In [1]:

```
!pip install transformers==2.8.0
```

```
Collecting transformers==2.8.0
  Downloading https://files.pythonhosted.org/packages/a3/78/92cedda05552398352ed9784908b834ee32a0bd0
71a9b32de287327370b7/transformers-2.8.0-py3-none-any.whl (563kB)
     |████████████████████████████████| 573kB 7.4MB/s
Requirement already satisfied: filelock in /usr/local/lib/python3.6/dist-packages (from transformers
==2.8.0) (3.0.12)
Requirement already satisfied: regex!=2019.12.17 in /usr/local/lib/python3.6/dist-packages (from tra
nsformers==2.8.0) (2019.12.20)
Collecting sacremoses
  Downloading https://files.pythonhosted.org/packages/7d/34/09d19aff26edcc8eb2a01bed8e98f13a1537005d
31e95233fd48216eed10/sacremoses-0.0.43.tar.gz (883kB)
     |████████████████████████████████| 890kB 20.5MB/s
Requirement already satisfied: boto3 in /usr/local/lib/python3.6/dist-packages (from transformers==
2.8.0) (1.14.22)
Requirement already satisfied: dataclasses; python_version < "3.7" in /usr/local/lib/python3.6/dist-
packages (from transformers==2.8.0) (0.7)
Requirement already satisfied: tqdm>=4.27 in /usr/local/lib/python3.6/dist-packages (from transforme
rs==2.8.0) (4.41.1)
Collecting sentencepiece
  Downloading https://files.pythonhosted.org/packages/d4/a4/d0a884c4300004a78cca907a6ff9a5e9fe4f090f
5d95ab341c53d28cbc58/sentencepiece-0.1.91-cp36-cp36m-manylinux1_x86_64.whl (1.1MB)
     |████████████████████████████████| 1.1MB 41.8MB/s
Requirement already satisfied: requests in /usr/local/lib/python3.6/dist-packages (from transformers
==2.8.0) (2.23.0)
Requirement already satisfied: numpy in /usr/local/lib/python3.6/dist-packages (from transformers==
2.8.0) (1.18.5)
Collecting tokenizers==0.5.2
  Downloading https://files.pythonhosted.org/packages/d1/3f/73c881ea4723e43c1e9acf317cf407fab3a278da
ab3a69c98dcac511c04f/tokenizers-0.5.2-cp36-cp36m-manylinux1_x86_64.whl (3.7MB)
     |████████████████████████████████| 3.7MB 57.5MB/s
Requirement already satisfied: six in /usr/local/lib/python3.6/dist-packages (from sacremoses->trans
formers==2.8.0) (1.15.0)
Requirement already satisfied: click in /usr/local/lib/python3.6/dist-packages (from sacremoses->tra
nsformers==2.8.0) (7.1.2)
Requirement already satisfied: joblib in /usr/local/lib/python3.6/dist-packages (from sacremoses->tr
ansformers==2.8.0) (0.16.0)
Requirement already satisfied: jmespath<1.0.0,>=0.7.1 in /usr/local/lib/python3.6/dist-packages (fro
m boto3->transformers==2.8.0) (0.10.0)
Requirement already satisfied: s3transfer<0.4.0,>=0.3.0 in /usr/local/lib/python3.6/dist-packages (f
rom boto3->transformers==2.8.0) (0.3.3)
Requirement already satisfied: botocore<1.18.0,>=1.17.22 in /usr/local/lib/python3.6/dist-packages
(from boto3->transformers==2.8.0) (1.17.22)
Requirement already satisfied: urllib3!=1.25.0,!=1.25.1,<1.26,>=1.21.1 in /usr/local/lib/python3.6/d
```

```
ist-packages (from requests->transformers==2.8.0) (1.24.3)
Requirement already satisfied: idna<3,>=2.5 in /usr/local/lib/python3.6/dist-packages (from requests
->transformers==2.8.0) (2.10)
Requirement already satisfied: certifi>=2017.4.17 in /usr/local/lib/python3.6/dist-packages (from re
quests->transformers==2.8.0) (2020.6.20)
Requirement already satisfied: chardet<4,>=3.0.2 in /usr/local/lib/python3.6/dist-packages (from req
uests->transformers==2.8.0) (3.0.4)
Requirement already satisfied: python-dateutil<3.0.0,>=2.1 in /usr/local/lib/python3.6/dist-packages
(from botocore<1.18.0,>=1.17.22->boto3->transformers==2.8.0) (2.8.1)
Requirement already satisfied: docutils<0.16,>=0.10 in /usr/local/lib/python3.6/dist-packages (from
botocore<1.18.0,>=1.17.22->boto3->transformers==2.8.0) (0.15.2)
Building wheels for collected packages: sacremoses
  Building wheel for sacremoses (setup.py) ... done
  Created wheel for sacremoses: filename=sacremoses-0.0.43-cp36-none-any.whl size=893260 sha256=cbd7
c1a6e23913a8ef39b75b3982de259d8be2c5294be333d16817ef226577a3
  Stored in directory: /root/.cache/pip/wheels/29/3c/fd/7ce5c3f0666dab31a50123635e6fb5e19ceb42ce38d4
e58f45
Successfully built sacremoses
Installing collected packages: sacremoses, sentencepiece, tokenizers, transformers
Successfully installed sacremoses-0.0.43 sentencepiece-0.1.91 tokenizers-0.5.2 transformers-2.8.0
```

In [2]:

```python
# importing necessary libraries
from typing import List, Tuple
import random
import html

import pandas as pd
import numpy as np
from sklearn.model_selection import GroupKFold, KFold
import matplotlib.pyplot as plt
from tqdm.notebook import tqdm
import tensorflow as tf
import tensorflow.keras.backend as K
import os
from scipy.stats import spearmanr
from scipy.optimize import minimize
from math import floor, ceil
from transformers import *
from tensorflow.keras.layers import Flatten, Dense, Dropout, GlobalAveragePooling1D
from tensorflow.keras.models import Model
```

In [3]:

```
# fixing random seeds
seed = 13
random.seed(seed)
os.environ['PYTHONHASHSEED'] = str(seed)
np.random.seed(seed)
tf.random.set_seed(seed)
```

In [4]:

```
from google.colab import drive
drive.mount('/content/drive')
```

```
Go to this URL in a browser: https://accounts.google.com/o/oauth2/auth?client_id=947318989803-6bn6qk
8qdgf4n4g3pfee6491hc0brc4i.apps.googleusercontent.com&redirect_uri=urn%3aietf%3awg%3aoauth%3a2.0%3ao
ob&response_type=code&scope=email%20https%3a%2f%2fwww.googleapis.com%2fauth%2fdocs.test%20https%3a%2
f%2fwww.googleapis.com%2fauth%2fdrive%20https%3a%2f%2fwww.googleapis.com%2fauth%2fdrive.photos.reado
nly%20https%3a%2f%2fwww.googleapis.com%2fauth%2fpeopleapi.readonly

Enter your authorization code:
··········
Mounted at /content/drive
```

In [5]:

```
# reading the data into dataframe using pandas
train = pd.read_csv('drive/My Drive/case_study_2/train.csv')
test = pd.read_csv('drive/My Drive/case_study_2/test.csv')
submission = pd.read_csv('drive/My Drive/case_study_2/sample_submission.csv')
```

In [6]:

```
# Selecting data for training and testing
y = train[train.columns[11:]] # storing the target values in y
X = train[['question_title', 'question_body', 'answer']]
X_test = test[['question_title', 'question_body', 'answer']]
```

In [7]:

```
# Cleaning the data
X.question_body = X.question_body.apply(html.unescape)
X.question_title = X.question_title.apply(html.unescape)
X.answer = X.answer.apply(html.unescape)

X_test.question_body = X_test.question_body.apply(html.unescape)
X_test.question_title = X_test.question_title.apply(html.unescape)
X_test.answer = X_test.answer.apply(html.unescape)
```

```
/usr/local/lib/python3.6/dist-packages/pandas/core/generic.py:5303: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: https://pandas.pydata.org/pandas-docs/stable/user_guide/indexi
ng.html#returning-a-view-versus-a-copy
  self[name] = value
```

In [8]:

```
tokenizer = RobertaTokenizer.from_pretrained('roberta-base')
MAX_SEQUENCE_LENGTH = 512

# this function trims the tokens with length > 512 to match with the bert input.
'''
In the function below, if the input sentence has the number of tokens > 512, the
sentence is trimmed down to 512. To trim the number of tokens, 256 tokens from
the start and 256 tokens from the end are kept and the remaining tokens are dropped.
Ex. suppose an answer has 700 tokens, to trim this down to 512, 256 tokens from the
beginning are taken and 256 tokens from the end are taken and concatenated to make
512 tokens. The remaining [700-(256+256) = 288] tokens that are in the middle of the
answer are dropped. The logic makes sense because in large texts, the beginning part
usually describes what the text is all about and the end part describes the conclusion
of the text. This is also closely related to the target features that we need to predict.
'''
def _trim_input(question_tokens, answer_tokens, max_sequence_length=512, q_max_len=254, a_max_len=254):
    q_len = len(question_tokens)
    a_len = len(answer_tokens)
    if q_len + a_len + 3 > max_sequence_length:
        if a_max_len <= a_len and q_max_len <= q_len:
            q_new_len_head = q_max_len//2
            question_tokens = question_tokens[:q_new_len_head] + question_tokens[-q_new_len_head:]
            a_new_len_head = a_max_len//2
            answer_tokens = answer_tokens[:a_new_len_head] + answer_tokens[-a_new_len_head:]
        elif q_len <= a_len and q_len < q_max_len:
            a_max_len = a_max_len + (q_max_len - q_len - 1)
            a_new_len_head = a_max_len//2
            answer_tokens = answer_tokens[:a_new_len_head] + answer_tokens[-a_new_len_head:]
        elif a_len < q_len:
            q_max_len = q_max_len + (a_max_len - a_len - 1)
            q_new_len_head = q_max_len//2
            question_tokens = question_tokens[:q_new_len_head] + question_tokens[-q_new_len_head:]

    return question_tokens, answer_tokens
```

In [9]:

```
# function for tokenizing the input data for bert
def _convert_to_transformer_inputs(title, question, answer, tokenizer, question_only=False):
    question = f"{title} [SEP] {question}"
    question_tokens = tokenizer.tokenize(question)
    if question_only:
        answer_tokens = []
    else:
        answer_tokens = tokenizer.tokenize(answer)
    question_tokens, answer_tokens = _trim_input(question_tokens, answer_tokens)
    ids = tokenizer.convert_tokens_to_ids(["[CLS]"] + question_tokens + ["[SEP]"] + answer_tokens + ["[SEP]"])
    padded_ids = ids + [tokenizer.pad_token_id] * (MAX_SEQUENCE_LENGTH - len(ids))
    token_type_ids = [0] * (1 + len(question_tokens) + 1) + [1] * (len(answer_tokens) + 1) + [0] * (MAX_SEQUENCE_LENGTH - len(ids))
    attention_mask = [1] * len(ids) + [0] * (MAX_SEQUENCE_LENGTH - len(ids))
    return padded_ids, token_type_ids, attention_mask
```

In [10]:

```
# function for creating the input_ids, masks and segments for the bert input
def compute_input_arrays(df, question_only=False):
    input_ids, input_token_type_ids, input_attention_masks = [], [], []
    for title, body, answer in zip(df["question_title"].values, df["question_body"].values, df["answer"].values):
        ids, type_ids, mask = _convert_to_transformer_inputs(title, body, answer, tokenizer, question_only=question_only)
        input_ids.append(ids)
        input_token_type_ids.append(type_ids)
        input_attention_masks.append(mask)
    return (
        np.asarray(input_ids, dtype=np.int32),
        np.asarray(input_attention_masks, dtype=np.int32),
        np.asarray(input_token_type_ids, dtype=np.int32)
    )


def compute_output_arrays(df):
    return np.asarray(df[output_categories])
```

In [11]:

```
tokenizer.vocab_size
```

Out[11]:

```
50265
```

In [12]:

```
# Creating the model
K.clear_session()
max_seq_length = 512

input_tokens = tf.keras.layers.Input(shape=(max_seq_length,), dtype=tf.int32, name="input_tokens")
input_mask = tf.keras.layers.Input(shape=(max_seq_length,), dtype=tf.int32, name="input_mask")
# input_segment = tf.keras.layers.Input(shape=(max_seq_length,), dtype=tf.int32, name="input_segment")

#bert layer
roberta_config = RobertaConfig.from_pretrained('roberta-base', output_hidden_states=True)
roberta_model = TFRobertaModel.from_pretrained('roberta-base', config=roberta_config)

sequence_output, pooler_output, hidden_states = roberta_model([input_tokens, input_mask])

# Last 4 hidden layers of bert
h12 = tf.reshape(hidden_states[-1][:,0],(-1,1,768))
h11 = tf.reshape(hidden_states[-2][:,0],(-1,1,768))
h10 = tf.reshape(hidden_states[-3][:,0],(-1,1,768))
h09 = tf.reshape(hidden_states[-4][:,0],(-1,1,768))
concat_hidden = tf.keras.layers.Concatenate(axis=2)([h12, h11, h10, h09])

x = GlobalAveragePooling1D()(concat_hidden)

x = Dropout(0.2)(x)

output = Dense(30, activation='sigmoid')(x)

model_qa = Model(inputs=[input_tokens, input_mask], outputs=output)
```

In [13]:

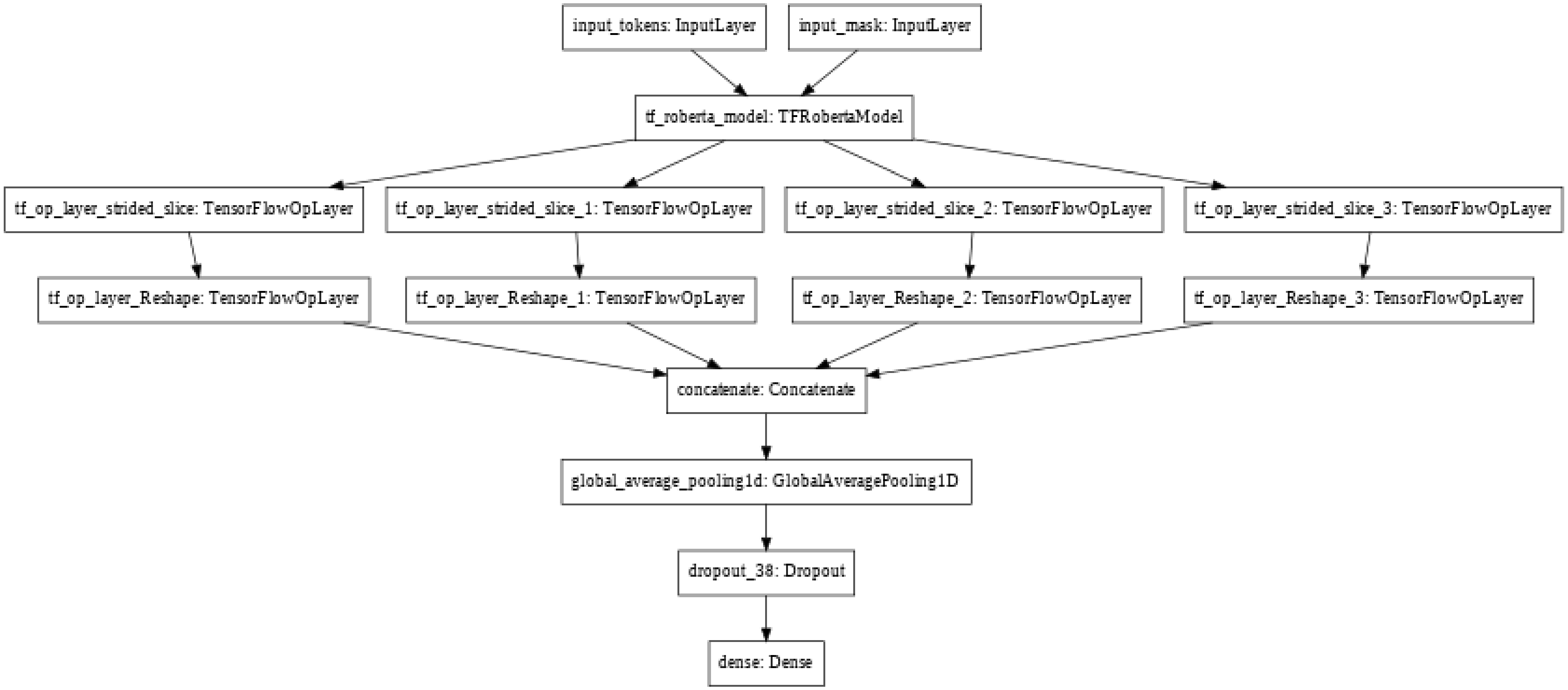
```
model_qa.summary()
```

```
Model: "model"
__________________________________________________________________________________________________
Layer (type)                    Output Shape         Param #     Connected to
==================================================================================================
input_tokens (InputLayer)       [(None, 512)]        0
__________________________________________________________________________________________________
input_mask (InputLayer)         [(None, 512)]        0
__________________________________________________________________________________________________
tf_roberta_model (TFRobertaMode ((None, 512, 768), ( 124645632   input_tokens[0][0]
                                                                 input_mask[0][0]
__________________________________________________________________________________________________
tf_op_layer_strided_slice (Tens [(None, 768)]        0           tf_roberta_model[0][14]
__________________________________________________________________________________________________
tf_op_layer_strided_slice_1 (Te [(None, 768)]        0           tf_roberta_model[0][13]
__________________________________________________________________________________________________
tf_op_layer_strided_slice_2 (Te [(None, 768)]        0           tf_roberta_model[0][12]
__________________________________________________________________________________________________
tf_op_layer_strided_slice_3 (Te [(None, 768)]        0           tf_roberta_model[0][11]
__________________________________________________________________________________________________
tf_op_layer_Reshape (TensorFlow [(None, 1, 768)]     0           tf_op_layer_strided_slice[0][0]
__________________________________________________________________________________________________
tf_op_layer_Reshape_1 (TensorFl [(None, 1, 768)]     0           tf_op_layer_strided_slice_1[0][0]
__________________________________________________________________________________________________
tf_op_layer_Reshape_2 (TensorFl [(None, 1, 768)]     0           tf_op_layer_strided_slice_2[0][0]
__________________________________________________________________________________________________
tf_op_layer_Reshape_3 (TensorFl [(None, 1, 768)]     0           tf_op_layer_strided_slice_3[0][0]
__________________________________________________________________________________________________
concatenate (Concatenate)       (None, 1, 3072)      0           tf_op_layer_Reshape[0][0]
                                                                 tf_op_layer_Reshape_1[0][0]
                                                                 tf_op_layer_Reshape_2[0][0]
                                                                 tf_op_layer_Reshape_3[0][0]
__________________________________________________________________________________________________
global_average_pooling1d (Globa (None, 3072)         0           concatenate[0][0]
__________________________________________________________________________________________________
dropout_38 (Dropout)            (None, 3072)         0           global_average_pooling1d[0][0]
__________________________________________________________________________________________________
dense (Dense)                   (None, 30)           92190       dropout_38[0][0]
==================================================================================================
Total params: 124,737,822
Trainable params: 124,737,822
Non-trainable params: 0
__________________________________________________________________________________________________
```

In [15]:

```
tf.keras.utils.plot_model(
    model_qa, to_file='model.png',
    show_shapes=False,
    show_layer_names=True,
    rankdir='TB',
    expand_nested=False, dpi=48
)
```

Out[15]:


input_tokens: InputLayer
input_mask: InputLayer
tf_roberta_model: TFRobertaModel
tf_op_layer_strided_slice: TensorFlowOpLayer
tf_op_layer_strided_slice_1: TensorFlowOpLayer
tf_op_layer_strided_slice_2: TensorFlowOpLayer
tf_op_layer_strided_slice_3: TensorFlowOpLayer
tf_op_layer_Reshape: TensorFlowOpLayer
tf_op_layer_Reshape_1: TensorFlowOpLayer
tf_op_layer_Reshape_2: TensorFlowOpLayer
tf_op_layer_Reshape_3: TensorFlowOpLayer
concatenate: Concatenate
global_average_pooling1d: GlobalAveragePooling1D
dropout_38: Dropout
dense: Dense

In [16]:

```
# test data
tokens, masks, segments = compute_input_arrays(X_test)
test_data = {'input_tokens': tokens,
             'input_mask': masks}
```

In [17]:

```
# Train data
tokens, masks, segments = compute_input_arrays(X)
def generate_data(tr, cv):
  train_data = {'input_tokens': tokens[tr],
              'input_mask': masks[tr]}

  cv_data = {'input_tokens': tokens[cv],
              'input_mask': masks[cv]}

  return train_data, cv_data, y.values[tr], y.values[cv]
```

In [18]:

```
# Function to calculate the Spearman's rank correlation coefficient 'rhos' of actual and predicted data.
from scipy.stats import spearmanr
def compute_spearmanr_ignore_nan(trues, preds):
    rhos = []
    for tcol, pcol in zip(np.transpose(trues), np.transpose(preds)):
        rhos.append(spearmanr(tcol, pcol).correlation)
    return np.nanmean(rhos)
```

In [19]:

```
# Making the 'rhos' metric to tensorflow graph compatible.
def rhos(y, y_pred):
  return tf.py_function(compute_spearmanr_ignore_nan, (y, y_pred), tf.double)
metrics = [rhos]
```

In [21]:

```
from sklearn.model_selection import KFold
# Compiling and training the model
optimizer = tf.keras.optimizers.Adam(learning_rate=0.00002)
model_qa.compile(loss='binary_crossentropy', optimizer=optimizer, metrics=metrics)
kf = KFold(n_splits=5, random_state=42)
for tr, cv in kf.split(np.arange(train.shape[0])):
  tr_data, cv_data, y_tr, y_cv = generate_data(tr, cv)
  model_qa.fit(tr_data, y_tr, epochs=1, batch_size=4, validation_data=(cv_data, y_cv))
```

```
/usr/local/lib/python3.6/dist-packages/sklearn/model_selection/_split.py:296: FutureWarning: Setting
a random_state has no effect since shuffle is False. This will raise an error in 0.24. You should le
ave random_state to its default (None), or set shuffle=True.
  FutureWarning


WARNING:tensorflow:Gradients do not exist for variables ['tf_roberta_model/roberta/pooler/dense/kern
el:0', 'tf_roberta_model/roberta/pooler/dense/bias:0'] when minimizing the loss.
WARNING:tensorflow:Gradients do not exist for variables ['tf_roberta_model/roberta/pooler/dense/kern
el:0', 'tf_roberta_model/roberta/pooler/dense/bias:0'] when minimizing the loss.
WARNING:tensorflow:Gradients do not exist for variables ['tf_roberta_model/roberta/pooler/dense/kern
el:0', 'tf_roberta_model/roberta/pooler/dense/bias:0'] when minimizing the loss.
WARNING:tensorflow:Gradients do not exist for variables ['tf_roberta_model/roberta/pooler/dense/kern
el:0', 'tf_roberta_model/roberta/pooler/dense/bias:0'] when minimizing the loss.

/usr/local/lib/python3.6/dist-packages/numpy/lib/function_base.py:2534: RuntimeWarning: invalid valu
e encountered in true_divide
  c /= stddev[:, None]
/usr/local/lib/python3.6/dist-packages/numpy/lib/function_base.py:2535: RuntimeWarning: invalid valu
e encountered in true_divide
  c /= stddev[None, :]
/usr/local/lib/python3.6/dist-packages/scipy/stats/_distn_infrastructure.py:903: RuntimeWarning: inv
alid value encountered in greater
  return (a < x) & (x < b)
/usr/local/lib/python3.6/dist-packages/scipy/stats/_distn_infrastructure.py:903: RuntimeWarning: inv
alid value encountered in less
  return (a < x) & (x < b)
/usr/local/lib/python3.6/dist-packages/scipy/stats/_distn_infrastructure.py:1912: RuntimeWarning: in
valid value encountered in less_equal
  cond2 = cond0 & (x <= _a)
```

```
1216/1216 [==============================] - 695s 572ms/step - loss: 0.4107 - rhos: 0.2305 - val_los
s: 0.3780 - val_rhos: 0.3702
1216/1216 [==============================] - 701s 576ms/step - loss: 0.3833 - rhos: 0.3282 - val_los
s: 0.3627 - val_rhos: 0.4061
1216/1216 [==============================] - 700s 576ms/step - loss: 0.3713 - rhos: 0.3700 - val_los
s: 0.3569 - val_rhos: 0.4558
1216/1216 [==============================] - 701s 577ms/step - loss: 0.3632 - rhos: 0.4050 - val_los
s: 0.3446 - val_rhos: 0.4830
WARNING:tensorflow:Gradients do not exist for variables ['tf_roberta_model/roberta/pooler/dense/kern
el:0', 'tf_roberta_model/roberta/pooler/dense/bias:0'] when minimizing the loss.
WARNING:tensorflow:Gradients do not exist for variables ['tf_roberta_model/roberta/pooler/dense/kern
el:0', 'tf_roberta_model/roberta/pooler/dense/bias:0'] when minimizing the loss.
1216/1216 [==============================] - 692s 569ms/step - loss: 0.3546 - rhos: 0.4305 - val_los
s: 0.3397 - val_rhos: 0.5082
```

In [22]:

```
model_qa.save_weights("drive/My Drive/roberta_model_qa.h5")
```

In [23]:

```
# Train data
tokens, masks, segments = compute_input_arrays(X)
train_data = {'input_tokens': tokens,
             'input_mask': masks}
```

In [25]:

```
# Predicting the train and test data labels
pred_a_test = model_qa.predict(test_data)
pred_a_train = model_qa.predict(train_data)

# saving the predicted labels as dataframes
df = pd.DataFrame(pred_a_train, columns=y.columns)
df.to_csv('roberta_pred_qa_train.csv', index=False)

df = pd.DataFrame(pred_a_test, columns=y.columns)
df.to_csv('roberta_pred_qa_test.csv', index=False)
```

In [ ]: