["Reviews"].head(30).tolist()
batch_size = 5
all_labels = []

for i in tqdm(range(0, len(review_texts), batch_size)):
    batch = review_texts[i:i+batch_size]

    reviews_block = "\n".join([f"{j+1}. {text}" for j, text in enumerate(batch

    try:
        response = client.chat.completions.create(
            model="gpt-4o",
            messages=[
                {
                    "role": "system",
                    "content": (
                        "You are a helpful assistant that classifies customer
                        "Only respond with a JSON list of labels."
                    )
                },
                {
                    "role": "user",
                    "content": (
                        f"Please classify the following customer reviews:\n\n{
                        "Respond with a JSON list like this: [\"Positive\", \"N
                    )
                }
            ],
            temperature=0,
            max_tokens=100
        )
        reply = response.choices[0].message.content.strip()
        labels = extract_json_list(reply)
        all_labels.extend(labels)
```

```
    except Exception as e:
        print(f"Error on batch {i//batch_size}: {e}")
        all_labels.extend([None] * len(batch))

    time.sleep(0.5)

if "chatgpt_label" in df.columns:
    df.loc[:29, "chatgpt_label"] = all_labels # Apply labels to the 30 reviews
else:
    labels_df = pd.DataFrame({'chatgpt_label': all_labels})
    df_labelled = pd.concat([df.head(30).reset_index(drop=True), labels_df], a

    df["chatgpt_label"] = None
    df.loc[:29, "chatgpt_label"] = all_labels

output_file_path = "/content/drive/MyDrive/Reviews std DAT490 labelled_labelle
df.to_excel(output_file_path, index=False)

print(f"Labels generated for the first 30 reviews and saved to: {output_file_pa
```

```
Mounted at /content/drive
100%|██████████| 6/6 [00:06<00:00,  1.14s/it]
Labels generated for the first 30 reviews and saved to: /content/drive/MyDriv
e/Reviews std DAT490 labelled_labelled.xlsx
```

In [ ]:
```
df_sample_pd["chatgpt_label"] = all_labels
```

In [ ]:
```
df_sample_pd.head()
```

Out[ ]:

	gmap_id	customer_name	rating	reviews	tim
0	0x0:0xde4ab363e58baf8	Glen Sikorski	5	Nice clean place and very friendly staff. Only...	161996385647
1	0x145e95d513a77c99:0x7aad3c9a54c17e9f	stephen travers	5	This company helped us buy our land 15 years a...	162198309140
2	0x14e037302ebfe6bd:0x483c80e39ebb0ab7	Shawn Bebej	5	Great place for kids and families to do sports...	157814209377
3	0x14e3db41cf753ebd:0x1d6536e7c20051ef	L C	5	He was able to fit me in at the last minute. A...	161660426447
4	0x1520f8e750be33d7:0xc5e501b57143e755	Lorelei Flaherty	4	I have had good experiences here for the past ...	14770723343C

5 rows × 28 columns

In [ ]:
```
# df_sample_pd.to_parquet("gs://final_dataset_dat490/sample_reviews_stratified_
```

In [ ]:
```
import pandas as pd
df_sample_lab = pd.read_parquet("gs://final_dataset_dat490/sample_reviews_strat
df_sample_lab = df_sample_lab.sort_values(["gmap_id", "timestamp"]).reset_inde
df_sample_lab.columns
```

Out[ ]:
```
Index(['gmap_id', 'customer_name', 'rating', 'reviews', 'time', 'avg_rating',
       'category', 'latitude', 'longitude', 'business_name', 'num_of_reviews',
       'state', 'standard_category', 'Monday', 'Tuesday', 'Wednesday',
       'Thursday', 'Friday', 'Saturday', 'Sunday', 'timestamp', 'week',
       'month', 'year', 'time_seconds', 'review_length', 'length_bucket',
       'chatgpt_label'],
      dtype='object')
```

In [ ]:
```
sentiment_map = {"Negative": 0, "Neutral": 1, "Positive": 2}
```

In [ ]:
```
df_sample_lab["chatgpt_label_encoded"] = df_sample_lab["chatgpt_label"].map(se
```

In [ ]:
```
df_yearly = (
    df_sample_lab
    .groupby(["business_name", "year"])
    .agg({
        "rating": "mean",
        "chatgpt_label_encoded": "mean",
        "num_of_reviews": "count",
        "avg_rating": "first",
        "state": "first",
        "standard_category": "first",
        "Monday": "first",
        "Tuesday": "first",
        "Wednesday": "first",
        "Thursday": "first",
        "Friday": "first",
        "Saturday": "first",
        "Sunday": "first"
    })
    .reset_index()
    .rename(columns={
        "rating": "avg_rating_year",
        "num_of_reviews": "review_count"
    })
)
```

In [ ]:
```
df_sample_pd['gmap_id'].nunique()
```

Out[ ]:
```
10001
```

In [ ]:
```
df_sample_pd.groupby(["business_name", "year"])['rating'].mean()
```

Out[ ]:

		rating
business_name	**year**	
"Kensington Storefront" Porch Light hub	**2020**	5.0
'49er Saloon	**2021**	5.0
1 Stop Computer's	**2020**	5.0
101 nails nsb	**2021**	5.0
110 Fwy Tires & Roadside Towing	**2019**	5.0
...	**...**	...
washateria	**2021**	4.0
Çka Ka Qellue	**2021**	4.0
Русские Магазины	**2019**	2.0
등촌 칼국수	**2018**	5.0
💈💈	**2018**	1.0

8867 rows × 1 columns

dtype: float64

In [ ]:
```
df_reviews_cleaned = pd.read_parquet("gs://final_dataset_dat490/dat490_final_da
```

In [ ]:
```
from pyspark.sql.functions import col, sum as spark_sum, when
from functools import reduce

weekday_cols = ["Monday", "Tuesday", "Wednesday", "Thursday", "Friday", "Saturd
```

```
df_cleaned = df_reviews_cleaned.dropna(subset=weekday_cols)

from pyspark.sql.functions import first

df_year_status = (
    df_cleaned
    .groupBy("business_name", "year")
    .agg(*[first(col(day)).alias(day) for day in weekday_cols])
)

df_year_status = df_year_status.withColumn(
    "days_open", reduce(lambda a, b: a + b, [col(day) for day in weekday_cols]
).withColumn(
    "is_closed", when(col("days_open") == 0, 1).otherwise(0)
)

open_2019 = df_year_status.filter((col("year") == 2019) & (col("is_closed") ==
closed_2020 = df_year_status.filter((col("year") == 2020) & (col("is_closed")

from pyspark.sql.functions import broadcast

open_then_closed = open_2019.join(broadcast(closed_2020), on="business_name",

open_then_closed.show(truncate=False)
print(f"Number of businesses open in 2019 and closed in 2020: {open_then_close
```

```
+-------------------------+
|business_name            |
+-------------------------+
|16 Handles               |
|Edison ParkFast          |
|Church's Chicken         |
|Bella Vista              |
|Checkers                 |
|Kate Spade Outlet        |
|Country Pride            |
|Coffee & Bagels          |
|City Perch Kitchen + Bar|
|Bruegger's Bagels        |
|Gloria's Jewelry         |
+-------------------------+

Number of businesses open in 2019 and closed in 2020: 11
```

In [ ]:

```
open_2020 = df_year_status.filter(
    (col("year") == 2020) & (col("is_closed") == 0)
).select("business_name")

closed_2021 = df_year_status.filter(
    (col("year") == 2021) & (col("is_closed") == 1)
).select("business_name")

open_then_closed_2021 = open_2020.join(
    broadcast(closed_2021), on="business_name", how="inner"
)

open_then_closed_2021.show(truncate=False)
print(f"Number of businesses open in 2020 and closed in 2021: {open_then_close
+-------------------------------------+
|business_name                        |
+-------------------------------------+
|Nick's Auto Repair                   |
|The Twisted Sicilian Market & Eatery|
|Savor                                |
|The Ski Shack                        |
|Nike Factory Store                   |
|Wells Fargo Museum                   |
|Godiva Chocolatier                   |
+-------------------------------------+

Number of businesses open in 2020 and closed in 2021: 7
```

In [ ]:
```
df_sample_lab.groupby('year')['gmap_id'].count()
```

Out[ ]:

	gmap_id
year	
2011	1
2012	5
2013	5
2014	4
2015	10
2016	92
2017	275
2018	586
2019	1190
2020	2099
2021	5734

dtype: int64

In [ ]:
```
df_sample_lab.columns
```

Out[ ]:
```
Index(['gmap_id', 'customer_name', 'rating', 'reviews', 'time', 'avg_rating',
       'category', 'latitude', 'longitude', 'business_name', 'num_of_reviews',
       'state', 'standard_category', 'Monday', 'Tuesday', 'Wednesday',
       'Thursday', 'Friday', 'Saturday', 'Sunday', 'timestamp', 'week',
       'month', 'year', 'time_seconds', 'review_length', 'length_bucket',
       'chatgpt_label'],
      dtype='object')
```

In [ ]:
```
df_filtered_years = df_sample_lab[df_sample_lab["year"].between(2018, 2021)]

business_years = df_filtered_years[["business_name", "year"]].drop_duplicates(

year_counts = business_years.groupby("business_name")["year"].nunique().reset_
year_counts = year_counts.rename(columns={"year": "year_count"})

businesses_all_4_years = year_counts[year_counts["year_count"] == 4]["business_
```

```
df_4yr = df_filtered_years[df_filtered_years["business_name"].isin(businesses_a

print(f"Number of businesses with reviews in all 4 years (2018–2021): {business
df_4yr[["business_name", "year"]].drop_duplicates().sort_values(["business_name
```

```
Number of businesses with reviews in all 4 years (2018–2021): 19
```

Out[ ]:

	business_name	year
4840	American Eagle Store	2018
8871	American Eagle Store	2019
3759	American Eagle Store	2020
7742	American Eagle Store	2021
5288	AutoZone Auto Parts	2018
6286	AutoZone Auto Parts	2019
2204	AutoZone Auto Parts	2020
2024	AutoZone Auto Parts	2021
8476	Baskin-Robbins	2018
256	Baskin-Robbins	2019

In [ ]:
```
weekday_cols = ["Monday", "Tuesday", "Wednesday", "Thursday", "Friday", "Satur

df_cleaned = df_reviews_cleaned.dropna(subset=weekday_cols)
```

In [ ]:
```
from pyspark.sql.functions import col, sum as spark_sum, when
from functools import reduce
df_filtered_years = df_cleaned.filter(col("year").between(2018, 2021))
```

In [ ]:
```
business_years = (
    df_filtered_years
    .select("business_name", "year")
    .dropDuplicates()
)
```

In [ ]:
```
from pyspark.sql.functions import count

year_counts = (
    business_years
    .groupBy("business_name")
    .agg(count("year").alias("year_count"))
)
```

In [ ]:
```
businesses_all_4_years = (
    year_counts
    .filter(col("year_count") == 4)
    .select("business_name")
)
```

In [ ]:
```
from pyspark.sql.functions import broadcast
df_4yr = (
    df_filtered_years
    .join(broadcast(businesses_all_4_years), on="business_name", how="inner")
)
```

In [ ]:
```
df_4yr.select("business_name", "year").dropDuplicates().orderBy("business_name'
print(f"Number of businesses with reviews in all 4 years (2018–2021): {busines
```

```
+-------------------------------+----+
|business_name                  |year|
+-------------------------------+----+
|#1 Nails                       |2018|
|#1 Nails                       |2019|
|#1 Nails                       |2020|
|#1 Nails                       |2021|
|$5 Pizza                       |2018|
|$5 Pizza                       |2019|
|$5 Pizza                       |2020|
|$5 Pizza                       |2021|
|.                              |2018|
|.                              |2019|
|.                              |2020|
|.                              |2021|
|1 Nails                        |2018|
|1 Nails                        |2019|
|1 Nails                        |2020|
|1 Nails                        |2021|
|1000 Degrees Pizza Salad Wings|2018|
|1000 Degrees Pizza Salad Wings|2019|
|1000 Degrees Pizza Salad Wings|2020|
|1000 Degrees Pizza Salad Wings|2021|
+-------------------------------+----+
only showing top 20 rows

Number of businesses with reviews in all 4 years (2018–2021): 5608
```

In [ ]:
```
df_4yr.printSchema()
```

```
root
 |-- business_name: string (nullable = true)
 |-- gmap_id: string (nullable = true)
 |-- customer_name: string (nullable = true)
 |-- rating: long (nullable = true)
 |-- reviews: string (nullable = true)
 |-- time: long (nullable = true)
 |-- avg_rating: double (nullable = true)
 |-- category: string (nullable = true)
 |-- latitude: double (nullable = true)
 |-- longitude: double (nullable = true)
 |-- num_of_reviews: long (nullable = true)
 |-- state: string (nullable = true)
 |-- standard_category: string (nullable = true)
 |-- Monday: integer (nullable = true)
 |-- Tuesday: integer (nullable = true)
 |-- Wednesday: integer (nullable = true)
 |-- Thursday: integer (nullable = true)
 |-- Friday: integer (nullable = true)
 |-- Saturday: integer (nullable = true)
 |-- Sunday: integer (nullable = true)
 |-- timestamp: string (nullable = true)
 |-- week: integer (nullable = true)
 |-- month: integer (nullable = true)
 |-- year: integer (nullable = true)
 |-- time_seconds: long (nullable = true)
```

In [ ]:
```
df_4yr.count()
```

Out[ ]:
```
658380
```

In [ ]:
```
df_4yr.select("business_name").distinct().count()
```

Out[ ]:
```
5608
```

In [ ]:
```
# df_4yr.write.mode("overwrite").parquet("gs://final_dataset_dat490/engagement_
```

Fine-tuning BERT on ChatGPT-4o labels so that we can use that to label 658k rows for 5608 businesses which are open through all 4 years, from 2018 to 2021.

In [ ]:
```
label_map = {"Negative": 0, "Neutral": 1, "Positive": 2}
df_sample_lab["label"] = df_sample_lab["chatgpt_label"].map(label_map)
df_sample_lab.head()
```

Out[ ]:

	gmap_id	customer_name	rating	reviews	tim
0	0x0:0xde4ab363e58baf8	Glen Sikorski	5	Nice clean place and very friendly staff. Only...	161996385647
1	0x145e95d513a77c99:0x7aad3c9a54c17e9f	stephen travers	5	This company helped us buy our land 15 years a...	162198309140
2	0x14e037302ebfe6bd:0x483c80e39ebb0ab7	Shawn Bebej	5	Great place for kids and families to do sports...	157814209377
3	0x14e3db41cf753ebd:0x1d6536e7c20051ef	L C	5	He was able to fit me in at the last minute. A...	161660426447
4	0x1520f8e750be33d7:0xc5e501b57143e755	Lorelei Flaherty	4	I have had good experiences here for the past ...	14770723343C

5 rows × 29 columns

In [ ]:
```python
from transformers import AutoTokenizer

# Choosing DistilBERT for less computational resources and more efficiency
MODEL_NAME = "distilbert-base-uncased"
tokenizer = AutoTokenizer.from_pretrained(MODEL_NAME)

# Tokenization function
def tokenize_function(example):
    return tokenizer(example["reviews"], truncation=True, padding="max_length"
```

```
/usr/local/lib/python3.11/dist-packages/huggingface_hub/utils/_auth.py:94: Use
rWarning:
The secret `HF_TOKEN` does not exist in your Colab secrets.
To authenticate with the Hugging Face Hub, create a token in your settings tab
(https://huggingface.co/settings/tokens), set it as secret in your Google Cola
b and restart your session.
You will be able to reuse this secret in all of your notebooks.
Please note that authentication is recommended but still optional to access pu
blic models or datasets.
  warnings.warn(
tokenizer_config.json:   0%|          | 0.00/48.0 [00:00<?, ?B/s]
config.json:   0%|          | 0.00/483 [00:00<?, ?B/s]
vocab.txt:   0%|          | 0.00/232k [00:00<?, ?B/s]
tokenizer.json:   0%|          | 0.00/466k [00:00<?, ?B/s]
```

In [ ]:
```
!pip install datasets
```

```
Collecting datasets
  Downloading datasets-3.5.0-py3-none-any.whl.metadata (19 kB)
Requirement already satisfied: filelock in /usr/local/lib/python3.11/dist-pack
ages (from datasets) (3.18.0)
Requirement already satisfied: numpy>=1.17 in /usr/local/lib/python3.11/dist-p
ackages (from datasets) (2.0.2)
Requirement already satisfied: pyarrow>=15.0.0 in /usr/local/lib/python3.11/di
st-packages (from datasets) (18.1.0)
Collecting dill<0.3.9,>=0.3.0 (from datasets)
  Downloading dill-0.3.8-py3-none-any.whl.metadata (10 kB)
Requirement already satisfied: pandas in /usr/local/lib/python3.11/dist-packag
es (from datasets) (2.2.2)
Requirement already satisfied: requests>=2.32.2 in /usr/local/lib/python3.11/d
ist-packages (from datasets) (2.32.3)
Requirement already satisfied: tqdm>=4.66.3 in /usr/local/lib/python3.11/dist-
packages (from datasets) (4.67.1)
Collecting xxhash (from datasets)
  Downloading xxhash-3.5.0-cp311-cp311-manylinux_2_17_x86_64.manylinux2014_x86
_64.whl.metadata (12 kB)
Collecting multiprocess<0.70.17 (from datasets)
  Downloading multiprocess-0.70.16-py311-none-any.whl.metadata (7.2 kB)
Collecting fsspec<=2024.12.0,>=2023.1.0 (from fsspec[http]<=2024.12.0,>=2023.
1.0->datasets)
  Downloading fsspec-2024.12.0-py3-none-any.whl.metadata (11 kB)
Requirement already satisfied: aiohttp in /usr/local/lib/python3.11/dist-packa
ges (from datasets) (3.11.15)
Requirement already satisfied: huggingface-hub>=0.24.0 in /usr/local/lib/pytho
n3.11/dist-packages (from datasets) (0.30.2)
Requirement already satisfied: packaging in /usr/local/lib/python3.11/dist-pac
kages (from datasets) (24.2)
Requirement already satisfied: pyyaml>=5.1 in /usr/local/lib/python3.11/dist-p
ackages (from datasets) (6.0.2)
Requirement already satisfied: aiohappyeyeballs>=2.3.0 in /usr/local/lib/pytho
n3.11/dist-packages (from aiohttp->datasets) (2.6.1)
Requirement already satisfied: aiosignal>=1.1.2 in /usr/local/lib/python3.11/d
ist-packages (from aiohttp->datasets) (1.3.2)
Requirement already satisfied: attrs>=17.3.0 in /usr/local/lib/python3.11/dist
-packages (from aiohttp->datasets) (25.3.0)
Requirement already satisfied: frozenlist>=1.1.1 in /usr/local/lib/python3.11/
dist-packages (from aiohttp->datasets) (1.5.0)
Requirement already satisfied: multidict<7.0,>=4.5 in /usr/local/lib/python3.1
1/dist-packages (from aiohttp->datasets) (6.4.2)
Requirement already satisfied: propcache>=0.2.0 in /usr/local/lib/python3.11/d
ist-packages (from aiohttp->datasets) (0.3.1)
Requirement already satisfied: yarl<2.0,>=1.17.0 in /usr/local/lib/python3.11/
dist-packages (from aiohttp->datasets) (1.19.0)
Requirement already satisfied: typing-extensions>=3.7.4.3 in /usr/local/lib/py
thon3.11/dist-packages (from huggingface-hub>=0.24.0->datasets) (4.13.1)
Requirement already satisfied: charset-normalizer<4,>=2 in /usr/local/lib/pyth
on3.11/dist-packages (from requests>=2.32.2->datasets) (3.4.1)
Requirement already satisfied: idna<4,>=2.5 in /usr/local/lib/python3.11/dist-
packages (from requests>=2.32.2->datasets) (3.10)
Requirement already satisfied: urllib3<3,>=1.21.1 in /usr/local/lib/python3.1
1/dist-packages (from requests>=2.32.2->datasets) (2.3.0)
Requirement already satisfied: certifi>=2017.4.17 in /usr/local/lib/python3.1
1/dist-packages (from requests>=2.32.2->datasets) (2025.1.31)
Requirement already satisfied: python-dateutil>=2.8.2 in /usr/local/lib/python
3.11/dist-packages (from pandas->datasets) (2.8.2)
Requirement already satisfied: pytz>=2020.1 in /usr/local/lib/python3.11/dist-
packages (from pandas->datasets) (2025.2)
```

```
Requirement already satisfied: tzdata>=2022.7 in /usr/local/lib/python3.11/dis
t-packages (from pandas->datasets) (2025.2)
Requirement already satisfied: six>=1.5 in /usr/local/lib/python3.11/dist-pack
ages (from python-dateutil>=2.8.2->pandas->datasets) (1.17.0)
Downloading datasets-3.5.0-py3-none-any.whl (491 kB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 491.2/491.2 kB 15.3 MB/s eta 0:00:
00
Downloading dill-0.3.8-py3-none-any.whl (116 kB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 116.3/116.3 kB 13.6 MB/s eta 0:00:
00
Downloading fsspec-2024.12.0-py3-none-any.whl (183 kB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 183.9/183.9 kB 21.0 MB/s eta 0:00:
00
Downloading multiprocess-0.70.16-py311-none-any.whl (143 kB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 143.5/143.5 kB 11.6 MB/s eta 0:00:
00
Downloading xxhash-3.5.0-cp311-cp311-manylinux_2_17_x86_64.manylinux2014_x86_6
4.whl (194 kB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 194.8/194.8 kB 21.0 MB/s eta 0:00:
00
Installing collected packages: xxhash, fsspec, dill, multiprocess, datasets
  Attempting uninstall: fsspec
    Found existing installation: fsspec 2025.3.2
    Uninstalling fsspec-2025.3.2:
      Successfully uninstalled fsspec-2025.3.2
ERROR: pip's dependency resolver does not currently take into account all the
packages that are installed. This behaviour is the source of the following dep
endency conflicts.
torch 2.6.0+cu124 requires nvidia-cublas-cu12==12.4.5.8; platform_system == "L
inux" and platform_machine == "x86_64", but you have nvidia-cublas-cu12 12.5.
3.2 which is incompatible.
torch 2.6.0+cu124 requires nvidia-cuda-cupti-cu12==12.4.127; platform_system =
= "Linux" and platform_machine == "x86_64", but you have nvidia-cuda-cupti-cu1
2 12.5.82 which is incompatible.
torch 2.6.0+cu124 requires nvidia-cuda-nvrtc-cu12==12.4.127; platform_system =
= "Linux" and platform_machine == "x86_64", but you have nvidia-cuda-nvrtc-cu1
2 12.5.82 which is incompatible.
torch 2.6.0+cu124 requires nvidia-cuda-runtime-cu12==12.4.127; platform_system
== "Linux" and platform_machine == "x86_64", but you have nvidia-cuda-runtime-
cu12 12.5.82 which is incompatible.
torch 2.6.0+cu124 requires nvidia-cudnn-cu12==9.1.0.70; platform_system == "Li
nux" and platform_machine == "x86_64", but you have nvidia-cudnn-cu12 9.3.0.75
which is incompatible.
torch 2.6.0+cu124 requires nvidia-cufft-cu12==11.2.1.3; platform_system == "Li
nux" and platform_machine == "x86_64", but you have nvidia-cufft-cu12 11.2.3.6
1 which is incompatible.
torch 2.6.0+cu124 requires nvidia-curand-cu12==10.3.5.147; platform_system ==
"Linux" and platform_machine == "x86_64", but you have nvidia-curand-cu12 10.
3.6.82 which is incompatible.
torch 2.6.0+cu124 requires nvidia-cusolver-cu12==11.6.1.9; platform_system ==
"Linux" and platform_machine == "x86_64", but you have nvidia-cusolver-cu12 1
1.6.3.83 which is incompatible.
torch 2.6.0+cu124 requires nvidia-cusparse-cu12==12.3.1.170; platform_system =
= "Linux" and platform_machine == "x86_64", but you have nvidia-cusparse-cu12
12.5.1.3 which is incompatible.
torch 2.6.0+cu124 requires nvidia-nvjitlink-cu12==12.4.127; platform_system ==
"Linux" and platform_machine == "x86_64", but you have nvidia-nvjitlink-cu12 1
2.5.82 which is incompatible.
gcsfs 2025.3.2 requires fsspec==2025.3.2, but you have fsspec 2024.12.0 which
is incompatible.
```

```
Successfully installed datasets-3.5.0 dill-0.3.8 fsspec-2024.12.0 multiprocess
-0.70.16 xxhash-3.5.0
```

In [ ]:
```
from datasets import Dataset
# Turning to huggingface dataset
hf_dataset = Dataset.from_pandas(df_sample_lab[["reviews", "label"]])
```

In [ ]:
```
tokenized_dataset = hf_dataset.map(tokenize_function, batched=True)
```

```
Map:   0%|          | 0/10001 [00:00<?, ? examples/s]
```

In [ ]:
```
tokenized_dataset[0].keys()
```

Out[ ]:
```
dict_keys(['reviews', 'label', 'input_ids', 'attention_mask'])
```

In [ ]:
```
tokenized_dataset = tokenized_dataset.train_test_split(test_size=0.2, seed=42)
```

In [ ]:
```
from transformers import AutoModelForSequenceClassification

model = AutoModelForSequenceClassification.from_pretrained("distilbert-base-un
```

```
Xet Storage is enabled for this repo, but the 'hf_xet' package is not installe
d. Falling back to regular HTTP download. For better performance, install the
package with: `pip install huggingface_hub[hf_xet]` or `pip install hf_xet`
WARNING:huggingface_hub.file_download:Xet Storage is enabled for this repo, bu
t the 'hf_xet' package is not installed. Falling back to regular HTTP downloa
d. For better performance, install the package with: `pip install huggingface_
hub[hf_xet]` or `pip install hf_xet`
model.safetensors:   0%|          | 0.00/268M [00:00<?, ?B/s]
Some weights of DistilBertForSequenceClassification were not initialized from
the model checkpoint at distilbert-base-uncased and are newly initialized: ['c
lassifier.bias', 'classifier.weight', 'pre_classifier.bias', 'pre_classifier.w
eight']
You should probably TRAIN this model on a down-stream task to be able to use i
t for predictions and inference.
```

In [ ]:
```
from sklearn.metrics import accuracy_score, f1_score

def compute_metrics(pred):
    labels = pred.label_ids
    preds = pred.predictions.argmax(-1)
    return {
        "accuracy": accuracy_score(labels, preds),
        "f1_macro": f1_score(labels, preds, average="macro")
    }
```

In [ ]:
```
from transformers import TrainingArguments

training_args = TrainingArguments(
    output_dir="./results",
    do_train=True,
    do_eval=True,
    per_device_train_batch_size=16,
    per_device_eval_batch_size=16,
    num_train_epochs=4,
    learning_rate=2e-5,
    weight_decay=0.01,
    logging_dir="./logs",
)
```

In [ ]:

```
from transformers import Trainer

trainer = Trainer(
    model=model,
    args=training_args,
    train_dataset=tokenized_dataset["train"],
    eval_dataset=tokenized_dataset["test"],
    tokenizer=tokenizer,
    compute_metrics=compute_metrics
)
```

```
<ipython-input-21-a8272fac4809>:3: FutureWarning: `tokenizer` is deprecated an
d will be removed in version 5.0.0 for `Trainer.__init__`. Use `processing_cla
ss` instead.
  trainer = Trainer(
```

In [ ]:

```
!pip install wandb
import wandb
wandb.login()
```

```
Requirement already satisfied: wandb in /usr/local/lib/python3.11/dist-package
s (0.19.9)
Requirement already satisfied: click!=8.0.0,>=7.1 in /usr/local/lib/python3.1
1/dist-packages (from wandb) (8.1.8)
Requirement already satisfied: docker-pycreds>=0.4.0 in /usr/local/lib/python
3.11/dist-packages (from wandb) (0.4.0)
Requirement already satisfied: gitpython!=3.1.29,>=1.0.0 in /usr/local/lib/pyt
hon3.11/dist-packages (from wandb) (3.1.44)
Requirement already satisfied: platformdirs in /usr/local/lib/python3.11/dist-
packages (from wandb) (4.3.7)
Requirement already satisfied: protobuf!=4.21.0,!=5.28.0,<6,>=3.19.0 in /usr/l
ocal/lib/python3.11/dist-packages (from wandb) (5.29.4)
Requirement already satisfied: psutil>=5.0.0 in /usr/local/lib/python3.11/dist
-packages (from wandb) (5.9.5)
Requirement already satisfied: pydantic<3 in /usr/local/lib/python3.11/dist-pa
ckages (from wandb) (2.11.3)
Requirement already satisfied: pyyaml in /usr/local/lib/python3.11/dist-packag
es (from wandb) (6.0.2)
Requirement already satisfied: requests<3,>=2.0.0 in /usr/local/lib/python3.1
1/dist-packages (from wandb) (2.32.3)
Requirement already satisfied: sentry-sdk>=2.0.0 in /usr/local/lib/python3.11/
dist-packages (from wandb) (2.25.1)
Requirement already satisfied: setproctitle in /usr/local/lib/python3.11/dist-
packages (from wandb) (1.3.5)
Requirement already satisfied: setuptools in /usr/local/lib/python3.11/dist-pa
ckages (from wandb) (75.2.0)
Requirement already satisfied: typing-extensions<5,>=4.4 in /usr/local/lib/pyt
hon3.11/dist-packages (from wandb) (4.13.1)
Requirement already satisfied: six>=1.4.0 in /usr/local/lib/python3.11/dist-pa
ckages (from docker-pycreds>=0.4.0->wandb) (1.17.0)
Requirement already satisfied: gitdb<5,>=4.0.1 in /usr/local/lib/python3.11/di
st-packages (from gitpython!=3.1.29,>=1.0.0->wandb) (4.0.12)
Requirement already satisfied: annotated-types>=0.6.0 in /usr/local/lib/python
3.11/dist-packages (from pydantic<3->wandb) (0.7.0)
Requirement already satisfied: pydantic-core==2.33.1 in /usr/local/lib/python
3.11/dist-packages (from pydantic<3->wandb) (2.33.1)
Requirement already satisfied: typing-inspection>=0.4.0 in /usr/local/lib/pyth
on3.11/dist-packages (from pydantic<3->wandb) (0.4.0)
Requirement already satisfied: charset-normalizer<4,>=2 in /usr/local/lib/pyth
on3.11/dist-packages (from requests<3,>=2.0.0->wandb) (3.4.1)
Requirement already satisfied: idna<4,>=2.5 in /usr/local/lib/python3.11/dist-
packages (from requests<3,>=2.0.0->wandb) (3.10)
Requirement already satisfied: urllib3<3,>=1.21.1 in /usr/local/lib/python3.1
1/dist-packages (from requests<3,>=2.0.0->wandb) (2.3.0)
Requirement already satisfied: certifi>=2017.4.17 in /usr/local/lib/python3.1
1/dist-packages (from requests<3,>=2.0.0->wandb) (2025.1.31)
Requirement already satisfied: smmap<6,>=3.0.1 in /usr/local/lib/python3.11/di
st-packages (from gitdb<5,>=4.0.1->gitpython!=3.1.29,>=1.0.0->wandb) (5.0.2)
```

```
wandb: Using wandb-core as the SDK backend.  Please refer to https://wandb.me/
wandb-core for more information.
```

```
wandb: WARNING If you're specifying your api key in code, ensure this code is
not shared publicly.
wandb: WARNING Consider setting the WANDB_API_KEY environment variable, or run
ning `wandb login` from the command line.
wandb: No netrc file found, creating one.
wandb: Appending key for api.wandb.ai to your netrc file: /root/.netrc
wandb: Currently logged in as: akuma332 (akuma332-arizona-state-university) to
https://api.wandb.ai. Use `wandb login --relogin` to force relogin
```

Out[ ]:
```
True
```

In [ ]:
```
wandb.init(project="DAT490")
```

Tracking run with wandb version 0.19.9

Run data is saved locally in `/content/wandb/run-20250418_041833-ihz0ggn7`

Syncing run **colorful-jazz-1** to Weights & Biases (docs)

View project at https://wandb.ai/akuma332-arizona-state-university/DAT490

View run at https://wandb.ai/akuma332-arizona-state-university/DAT490/runs/ihz0ggn7

Out[ ]: Display W&B run

In [ ]:
```
trainer.train()
```

```
wandb: WARNING The `run_name` is currently set to the same value as `TrainingA
rguments.output_dir`. If this was not intended, please specify a different run
name by setting the `TrainingArguments.run_name` parameter.
```

[2000/2000 11:46, Epoch 4/4]

Step	Training Loss
500	0.411800
1000	0.228500
1500	0.137500
2000	0.081900

Out[ ]:
```
TrainOutput(global_step=2000, training_loss=0.21491548728942872, metrics={'tra
in_runtime': 707.5335, 'train_samples_per_second': 45.228, 'train_steps_per_se
cond': 2.827, 'total_flos': 2119516176384000.0, 'train_loss': 0.21491548728942
872, 'epoch': 4.0})
```

In [ ]:
```
from sklearn.metrics import classification_report

predictions = trainer.predict(tokenized_dataset["test"])
y_pred = predictions.predictions.argmax(-1)
y_true = predictions.label_ids

# Report
print(classification_report(y_true, y_pred, target_names=["Negative", "Neutral'
```

```
              precision    recall  f1-score   support

    Negative       0.89      0.87      0.88       239
     Neutral       0.63      0.63      0.63       298
    Positive       0.94      0.94      0.94      1464

    accuracy                           0.89      2001
   macro avg       0.82      0.82      0.82      2001
weighted avg       0.89      0.89      0.89      2001
```

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

```
Mounted at /content/drive
```

In [ ]:
```
model.save_pretrained("/content/drive/MyDrive/bert_sentiment_model")
tokenizer.save_pretrained("/content/drive/MyDrive/bert_sentiment_model")
```

Out[ ]:
```
('/content/drive/MyDrive/bert_sentiment_model/tokenizer_config.json',
 '/content/drive/MyDrive/bert_sentiment_model/special_tokens_map.json',
 '/content/drive/MyDrive/bert_sentiment_model/vocab.txt',
 '/content/drive/MyDrive/bert_sentiment_model/added_tokens.json',
 '/content/drive/MyDrive/bert_sentiment_model/tokenizer.json')
```

In [ ]:
```
df_4yr_pd = pd.read_parquet("gs://final_dataset_dat490/engagement_parquet")
df_4yr_pd = df_4yr_pd.sort_values(["business_name", "year"])
```

In [ ]:
```
model_path = "/content/drive/MyDrive/bert_sentiment_model"

tokenizer = AutoTokenizer.from_pretrained(model_path)
model = AutoModelForSequenceClassification.from_pretrained(model_path)
model.eval()
# Checking for GPU availability in Colab
device = torch.device("cuda" if torch.cuda.is_available() else "cpu")
model.to(device)
```

Out[ ]:
```
DistilBertForSequenceClassification(
  (distilbert): DistilBertModel(
    (embeddings): Embeddings(
      (word_embeddings): Embedding(30522, 768, padding_idx=0)
      (position_embeddings): Embedding(512, 768)
      (LayerNorm): LayerNorm((768,), eps=1e-12, elementwise_affine=True)
      (dropout): Dropout(p=0.1, inplace=False)
    )
    (transformer): Transformer(
      (layer): ModuleList(
        (0-5): 6 x TransformerBlock(
          (attention): DistilBertSdpaAttention(
            (dropout): Dropout(p=0.1, inplace=False)
            (q_lin): Linear(in_features=768, out_features=768, bias=True)
            (k_lin): Linear(in_features=768, out_features=768, bias=True)
            (v_lin): Linear(in_features=768, out_features=768, bias=True)
            (out_lin): Linear(in_features=768, out_features=768, bias=True)
          )
          (sa_layer_norm): LayerNorm((768,), eps=1e-12, elementwise_affine=Tru
e)
          (ffn): FFN(
            (dropout): Dropout(p=0.1, inplace=False)
            (lin1): Linear(in_features=768, out_features=3072, bias=True)
            (lin2): Linear(in_features=3072, out_features=768, bias=True)
            (activation): GELUActivation()
          )
          (output_layer_norm): LayerNorm((768,), eps=1e-12, elementwise_affine
=True)
        )
      )
    )
  )
  (pre_classifier): Linear(in_features=768, out_features=768, bias=True)
  (classifier): Linear(in_features=768, out_features=3, bias=True)
  (dropout): Dropout(p=0.2, inplace=False)
)
```

In [ ]:
```python
import torch
from torch.utils.data import Dataset, DataLoader
from transformers import AutoModelForSequenceClassification, AutoTokenizer
from tqdm.notebook import tqdm # For progress bar

MAX_LEN = 256

BATCH_SIZE = 128

class ReviewDataset(Dataset):
    def __init__(self, reviews, tokenizer, max_len):
        # Ensuring reviews are strings and handle potential NaN values
        self.reviews = [str(review) if pd.notna(review) else "" for review in
        self.tokenizer = tokenizer
        self.max_len = max_len

    def __len__(self):
        return len(self.reviews)

    def __getitem__(self, item):
        review = self.reviews[item]
        encoding = self.tokenizer.encode_plus(
            review,
            add_special_tokens=True,
            max_length=self.max_len,
            return_token_type_ids=False,
            padding='max_length',
            truncation=True,
            return_attention_mask=True,
            return_tensors='pt',
        )

        return {
            'review_text': review,
            'input_ids': encoding['input_ids'].flatten(),
            'attention_mask': encoding['attention_mask'].flatten()
        }

review_texts = df_4yr_pd['reviews'].tolist()

review_dataset = ReviewDataset(
    reviews=review_texts,
    tokenizer=tokenizer,
    max_len=MAX_LEN
)

review_data_loader = DataLoader(
    review_dataset,
    batch_size=BATCH_SIZE,
    shuffle=False, # No need to shuffle for inference
    num_workers=0
)

all_predictions = []
model.eval() # Ensuring model is in evaluation mode

print(f"Starting inference on {len(review_dataset)} reviews with batch size {B

# Disable gradient calculations for inference to save memory and compute
```

```
with torch.no_grad():
    # Progress bar
    for batch in tqdm(review_data_loader, total=len(review_data_loader)):
        # Moving input tensors to the GPU
        input_ids = batch['input_ids'].to(device)
        attention_mask = batch['attention_mask'].to(device)

        outputs = model(input_ids=input_ids, attention_mask=attention_mask)

        # Logits are the raw scores output by the last layer
        logits = outputs.logits

        # torch.argmax finds the index of the maximum value along dimension 1
        preds = torch.argmax(logits, dim=1)

        # Moving predictions back to CPU and convert to numpy array
        all_predictions.extend(preds.cpu().numpy())

print(f"Inference complete. Obtained {len(all_predictions)} predictions.")


df_4yr_pd['label'] = all_predictions
print("Predictions added to the 'label' column in the DataFrame.")

print("\nDataFrame head with new labels:")
print(df_4yr_pd[['reviews', 'label']].head())
```

```
Starting inference on 658380 reviews with batch size 128...
  0%|          | 0/5144 [00:00<?, ?it/s]
Inference complete. Obtained 658380 predictions.
Predictions added to the 'label' column in the DataFrame.

DataFrame head with new labels:
                                                  reviews  label
9535    Nice place. Steve did my nails. LeLe hooked my...      2
68314   Emmy is my go to nail tech. She understands me...      2
478224  Loved how they did my nails. They had mood cha...      2
127831  Best pedicure ever! I will never go anywhere e...      2
294374  Okay so it wasn't the nails or  the eyebrows. ...      0
```

In [ ]:
```
df_4yr_pd.groupby('label')['gmap_id'].count()
```

Out[ ]:

	gmap_id
label	
0	126454
1	120354
2	411572

dtype: int64

In [ ]:
```
df_4yr_pd.to_parquet("gs://final_dataset_dat490/df_4yr_with_bert_labels.parque
```

In [ ]:
```
file_path = "/content/drive/MyDrive/Reviews std DAT490 labelled.xlsx"

df_reviews_30 = pd.read_excel(file_path)
```

In [ ]:
```
review_texts_30 = df_reviews_30['Reviews'].astype(str).tolist()

dataset_30 = ReviewDataset(
    reviews=review_texts_30,
    tokenizer=tokenizer,
    max_len=MAX_LEN
)

loader_30 = DataLoader(
    dataset_30,
    batch_size=8,  # Small batch is fine for 30 reviews
    shuffle=False
)
```

In [ ]:
```
model.eval()
predictions_30 = []

with torch.no_grad():
    for batch in loader_30:
        input_ids = batch['input_ids'].to(device)
        attention_mask = batch['attention_mask'].to(device)

        outputs = model(input_ids=input_ids, attention_mask=attention_mask)
        preds = torch.argmax(outputs.logits, dim=1)
        predictions_30.extend(preds.cpu().numpy())
```

In [ ]:
```
# Mapping numeric labels to sentiment
label_map = {0: "Negative", 1: "Neutral", 2: "Positive"}

df_reviews_30["bert_label"] = [label_map[p] for p in predictions_30]

df_reviews_30[["Reviews", "bert_label"]].head()
```

Out[ ]:

	Reviews	bert_label
0	You need a good fab guy? Danny is your man.	Neutral
1	This was such a great place to have work done....	Neutral
2	Great customer service even during the pandemi...	Positive
3	Always has nice clothes and some good sales bu...	Neutral
4	Great honest shop.\n\nI brought in brake pads,...	Positive

In [167…
```
# df_reviews_30.to_excel("/content/drive/MyDrive/Reviews_30_with_BERT_labels.x
```

In [7]:
```
df_4yr_pd = pd.read_parquet("gs://final_dataset_dat490/df_4yr_with_bert_labels
df_4yr_pd = df_4yr_pd.sort_values(["business_name", "year"])
```

In [8]:
```
df_4yr_pd.groupby('standard_category')['gmap_id'].count()
```

Out[8]:

	gmap_id
standard_category	
Automotive	40118
Bakery	5953
Bar	1264
Beauty & Wellness	30314
Business Services	19240
Cafe	10260
Construction	106
Consulting	1552
Education	47
Entertainment	15
Event Venue	537
Finance	6188
Fitness	5490
Grocery Store	52541
Healthcare	6978
Insurance	276
Laundry Services	724
Legal Services	11
Non-Profit	1842
Other	2625
Pet Services	905
Public Services	995
Real Estate	274
Religious Institution	4112
Restaurant	233394
Retail	229714
Storage Services	725
Tourism & Attractions	1389
Transportation	791

dtype: int64

In [9]:

```
import pandas as pd

# Copying the dataframe to avoid modifying original
df = df_4yr_pd.copy()
```

```
weekday_cols = ["Monday", "Tuesday", "Wednesday", "Thursday", "Friday", "Saturc
df["days_open"] = df[weekday_cols].sum(axis=1)

df_yearly = (
    df.groupby(["business_name", "year"])
    .agg({
        "rating": "mean",
        "label": "mean",
        "reviews": "count",
        "days_open": "mean",
        "state": "first",
        "standard_category": "first"
    })
    .reset_index()
    .rename(columns={
        "rating": "avg_yearly_rating",
        "label": "avg_sentiment",
        "reviews": "review_count",
        "days_open": "avg_days_open"
    })
)

df_yearly.head()
```

Out[9]:

	business_name	year	avg_yearly_rating	avg_sentiment	review_count	avg_days_open	
0	#1 Nails	2018	3.00	2.00	1	7.000000	
1	#1 Nails	2019	5.00	2.00	2	5.500000	Conı
2	#1 Nails	2020	3.00	1.00	2	5.500000	
3	#1 Nails	2021	4.75	1.75	12	6.583333	
4	$5 Pizza	2018	4.00	1.00	1	7.000000	

In [10]:
```
from sklearn.preprocessing import MinMaxScaler

features = ["avg_yearly_rating", "avg_sentiment", "review_count", "avg_days_ope

scaler = MinMaxScaler()
df_yearly[features] = scaler.fit_transform(df_yearly[features])
df_yearly.head()
```

Out[10]:

	business_name	year	avg_yearly_rating	avg_sentiment	review_count	avg_days_open	
0	#1 Nails	2018	0.5000	1.000	0.000000	1.000000	
1	#1 Nails	2019	1.0000	1.000	0.000078	0.785714	Conı
2	#1 Nails	2020	0.5000	0.500	0.000078	0.785714	
3	#1 Nails	2021	0.9375	0.875	0.000862	0.940476	
4	$5 Pizza	2018	0.7500	0.500	0.000000	1.000000	

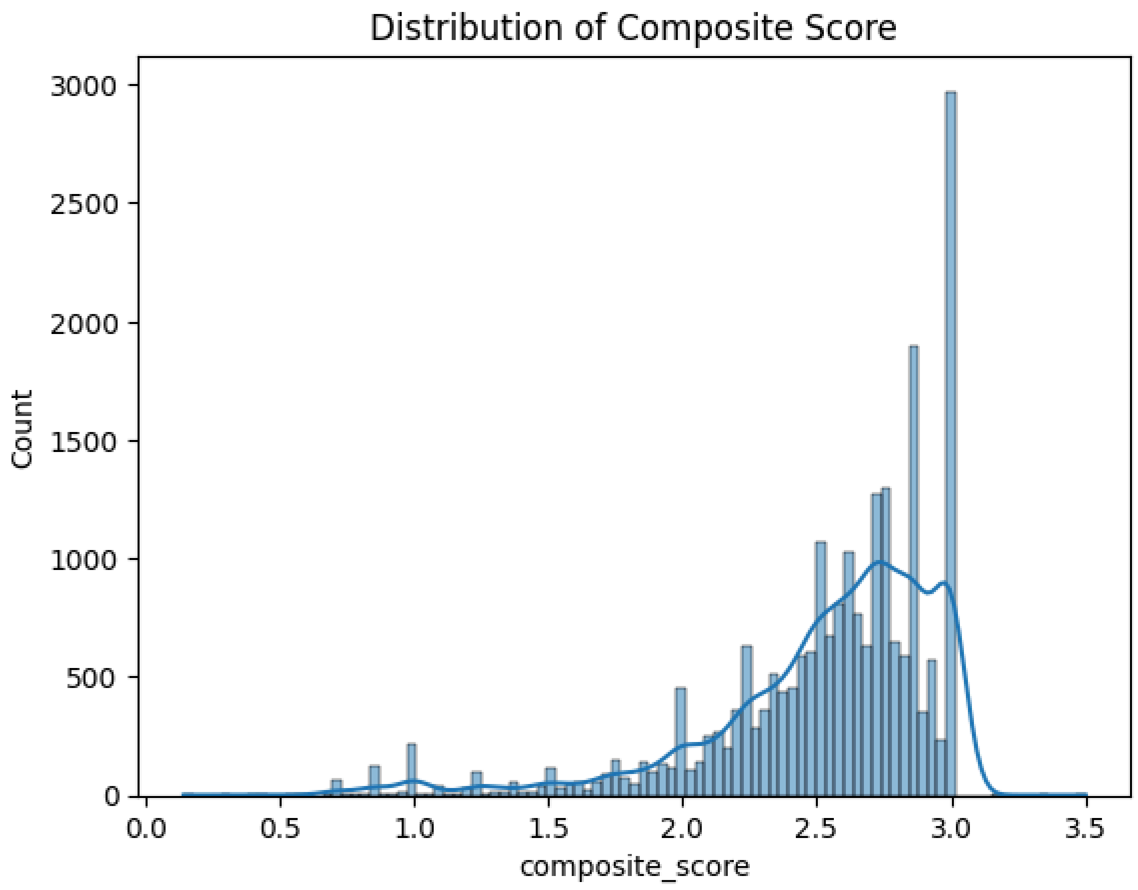
In [11]:
```
df_yearly["composite_score"] = df_yearly[features].sum(axis=1)
df_yearly.head()
```

Out[11]:

	business_name	year	avg_yearly_rating	avg_sentiment	review_count	avg_days_open	
0	#1 Nails	2018	0.5000	1.000	0.000000	1.000000	
1	#1 Nails	2019	1.0000	1.000	0.000078	0.785714	Con
2	#1 Nails	2020	0.5000	0.500	0.000078	0.785714	
3	#1 Nails	2021	0.9375	0.875	0.000862	0.940476	
4	$5 Pizza	2018	0.7500	0.500	0.000000	1.000000	

In [12]:
```
print("max:", round(df_yearly['composite_score'].max(), 2), "min:", (round(df_y
```
```
max: 3.5 min: 0.14
```

In [13]:
```
import matplotlib.pyplot as plt
import seaborn as sns

sns.histplot(df_yearly["composite_score"], kde=True)
plt.title("Distribution of Composite Score")
plt.show()
```



The distribution of composite score is skewed to the left. This means that we have more businesses with higher composite score. We must address this imbalance while using the model.

In [14]:
```
# Pivoting composite_score
pivot = df_yearly.pivot(index='business_name', columns='year', values='composi
pivot.columns = [f"year_{col}" for col in pivot.columns]
```

```
pivot = pivot.dropna(subset=["year_2018", "year_2019", "year_2020", "year_2021"

category_df = df_yearly[df_yearly["year"] == 2021][["business_name", "standard_

# Merging category back into pivot
pivot = pivot.merge(category_df, on="business_name", how="left")

# Change in composite score - patterns in one year gap
pivot["delta_18_19"] = pivot["year_2019"] - pivot["year_2018"]
pivot["delta_19_20"] = pivot["year_2020"] - pivot["year_2019"]
pivot["pct_change_20_21"] = ((pivot["year_2021"] - pivot["year_2020"]) / pivot

# Engagement metrics
def classify_change(pct):
    if pct <= -20:
        return 0
    elif pct >= 20:
        return 2
    else:
        return 1

pivot["engagement_label"] = pivot["pct_change_20_21"].apply(classify_change)

X = pivot[["delta_18_19", "delta_19_20", "standard_category"]]
X = pd.get_dummies(X, columns=["standard_category"])
y = pivot["engagement_label"].values
```

In [15]:
```
X.shape
```
Out[15]:
```
(5608, 30)
```

In [16]:
```
y.shape
```
Out[16]:
```
(5608,)
```

In [17]:
```
from sklearn.model_selection import train_test_split

# train+val and test (80/20)
X_temp, X_test, y_temp, y_test = train_test_split(
    X, y, test_size=0.2, stratify=y, random_state=42
)

# Split train+val into train and val (75/25 of the 80% => 60/20 overall)
X_train_full, X_val, y_train_full, y_val = train_test_split(
    X_temp, y_temp, test_size=0.25, stratify=y_temp, random_state=42
)

print(f"Train: {X_train_full.shape[0]}, Val: {X_val.shape[0]}, Test: {X_test.sl
```
```
Train: 3364, Val: 1122, Test: 1122
```

In [18]:
```
from xgboost import XGBClassifier
from sklearn.metrics import accuracy_score, f1_score, confusion_matrix, Confus
from sklearn.model_selection import StratifiedShuffleSplit
from sklearn.utils.class_weight import compute_sample_weight
```

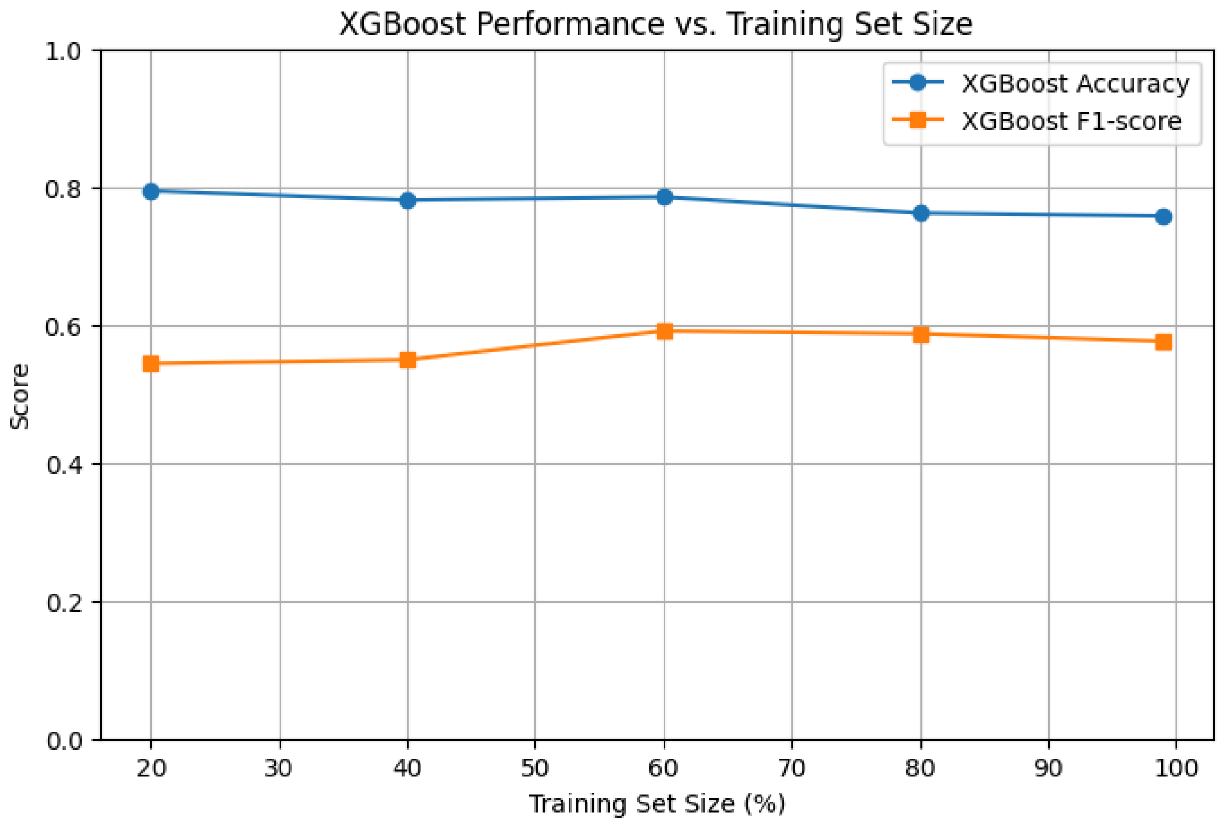
In [19]:
```
def get_stratified_subset(X, y, fraction, random_state=42):
    splitter = StratifiedShuffleSplit(n_splits=1, train_size=fraction, random_
    train_idx, test_idx = next(splitter.split(X, y))

    if isinstance(X, pd.DataFrame):
        return X.iloc[train_idx], y[train_idx]
    else:
        return X[train_idx], y[train_idx]
```

In [20]:
```
def train_xgb_subset(X_train_full, y_train_full, train_fraction, X_val, y_val)
    X_train, y_train = get_stratified_subset(X_train_full, y_train_full, train_

    sample_weights = compute_sample_weight(class_weight='balanced', y=y_train)

    model = XGBClassifier(
        objective='multi:softmax',
        num_class=3,
        eval_metric='mlogloss',
        random_state=42
    )
    model.fit(X_train, y_train, sample_weight=sample_weights)

    preds = model.predict(X_val)
    acc = accuracy_score(y_val, preds)
    f1 = f1_score(y_val, preds, average='macro')
    cm = confusion_matrix(y_val, preds)
    auc = roc_auc_score(y_val, model.predict_proba(X_val), multi_class='ovr')
    rep = classification_report(y_val, preds)

    return acc, f1, model
```

In [21]:
```
train_sizes = [0.2, 0.4, 0.6, 0.8, 0.99]
xgb_accuracies = []
xgb_f1s = []

X_temp, X_val, y_temp, y_val = train_test_split(X, y, test_size=0.2, stratify=

for frac in train_sizes:
    acc, f1, model = train_xgb_subset(X_train_full, y_train_full, frac, X_val,
    xgb_accuracies.append(acc)
    xgb_f1s.append(f1)
    print(f"Train size: {int(frac*100)}% — Accuracy: {acc:.4f} — F1-score: {f1
```

```
Train size: 20% — Accuracy: 0.7941 — F1-score: 0.5438
Train size: 40% — Accuracy: 0.7807 — F1-score: 0.5492
Train size: 60% — Accuracy: 0.7852 — F1-score: 0.5910
Train size: 80% — Accuracy: 0.7620 — F1-score: 0.5871
Train size: 99% — Accuracy: 0.7576 — F1-score: 0.5761
```

In [22]:
```
import matplotlib.pyplot as plt

x_vals = [int(f * 100) for f in train_sizes]

plt.figure(figsize=(8, 5))
plt.plot(x_vals, xgb_accuracies, marker='o', label="XGBoost Accuracy")
plt.plot(x_vals, xgb_f1s, marker='s', label="XGBoost F1-score")
plt.xlabel("Training Set Size (%)")
plt.ylabel("Score")
plt.title("XGBoost Performance vs. Training Set Size")
plt.legend()
plt.ylim(0, 1)
plt.grid(True)
plt.show()
```



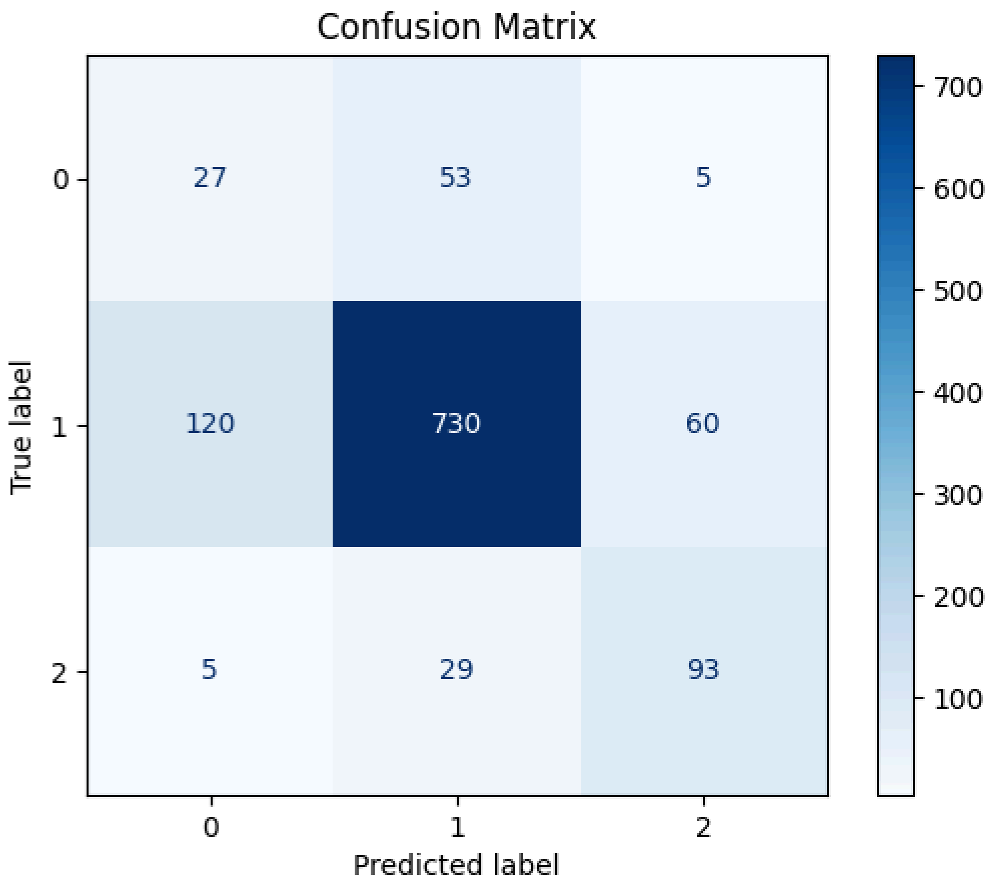
In [25]:
```
final_preds = model.predict(X_test)

print(f"Test Set, Accuracy: {acc:.4f} — F1-score: {f1:.4f}")
```

```
Test Set, Accuracy: 0.7576 — F1-score: 0.5761
```

In [26]:
```
print(classification_report(y_test, final_preds))
```

```
              precision    recall  f1-score   support

           0       0.18      0.32      0.23        85
           1       0.90      0.80      0.85       910
           2       0.59      0.73      0.65       127

    accuracy                           0.76      1122
   macro avg       0.56      0.62      0.58      1122
weighted avg       0.81      0.76      0.78      1122
```

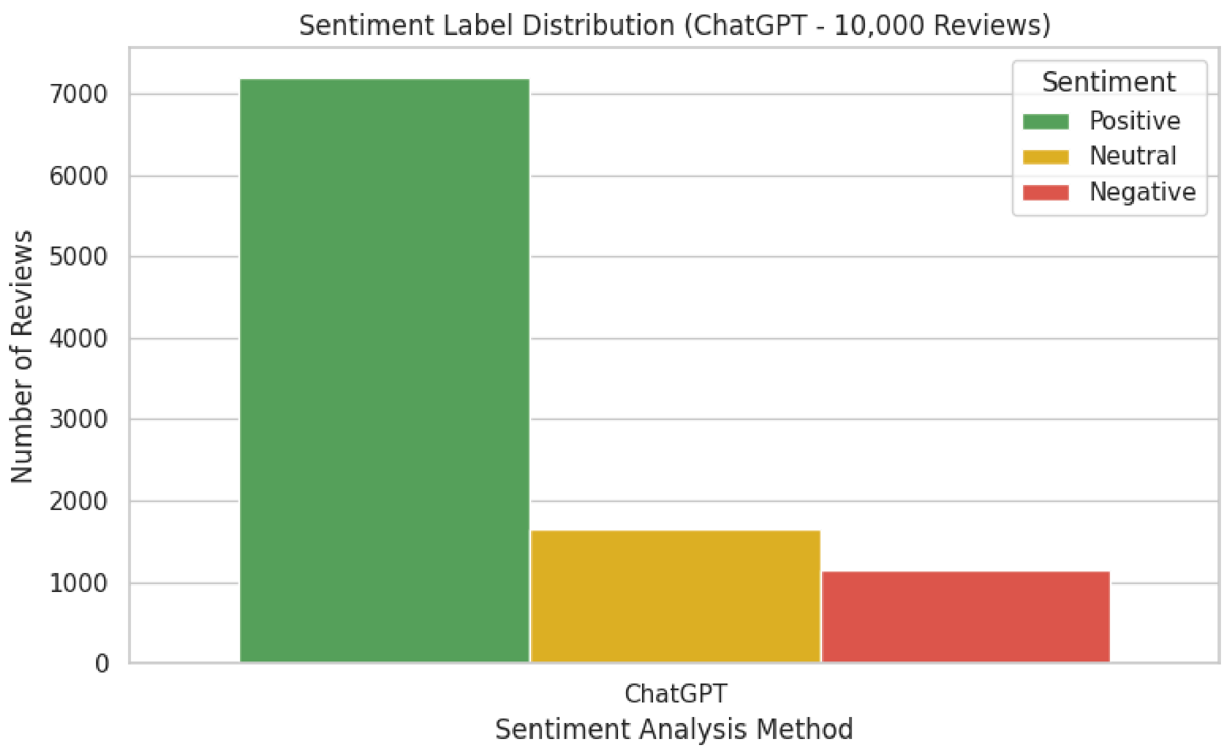
In [24]:
```
cm = confusion_matrix(y_test, final_preds)

disp = ConfusionMatrixDisplay(confusion_matrix=cm, display_labels=model.classe
disp.plot(cmap=plt.cm.Blues)
plt.title("Confusion Matrix")
plt.show()
```



In [28]:
```
df_10k = pd.read_parquet("gs://final_dataset_dat490/sample_reviews_stratified_
df_10k.columns
```

Out[28]:
```
Index(['gmap_id', 'customer_name', 'rating', 'reviews', 'time', 'avg_rating',
       'category', 'latitude', 'longitude', 'business_name', 'num_of_reviews',
       'state', 'standard_category', 'Monday', 'Tuesday', 'Wednesday',
       'Thursday', 'Friday', 'Saturday', 'Sunday', 'timestamp', 'week',
       'month', 'year', 'time_seconds', 'review_length', 'length_bucket',
       'chatgpt_label'],
      dtype='object')
```

In [30]:
```
sns.set(style="whitegrid")

label_counts = df_10k['chatgpt_label'].value_counts().reindex(['Positive', 'Ne

plot_df = pd.DataFrame({
    'Sentiment': label_counts.index,
    'Count': label_counts.values,
    'Method': 'ChatGPT'
})

plt.figure(figsize=(8, 5))
sns.barplot(data=plot_df, x='Method', y='Count', hue='Sentiment', palette={
    'Positive': '#4CAF50', 'Neutral': '#FFC107', 'Negative': '#F44336'
})

plt.title("Sentiment Label Distribution (ChatGPT - 10,000 Reviews)")
plt.ylabel("Number of Reviews")
plt.xlabel("Sentiment Analysis Method")
plt.legend(title='Sentiment')
plt.tight_layout()
plt.show()
```



In [3]:
```
import json
# Change this to the name of your broken notebook
notebook_filename = "DAT490_Capstone_label_model_1 (1).ipynb"
# Load the notebook
with open(notebook_filename, 'r', encoding='utf-8') as f:
    notebook_data = json.load(f)
# Fix metadata.widgets if missing 'state'
widgets = notebook_data.get('metadata', {}).get('widgets', {})
if 'application/vnd.jupyter.widget-state+json' in widgets:
    widget_meta = widgets['application/vnd.jupyter.widget-state+json']
    if 'state' not in widget_meta:
        widget_meta['state'] = {}
        widget_meta['version_major'] = 2
        widget_meta['version_minor'] = 0
        print(":white_check_mark: 'state' key added to metadata.widgets.")
else:
    print(":information_source: No widget metadata found or already fixed.")
# Save the fixed notebook (overwrites the original!)
with open(notebook_filename, 'w', encoding='utf-8') as f:
    json.dump(notebook_data, f, indent=2)
print(f":white_check_mark: Notebook '{notebook_filename}' fixed.")
```

```
:white_check_mark: 'state' key added to metadata.widgets.
:white_check_mark: Notebook 'DAT490_Capstone_label_model_1 (1).ipynb' fixed.
```

In [ ]: