3_1_Lexical_Complexity_Binary_Classification_Prediction_Transformers_

April 8, 2025

0.1 Packages, Library Imports, File Mounts, & Data Imports

[1]:
```
!pip install -q transformers
!pip install -q torchinfo
!pip install -q datasets
!pip install -q evaluate
!pip install -q nltk
!pip install -q contractions
!pip install -q hf_xet
!pip install -q sentencepiece
```

```
                         491.2/491.2 kB
9.7 MB/s eta 0:00:00
                         116.3/116.3 kB
10.6 MB/s eta 0:00:00
                         183.9/183.9 kB
17.7 MB/s eta 0:00:00
                         143.5/143.5 kB
15.2 MB/s eta 0:00:00
                         194.8/194.8 kB
18.4 MB/s eta 0:00:00
                         84.0/84.0 kB
2.3 MB/s eta 0:00:00
                         289.9/289.9 kB
5.0 MB/s eta 0:00:00
                         118.3/118.3 kB
12.4 MB/s eta 0:00:00
                         53.8/53.8 MB
24.5 MB/s eta 0:00:00
```

[2]:
```
!sudo apt-get update
! sudo apt-get install tree
```

```
Get:1 https://cloud.r-project.org/bin/linux/ubuntu jammy-cran40/ InRelease
[3,632 B]
Hit:2 http://archive.ubuntu.com/ubuntu jammy InRelease
```

```
Get:3 http://security.ubuntu.com/ubuntu jammy-security InRelease [129 kB]
Get:4 https://r2u.stat.illinois.edu/ubuntu jammy InRelease [6,555 B]
Get:5 http://archive.ubuntu.com/ubuntu jammy-updates InRelease [128 kB]
Hit:6 https://ppa.launchpadcontent.net/deadsnakes/ppa/ubuntu jammy InRelease
Hit:7 https://ppa.launchpadcontent.net/ubuntugis/ppa/ubuntu jammy InRelease
Get:8 http://archive.ubuntu.com/ubuntu jammy-backports InRelease [127 kB]
Get:9 https://r2u.stat.illinois.edu/ubuntu jammy/main amd64 Packages [2,684 kB]
Get:10 http://security.ubuntu.com/ubuntu jammy-security/restricted amd64
Packages [4,000 kB]
Get:11 https://r2u.stat.illinois.edu/ubuntu jammy/main all Packages [8,810 kB]
Get:12 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 Packages [3,099
kB]
Get:13 http://archive.ubuntu.com/ubuntu jammy-updates/universe amd64 Packages
[1,542 kB]
Get:14 http://security.ubuntu.com/ubuntu jammy-security/main amd64 Packages
[2,788 kB]
Get:15 http://security.ubuntu.com/ubuntu jammy-security/universe amd64 Packages
[1,243 kB]
Fetched 24.6 MB in 2s (10.9 MB/s)
Reading package lists… Done
W: Skipping acquire of configured file 'main/source/Sources' as repository
'https://r2u.stat.illinois.edu/ubuntu jammy InRelease' does not seem to provide
it (sources.list entry misspelt?)
Reading package lists… Done
Building dependency tree… Done
Reading state information… Done
The following NEW packages will be installed:
  tree
0 upgraded, 1 newly installed, 0 to remove and 21 not upgraded.
Need to get 47.9 kB of archives.
After this operation, 116 kB of additional disk space will be used.
Get:1 http://archive.ubuntu.com/ubuntu jammy/universe amd64 tree amd64 2.0.2-1
[47.9 kB]
Fetched 47.9 kB in 0s (111 kB/s)
debconf: unable to initialize frontend: Dialog
debconf: (No usable dialog-like program is installed, so the dialog based
frontend cannot be used. at /usr/share/perl5/Debconf/FrontEnd/Dialog.pm line 78,
<> line 1.)
debconf: falling back to frontend: Readline
debconf: unable to initialize frontend: Readline
debconf: (This frontend requires a controlling tty.)
debconf: falling back to frontend: Teletype
dpkg-preconfigure: unable to re-open stdin:
Selecting previously unselected package tree.
(Reading database … 122056 files and directories currently installed.)
Preparing to unpack …/tree_2.0.2-1_amd64.deb …
Unpacking tree (2.0.2-1) …
Setting up tree (2.0.2-1) …
```

```
Processing triggers for man-db (2.10.2-1) …
```

[3]:
```
#@title Imports
import nltk
from nltk.tokenize import RegexpTokenizer
import sentencepiece
import contractions
import spacy


import evaluate
from datasets import load_dataset, Dataset, DatasetDict

import torch
import torch.nn as nn
from torchinfo import summary

import transformers
from transformers import AutoTokenizer, AutoModel,␣
 ↪AutoModelForSequenceClassification, TrainingArguments, Trainer, BertConfig,␣
 ↪BertForSequenceClassification

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

import sklearn
from sklearn.feature_extraction.text import TfidfVectorizer
from sklearn.naive_bayes import MultinomialNB
from sklearn.metrics import classification_report,␣
 ↪precision_recall_fscore_support, accuracy_score

import json
import datetime
import zoneinfo
```

[4]:
```
# @title Mount Google Drive
```

[6]:
```
from google.colab import drive
drive.mount('/content/drive')
```

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

[8]:
```
dir_root = '/content/drive/MyDrive/266-final/'
# dir_data = '/content/drive/MyDrive/266-final/data/'
# dir_data = '/content/drive/MyDrive/266-final/data/se21-t1-comp-lex-master/'
```

```
dir_data = '/content/drive/MyDrive/266-final/data/266-comp-lex-master'
dir_models = '/content/drive/MyDrive/266-final/models/'
dir_results = '/content/drive/MyDrive/266-final/results/'
log_filename = "experiment_runs.txt"
log_filepath = os.path.join(dir_results, log_filename)
```

[9]:
```
wandbai_api_key = ""
```

[10]:
```
!tree /content/drive/MyDrive/266-final/data/266-comp-lex-master/
```

```
/content/drive/MyDrive/266-final/data/266-comp-lex-master/
  fe-test-labels
      test_multi_df.csv
      test_single_df.csv
  fe-train
      train_multi_df.csv
      train_single_df.csv
  fe-trial-val
      trial_val_multi_df.csv
      trial_val_single_df.csv
  test-labels
      lcp_multi_test.tsv
      lcp_single_test.tsv
  train
      lcp_multi_train.tsv
      lcp_single_train.tsv
  trial
       lcp_multi_trial.tsv
       lcp_single_trial.tsv

6 directories, 12 files
```

[11]:
```
!ls -R /content/drive/MyDrive/266-final/data/266-comp-lex-master/
```

```
/content/drive/MyDrive/266-final/data/266-comp-lex-master/:
fe-test-labels  fe-train  fe-trial-val  test-labels  train  trial

/content/drive/MyDrive/266-final/data/266-comp-lex-master/fe-test-labels:
test_multi_df.csv  test_single_df.csv

/content/drive/MyDrive/266-final/data/266-comp-lex-master/fe-train:
train_multi_df.csv  train_single_df.csv

/content/drive/MyDrive/266-final/data/266-comp-lex-master/fe-trial-val:
trial_val_multi_df.csv  trial_val_single_df.csv

/content/drive/MyDrive/266-final/data/266-comp-lex-master/test-labels:
lcp_multi_test.tsv  lcp_single_test.tsv
```

```
/content/drive/MyDrive/266-final/data/266-comp-lex-master/train:
lcp_multi_train.tsv  lcp_single_train.tsv

/content/drive/MyDrive/266-final/data/266-comp-lex-master/trial:
lcp_multi_trial.tsv  lcp_single_trial.tsv
```

[12]:
```
!tree /content/drive/MyDrive/266-final/data/266-comp-lex-master/
```

```
/content/drive/MyDrive/266-final/data/266-comp-lex-master/
  fe-test-labels
      test_multi_df.csv
      test_single_df.csv
  fe-train
      train_multi_df.csv
      train_single_df.csv
  fe-trial-val
      trial_val_multi_df.csv
      trial_val_single_df.csv
  test-labels
      lcp_multi_test.tsv
      lcp_single_test.tsv
  train
      lcp_multi_train.tsv
      lcp_single_train.tsv
  trial
       lcp_multi_trial.tsv
       lcp_single_trial.tsv

6 directories, 12 files
```

[13]:
```
#@title Import Data
```

[14]:
```
df_names = [
    "train_single_df",
    "train_multi_df",
    "trial_val_single_df",
    "trial_val_multi_df",
    "test_single_df",
    "test_multi_df"
]

loaded_dataframes = {}

for df_name in df_names:
    if "train" in df_name:
        subdir = "fe-train"
    elif "trial_val" in df_name:
```

```
        subdir = "fe-trial-val"
    elif "test" in df_name:
        subdir = "fe-test-labels"
    else:
        subdir = None

    if subdir:
        read_path = os.path.join(dir_data, subdir, f"{df_name}.csv")
        loaded_df = pd.read_csv(read_path)
        loaded_dataframes[df_name] = loaded_df
        print(f"Loaded {df_name} from {read_path}")

# for df_name, df in loaded_dataframes.items():
#     print(f"\n>>> {df_name} shape: {df.shape}")
#     if 'binary_complexity' in df.columns:
#         print(df['binary_complexity'].value_counts())
#         print(df.info())
#         print(df.head())

for df_name, df in loaded_dataframes.items():
    globals()[df_name] = df
    print(f"{df_name} loaded into global namespace.")
```

```
Loaded train_single_df from /content/drive/MyDrive/266-final/data/266-comp-lex-
master/fe-train/train_single_df.csv
Loaded train_multi_df from /content/drive/MyDrive/266-final/data/266-comp-lex-
master/fe-train/train_multi_df.csv
Loaded trial_val_single_df from /content/drive/MyDrive/266-final/data/266-comp-
lex-master/fe-trial-val/trial_val_single_df.csv
Loaded trial_val_multi_df from /content/drive/MyDrive/266-final/data/266-comp-
lex-master/fe-trial-val/trial_val_multi_df.csv
Loaded test_single_df from /content/drive/MyDrive/266-final/data/266-comp-lex-
master/fe-test-labels/test_single_df.csv
Loaded test_multi_df from /content/drive/MyDrive/266-final/data/266-comp-lex-
master/fe-test-labels/test_multi_df.csv
train_single_df loaded into global namespace.
train_multi_df loaded into global namespace.
trial_val_single_df loaded into global namespace.
trial_val_multi_df loaded into global namespace.
test_single_df loaded into global namespace.
test_multi_df loaded into global namespace.
```

- Functional tests pass, we can proceed with Baseline Modeling

0.2 Experiments

0.2.1 Helper Functions

[15]:
```
# MODEL_LINEAGE = {}

# def get_model_and_tokenizer(
#     remote_model_name: str = None,
#     local_model_path: str = None,
#     config=None
# ):
#     """
#     Loads the model & tokenizer for classification.
#     If 'local_model_path' is specified, load from that path.
#     Otherwise, fall back to 'remote_model_name'.

#     Optional: 'config' can be a custom BertConfig/AutoConfig object
#               to override certain configuration parameters.

#     Records complete traceable lineage in the global MODEL_LINEAGE.
#     """
#     global MODEL_LINEAGE

#     if local_model_path:
#         print(f"Loading from local path: {local_model_path}")
#         tokenizer = AutoTokenizer.from_pretrained(local_model_path)

#         # If a config object is provided, we pass it to from_pretrained.
#         # Otherwise, it just uses the config that is part of local_model_path.
#         if config is not None:
#             model = AutoModelForSequenceClassification.from_pretrained(
#                 local_model_path,
#                 config=config
#             )
#         else:
#             model = AutoModelForSequenceClassification.
 ↪from_pretrained(local_model_path)

#         MODEL_LINEAGE = {
#             "type": "offline_checkpoint",
#             "path": local_model_path,
#             "timestamp": datetime.datetime.now().strftime("%Y-%m-%d %H:%M:%S")
#         }
#     elif remote_model_name:
#         print(f"Loading from Hugging Face model: {remote_model_name}")
#         tokenizer = AutoTokenizer.from_pretrained(remote_model_name)

#         if config is not None:
```

```
#             model = AutoModelForSequenceClassification.from_pretrained(
#                 remote_model_name,
#                 config=config
#             )
#         else:
#             model = AutoModelForSequenceClassification.
 ↪from_pretrained(remote_model_name)

#         MODEL_LINEAGE = {
#             "type": "huggingface_hub",
#             "path": remote_model_name,
#             "timestamp": datetime.now().strftime("%Y-%m-%d %H:%M:%S")
#         }
#     else:
#         raise ValueError("You must provide either a remote_model_name or a␣
 ↪local_model_path!")

#     return model, tokenizer
```

[19]:
```
MODEL_LINEAGE = {}

def get_model_and_tokenizer(
    remote_model_name: str = None,
    local_model_path: str = None,
    config=None,
    name: str = None
):
    """
    Loads the model & tokenizer for classification.
    If 'local_model_path' is specified, load from that path.
    Otherwise, fall back to 'remote_model_name'.

    Optional: 'config' can be a custom BertConfig/AutoConfig object
              to override certain configuration parameters.

    Optional: 'name' can be any string you want to attach to the lineage
              for readability (e.g. 'my_custom_model_v2').

    Records complete traceable lineage in the global MODEL_LINEAGE.
    """
    global MODEL_LINEAGE

    now_str = datetime.datetime.now().strftime("%Y-%m-%d %H:%M:%S")

    if local_model_path:
        print(f"Loading from local path: {local_model_path}")
        tokenizer = AutoTokenizer.from_pretrained(local_model_path)
```

```
        if config is not None:
            model = AutoModelForSequenceClassification.from_pretrained(
                local_model_path,
                config=config
            )
        else:
            model = AutoModelForSequenceClassification.
↪from_pretrained(local_model_path)

        MODEL_LINEAGE = {
            "type": "offline_checkpoint",
            "path": local_model_path,
            "timestamp": now_str
        }

    elif remote_model_name:
        print(f"Loading from Hugging Face model: {remote_model_name}")
        tokenizer = AutoTokenizer.from_pretrained(remote_model_name)

        if config is not None:
            model = AutoModelForSequenceClassification.from_pretrained(
                remote_model_name,
                config=config
            )
        else:
            model = AutoModelForSequenceClassification.
↪from_pretrained(remote_model_name)

        MODEL_LINEAGE = {
            "type": "huggingface_hub",
            "path": remote_model_name,
            "timestamp": now_str
        }
    else:
        raise ValueError("You must provide either a remote_model_name or a␣
↪local_model_path!")

    # If a custom name is provided, add it to the lineage.
    if name:
        MODEL_LINEAGE["name"] = name

    return model, tokenizer
```

[16]:
```
def freeze_unfreeze_layers(model, layers_to_unfreeze=None):
    """
    Toggles requires_grad = False for all parameters
```

```
    except for those whose names contain any string in layers_to_unfreeze.
    By default, always unfreeze classifier/heads.
    """
    if layers_to_unfreeze is None:
        layers_to_unfreeze = ["classifier.", "pooler."]

    for name, param in model.named_parameters():
        if any(substring in name for substring in layers_to_unfreeze):
            param.requires_grad = True
        else:
            param.requires_grad = False
```

[ ]:
```
def encode_examples(examples, tokenizer, text_col, max_length=256):
    """
    Tokenizes a batch of texts from 'examples[text_col]' using the given␣
 ↪tokenizer.
    Returns a dict with 'input_ids', 'attention_mask', etc.
    """
    texts = examples[text_col]
    encoded = tokenizer(
        texts,
        truncation=True,
        padding='max_length',
        max_length=max_length
    )
    return encoded
```

[ ]:
```
def prepare_dataset(df, tokenizer, text_col, label_col, max_length=256):
    """
    Converts a Pandas DataFrame to a Hugging Face Dataset,
    then applies 'encode_examples' to tokenize.
    """
    dataset = Dataset.from_pandas(df)

    dataset = dataset.map(
        lambda batch: encode_examples(batch, tokenizer, text_col, max_length),
        batched=True
    )

    dataset = dataset.rename_column(label_col, "labels")
    dataset.set_format(type='torch',
                       columns=['input_ids', 'attention_mask', 'labels'])
    return dataset
```

[ ]:
```
def compute_metrics(eval_pred):
    """
```

```
    Computes classification metrics, including accuracy, precision, recall, and␣
↪F1.
    """
    logits, labels = eval_pred
    preds = np.argmax(logits, axis=1)

    metric_accuracy  = evaluate.load("accuracy")
    metric_precision = evaluate.load("precision")
    metric_recall    = evaluate.load("recall")
    metric_f1        = evaluate.load("f1")

    accuracy_result  = metric_accuracy.compute(predictions=preds,␣
↪references=labels)
    precision_result = metric_precision.compute(predictions=preds,␣
↪references=labels, average="binary")
    recall_result    = metric_recall.compute(predictions=preds,␣
↪references=labels, average="binary")
    f1_result        = metric_f1.compute(predictions=preds, references=labels,␣
↪average="binary")

    return {
        "accuracy"       : accuracy_result["accuracy"],
        "precision": precision_result["precision"],
        "recall"   : recall_result["recall"],
        "f1"       : f1_result["f1"]
    }
```

[20]:
```
def gather_config_details(model):
    """
    Enumerates every attribute in model.config
    """
    config_items = {}
    for attr_name, attr_value in vars(model.config).items():
        config_items[attr_name] = attr_value
    return config_items

def gather_model_details(model):
    """
    Extracts total layers, total params, trainable params, and activation␣
↪function
    from a Transformers model. Adjust logic as needed for different␣
↪architectures.
    """
    details = {}

    try:
```

```
        total_params = model.num_parameters()
        trainable_params = model.num_parameters(only_trainable=True)
    except AttributeError:
        all_params = list(model.parameters())
        total_params = sum(p.numel() for p in all_params)
        trainable_params = sum(p.numel() for p in all_params if p.requires_grad)

    details["model_total_params"] = total_params
    details["model_trainable_params"] = trainable_params

    if hasattr(model, "bert") and hasattr(model.bert, "pooler"):
        act_obj = getattr(model.bert.pooler, "activation", None)
        details["pooler_activation_function"] = act_obj.__class__.__name__ if␣
↪act_obj else "N/A"
    else:
        details["pooler_activation_function"] = "N/A"

    details["config_attributes"] = gather_config_details(model)
    return details

def gather_all_run_metrics(trainer, train_dataset=None, val_dataset=None,␣
↪test_dataset=None):
    """
    Gathers final training metrics, final validation metrics, final test␣
↪metrics.
    Instead of only parsing the final train_loss from the log, we also do a full
    trainer.evaluate(train_dataset) to get the same set of metrics that val/
↪test have.
    """
    results = {}

    if train_dataset is not None:
        train_metrics = trainer.evaluate(train_dataset)
        for k, v in train_metrics.items():
            results[f"train_{k}"] = v
    else:
        results["train_metrics"] = "No train dataset provided"

    if val_dataset is not None:
        val_metrics = trainer.evaluate(val_dataset)
        for k, v in val_metrics.items():
            results[f"val_{k}"] = v
    else:
        results["val_metrics"] = "No val dataset provided"

    if test_dataset is not None:
        test_metrics = trainer.evaluate(test_dataset)
```

```
        for k, v in test_metrics.items():
            results[f"test_{k}"] = v
    else:
        results["test_metrics"] = "No test dataset provided"

    return results

# def log_experiment_results_json(experiment_meta, model_details, run_metrics,␣
 ↪log_file):
#     """
#     Logs experiment metadata, model details, and metrics to a JSON lines file.
#     Automatically concatenates the 'checkpoint_path' to the 'model_lineage'.
#     """
#     checkpoint_path = model_details.get("checkpoint_path")
#     if checkpoint_path:
#         if "model_lineage" not in model_details:
#             model_details["model_lineage"] = ""
#         if model_details["model_lineage"]:
#             model_details["model_lineage"] += " -> "
#         model_details["model_lineage"] += checkpoint_path

#     record = {
#         "timestamp": str(datetime.datetime.now()),
#         "experiment_meta": experiment_meta,
#         "model_details": model_details,
#         "run_metrics": run_metrics
#     }

#     with open(log_file, "a", encoding="utf-8") as f:
#         json.dump(record, f)
#         f.write("\n")

# def log_experiment_results_json(experiment_meta, model_details, run_metrics,␣
 ↪log_file):
#     """
#     Logs experiment metadata, model details, and metrics to a JSON lines file.
#     Automatically concatenates the 'checkpoint_path' to the 'model_lineage'
#     and uses Pacific time for the timestamp.
#     """
#     checkpoint_path = model_details.get("checkpoint_path")
#     if checkpoint_path:
#         if "model_lineage" not in model_details:
#             model_details["model_lineage"] = ""
#         if model_details["model_lineage"]:
#             model_details["model_lineage"] += " -> "
#         model_details["model_lineage"] += checkpoint_path
```

```
#     pacific_time = datetime.datetime.now(zoneinfo.ZoneInfo("America/
 ↪Los_Angeles"))
#     timestamp_str = pacific_time.isoformat()

#     record = {
#         "timestamp": timestamp_str,
#         "experiment_meta": experiment_meta,
#         "model_details": model_details,
#         "run_metrics": run_metrics
#     }

#     with open(log_file, "a", encoding="utf-8") as f:
#         json.dump(record, f)
#         f.write("\n")

def log_experiment_results_json(experiment_meta, model_details, run_metrics,␣
 ↪log_file):
    """
    Logs experiment metadata, model details, and metrics to a JSON lines file.
    Automatically concatenates:
      - the custom 'name' from MODEL_LINEAGE (if any),
      - the 'checkpoint_path' from model_details (if any),
    onto the 'model_lineage' string in model_details.
    Also uses Pacific time for the record-level timestamp.
    """
    if "name" in MODEL_LINEAGE:
        if "model_lineage" not in model_details:
            model_details["model_lineage"] = ""
        if model_details["model_lineage"]:
            model_details["model_lineage"] += " -> "
        model_details["model_lineage"] += MODEL_LINEAGE["name"]

    checkpoint_path = model_details.get("checkpoint_path")
    if checkpoint_path:
        if "model_lineage" not in model_details:
            model_details["model_lineage"] = ""
        if model_details["model_lineage"]:
            model_details["model_lineage"] += " -> "
        model_details["model_lineage"] += checkpoint_path

    pacific_time = datetime.datetime.now(zoneinfo.ZoneInfo("America/
 ↪Los_Angeles"))
    timestamp_str = pacific_time.isoformat()

    record = {
        "timestamp": timestamp_str,
        "experiment_meta": experiment_meta,
```

```
        "model_details": model_details,
        "run_metrics": run_metrics
    }

    with open(log_file, "a", encoding="utf-8") as f:
        json.dump(record, f)
        f.write("\n")
```

0.2.2 Experiment Design

[ ]:
```
# Define Experiment Parameters

named_model = "bert-base-cased"
# named_model = "roberta-base"
# named_model = "bert-large"
# named_model = "roberta-large"
# named_model = "" # modern bert

# learning_rate = 1e-3
# learning_rate = 1e-4
# learning_rate = 1e-5
learning_rate = 5e-6
# learning_rate = 5e-7
# learning_rate = 5e-8

num_epochs = 1
# num_epochs = 3
# num_epochs = 5
# num_epochs = 10
# num_epochs = 15
# num_epochs = 20

length_max = 128
# length_max = 256
# length_max = 348
# length_max = 512

# size_batch = 1
# size_batch = 4
# size_batch = 8
# size_batch = 16
# size_batch = 24
# size_batch = 32
# size_batch = 64
size_batch = 128

# regularization_weight_decay = 0
```

```
# regularization_weight_decay = 0.1
regularization_weight_decay = 0.5

y_col = "binary_complexity"
# y_col = "complexity"

x_task = "single"
# x_task = "multi"

# x_col = "sentence"
x_col = "sentence_no_contractions"
# x_col = "pos_sequence"
# x_col = "dep_sequence"
# x_col = "morph_sequence"

if x_task == "single":
    df_train = train_single_df
    df_val   = trial_val_single_df
    df_test  = test_single_df
else:
    df_train = train_multi_df
    df_val   = trial_val_multi_df
    df_test  = test_multi_df


# bert_config = BertConfig(
#     # vocab_size=28996,
#     hidden_size=768,
#     # num_hidden_layers=12,
#     # num_attention_heads=12,
#     intermediate_size=3072,
#     # intermediate_size=6144,
#     # max_position_embeddings=512,
#     type_vocab_size=2,

#     hidden_dropout_prob=0.1,
#     attention_probs_dropout_prob=0.1,
#     # classifier_dropout=None,
#     # initializer_range=0.02,
#     # layer_norm_eps=1e-12,

#     hidden_act="gelu",
#     gradient_checkpointing=True,
#     position_embedding_type="absolute",
#     use_cache=True,
#     pad_token_id=0
# )
```

```
custom_config = BertConfig.from_pretrained("bert-base-cased")

custom_config.hidden_dropout_prob = 0.1
# custom_config.intermediate_size = 3072
# custom_config.intermediate_size = 6144
# custom_config.num_attention_heads = 12
# custom_config.num_hidden_layers = 12
custom_config.gradient_checkpointing = False
custom_config.attention_probs_dropout_prob = 0.1
# custom_config.max_position_embeddings = 512
# custom_config.type_vocab_size = 2
custom_config.hidden_act = "gelu"  # alts: "relu" "silu"
# custom_config.vocab_size = 28996  # must match

# model.bert.pooler.activation = nn.ReLU() # Tanh() replaced as the pooler␣
↪layer activation function in side-by-side with 1.1
```

[ ]:
```
def train_transformer_model(
    model,
    tokenizer,
    train_dataset,
    val_dataset,
    output_dir=dir_results,
    num_epochs=num_epochs,
    batch_size=size_batch,
    lr=learning_rate,
    weight_decay=regularization_weight_decay
):
    """
    Sets up a Trainer and trains the model for 'num_epochs' using the given␣
↪dataset.
    Returns the trained model and the Trainer object for possible re-use or␣
↪analysis.
    """

    training_args = TrainingArguments(
        output_dir=output_dir,
        num_train_epochs=num_epochs,
        per_device_train_batch_size=batch_size,
        per_device_eval_batch_size=batch_size,
        evaluation_strategy="epoch",
        save_strategy="no",
        logging_strategy="epoch",
        learning_rate=lr,
        weight_decay=weight_decay,
        report_to=["none"],  # or "wandb"
```

```
    )

    trainer = Trainer(
        model=model,
        args=training_args,
        train_dataset=train_dataset,
        eval_dataset=val_dataset,
        tokenizer=tokenizer,  # optional
        compute_metrics=compute_metrics
    )

    trainer.train()
    return model, trainer
```

0.2.3 1.0: from pretrained bert-base-cased single task 1

Model Inspection

[ ]:
```
print("model checkpoints:", dir_models)
!ls /content/drive/MyDrive/266-final/models/
```

```
model checkpoints: /content/drive/MyDrive/266-final/models/
multi_bert-base-cased_binary_complexity_20250408_143322
single_bert-base-cased_binary_complexity_20250408_043334
single_bert-base-cased_binary_complexity_20250408_043750
```

[ ]:
```
# Load Model & Tokenizer
# model, tokenizer = get_model_and_tokenizer(named_model) # deprecated argument␣
 ↪structure
# model, tokenizer = get_model_and_tokenizer("/content/drive/MyDrive/266-final/
 ↪models/....") # proposed argument usage for checkpointed models

# for name, param in model.named_parameters():
#     print(name)

model, tokenizer = get_model_and_tokenizer(
    remote_model_name="bert-base-cased",
    local_model_path=None,
    config=custom_config
)

# model, tokenizer = get_model_and_tokenizer(
#     local_model_path="my_local_bert_path",
#     config=custom_config
# )
```

```
print("=============")
print(named_model, ":")
print("=============")
# print(model)
print("=============")
print(model.config)
print("=============")
print("num_parameters:", model.num_parameters())
print("=============")
print("num_trainable_parameters:", model.num_parameters(only_trainable=True))
```

```
Loading from Hugging Face model: bert-base-cased
```

```
tokenizer_config.json:   0%|          | 0.00/49.0 [00:00<?, ?B/s]
```

```
vocab.txt:   0%|          | 0.00/213k [00:00<?, ?B/s]
```

```
tokenizer.json:   0%|          | 0.00/436k [00:00<?, ?B/s]
```

```
model.safetensors:   0%|          | 0.00/436M [00:00<?, ?B/s]
```

```
Some weights of BertForSequenceClassification were not initialized from the
model checkpoint at bert-base-cased and are newly initialized:
['classifier.bias', 'classifier.weight']
You should probably TRAIN this model on a down-stream task to be able to use it
for predictions and inference.
```

```
---------------------------------------------------------------------------
AttributeError                            Traceback (most recent call last)
<ipython-input-23-5648a92949e1> in <cell line: 0>()
      6 #     print(name)
      7
----> 8 model, tokenizer = get_model_and_tokenizer(
      9     remote_model_name="bert-base-cased",
     10     local_model_path=None,

<ipython-input-13-1270c9f70310> in get_model_and_tokenizer(remote_model_name,␣
 ↪local_model_path, config)
     52             "type": "huggingface_hub",
     53             "path": remote_model_name,
---> 54             "timestamp": datetime.now().strftime("%Y-%m-%d %H:%M:%S")
     55         }
     56     else:

AttributeError: module 'datetime' has no attribute 'now'
```

Layer Configuration

[ ]:
```
# Freeze/Unfreeze Layers & Additional Activation Function Configuration

layers_to_unfreeze = [
    # "bert.embeddings.",
    "bert.encoder.layer.0.",
    # "bert.encoder.layer.1.",
    # "bert.encoder.layer.9.",
    # "bert.encoder.layer.10.",
    "bert.encoder.layer.11.",
    "bert.pooler.",
    "classifier.",
]

freeze_unfreeze_layers(model, layers_to_unfreeze=layers_to_unfreeze)

for name, param in model.named_parameters():
    print(name, "requires_grad=", param.requires_grad)

print("\nLayers that are 'True' are trainable. 'False' are frozen.")

print("=============")
print(named_model, ":")
print("=============")
# print(model)
print("=============")
print(model.config)
print("=============")
print("num_parameters:", model.num_parameters())
print("=============")
print("num_trainable_parameters:", model.num_parameters(only_trainable=True))
```

```
bert.embeddings.word_embeddings.weight requires_grad= False
bert.embeddings.position_embeddings.weight requires_grad= False
bert.embeddings.token_type_embeddings.weight requires_grad= False
bert.embeddings.LayerNorm.weight requires_grad= False
bert.embeddings.LayerNorm.bias requires_grad= False
bert.encoder.layer.0.attention.self.query.weight requires_grad= True
bert.encoder.layer.0.attention.self.query.bias requires_grad= True
bert.encoder.layer.0.attention.self.key.weight requires_grad= True
bert.encoder.layer.0.attention.self.key.bias requires_grad= True
bert.encoder.layer.0.attention.self.value.weight requires_grad= True
bert.encoder.layer.0.attention.self.value.bias requires_grad= True
bert.encoder.layer.0.attention.output.dense.weight requires_grad= True
bert.encoder.layer.0.attention.output.dense.bias requires_grad= True
bert.encoder.layer.0.attention.output.LayerNorm.weight requires_grad= True
bert.encoder.layer.0.attention.output.LayerNorm.bias requires_grad= True
bert.encoder.layer.0.intermediate.dense.weight requires_grad= True
bert.encoder.layer.0.intermediate.dense.bias requires_grad= True
```

```
bert.encoder.layer.0.output.dense.weight requires_grad= True
bert.encoder.layer.0.output.dense.bias requires_grad= True
bert.encoder.layer.0.output.LayerNorm.weight requires_grad= True
bert.encoder.layer.0.output.LayerNorm.bias requires_grad= True
bert.encoder.layer.1.attention.self.query.weight requires_grad= False
bert.encoder.layer.1.attention.self.query.bias requires_grad= False
bert.encoder.layer.1.attention.self.key.weight requires_grad= False
bert.encoder.layer.1.attention.self.key.bias requires_grad= False
bert.encoder.layer.1.attention.self.value.weight requires_grad= False
bert.encoder.layer.1.attention.self.value.bias requires_grad= False
bert.encoder.layer.1.attention.output.dense.weight requires_grad= False
bert.encoder.layer.1.attention.output.dense.bias requires_grad= False
bert.encoder.layer.1.attention.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.1.attention.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.1.intermediate.dense.weight requires_grad= False
bert.encoder.layer.1.intermediate.dense.bias requires_grad= False
bert.encoder.layer.1.output.dense.weight requires_grad= False
bert.encoder.layer.1.output.dense.bias requires_grad= False
bert.encoder.layer.1.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.1.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.2.attention.self.query.weight requires_grad= False
bert.encoder.layer.2.attention.self.query.bias requires_grad= False
bert.encoder.layer.2.attention.self.key.weight requires_grad= False
bert.encoder.layer.2.attention.self.key.bias requires_grad= False
bert.encoder.layer.2.attention.self.value.weight requires_grad= False
bert.encoder.layer.2.attention.self.value.bias requires_grad= False
bert.encoder.layer.2.attention.output.dense.weight requires_grad= False
bert.encoder.layer.2.attention.output.dense.bias requires_grad= False
bert.encoder.layer.2.attention.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.2.attention.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.2.intermediate.dense.weight requires_grad= False
bert.encoder.layer.2.intermediate.dense.bias requires_grad= False
bert.encoder.layer.2.output.dense.weight requires_grad= False
bert.encoder.layer.2.output.dense.bias requires_grad= False
bert.encoder.layer.2.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.2.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.3.attention.self.query.weight requires_grad= False
bert.encoder.layer.3.attention.self.query.bias requires_grad= False
bert.encoder.layer.3.attention.self.key.weight requires_grad= False
bert.encoder.layer.3.attention.self.key.bias requires_grad= False
bert.encoder.layer.3.attention.self.value.weight requires_grad= False
bert.encoder.layer.3.attention.self.value.bias requires_grad= False
bert.encoder.layer.3.attention.output.dense.weight requires_grad= False
bert.encoder.layer.3.attention.output.dense.bias requires_grad= False
bert.encoder.layer.3.attention.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.3.attention.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.3.intermediate.dense.weight requires_grad= False
bert.encoder.layer.3.intermediate.dense.bias requires_grad= False
```

```
bert.encoder.layer.3.output.dense.weight requires_grad= False
bert.encoder.layer.3.output.dense.bias requires_grad= False
bert.encoder.layer.3.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.3.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.4.attention.self.query.weight requires_grad= False
bert.encoder.layer.4.attention.self.query.bias requires_grad= False
bert.encoder.layer.4.attention.self.key.weight requires_grad= False
bert.encoder.layer.4.attention.self.key.bias requires_grad= False
bert.encoder.layer.4.attention.self.value.weight requires_grad= False
bert.encoder.layer.4.attention.self.value.bias requires_grad= False
bert.encoder.layer.4.attention.output.dense.weight requires_grad= False
bert.encoder.layer.4.attention.output.dense.bias requires_grad= False
bert.encoder.layer.4.attention.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.4.attention.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.4.intermediate.dense.weight requires_grad= False
bert.encoder.layer.4.intermediate.dense.bias requires_grad= False
bert.encoder.layer.4.output.dense.weight requires_grad= False
bert.encoder.layer.4.output.dense.bias requires_grad= False
bert.encoder.layer.4.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.4.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.5.attention.self.query.weight requires_grad= False
bert.encoder.layer.5.attention.self.query.bias requires_grad= False
bert.encoder.layer.5.attention.self.key.weight requires_grad= False
bert.encoder.layer.5.attention.self.key.bias requires_grad= False
bert.encoder.layer.5.attention.self.value.weight requires_grad= False
bert.encoder.layer.5.attention.self.value.bias requires_grad= False
bert.encoder.layer.5.attention.output.dense.weight requires_grad= False
bert.encoder.layer.5.attention.output.dense.bias requires_grad= False
bert.encoder.layer.5.attention.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.5.attention.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.5.intermediate.dense.weight requires_grad= False
bert.encoder.layer.5.intermediate.dense.bias requires_grad= False
bert.encoder.layer.5.output.dense.weight requires_grad= False
bert.encoder.layer.5.output.dense.bias requires_grad= False
bert.encoder.layer.5.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.5.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.6.attention.self.query.weight requires_grad= False
bert.encoder.layer.6.attention.self.query.bias requires_grad= False
bert.encoder.layer.6.attention.self.key.weight requires_grad= False
bert.encoder.layer.6.attention.self.key.bias requires_grad= False
bert.encoder.layer.6.attention.self.value.weight requires_grad= False
bert.encoder.layer.6.attention.self.value.bias requires_grad= False
bert.encoder.layer.6.attention.output.dense.weight requires_grad= False
bert.encoder.layer.6.attention.output.dense.bias requires_grad= False
bert.encoder.layer.6.attention.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.6.attention.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.6.intermediate.dense.weight requires_grad= False
bert.encoder.layer.6.intermediate.dense.bias requires_grad= False
```

```
bert.encoder.layer.6.output.dense.weight requires_grad= False
bert.encoder.layer.6.output.dense.bias requires_grad= False
bert.encoder.layer.6.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.6.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.7.attention.self.query.weight requires_grad= False
bert.encoder.layer.7.attention.self.query.bias requires_grad= False
bert.encoder.layer.7.attention.self.key.weight requires_grad= False
bert.encoder.layer.7.attention.self.key.bias requires_grad= False
bert.encoder.layer.7.attention.self.value.weight requires_grad= False
bert.encoder.layer.7.attention.self.value.bias requires_grad= False
bert.encoder.layer.7.attention.output.dense.weight requires_grad= False
bert.encoder.layer.7.attention.output.dense.bias requires_grad= False
bert.encoder.layer.7.attention.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.7.attention.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.7.intermediate.dense.weight requires_grad= False
bert.encoder.layer.7.intermediate.dense.bias requires_grad= False
bert.encoder.layer.7.output.dense.weight requires_grad= False
bert.encoder.layer.7.output.dense.bias requires_grad= False
bert.encoder.layer.7.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.7.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.8.attention.self.query.weight requires_grad= False
bert.encoder.layer.8.attention.self.query.bias requires_grad= False
bert.encoder.layer.8.attention.self.key.weight requires_grad= False
bert.encoder.layer.8.attention.self.key.bias requires_grad= False
bert.encoder.layer.8.attention.self.value.weight requires_grad= False
bert.encoder.layer.8.attention.self.value.bias requires_grad= False
bert.encoder.layer.8.attention.output.dense.weight requires_grad= False
bert.encoder.layer.8.attention.output.dense.bias requires_grad= False
bert.encoder.layer.8.attention.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.8.attention.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.8.intermediate.dense.weight requires_grad= False
bert.encoder.layer.8.intermediate.dense.bias requires_grad= False
bert.encoder.layer.8.output.dense.weight requires_grad= False
bert.encoder.layer.8.output.dense.bias requires_grad= False
bert.encoder.layer.8.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.8.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.9.attention.self.query.weight requires_grad= False
bert.encoder.layer.9.attention.self.query.bias requires_grad= False
bert.encoder.layer.9.attention.self.key.weight requires_grad= False
bert.encoder.layer.9.attention.self.key.bias requires_grad= False
bert.encoder.layer.9.attention.self.value.weight requires_grad= False
bert.encoder.layer.9.attention.self.value.bias requires_grad= False
bert.encoder.layer.9.attention.output.dense.weight requires_grad= False
bert.encoder.layer.9.attention.output.dense.bias requires_grad= False
bert.encoder.layer.9.attention.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.9.attention.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.9.intermediate.dense.weight requires_grad= False
bert.encoder.layer.9.intermediate.dense.bias requires_grad= False
```

```
bert.encoder.layer.9.output.dense.weight requires_grad= False
bert.encoder.layer.9.output.dense.bias requires_grad= False
bert.encoder.layer.9.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.9.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.10.attention.self.query.weight requires_grad= False
bert.encoder.layer.10.attention.self.query.bias requires_grad= False
bert.encoder.layer.10.attention.self.key.weight requires_grad= False
bert.encoder.layer.10.attention.self.key.bias requires_grad= False
bert.encoder.layer.10.attention.self.value.weight requires_grad= False
bert.encoder.layer.10.attention.self.value.bias requires_grad= False
bert.encoder.layer.10.attention.output.dense.weight requires_grad= False
bert.encoder.layer.10.attention.output.dense.bias requires_grad= False
bert.encoder.layer.10.attention.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.10.attention.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.10.intermediate.dense.weight requires_grad= False
bert.encoder.layer.10.intermediate.dense.bias requires_grad= False
bert.encoder.layer.10.output.dense.weight requires_grad= False
bert.encoder.layer.10.output.dense.bias requires_grad= False
bert.encoder.layer.10.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.10.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.11.attention.self.query.weight requires_grad= True
bert.encoder.layer.11.attention.self.query.bias requires_grad= True
bert.encoder.layer.11.attention.self.key.weight requires_grad= True
bert.encoder.layer.11.attention.self.key.bias requires_grad= True
bert.encoder.layer.11.attention.self.value.weight requires_grad= True
bert.encoder.layer.11.attention.self.value.bias requires_grad= True
bert.encoder.layer.11.attention.output.dense.weight requires_grad= True
bert.encoder.layer.11.attention.output.dense.bias requires_grad= True
bert.encoder.layer.11.attention.output.LayerNorm.weight requires_grad= True
bert.encoder.layer.11.attention.output.LayerNorm.bias requires_grad= True
bert.encoder.layer.11.intermediate.dense.weight requires_grad= True
bert.encoder.layer.11.intermediate.dense.bias requires_grad= True
bert.encoder.layer.11.output.dense.weight requires_grad= True
bert.encoder.layer.11.output.dense.bias requires_grad= True
bert.encoder.layer.11.output.LayerNorm.weight requires_grad= True
bert.encoder.layer.11.output.LayerNorm.bias requires_grad= True
bert.pooler.dense.weight requires_grad= True
bert.pooler.dense.bias requires_grad= True
classifier.weight requires_grad= True
classifier.bias requires_grad= True

Layers that are 'True' are trainable. 'False' are frozen.
=============
bert-base-cased :
=============
=============
BertConfig {
  "_attn_implementation_autoset": true,
```

```
  "architectures": [
    "BertForMaskedLM"
  ],
  "attention_probs_dropout_prob": 0.1,
  "classifier_dropout": null,
  "gradient_checkpointing": false,
  "hidden_act": "gelu",
  "hidden_dropout_prob": 0.1,
  "hidden_size": 768,
  "initializer_range": 0.02,
  "intermediate_size": 3072,
  "layer_norm_eps": 1e-12,
  "max_position_embeddings": 512,
  "model_type": "bert",
  "num_attention_heads": 12,
  "num_hidden_layers": 12,
  "pad_token_id": 0,
  "position_embedding_type": "absolute",
  "torch_dtype": "float32",
  "transformers_version": "4.50.3",
  "type_vocab_size": 2,
  "use_cache": true,
  "vocab_size": 28996
}

=============
num_parameters: 108311810
=============
num_trainable_parameters: 14767874
```

**** Dataset Preparation**

[ ]:
```
# Tokenize & Prepare Datasets

train_data_hf = prepare_dataset(
    df_train,
    tokenizer,
    text_col=x_col,
    label_col=y_col,
    max_length=length_max
)

val_data_hf = prepare_dataset(
    df_val,
    tokenizer,
    text_col=x_col,
    label_col=y_col,
    max_length=length_max
```

```
)

test_data_hf = prepare_dataset(
    df_test,
    tokenizer,
    text_col=x_col,
    label_col=y_col,
    max_length=length_max

)

print("Datasets prepared. Sample from train_data_hf:\n", train_data_hf[10])
# print("Datasets prepared. Sample from train_data_hf:\n", val_data_hf[10])
# print("Datasets prepared. Sample from train_data_hf:\n", test_data_hf[10])
```

```
Map:   0%|          | 0/7662 [00:00<?, ? examples/s]

Map:   0%|          | 0/421 [00:00<?, ? examples/s]

Map:   0%|          | 0/917 [00:00<?, ? examples/s]

Datasets prepared. Sample from train_data_hf:
 {'labels': tensor(0), 'input_ids': tensor([  101,  1252,  1106,  1103,  3824,
1104, 19892, 11220,  1324,  1119,
         1522,  3839,   117,  1272,  1103,  1555,  1104,  1103, 11563,  5609,
         1106,  1172,   132,  1152,  2446,  1122,  1113,  1147,  3221,   119,
          102,     0,     0,     0,     0,     0,     0,     0,     0,     0,
            0,     0,     0,     0,     0,     0,     0,     0,     0,     0,
            0,     0,     0,     0,     0,     0,     0,     0,     0,     0,
            0,     0,     0,     0,     0,     0,     0,     0,     0,     0,
            0,     0,     0,     0,     0,     0,     0,     0,     0,     0,
            0,     0,     0,     0,     0,     0,     0,     0,     0,     0,
            0,     0,     0,     0,     0,     0,     0,     0,     0,     0,
            0,     0,     0,     0,     0,     0,     0,     0]),
'attention_mask': tensor([1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,
1, 1, 1, 1, 1, 1,
        1, 1, 1, 1, 1, 1, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
        0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
        0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
        0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
        0, 0, 0, 0, 0, 0, 0, 0])}
```

1.0 Results

[ ]:
```
# Train & Evaluate

trained_model, trainer_obj = train_transformer_model(
    model=model,
```

```
    tokenizer=tokenizer,
    train_dataset=train_data_hf,
    val_dataset=val_data_hf,
    output_dir=dir_results,
    num_epochs=num_epochs,
    batch_size=size_batch,
    lr=learning_rate,
    weight_decay=regularization_weight_decay
)

metrics = trainer_obj.evaluate()
print("Validation metrics:", metrics)

test_metrics = trainer_obj.evaluate(test_data_hf) if test_data_hf else None
print("Test metrics:", test_metrics)
```

```
/usr/local/lib/python3.11/dist-packages/transformers/training_args.py:1611:
FutureWarning: `evaluation_strategy` is deprecated and will be removed in
version 4.46 of  Transformers. Use `eval_strategy` instead
  warnings.warn(
<ipython-input-22-295bdbf803a2>:30: FutureWarning: `tokenizer` is deprecated and
will be removed in version 5.0.0 for `Trainer.__init__`. Use `processing_class`
instead.
  trainer = Trainer(
```

```
<IPython.core.display.HTML object>
```

```
Downloading builder script:   0%|          | 0.00/4.20k [00:00<?, ?B/s]
```

```
Downloading builder script:   0%|          | 0.00/7.56k [00:00<?, ?B/s]
```

```
Downloading builder script:   0%|          | 0.00/7.38k [00:00<?, ?B/s]
```

```
Downloading builder script:   0%|          | 0.00/6.79k [00:00<?, ?B/s]
```

```
<IPython.core.display.HTML object>
```

```
Validation metrics: {'eval_loss': 0.7350462675094604, 'eval_accuracy':
0.47980997624703087, 'eval_precision': 0.46511627906976744, 'eval_recall':
0.9375, 'eval_f1': 0.6217616580310881, 'eval_runtime': 5.6164,
'eval_samples_per_second': 74.959, 'eval_steps_per_second': 0.712, 'epoch': 1.0}
Test metrics: {'eval_loss': 0.7245147228240967, 'eval_accuracy':
0.5005452562704471, 'eval_precision': 0.4900117508813161, 'eval_recall':
0.9455782312925171, 'eval_f1': 0.6455108359133127, 'eval_runtime': 6.346,
'eval_samples_per_second': 144.499, 'eval_steps_per_second': 1.261, 'epoch':
1.0}
```

[ ]:
```
print("Experiment configuration used with this experiment:")
print("model used:", named_model)
print("learning rate used:", learning_rate)
print("number of epochs:", num_epochs)
```

```
print("maximum sequence length:", length_max)
print("batch size used:", size_batch)
print("regularization value:", regularization_weight_decay)
print("outcome variable:", y_col)
print("task:", x_task)
print("input column:", x_col)
```

```
Experiment configuration used with this experiment:
model used: bert-base-cased
learning rate used: 5e-06
number of epochs: 1
maximum sequence length: 128
batch size used: 128
regularization value: 0.5
outcome variable: binary_complexity
task: single
input column: sentence_no_contractions
```

[ ]:
```
# save model checkpoint

timestamp = datetime.now().strftime("%Y%m%d_%H%M%S")
model_save_path = os.path.join(dir_models,␣
  ↪f"{x_task}_{named_model}_{y_col}_{timestamp}")

trainer_obj.save_model(model_save_path)
print(f"Model checkpoint saved to: {model_save_path}")
```

```
Model checkpoint saved to: /content/drive/MyDrive/266-final/models/single_bert-
base-cased_binary_complexity_20250408_043117
```

[ ]:
```
import datetime

experiment_info = {
    "model_name": named_model,
    "learning_rate": learning_rate,
    "epochs": num_epochs,
    "batch_size": size_batch,
    "weight_decay": regularization_weight_decay,
    "x_task": x_task,
    "x_col": x_col,
    "y_col": y_col,
    "layers_to_unfreeze": layers_to_unfreeze
}

model_info = gather_model_details(trained_model)

all_run_metrics = gather_all_run_metrics(
    trainer=trainer_obj,
```

```
    train_dataset=train_data_hf,
    val_dataset=val_data_hf,
    test_dataset=test_data_hf
)

log_experiment_results_json(
    experiment_meta=experiment_info,
    model_details=model_info,
    run_metrics=all_run_metrics,
    log_file=log_filepath
)

print(f"EXPERIMENT LOGGED TO: {log_filepath}")
```

```
<IPython.core.display.HTML object>
```

```
EXPERIMENT LOGGED TO:
/content/drive/MyDrive/266-final/results/experiment_runs.txt
```

0.2.4 Experiment 1.1: from checkpoint bert-base-cased single task 1

[ ]:
```
# Load Model & Tokenizer

# model, tokenizer = get_model_and_tokenizer(
#     remote_model_name="bert-base-cased",
#     config=custom_config
# )

model, tokenizer = get_model_and_tokenizer(
    remote_model_name=None,
    local_model_path="/content/drive/MyDrive/266-final/models/
 ↪single_bert-base-cased_binary_complexity_20250408_043117",
    config=custom_config
)

print("==============")
print(named_model, ":")
print("==============")
# print(model)
print("==============")
print(model.config)
# print("==============")
```

```
Loading from local path: /content/drive/MyDrive/266-final/models/single_bert-
base-cased_binary_complexity_20250408_043117
==============
bert-base-cased :
==============
==============
```

```
BertConfig {
  "_attn_implementation_autoset": true,
  "architectures": [
    "BertForMaskedLM"
  ],
  "attention_probs_dropout_prob": 0,
  "classifier_dropout": null,
  "gradient_checkpointing": false,
  "hidden_act": "gelu",
  "hidden_dropout_prob": 0,
  "hidden_size": 768,
  "initializer_range": 0.02,
  "intermediate_size": 3072,
  "layer_norm_eps": 1e-12,
  "max_position_embeddings": 512,
  "model_type": "bert",
  "num_attention_heads": 12,
  "num_hidden_layers": 12,
  "pad_token_id": 0,
  "position_embedding_type": "absolute",
  "torch_dtype": "float32",
  "transformers_version": "4.50.3",
  "type_vocab_size": 2,
  "use_cache": true,
  "vocab_size": 28996
}
```

[ ]:
```python
# Define Experiment Parameters

named_model = "bert-base-cased"
# named_model = "roberta-base"
# named_model = "bert-large"
# named_model = "roberta-large"
# named_model = "" # modern bert

# learning_rate = 1e-3
# learning_rate = 1e-4
# learning_rate = 1e-5
learning_rate = 5e-6
# learning_rate = 5e-7
# learning_rate = 5e-8

# num_epochs = 1
num_epochs = 3
# num_epochs = 5
# num_epochs = 10
```

```
# num_epochs = 15
# num_epochs = 20

length_max = 128
# length_max = 256
# length_max = 348
# length_max = 512

# size_batch = 1
# size_batch = 4
# size_batch = 8
# size_batch = 16
# size_batch = 24
# size_batch = 32
# size_batch = 64
size_batch = 128

# regularization_weight_decay = 0
# regularization_weight_decay = 0.1
regularization_weight_decay = 0.5

y_col = "binary_complexity"
# y_col = "complexity"

x_task = "single"
# x_task = "multi"

# x_col = "sentence"
x_col = "sentence_no_contractions"
# x_col = "pos_sequence"
# x_col = "dep_sequence"
# x_col = "morph_sequence"

if x_task == "single":
    df_train = train_single_df
    df_val   = trial_val_single_df
    df_test  = test_single_df
else:
    df_train = train_multi_df
    df_val   = trial_val_multi_df
    df_test  = test_multi_df


# bert_config = BertConfig(
#     # vocab_size=28996,
#     hidden_size=768,
#     # num_hidden_layers=12,
```

```
#     # num_attention_heads=12,
#     intermediate_size=3072,
#     # intermediate_size=6144,
#     # max_position_embeddings=512,
#     type_vocab_size=2,

#     hidden_dropout_prob=0.1,
#     attention_probs_dropout_prob=0.1,
#     # classifier_dropout=None,
#     # initializer_range=0.02,
#     # layer_norm_eps=1e-12,

#     hidden_act="gelu",
#     gradient_checkpointing=True,
#     position_embedding_type="absolute",
#     use_cache=True,
#     pad_token_id=0
# )

custom_config = BertConfig.from_pretrained("bert-base-cased")

custom_config.hidden_dropout_prob = 0.1
# custom_config.intermediate_size = 3072
# custom_config.intermediate_size = 6144
# custom_config.num_attention_heads = 12
# custom_config.num_hidden_layers = 12
custom_config.gradient_checkpointing = False
custom_config.attention_probs_dropout_prob = 0.1
# custom_config.max_position_embeddings = 512
# custom_config.type_vocab_size = 2
custom_config.hidden_act = "gelu"  # alts: "relu" "silu"
# custom_config.vocab_size = 28996  # must match

# model.bert.pooler.activation = nn.ReLU() # Tanh() replaced as the pooler␣
 ↪layer activation function in side-by-side with 1.1
```

[ ]:
```
# Freeze/Unfreeze Layers & Additional Activation Function Configuration

layers_to_unfreeze = [
    # "bert.embeddings.",
    "bert.encoder.layer.0.",
    # "bert.encoder.layer.1.",
    # "bert.encoder.layer.9.",
    # "bert.encoder.layer.10.",
    "bert.encoder.layer.11.",
    "bert.pooler.",
    "classifier.",
```

```
]

freeze_unfreeze_layers(model, layers_to_unfreeze=layers_to_unfreeze)

for name, param in model.named_parameters():
    print(name, "requires_grad=", param.requires_grad)

print("\nLayers that are 'True' are trainable. 'False' are frozen.")

print("=============")
print(named_model, ":")
print("=============")
# print(model)
print("=============")
print(model.config)
print("=============")
print("num_parameters:", model.num_parameters())
print("=============")
print("num_trainable_parameters:", model.num_parameters(only_trainable=True))
```

```
bert.embeddings.word_embeddings.weight requires_grad= False
bert.embeddings.position_embeddings.weight requires_grad= False
bert.embeddings.token_type_embeddings.weight requires_grad= False
bert.embeddings.LayerNorm.weight requires_grad= False
bert.embeddings.LayerNorm.bias requires_grad= False
bert.encoder.layer.0.attention.self.query.weight requires_grad= True
bert.encoder.layer.0.attention.self.query.bias requires_grad= True
bert.encoder.layer.0.attention.self.key.weight requires_grad= True
bert.encoder.layer.0.attention.self.key.bias requires_grad= True
bert.encoder.layer.0.attention.self.value.weight requires_grad= True
bert.encoder.layer.0.attention.self.value.bias requires_grad= True
bert.encoder.layer.0.attention.output.dense.weight requires_grad= True
bert.encoder.layer.0.attention.output.dense.bias requires_grad= True
bert.encoder.layer.0.attention.output.LayerNorm.weight requires_grad= True
bert.encoder.layer.0.attention.output.LayerNorm.bias requires_grad= True
bert.encoder.layer.0.intermediate.dense.weight requires_grad= True
bert.encoder.layer.0.intermediate.dense.bias requires_grad= True
bert.encoder.layer.0.output.dense.weight requires_grad= True
bert.encoder.layer.0.output.dense.bias requires_grad= True
bert.encoder.layer.0.output.LayerNorm.weight requires_grad= True
bert.encoder.layer.0.output.LayerNorm.bias requires_grad= True
bert.encoder.layer.1.attention.self.query.weight requires_grad= False
bert.encoder.layer.1.attention.self.query.bias requires_grad= False
bert.encoder.layer.1.attention.self.key.weight requires_grad= False
bert.encoder.layer.1.attention.self.key.bias requires_grad= False
bert.encoder.layer.1.attention.self.value.weight requires_grad= False
bert.encoder.layer.1.attention.self.value.bias requires_grad= False
bert.encoder.layer.1.attention.output.dense.weight requires_grad= False
```

```
bert.encoder.layer.1.attention.output.dense.bias requires_grad= False
bert.encoder.layer.1.attention.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.1.attention.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.1.intermediate.dense.weight requires_grad= False
bert.encoder.layer.1.intermediate.dense.bias requires_grad= False
bert.encoder.layer.1.output.dense.weight requires_grad= False
bert.encoder.layer.1.output.dense.bias requires_grad= False
bert.encoder.layer.1.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.1.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.2.attention.self.query.weight requires_grad= False
bert.encoder.layer.2.attention.self.query.bias requires_grad= False
bert.encoder.layer.2.attention.self.key.weight requires_grad= False
bert.encoder.layer.2.attention.self.key.bias requires_grad= False
bert.encoder.layer.2.attention.self.value.weight requires_grad= False
bert.encoder.layer.2.attention.self.value.bias requires_grad= False
bert.encoder.layer.2.attention.output.dense.weight requires_grad= False
bert.encoder.layer.2.attention.output.dense.bias requires_grad= False
bert.encoder.layer.2.attention.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.2.attention.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.2.intermediate.dense.weight requires_grad= False
bert.encoder.layer.2.intermediate.dense.bias requires_grad= False
bert.encoder.layer.2.output.dense.weight requires_grad= False
bert.encoder.layer.2.output.dense.bias requires_grad= False
bert.encoder.layer.2.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.2.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.3.attention.self.query.weight requires_grad= False
bert.encoder.layer.3.attention.self.query.bias requires_grad= False
bert.encoder.layer.3.attention.self.key.weight requires_grad= False
bert.encoder.layer.3.attention.self.key.bias requires_grad= False
bert.encoder.layer.3.attention.self.value.weight requires_grad= False
bert.encoder.layer.3.attention.self.value.bias requires_grad= False
bert.encoder.layer.3.attention.output.dense.weight requires_grad= False
bert.encoder.layer.3.attention.output.dense.bias requires_grad= False
bert.encoder.layer.3.attention.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.3.attention.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.3.intermediate.dense.weight requires_grad= False
bert.encoder.layer.3.intermediate.dense.bias requires_grad= False
bert.encoder.layer.3.output.dense.weight requires_grad= False
bert.encoder.layer.3.output.dense.bias requires_grad= False
bert.encoder.layer.3.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.3.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.4.attention.self.query.weight requires_grad= False
bert.encoder.layer.4.attention.self.query.bias requires_grad= False
bert.encoder.layer.4.attention.self.key.weight requires_grad= False
bert.encoder.layer.4.attention.self.key.bias requires_grad= False
bert.encoder.layer.4.attention.self.value.weight requires_grad= False
bert.encoder.layer.4.attention.self.value.bias requires_grad= False
bert.encoder.layer.4.attention.output.dense.weight requires_grad= False
```

```
bert.encoder.layer.4.attention.output.dense.bias requires_grad= False
bert.encoder.layer.4.attention.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.4.attention.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.4.intermediate.dense.weight requires_grad= False
bert.encoder.layer.4.intermediate.dense.bias requires_grad= False
bert.encoder.layer.4.output.dense.weight requires_grad= False
bert.encoder.layer.4.output.dense.bias requires_grad= False
bert.encoder.layer.4.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.4.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.5.attention.self.query.weight requires_grad= False
bert.encoder.layer.5.attention.self.query.bias requires_grad= False
bert.encoder.layer.5.attention.self.key.weight requires_grad= False
bert.encoder.layer.5.attention.self.key.bias requires_grad= False
bert.encoder.layer.5.attention.self.value.weight requires_grad= False
bert.encoder.layer.5.attention.self.value.bias requires_grad= False
bert.encoder.layer.5.attention.output.dense.weight requires_grad= False
bert.encoder.layer.5.attention.output.dense.bias requires_grad= False
bert.encoder.layer.5.attention.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.5.attention.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.5.intermediate.dense.weight requires_grad= False
bert.encoder.layer.5.intermediate.dense.bias requires_grad= False
bert.encoder.layer.5.output.dense.weight requires_grad= False
bert.encoder.layer.5.output.dense.bias requires_grad= False
bert.encoder.layer.5.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.5.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.6.attention.self.query.weight requires_grad= False
bert.encoder.layer.6.attention.self.query.bias requires_grad= False
bert.encoder.layer.6.attention.self.key.weight requires_grad= False
bert.encoder.layer.6.attention.self.key.bias requires_grad= False
bert.encoder.layer.6.attention.self.value.weight requires_grad= False
bert.encoder.layer.6.attention.self.value.bias requires_grad= False
bert.encoder.layer.6.attention.output.dense.weight requires_grad= False
bert.encoder.layer.6.attention.output.dense.bias requires_grad= False
bert.encoder.layer.6.attention.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.6.attention.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.6.intermediate.dense.weight requires_grad= False
bert.encoder.layer.6.intermediate.dense.bias requires_grad= False
bert.encoder.layer.6.output.dense.weight requires_grad= False
bert.encoder.layer.6.output.dense.bias requires_grad= False
bert.encoder.layer.6.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.6.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.7.attention.self.query.weight requires_grad= False
bert.encoder.layer.7.attention.self.query.bias requires_grad= False
bert.encoder.layer.7.attention.self.key.weight requires_grad= False
bert.encoder.layer.7.attention.self.key.bias requires_grad= False
bert.encoder.layer.7.attention.self.value.weight requires_grad= False
bert.encoder.layer.7.attention.self.value.bias requires_grad= False
bert.encoder.layer.7.attention.output.dense.weight requires_grad= False
```

```
bert.encoder.layer.7.attention.output.dense.bias requires_grad= False
bert.encoder.layer.7.attention.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.7.attention.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.7.intermediate.dense.weight requires_grad= False
bert.encoder.layer.7.intermediate.dense.bias requires_grad= False
bert.encoder.layer.7.output.dense.weight requires_grad= False
bert.encoder.layer.7.output.dense.bias requires_grad= False
bert.encoder.layer.7.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.7.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.8.attention.self.query.weight requires_grad= False
bert.encoder.layer.8.attention.self.query.bias requires_grad= False
bert.encoder.layer.8.attention.self.key.weight requires_grad= False
bert.encoder.layer.8.attention.self.key.bias requires_grad= False
bert.encoder.layer.8.attention.self.value.weight requires_grad= False
bert.encoder.layer.8.attention.self.value.bias requires_grad= False
bert.encoder.layer.8.attention.output.dense.weight requires_grad= False
bert.encoder.layer.8.attention.output.dense.bias requires_grad= False
bert.encoder.layer.8.attention.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.8.attention.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.8.intermediate.dense.weight requires_grad= False
bert.encoder.layer.8.intermediate.dense.bias requires_grad= False
bert.encoder.layer.8.output.dense.weight requires_grad= False
bert.encoder.layer.8.output.dense.bias requires_grad= False
bert.encoder.layer.8.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.8.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.9.attention.self.query.weight requires_grad= False
bert.encoder.layer.9.attention.self.query.bias requires_grad= False
bert.encoder.layer.9.attention.self.key.weight requires_grad= False
bert.encoder.layer.9.attention.self.key.bias requires_grad= False
bert.encoder.layer.9.attention.self.value.weight requires_grad= False
bert.encoder.layer.9.attention.self.value.bias requires_grad= False
bert.encoder.layer.9.attention.output.dense.weight requires_grad= False
bert.encoder.layer.9.attention.output.dense.bias requires_grad= False
bert.encoder.layer.9.attention.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.9.attention.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.9.intermediate.dense.weight requires_grad= False
bert.encoder.layer.9.intermediate.dense.bias requires_grad= False
bert.encoder.layer.9.output.dense.weight requires_grad= False
bert.encoder.layer.9.output.dense.bias requires_grad= False
bert.encoder.layer.9.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.9.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.10.attention.self.query.weight requires_grad= False
bert.encoder.layer.10.attention.self.query.bias requires_grad= False
bert.encoder.layer.10.attention.self.key.weight requires_grad= False
bert.encoder.layer.10.attention.self.key.bias requires_grad= False
bert.encoder.layer.10.attention.self.value.weight requires_grad= False
bert.encoder.layer.10.attention.self.value.bias requires_grad= False
bert.encoder.layer.10.attention.output.dense.weight requires_grad= False
```

```
bert.encoder.layer.10.attention.output.dense.bias requires_grad= False
bert.encoder.layer.10.attention.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.10.attention.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.10.intermediate.dense.weight requires_grad= False
bert.encoder.layer.10.intermediate.dense.bias requires_grad= False
bert.encoder.layer.10.output.dense.weight requires_grad= False
bert.encoder.layer.10.output.dense.bias requires_grad= False
bert.encoder.layer.10.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.10.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.11.attention.self.query.weight requires_grad= True
bert.encoder.layer.11.attention.self.query.bias requires_grad= True
bert.encoder.layer.11.attention.self.key.weight requires_grad= True
bert.encoder.layer.11.attention.self.key.bias requires_grad= True
bert.encoder.layer.11.attention.self.value.weight requires_grad= True
bert.encoder.layer.11.attention.self.value.bias requires_grad= True
bert.encoder.layer.11.attention.output.dense.weight requires_grad= True
bert.encoder.layer.11.attention.output.dense.bias requires_grad= True
bert.encoder.layer.11.attention.output.LayerNorm.weight requires_grad= True
bert.encoder.layer.11.attention.output.LayerNorm.bias requires_grad= True
bert.encoder.layer.11.intermediate.dense.weight requires_grad= True
bert.encoder.layer.11.intermediate.dense.bias requires_grad= True
bert.encoder.layer.11.output.dense.weight requires_grad= True
bert.encoder.layer.11.output.dense.bias requires_grad= True
bert.encoder.layer.11.output.LayerNorm.weight requires_grad= True
bert.encoder.layer.11.output.LayerNorm.bias requires_grad= True
bert.pooler.dense.weight requires_grad= True
bert.pooler.dense.bias requires_grad= True
classifier.weight requires_grad= True
classifier.bias requires_grad= True

Layers that are 'True' are trainable. 'False' are frozen.
=============
bert-base-cased :
=============
=============
BertConfig {
  "_attn_implementation_autoset": true,
  "architectures": [
    "BertForMaskedLM"
  ],
  "attention_probs_dropout_prob": 0.1,
  "classifier_dropout": null,
  "gradient_checkpointing": false,
  "hidden_act": "gelu",
  "hidden_dropout_prob": 0.1,
  "hidden_size": 768,
  "initializer_range": 0.02,
  "intermediate_size": 3072,
```

```
  "layer_norm_eps": 1e-12,
  "max_position_embeddings": 512,
  "model_type": "bert",
  "num_attention_heads": 12,
  "num_hidden_layers": 12,
  "pad_token_id": 0,
  "position_embedding_type": "absolute",
  "torch_dtype": "float32",
  "transformers_version": "4.50.3",
  "type_vocab_size": 2,
  "use_cache": true,
  "vocab_size": 28996
}

=============
num_parameters: 108311810
=============
num_trainable_parameters: 14767874
```

1.1 Results

[ ]:
```
print("Experiment configuration used with this experiment:")
print("model used:", named_model)
print("learning rate used:", learning_rate)
print("number of epochs:", num_epochs)
print("maximum sequence length:", length_max)
print("batch size used:", size_batch)
print("regularization value:", regularization_weight_decay)
print("outcome variable:", y_col)
print("task:", x_task)
print("input column:", x_col)
```

```
Experiment configuration used with this experiment:
model used: bert-base-cased
learning rate used: 5e-06
number of epochs: 1
maximum sequence length: 128
batch size used: 128
regularization value: 0.5
outcome variable: binary_complexity
task: multi
input column: sentence_no_contractions
```

[ ]:
```
# Train & Evaluate

trained_model, trainer_obj = train_transformer_model(
    model=model,
    tokenizer=tokenizer,
    train_dataset=train_data_hf,
```

```
    val_dataset=val_data_hf,
    output_dir=dir_results,
    num_epochs=num_epochs,
    batch_size=size_batch,
    lr=learning_rate,
    weight_decay=regularization_weight_decay
)

metrics = trainer_obj.evaluate()
print("Validation metrics:", metrics)

test_metrics = trainer_obj.evaluate(test_data_hf) if test_data_hf else None
print("Test metrics:", test_metrics)
```

```
/usr/local/lib/python3.11/dist-packages/transformers/training_args.py:1611:
FutureWarning: `evaluation_strategy` is deprecated and will be removed in
version 4.46 of  Transformers. Use `eval_strategy` instead
  warnings.warn(
<ipython-input-22-295bdbf803a2>:30: FutureWarning: `tokenizer` is deprecated and
will be removed in version 5.0.0 for `Trainer.__init__`. Use `processing_class`
instead.
  trainer = Trainer(
```

```
<IPython.core.display.HTML object>
```

```
<IPython.core.display.HTML object>
```

```
Validation metrics: {'eval_loss': 0.681236982345581, 'eval_accuracy':
0.5653206650831354, 'eval_precision': 0.5217391304347826, 'eval_recall': 0.5625,
'eval_f1': 0.5413533834586466, 'eval_runtime': 5.4089,
'eval_samples_per_second': 77.835, 'eval_steps_per_second': 0.74, 'epoch': 3.0}
Test metrics: {'eval_loss': 0.6863542199134827, 'eval_accuracy':
0.5627044711014176, 'eval_precision': 0.5540540540540541, 'eval_recall':
0.46485260770975056, 'eval_f1': 0.5055487053020962, 'eval_runtime': 6.2945,
'eval_samples_per_second': 145.682, 'eval_steps_per_second': 1.271, 'epoch':
3.0}
```

[ ]:
```
# save model checkpoint

timestamp = datetime.now().strftime("%Y%m%d_%H%M%S")
model_save_path = os.path.join(dir_models,␣
  ↪f"{x_task}_{named_model}_{y_col}_{timestamp}")

trainer_obj.save_model(model_save_path)
print(f"Model checkpoint saved to: {model_save_path}")
```

```
Model checkpoint saved to: /content/drive/MyDrive/266-final/models/single_bert-
base-cased_binary_complexity_20250408_043750
```

[ ]:
```
experiment_info = {
    "model_name": named_model,
    "learning_rate": learning_rate,
    "epochs": num_epochs,
    "batch_size": size_batch,
    "weight_decay": regularization_weight_decay,
    "x_task": x_task,
    "x_col": x_col,
    "y_col": y_col,
    "layers_to_unfreeze": layers_to_unfreeze
}

model_info = gather_model_details(trained_model)

all_run_metrics = gather_all_run_metrics(
    trainer=trainer_obj,
    train_dataset=train_data_hf,
    val_dataset=val_data_hf,
    test_dataset=test_data_hf
)

log_experiment_results_json(
    experiment_meta=experiment_info,
    model_details=model_info,
    run_metrics=all_run_metrics,
    log_file=log_filepath
)

print(f"EXPERIMENT LOGGED TO: {log_filepath}")
```

```
<IPython.core.display.HTML object>
```

```
EXPERIMENT LOGGED TO:
/content/drive/MyDrive/266-final/results/experiment_runs.txt
```

0.2.5 1.2: from pre-trained bert-base-cased multi task 2

[ ]:
```
# Define Experiment Parameters

named_model = "bert-base-cased"
# named_model = "roberta-base"
# named_model = "bert-large"
# named_model = "roberta-large"
# named_model = "" # modern bert

# learning_rate = 1e-3
# learning_rate = 1e-4
# learning_rate = 1e-5
```

```
learning_rate = 5e-6
# learning_rate = 5e-7
# learning_rate = 5e-8

num_epochs = 1
# num_epochs = 3
# num_epochs = 5
# num_epochs = 10
# num_epochs = 15
# num_epochs = 20

length_max = 128
# length_max = 256
# length_max = 348
# length_max = 512

# size_batch = 1
# size_batch = 4
# size_batch = 8
# size_batch = 16
# size_batch = 24
# size_batch = 32
# size_batch = 64
size_batch = 128

# regularization_weight_decay = 0
# regularization_weight_decay = 0.1
regularization_weight_decay = 0.5

y_col = "binary_complexity"
# y_col = "complexity"

# x_task = "single"
x_task = "multi"

# x_col = "sentence"
x_col = "sentence_no_contractions"
# x_col = "pos_sequence"
# x_col = "dep_sequence"
# x_col = "morph_sequence"

if x_task == "single":
    df_train = train_single_df
    df_val   = trial_val_single_df
    df_test  = test_single_df
else:
    df_train = train_multi_df
```

```
    df_val   = trial_val_multi_df
    df_test  = test_multi_df


custom_config = BertConfig.from_pretrained("bert-base-cased")

custom_config.hidden_dropout_prob = 0.1
# custom_config.intermediate_size = 3072
# custom_config.intermediate_size = 6144
# custom_config.num_attention_heads = 12
# custom_config.num_hidden_layers = 12
custom_config.gradient_checkpointing = False
custom_config.attention_probs_dropout_prob = 0.1
# custom_config.max_position_embeddings = 512
# custom_config.type_vocab_size = 2
custom_config.hidden_act = "gelu"  # alts: "relu" "silu"
# custom_config.vocab_size = 28996  # must match

# model.bert.pooler.activation = nn.ReLU() # Tanh() replaced as the pooler␣
 ↪layer activation function in side-by-side with 1.1
```

[ ]:
```
print("model checkpoints:", dir_models)
!ls /content/drive/MyDrive/266-final/models/
```

```
model checkpoints: /content/drive/MyDrive/266-final/models/
multi_bert-base-cased_binary_complexity_20250408_143322
single_bert-base-cased_binary_complexity_20250408_043334
single_bert-base-cased_binary_complexity_20250408_043750
```

[ ]:
```
# Load Model & Tokenizer
# model, tokenizer = get_model_and_tokenizer(named_model) # deprecated argument␣
 ↪structure
# model, tokenizer = get_model_and_tokenizer("/content/drive/MyDrive/266-final/
 ↪models/....") # proposed argument usage for checkpointed models

# for name, param in model.named_parameters():
#     print(name)

model, tokenizer = get_model_and_tokenizer(
    remote_model_name="bert-base-cased",
    local_model_path=None,
    config=custom_config
)

# model, tokenizer = get_model_and_tokenizer(
#     local_model_path="my_local_bert_path",
#     config=custom_config
```

```python
# )

print("=============")
print(named_model, ":")
print("=============")
# print(model)
print("=============")
print(model.config)
print("=============")
print("num_parameters:", model.num_parameters())
print("=============")
print("num_trainable_parameters:", model.num_parameters(only_trainable=True))
```

```
Loading from Hugging Face model: bert-base-cased
```

```
tokenizer_config.json:   0%|          | 0.00/49.0 [00:00<?, ?B/s]
```

```
vocab.txt:   0%|          | 0.00/213k [00:00<?, ?B/s]
```

```
tokenizer.json:   0%|          | 0.00/436k [00:00<?, ?B/s]
```

```
model.safetensors:   0%|          | 0.00/436M [00:00<?, ?B/s]
```

```
Some weights of BertForSequenceClassification were not initialized from the
model checkpoint at bert-base-cased and are newly initialized:
['classifier.bias', 'classifier.weight']
You should probably TRAIN this model on a down-stream task to be able to use it
for predictions and inference.
```

```
=============
bert-base-cased :
=============
=============
BertConfig {
  "_attn_implementation_autoset": true,
  "architectures": [
    "BertForMaskedLM"
  ],
  "attention_probs_dropout_prob": 0.1,
  "classifier_dropout": null,
  "gradient_checkpointing": false,
  "hidden_act": "gelu",
  "hidden_dropout_prob": 0.1,
  "hidden_size": 768,
  "initializer_range": 0.02,
  "intermediate_size": 3072,
  "layer_norm_eps": 1e-12,
  "max_position_embeddings": 512,
  "model_type": "bert",
  "num_attention_heads": 12,
  "num_hidden_layers": 12,
```

```
  "pad_token_id": 0,
  "position_embedding_type": "absolute",
  "torch_dtype": "float32",
  "transformers_version": "4.50.3",
  "type_vocab_size": 2,
  "use_cache": true,
  "vocab_size": 28996
}

=============
num_parameters: 108311810
=============
num_trainable_parameters: 108311810
```

[ ]:
```python
# Freeze/Unfreeze Layers & Additional Activation Function Configuration

layers_to_unfreeze = [
    # "bert.embeddings.",
    "bert.encoder.layer.0.",
    # "bert.encoder.layer.1.",
    # "bert.encoder.layer.9.",
    # "bert.encoder.layer.10.",
    "bert.encoder.layer.11.",
    "bert.pooler.",
    "classifier.",
]

freeze_unfreeze_layers(model, layers_to_unfreeze=layers_to_unfreeze)

for name, param in model.named_parameters():
    print(name, "requires_grad=", param.requires_grad)

print("\nLayers that are 'True' are trainable. 'False' are frozen.")

print("=============")
print(named_model, ":")
print("=============")
# print(model)
print("=============")
print(model.config)
print("=============")
print("num_parameters:", model.num_parameters())
print("=============")
print("num_trainable_parameters:", model.num_parameters(only_trainable=True))
```

```
bert.embeddings.word_embeddings.weight requires_grad= False
bert.embeddings.position_embeddings.weight requires_grad= False
bert.embeddings.token_type_embeddings.weight requires_grad= False
```

```
bert.embeddings.LayerNorm.weight requires_grad= False
bert.embeddings.LayerNorm.bias requires_grad= False
bert.encoder.layer.0.attention.self.query.weight requires_grad= True
bert.encoder.layer.0.attention.self.query.bias requires_grad= True
bert.encoder.layer.0.attention.self.key.weight requires_grad= True
bert.encoder.layer.0.attention.self.key.bias requires_grad= True
bert.encoder.layer.0.attention.self.value.weight requires_grad= True
bert.encoder.layer.0.attention.self.value.bias requires_grad= True
bert.encoder.layer.0.attention.output.dense.weight requires_grad= True
bert.encoder.layer.0.attention.output.dense.bias requires_grad= True
bert.encoder.layer.0.attention.output.LayerNorm.weight requires_grad= True
bert.encoder.layer.0.attention.output.LayerNorm.bias requires_grad= True
bert.encoder.layer.0.intermediate.dense.weight requires_grad= True
bert.encoder.layer.0.intermediate.dense.bias requires_grad= True
bert.encoder.layer.0.output.dense.weight requires_grad= True
bert.encoder.layer.0.output.dense.bias requires_grad= True
bert.encoder.layer.0.output.LayerNorm.weight requires_grad= True
bert.encoder.layer.0.output.LayerNorm.bias requires_grad= True
bert.encoder.layer.1.attention.self.query.weight requires_grad= False
bert.encoder.layer.1.attention.self.query.bias requires_grad= False
bert.encoder.layer.1.attention.self.key.weight requires_grad= False
bert.encoder.layer.1.attention.self.key.bias requires_grad= False
bert.encoder.layer.1.attention.self.value.weight requires_grad= False
bert.encoder.layer.1.attention.self.value.bias requires_grad= False
bert.encoder.layer.1.attention.output.dense.weight requires_grad= False
bert.encoder.layer.1.attention.output.dense.bias requires_grad= False
bert.encoder.layer.1.attention.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.1.attention.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.1.intermediate.dense.weight requires_grad= False
bert.encoder.layer.1.intermediate.dense.bias requires_grad= False
bert.encoder.layer.1.output.dense.weight requires_grad= False
bert.encoder.layer.1.output.dense.bias requires_grad= False
bert.encoder.layer.1.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.1.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.2.attention.self.query.weight requires_grad= False
bert.encoder.layer.2.attention.self.query.bias requires_grad= False
bert.encoder.layer.2.attention.self.key.weight requires_grad= False
bert.encoder.layer.2.attention.self.key.bias requires_grad= False
bert.encoder.layer.2.attention.self.value.weight requires_grad= False
bert.encoder.layer.2.attention.self.value.bias requires_grad= False
bert.encoder.layer.2.attention.output.dense.weight requires_grad= False
bert.encoder.layer.2.attention.output.dense.bias requires_grad= False
bert.encoder.layer.2.attention.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.2.attention.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.2.intermediate.dense.weight requires_grad= False
bert.encoder.layer.2.intermediate.dense.bias requires_grad= False
bert.encoder.layer.2.output.dense.weight requires_grad= False
bert.encoder.layer.2.output.dense.bias requires_grad= False
```

```
bert.encoder.layer.2.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.2.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.3.attention.self.query.weight requires_grad= False
bert.encoder.layer.3.attention.self.query.bias requires_grad= False
bert.encoder.layer.3.attention.self.key.weight requires_grad= False
bert.encoder.layer.3.attention.self.key.bias requires_grad= False
bert.encoder.layer.3.attention.self.value.weight requires_grad= False
bert.encoder.layer.3.attention.self.value.bias requires_grad= False
bert.encoder.layer.3.attention.output.dense.weight requires_grad= False
bert.encoder.layer.3.attention.output.dense.bias requires_grad= False
bert.encoder.layer.3.attention.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.3.attention.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.3.intermediate.dense.weight requires_grad= False
bert.encoder.layer.3.intermediate.dense.bias requires_grad= False
bert.encoder.layer.3.output.dense.weight requires_grad= False
bert.encoder.layer.3.output.dense.bias requires_grad= False
bert.encoder.layer.3.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.3.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.4.attention.self.query.weight requires_grad= False
bert.encoder.layer.4.attention.self.query.bias requires_grad= False
bert.encoder.layer.4.attention.self.key.weight requires_grad= False
bert.encoder.layer.4.attention.self.key.bias requires_grad= False
bert.encoder.layer.4.attention.self.value.weight requires_grad= False
bert.encoder.layer.4.attention.self.value.bias requires_grad= False
bert.encoder.layer.4.attention.output.dense.weight requires_grad= False
bert.encoder.layer.4.attention.output.dense.bias requires_grad= False
bert.encoder.layer.4.attention.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.4.attention.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.4.intermediate.dense.weight requires_grad= False
bert.encoder.layer.4.intermediate.dense.bias requires_grad= False
bert.encoder.layer.4.output.dense.weight requires_grad= False
bert.encoder.layer.4.output.dense.bias requires_grad= False
bert.encoder.layer.4.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.4.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.5.attention.self.query.weight requires_grad= False
bert.encoder.layer.5.attention.self.query.bias requires_grad= False
bert.encoder.layer.5.attention.self.key.weight requires_grad= False
bert.encoder.layer.5.attention.self.key.bias requires_grad= False
bert.encoder.layer.5.attention.self.value.weight requires_grad= False
bert.encoder.layer.5.attention.self.value.bias requires_grad= False
bert.encoder.layer.5.attention.output.dense.weight requires_grad= False
bert.encoder.layer.5.attention.output.dense.bias requires_grad= False
bert.encoder.layer.5.attention.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.5.attention.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.5.intermediate.dense.weight requires_grad= False
bert.encoder.layer.5.intermediate.dense.bias requires_grad= False
bert.encoder.layer.5.output.dense.weight requires_grad= False
bert.encoder.layer.5.output.dense.bias requires_grad= False
```

```
bert.encoder.layer.5.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.5.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.6.attention.self.query.weight requires_grad= False
bert.encoder.layer.6.attention.self.query.bias requires_grad= False
bert.encoder.layer.6.attention.self.key.weight requires_grad= False
bert.encoder.layer.6.attention.self.key.bias requires_grad= False
bert.encoder.layer.6.attention.self.value.weight requires_grad= False
bert.encoder.layer.6.attention.self.value.bias requires_grad= False
bert.encoder.layer.6.attention.output.dense.weight requires_grad= False
bert.encoder.layer.6.attention.output.dense.bias requires_grad= False
bert.encoder.layer.6.attention.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.6.attention.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.6.intermediate.dense.weight requires_grad= False
bert.encoder.layer.6.intermediate.dense.bias requires_grad= False
bert.encoder.layer.6.output.dense.weight requires_grad= False
bert.encoder.layer.6.output.dense.bias requires_grad= False
bert.encoder.layer.6.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.6.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.7.attention.self.query.weight requires_grad= False
bert.encoder.layer.7.attention.self.query.bias requires_grad= False
bert.encoder.layer.7.attention.self.key.weight requires_grad= False
bert.encoder.layer.7.attention.self.key.bias requires_grad= False
bert.encoder.layer.7.attention.self.value.weight requires_grad= False
bert.encoder.layer.7.attention.self.value.bias requires_grad= False
bert.encoder.layer.7.attention.output.dense.weight requires_grad= False
bert.encoder.layer.7.attention.output.dense.bias requires_grad= False
bert.encoder.layer.7.attention.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.7.attention.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.7.intermediate.dense.weight requires_grad= False
bert.encoder.layer.7.intermediate.dense.bias requires_grad= False
bert.encoder.layer.7.output.dense.weight requires_grad= False
bert.encoder.layer.7.output.dense.bias requires_grad= False
bert.encoder.layer.7.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.7.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.8.attention.self.query.weight requires_grad= False
bert.encoder.layer.8.attention.self.query.bias requires_grad= False
bert.encoder.layer.8.attention.self.key.weight requires_grad= False
bert.encoder.layer.8.attention.self.key.bias requires_grad= False
bert.encoder.layer.8.attention.self.value.weight requires_grad= False
bert.encoder.layer.8.attention.self.value.bias requires_grad= False
bert.encoder.layer.8.attention.output.dense.weight requires_grad= False
bert.encoder.layer.8.attention.output.dense.bias requires_grad= False
bert.encoder.layer.8.attention.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.8.attention.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.8.intermediate.dense.weight requires_grad= False
bert.encoder.layer.8.intermediate.dense.bias requires_grad= False
bert.encoder.layer.8.output.dense.weight requires_grad= False
bert.encoder.layer.8.output.dense.bias requires_grad= False
```

```
bert.encoder.layer.8.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.8.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.9.attention.self.query.weight requires_grad= False
bert.encoder.layer.9.attention.self.query.bias requires_grad= False
bert.encoder.layer.9.attention.self.key.weight requires_grad= False
bert.encoder.layer.9.attention.self.key.bias requires_grad= False
bert.encoder.layer.9.attention.self.value.weight requires_grad= False
bert.encoder.layer.9.attention.self.value.bias requires_grad= False
bert.encoder.layer.9.attention.output.dense.weight requires_grad= False
bert.encoder.layer.9.attention.output.dense.bias requires_grad= False
bert.encoder.layer.9.attention.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.9.attention.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.9.intermediate.dense.weight requires_grad= False
bert.encoder.layer.9.intermediate.dense.bias requires_grad= False
bert.encoder.layer.9.output.dense.weight requires_grad= False
bert.encoder.layer.9.output.dense.bias requires_grad= False
bert.encoder.layer.9.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.9.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.10.attention.self.query.weight requires_grad= False
bert.encoder.layer.10.attention.self.query.bias requires_grad= False
bert.encoder.layer.10.attention.self.key.weight requires_grad= False
bert.encoder.layer.10.attention.self.key.bias requires_grad= False
bert.encoder.layer.10.attention.self.value.weight requires_grad= False
bert.encoder.layer.10.attention.self.value.bias requires_grad= False
bert.encoder.layer.10.attention.output.dense.weight requires_grad= False
bert.encoder.layer.10.attention.output.dense.bias requires_grad= False
bert.encoder.layer.10.attention.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.10.attention.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.10.intermediate.dense.weight requires_grad= False
bert.encoder.layer.10.intermediate.dense.bias requires_grad= False
bert.encoder.layer.10.output.dense.weight requires_grad= False
bert.encoder.layer.10.output.dense.bias requires_grad= False
bert.encoder.layer.10.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.10.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.11.attention.self.query.weight requires_grad= True
bert.encoder.layer.11.attention.self.query.bias requires_grad= True
bert.encoder.layer.11.attention.self.key.weight requires_grad= True
bert.encoder.layer.11.attention.self.key.bias requires_grad= True
bert.encoder.layer.11.attention.self.value.weight requires_grad= True
bert.encoder.layer.11.attention.self.value.bias requires_grad= True
bert.encoder.layer.11.attention.output.dense.weight requires_grad= True
bert.encoder.layer.11.attention.output.dense.bias requires_grad= True
bert.encoder.layer.11.attention.output.LayerNorm.weight requires_grad= True
bert.encoder.layer.11.attention.output.LayerNorm.bias requires_grad= True
bert.encoder.layer.11.intermediate.dense.weight requires_grad= True
bert.encoder.layer.11.intermediate.dense.bias requires_grad= True
bert.encoder.layer.11.output.dense.weight requires_grad= True
bert.encoder.layer.11.output.dense.bias requires_grad= True
```

```
bert.encoder.layer.11.output.LayerNorm.weight requires_grad= True
bert.encoder.layer.11.output.LayerNorm.bias requires_grad= True
bert.pooler.dense.weight requires_grad= True
bert.pooler.dense.bias requires_grad= True
classifier.weight requires_grad= True
classifier.bias requires_grad= True

Layers that are 'True' are trainable. 'False' are frozen.
=============
bert-base-cased :
=============
=============
BertConfig {
  "_attn_implementation_autoset": true,
  "architectures": [
    "BertForMaskedLM"
  ],
  "attention_probs_dropout_prob": 0.1,
  "classifier_dropout": null,
  "gradient_checkpointing": false,
  "hidden_act": "gelu",
  "hidden_dropout_prob": 0.1,
  "hidden_size": 768,
  "initializer_range": 0.02,
  "intermediate_size": 3072,
  "layer_norm_eps": 1e-12,
  "max_position_embeddings": 512,
  "model_type": "bert",
  "num_attention_heads": 12,
  "num_hidden_layers": 12,
  "pad_token_id": 0,
  "position_embedding_type": "absolute",
  "torch_dtype": "float32",
  "transformers_version": "4.50.3",
  "type_vocab_size": 2,
  "use_cache": true,
  "vocab_size": 28996
}

=============
num_parameters: 108311810
=============
num_trainable_parameters: 14767874
```

1.2 Results

[ ]:
```
print("Experiment configuration used with this experiment:")
print("model used:", named_model)
```

```
print("learning rate used:", learning_rate)
print("number of epochs:", num_epochs)
print("maximum sequence length:", length_max)
print("batch size used:", size_batch)
print("regularization value:", regularization_weight_decay)
print("outcome variable:", y_col)
print("task:", x_task)
print("input column:", x_col)
```

```
Experiment configuration used with this experiment:
model used: bert-base-cased
learning rate used: 5e-06
number of epochs: 1
maximum sequence length: 128
batch size used: 128
regularization value: 0.5
outcome variable: binary_complexity
task: multi
input column: sentence_no_contractions
```

[ ]:
```
# Train & Evaluate

trained_model, trainer_obj = train_transformer_model(
    model = model,
    tokenizer = tokenizer,
    train_dataset = train_data_hf,
    val_dataset = val_data_hf,
    output_dir = dir_results,
    num_epochs = num_epochs,
    batch_size = size_batch,
    lr = learning_rate,
    weight_decay = regularization_weight_decay
)

metrics = trainer_obj.evaluate()
print("Validation metrics:", metrics)

test_metrics = trainer_obj.evaluate(test_data_hf) if test_data_hf else None
print("Test metrics:", test_metrics)
```

```
/usr/local/lib/python3.11/dist-packages/transformers/training_args.py:1611:
FutureWarning: `evaluation_strategy` is deprecated and will be removed in
version 4.46 of  Transformers. Use `eval_strategy` instead
  warnings.warn(
<ipython-input-31-295bdbf803a2>:30: FutureWarning: `tokenizer` is deprecated and
will be removed in version 5.0.0 for `Trainer.__init__`. Use `processing_class`
instead.
  trainer = Trainer(
```

```
<IPython.core.display.HTML object>
Downloading builder script:   0%|          | 0.00/4.20k [00:00<?, ?B/s]
Downloading builder script:   0%|          | 0.00/7.56k [00:00<?, ?B/s]
Downloading builder script:   0%|          | 0.00/7.38k [00:00<?, ?B/s]
Downloading builder script:   0%|          | 0.00/6.79k [00:00<?, ?B/s]
<IPython.core.display.HTML object>
Validation metrics: {'eval_loss': 0.6868308186531067, 'eval_accuracy':
0.5454545454545454, 'eval_precision': 0.5365853658536586, 'eval_recall':
0.8627450980392157, 'eval_f1': 0.6616541353383458, 'eval_runtime': 2.4697,
'eval_samples_per_second': 40.086, 'eval_steps_per_second': 0.405, 'epoch': 1.0}
Test metrics: {'eval_loss': 0.6873067617416382, 'eval_accuracy':
0.5217391304347826, 'eval_precision': 0.535031847133758, 'eval_recall':
0.8484848484848485, 'eval_f1': 0.65625, 'eval_runtime': 1.6747,
'eval_samples_per_second': 109.869, 'eval_steps_per_second': 1.194, 'epoch':
1.0}
```

[ ]:
```python
# save model checkpoint

timestamp = datetime.now().strftime("%Y%m%d_%H%M%S")
model_save_path = os.path.join(dir_models,␣
  ↪f"{x_task}_{named_model}_{y_col}_{timestamp}")

trainer_obj.save_model(model_save_path)
print(f"Model checkpoint saved to: {model_save_path}")
```

```
Model checkpoint saved to: /content/drive/MyDrive/266-final/models/multi_bert-
base-cased_binary_complexity_20250408_143322
```

[ ]:
```python
experiment_info = {
    "model_name": named_model,
    "learning_rate": learning_rate,
    "epochs": num_epochs,
    "batch_size": size_batch,
    "weight_decay": regularization_weight_decay,
    "x_task": x_task,
    "x_col": x_col,
    "y_col": y_col,
    "layers_to_unfreeze": layers_to_unfreeze
}

model_info = gather_model_details(trained_model)

all_run_metrics = gather_all_run_metrics(
    trainer=trainer_obj,
    train_dataset=train_data_hf,
```

```
    val_dataset=val_data_hf,
    test_dataset=test_data_hf
)

log_experiment_results_json(
    experiment_meta=experiment_info,
    model_details=model_info,
    run_metrics=all_run_metrics,
    log_file=log_filepath
)

print(f"EXPERIMENT LOGGED TO: {log_filepath}")
```

```
<IPython.core.display.HTML object>
```

```
EXPERIMENT LOGGED TO:
/content/drive/MyDrive/266-final/results/experiment_runs.txt
```

0.2.6 Experiment 1.3: from checkpoint 1.2 bert-base-cased continued'd FT with additional epochs

[ ]:
```
# Define Experiment Parameters

named_model = "bert-base-cased"
# named_model = "roberta-base"
# named_model = "bert-large"
# named_model = "roberta-large"
# named_model = "" # modern bert

# learning_rate = 1e-3
# learning_rate = 1e-4
# learning_rate = 1e-5
learning_rate = 5e-6
# learning_rate = 5e-7
# learning_rate = 5e-8

# num_epochs = 1
num_epochs = 3
# num_epochs = 5
# num_epochs = 10
# num_epochs = 15
# num_epochs = 20

length_max = 128
# length_max = 256
# length_max = 348
# length_max = 512
```

```
# size_batch = 1
# size_batch = 4
# size_batch = 8
# size_batch = 16
# size_batch = 24
# size_batch = 32
# size_batch = 64
size_batch = 128

# regularization_weight_decay = 0
# regularization_weight_decay = 0.1
regularization_weight_decay = 0.5

y_col = "binary_complexity"
# y_col = "complexity"

# x_task = "single"
x_task = "multi"

# x_col = "sentence"
x_col = "sentence_no_contractions"
# x_col = "pos_sequence"
# x_col = "dep_sequence"
# x_col = "morph_sequence"

if x_task == "single":
    df_train = train_single_df
    df_val   = trial_val_single_df
    df_test  = test_single_df
else:
    df_train = train_multi_df
    df_val   = trial_val_multi_df
    df_test  = test_multi_df


custom_config = BertConfig.from_pretrained("bert-base-cased")

custom_config.hidden_dropout_prob = 0.1
# custom_config.intermediate_size = 3072
# custom_config.intermediate_size = 6144
# custom_config.num_attention_heads = 12
# custom_config.num_hidden_layers = 12
custom_config.gradient_checkpointing = False
custom_config.attention_probs_dropout_prob = 0.1
# custom_config.max_position_embeddings = 512
# custom_config.type_vocab_size = 2
custom_config.hidden_act = "gelu"  # alts: "relu" "silu"
```

```
# custom_config.vocab_size = 28996  # must match

# model.bert.pooler.activation = nn.ReLU() # Tanh() replaced as the pooler layer activation function in side-by-side with 1.1
```

[ ]:
```
print("model checkpoints:", dir_models)
!ls /content/drive/MyDrive/266-final/models/
```

```
model checkpoints: /content/drive/MyDrive/266-final/models/
multi_bert-base-cased_binary_complexity_20250408_143322
single_bert-base-cased_binary_complexity_20250408_043334
single_bert-base-cased_binary_complexity_20250408_043750
```

[ ]:
```
# Load Model & Tokenizer
# model, tokenizer = get_model_and_tokenizer(named_model) # deprecated argument structure
# model, tokenizer = get_model_and_tokenizer("/content/drive/MyDrive/266-final/models/....") # proposed argument usage for checkpointed models

# for name, param in model.named_parameters():
#     print(name)

# model, tokenizer = get_model_and_tokenizer(
#     remote_model_name="bert-base-cased",
#     local_model_path=None,
#     config=custom_config
# )

model, tokenizer = get_model_and_tokenizer(
    remote_model_name=None,
    local_model_path="/content/drive/MyDrive/266-final/models/multi_bert-base-cased_binary_complexity_20250408_143322",
    config=custom_config
)

print("=============")
print(named_model, ":")
print("=============")
# print(model)
print("=============")
print(model.config)
print("=============")
print("num_parameters:", model.num_parameters())
print("=============")
print("num_trainable_parameters:", model.num_parameters(only_trainable=True))
print("=============")
print("recorded model_lineage:", MODEL_LINEAGE)
```

```
Loading from local path: /content/drive/MyDrive/266-final/models/multi_bert-
base-cased_binary_complexity_20250408_143322
=============
bert-base-cased :
=============
=============
BertConfig {
  "_attn_implementation_autoset": true,
  "architectures": [
    "BertForMaskedLM"
  ],
  "attention_probs_dropout_prob": 0.1,
  "classifier_dropout": null,
  "gradient_checkpointing": false,
  "hidden_act": "gelu",
  "hidden_dropout_prob": 0.1,
  "hidden_size": 768,
  "initializer_range": 0.02,
  "intermediate_size": 3072,
  "layer_norm_eps": 1e-12,
  "max_position_embeddings": 512,
  "model_type": "bert",
  "num_attention_heads": 12,
  "num_hidden_layers": 12,
  "pad_token_id": 0,
  "position_embedding_type": "absolute",
  "torch_dtype": "float32",
  "transformers_version": "4.50.3",
  "type_vocab_size": 2,
  "use_cache": true,
  "vocab_size": 28996
}

=============
num_parameters: 108311810
=============
num_trainable_parameters: 108311810
=============
recorded model_lineage: {'type': 'offline_checkpoint', 'path':
'/content/drive/MyDrive/266-final/models/multi_bert-base-
cased_binary_complexity_20250408_143322', 'timestamp': '2025-04-08 20:03:23'}
```

[ ]:
```python
# Freeze/Unfreeze Layers & Additional Activation Function Configuration

layers_to_unfreeze = [
    # "bert.embeddings.",
    "bert.encoder.layer.0.",
```

```
    # "bert.encoder.layer.1.",
    # "bert.encoder.layer.9.",
    # "bert.encoder.layer.10.",
    "bert.encoder.layer.11.",
    "bert.pooler.",
    "classifier.",
]

freeze_unfreeze_layers(model, layers_to_unfreeze=layers_to_unfreeze)

for name, param in model.named_parameters():
    print(name, "requires_grad=", param.requires_grad)

print("\nLayers that are 'True' are trainable. 'False' are frozen.")

print("=============")
print(named_model, ":")
print("=============")
# print(model)
print("=============")
print(model.config)
print("=============")
print("num_parameters:", model.num_parameters())
print("=============")
print("num_trainable_parameters:", model.num_parameters(only_trainable=True))
print("=============")
print("recorded model_lineage:", MODEL_LINEAGE)
```

```
bert.embeddings.word_embeddings.weight requires_grad= False
bert.embeddings.position_embeddings.weight requires_grad= False
bert.embeddings.token_type_embeddings.weight requires_grad= False
bert.embeddings.LayerNorm.weight requires_grad= False
bert.embeddings.LayerNorm.bias requires_grad= False
bert.encoder.layer.0.attention.self.query.weight requires_grad= True
bert.encoder.layer.0.attention.self.query.bias requires_grad= True
bert.encoder.layer.0.attention.self.key.weight requires_grad= True
bert.encoder.layer.0.attention.self.key.bias requires_grad= True
bert.encoder.layer.0.attention.self.value.weight requires_grad= True
bert.encoder.layer.0.attention.self.value.bias requires_grad= True
bert.encoder.layer.0.attention.output.dense.weight requires_grad= True
bert.encoder.layer.0.attention.output.dense.bias requires_grad= True
bert.encoder.layer.0.attention.output.LayerNorm.weight requires_grad= True
bert.encoder.layer.0.attention.output.LayerNorm.bias requires_grad= True
bert.encoder.layer.0.intermediate.dense.weight requires_grad= True
bert.encoder.layer.0.intermediate.dense.bias requires_grad= True
bert.encoder.layer.0.output.dense.weight requires_grad= True
bert.encoder.layer.0.output.dense.bias requires_grad= True
bert.encoder.layer.0.output.LayerNorm.weight requires_grad= True
```

```
bert.encoder.layer.0.output.LayerNorm.bias requires_grad= True
bert.encoder.layer.1.attention.self.query.weight requires_grad= False
bert.encoder.layer.1.attention.self.query.bias requires_grad= False
bert.encoder.layer.1.attention.self.key.weight requires_grad= False
bert.encoder.layer.1.attention.self.key.bias requires_grad= False
bert.encoder.layer.1.attention.self.value.weight requires_grad= False
bert.encoder.layer.1.attention.self.value.bias requires_grad= False
bert.encoder.layer.1.attention.output.dense.weight requires_grad= False
bert.encoder.layer.1.attention.output.dense.bias requires_grad= False
bert.encoder.layer.1.attention.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.1.attention.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.1.intermediate.dense.weight requires_grad= False
bert.encoder.layer.1.intermediate.dense.bias requires_grad= False
bert.encoder.layer.1.output.dense.weight requires_grad= False
bert.encoder.layer.1.output.dense.bias requires_grad= False
bert.encoder.layer.1.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.1.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.2.attention.self.query.weight requires_grad= False
bert.encoder.layer.2.attention.self.query.bias requires_grad= False
bert.encoder.layer.2.attention.self.key.weight requires_grad= False
bert.encoder.layer.2.attention.self.key.bias requires_grad= False
bert.encoder.layer.2.attention.self.value.weight requires_grad= False
bert.encoder.layer.2.attention.self.value.bias requires_grad= False
bert.encoder.layer.2.attention.output.dense.weight requires_grad= False
bert.encoder.layer.2.attention.output.dense.bias requires_grad= False
bert.encoder.layer.2.attention.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.2.attention.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.2.intermediate.dense.weight requires_grad= False
bert.encoder.layer.2.intermediate.dense.bias requires_grad= False
bert.encoder.layer.2.output.dense.weight requires_grad= False
bert.encoder.layer.2.output.dense.bias requires_grad= False
bert.encoder.layer.2.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.2.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.3.attention.self.query.weight requires_grad= False
bert.encoder.layer.3.attention.self.query.bias requires_grad= False
bert.encoder.layer.3.attention.self.key.weight requires_grad= False
bert.encoder.layer.3.attention.self.key.bias requires_grad= False
bert.encoder.layer.3.attention.self.value.weight requires_grad= False
bert.encoder.layer.3.attention.self.value.bias requires_grad= False
bert.encoder.layer.3.attention.output.dense.weight requires_grad= False
bert.encoder.layer.3.attention.output.dense.bias requires_grad= False
bert.encoder.layer.3.attention.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.3.attention.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.3.intermediate.dense.weight requires_grad= False
bert.encoder.layer.3.intermediate.dense.bias requires_grad= False
bert.encoder.layer.3.output.dense.weight requires_grad= False
bert.encoder.layer.3.output.dense.bias requires_grad= False
bert.encoder.layer.3.output.LayerNorm.weight requires_grad= False
```

```
bert.encoder.layer.3.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.4.attention.self.query.weight requires_grad= False
bert.encoder.layer.4.attention.self.query.bias requires_grad= False
bert.encoder.layer.4.attention.self.key.weight requires_grad= False
bert.encoder.layer.4.attention.self.key.bias requires_grad= False
bert.encoder.layer.4.attention.self.value.weight requires_grad= False
bert.encoder.layer.4.attention.self.value.bias requires_grad= False
bert.encoder.layer.4.attention.output.dense.weight requires_grad= False
bert.encoder.layer.4.attention.output.dense.bias requires_grad= False
bert.encoder.layer.4.attention.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.4.attention.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.4.intermediate.dense.weight requires_grad= False
bert.encoder.layer.4.intermediate.dense.bias requires_grad= False
bert.encoder.layer.4.output.dense.weight requires_grad= False
bert.encoder.layer.4.output.dense.bias requires_grad= False
bert.encoder.layer.4.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.4.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.5.attention.self.query.weight requires_grad= False
bert.encoder.layer.5.attention.self.query.bias requires_grad= False
bert.encoder.layer.5.attention.self.key.weight requires_grad= False
bert.encoder.layer.5.attention.self.key.bias requires_grad= False
bert.encoder.layer.5.attention.self.value.weight requires_grad= False
bert.encoder.layer.5.attention.self.value.bias requires_grad= False
bert.encoder.layer.5.attention.output.dense.weight requires_grad= False
bert.encoder.layer.5.attention.output.dense.bias requires_grad= False
bert.encoder.layer.5.attention.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.5.attention.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.5.intermediate.dense.weight requires_grad= False
bert.encoder.layer.5.intermediate.dense.bias requires_grad= False
bert.encoder.layer.5.output.dense.weight requires_grad= False
bert.encoder.layer.5.output.dense.bias requires_grad= False
bert.encoder.layer.5.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.5.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.6.attention.self.query.weight requires_grad= False
bert.encoder.layer.6.attention.self.query.bias requires_grad= False
bert.encoder.layer.6.attention.self.key.weight requires_grad= False
bert.encoder.layer.6.attention.self.key.bias requires_grad= False
bert.encoder.layer.6.attention.self.value.weight requires_grad= False
bert.encoder.layer.6.attention.self.value.bias requires_grad= False
bert.encoder.layer.6.attention.output.dense.weight requires_grad= False
bert.encoder.layer.6.attention.output.dense.bias requires_grad= False
bert.encoder.layer.6.attention.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.6.attention.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.6.intermediate.dense.weight requires_grad= False
bert.encoder.layer.6.intermediate.dense.bias requires_grad= False
bert.encoder.layer.6.output.dense.weight requires_grad= False
bert.encoder.layer.6.output.dense.bias requires_grad= False
bert.encoder.layer.6.output.LayerNorm.weight requires_grad= False
```

```
bert.encoder.layer.6.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.7.attention.self.query.weight requires_grad= False
bert.encoder.layer.7.attention.self.query.bias requires_grad= False
bert.encoder.layer.7.attention.self.key.weight requires_grad= False
bert.encoder.layer.7.attention.self.key.bias requires_grad= False
bert.encoder.layer.7.attention.self.value.weight requires_grad= False
bert.encoder.layer.7.attention.self.value.bias requires_grad= False
bert.encoder.layer.7.attention.output.dense.weight requires_grad= False
bert.encoder.layer.7.attention.output.dense.bias requires_grad= False
bert.encoder.layer.7.attention.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.7.attention.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.7.intermediate.dense.weight requires_grad= False
bert.encoder.layer.7.intermediate.dense.bias requires_grad= False
bert.encoder.layer.7.output.dense.weight requires_grad= False
bert.encoder.layer.7.output.dense.bias requires_grad= False
bert.encoder.layer.7.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.7.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.8.attention.self.query.weight requires_grad= False
bert.encoder.layer.8.attention.self.query.bias requires_grad= False
bert.encoder.layer.8.attention.self.key.weight requires_grad= False
bert.encoder.layer.8.attention.self.key.bias requires_grad= False
bert.encoder.layer.8.attention.self.value.weight requires_grad= False
bert.encoder.layer.8.attention.self.value.bias requires_grad= False
bert.encoder.layer.8.attention.output.dense.weight requires_grad= False
bert.encoder.layer.8.attention.output.dense.bias requires_grad= False
bert.encoder.layer.8.attention.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.8.attention.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.8.intermediate.dense.weight requires_grad= False
bert.encoder.layer.8.intermediate.dense.bias requires_grad= False
bert.encoder.layer.8.output.dense.weight requires_grad= False
bert.encoder.layer.8.output.dense.bias requires_grad= False
bert.encoder.layer.8.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.8.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.9.attention.self.query.weight requires_grad= False
bert.encoder.layer.9.attention.self.query.bias requires_grad= False
bert.encoder.layer.9.attention.self.key.weight requires_grad= False
bert.encoder.layer.9.attention.self.key.bias requires_grad= False
bert.encoder.layer.9.attention.self.value.weight requires_grad= False
bert.encoder.layer.9.attention.self.value.bias requires_grad= False
bert.encoder.layer.9.attention.output.dense.weight requires_grad= False
bert.encoder.layer.9.attention.output.dense.bias requires_grad= False
bert.encoder.layer.9.attention.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.9.attention.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.9.intermediate.dense.weight requires_grad= False
bert.encoder.layer.9.intermediate.dense.bias requires_grad= False
bert.encoder.layer.9.output.dense.weight requires_grad= False
bert.encoder.layer.9.output.dense.bias requires_grad= False
bert.encoder.layer.9.output.LayerNorm.weight requires_grad= False
```

```
bert.encoder.layer.9.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.10.attention.self.query.weight requires_grad= False
bert.encoder.layer.10.attention.self.query.bias requires_grad= False
bert.encoder.layer.10.attention.self.key.weight requires_grad= False
bert.encoder.layer.10.attention.self.key.bias requires_grad= False
bert.encoder.layer.10.attention.self.value.weight requires_grad= False
bert.encoder.layer.10.attention.self.value.bias requires_grad= False
bert.encoder.layer.10.attention.output.dense.weight requires_grad= False
bert.encoder.layer.10.attention.output.dense.bias requires_grad= False
bert.encoder.layer.10.attention.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.10.attention.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.10.intermediate.dense.weight requires_grad= False
bert.encoder.layer.10.intermediate.dense.bias requires_grad= False
bert.encoder.layer.10.output.dense.weight requires_grad= False
bert.encoder.layer.10.output.dense.bias requires_grad= False
bert.encoder.layer.10.output.LayerNorm.weight requires_grad= False
bert.encoder.layer.10.output.LayerNorm.bias requires_grad= False
bert.encoder.layer.11.attention.self.query.weight requires_grad= True
bert.encoder.layer.11.attention.self.query.bias requires_grad= True
bert.encoder.layer.11.attention.self.key.weight requires_grad= True
bert.encoder.layer.11.attention.self.key.bias requires_grad= True
bert.encoder.layer.11.attention.self.value.weight requires_grad= True
bert.encoder.layer.11.attention.self.value.bias requires_grad= True
bert.encoder.layer.11.attention.output.dense.weight requires_grad= True
bert.encoder.layer.11.attention.output.dense.bias requires_grad= True
bert.encoder.layer.11.attention.output.LayerNorm.weight requires_grad= True
bert.encoder.layer.11.attention.output.LayerNorm.bias requires_grad= True
bert.encoder.layer.11.intermediate.dense.weight requires_grad= True
bert.encoder.layer.11.intermediate.dense.bias requires_grad= True
bert.encoder.layer.11.output.dense.weight requires_grad= True
bert.encoder.layer.11.output.dense.bias requires_grad= True
bert.encoder.layer.11.output.LayerNorm.weight requires_grad= True
bert.encoder.layer.11.output.LayerNorm.bias requires_grad= True
bert.pooler.dense.weight requires_grad= True
bert.pooler.dense.bias requires_grad= True
classifier.weight requires_grad= True
classifier.bias requires_grad= True

Layers that are 'True' are trainable. 'False' are frozen.
=============
bert-base-cased :
=============
=============
BertConfig {
  "_attn_implementation_autoset": true,
  "architectures": [
    "BertForMaskedLM"
  ],
```

```
  "attention_probs_dropout_prob": 0.1,
  "classifier_dropout": null,
  "gradient_checkpointing": false,
  "hidden_act": "gelu",
  "hidden_dropout_prob": 0.1,
  "hidden_size": 768,
  "initializer_range": 0.02,
  "intermediate_size": 3072,
  "layer_norm_eps": 1e-12,
  "max_position_embeddings": 512,
  "model_type": "bert",
  "num_attention_heads": 12,
  "num_hidden_layers": 12,
  "pad_token_id": 0,
  "position_embedding_type": "absolute",
  "torch_dtype": "float32",
  "transformers_version": "4.50.3",
  "type_vocab_size": 2,
  "use_cache": true,
  "vocab_size": 28996
}

=============
num_parameters: 108311810
=============
num_trainable_parameters: 14767874
=============
recorded model_lineage: {'type': 'offline_checkpoint', 'path':
'/content/drive/MyDrive/266-final/models/multi_bert-base-
cased_binary_complexity_20250408_143322', 'timestamp': '2025-04-08 20:03:23'}
```

1.3 Results

[ ]:
```
# Train & Evaluate

trained_model, trainer_obj = train_transformer_model(
    model=model,
    tokenizer=tokenizer,
    train_dataset=train_data_hf,
    val_dataset=val_data_hf,
    output_dir=dir_results,
    num_epochs=num_epochs,
    batch_size=size_batch,
    lr=learning_rate,
    weight_decay=regularization_weight_decay
)

metrics = trainer_obj.evaluate()
```

```
print("Validation metrics:", metrics)

test_metrics = trainer_obj.evaluate(test_data_hf) if test_data_hf else None
print("Test metrics:", test_metrics)
```

```
<IPython.core.display.HTML object>
```

[ ]:
```
print("Experiment configuration used with this experiment:")
print("model used:", named_model)
print("learning rate used:", learning_rate)
print("number of epochs:", num_epochs)
print("maximum sequence length:", length_max)
print("batch size used:", size_batch)
print("regularization value:", regularization_weight_decay)
print("outcome variable:", y_col)
print("task:", x_task)
print("input column:", x_col)
```

[ ]:
```
# save model checkpoint

timestamp = datetime.now().strftime("%Y%m%d_%H%M%S")
model_save_path = os.path.join(dir_models,␣
 ↪f"{x_task}_{named_model}_{y_col}_{timestamp}")

trainer_obj.save_model(model_save_path)
print(f"Model checkpoint saved to: {model_save_path}")
```

[ ]:
```
# experiment_info = {
#     "model_name": named_model,
#     "learning_rate": learning_rate,
#     "epochs": num_epochs,
#     "batch_size": size_batch,
#     "weight_decay": regularization_weight_decay,
#     "x_task": x_task,
#     "x_col": x_col,
#     "y_col": y_col,
#     "layers_to_unfreeze": layers_to_unfreeze
# }

# model_info = gather_model_details(trained_model)

# all_run_metrics = gather_all_run_metrics(
#     trainer=trainer_obj,
#     train_dataset=train_data_hf,
#     val_dataset=val_data_hf,
#     test_dataset=test_data_hf
# )
```

```
# log_experiment_results(
#     experiment_meta=experiment_info,
#     model_details=model_info,
#     run_metrics=all_run_metrics,
#     log_file=log_filepath
# )

# print(f"EXPERIMENT LOGGED TO: {log_filepath}")
```

[ ]: