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May 11, 2022

1 Tuning Neural Networks with Regularization - Lab

1.1 Introduction

In this lab, you'll use a train-test partition as well as a validation set to get better insights about how to tune neural networks using regularization techniques. You'll start by repeating the process from the last section: importing the data and performing preprocessing including one-hot encoding. From there, you'll define and compile the model like before.

1.2 Objectives

You will be able to:

- Apply early stopping criteria with a neural network
- Apply L1, L2, and dropout regularization on a neural network

- Examine the effects of training with more data on a neural network

1.3 Load the Data

Run the following cell to import some of the libraries and classes you'll need in this lab.

[1]:
```
import pandas as pd
import numpy as np
import random
import matplotlib.pyplot as plt
%matplotlib inline
from sklearn.model_selection import train_test_split
from keras.utils.np_utils import to_categorical
from sklearn.preprocessing import LabelBinarizer
from keras.preprocessing.text import Tokenizer

import warnings
warnings.filterwarnings(action='ignore', category=FutureWarning)
```

The data is stored in the file `'Bank_complaints.csv'`. Load and preview the dataset.

[2]:
```
# Load and preview the dataset
df = pd.read_csv('Bank_complaints.csv')
df.head()
```

[2]:
```
        Product                              Consumer complaint narrative
0  Student loan  In XX/XX/XXXX I filled out the Fedlaon applica…
1  Student loan  I am being contacted by a debt collector for p…
2  Student loan  I cosigned XXXX student loans at SallieMae for…
3  Student loan  Navient has sytematically and illegally failed…
4  Student loan  My wife became eligible for XXXX Loan Forgiven…
```

1.4 Preprocessing Overview

Before you begin to practice some of your new tools such as regularization and optimization, let's practice munging some data as you did in the previous section with bank complaints. Recall some techniques:

- Sampling in order to reduce training time (investigate model accuracy vs data size later on)
- Train - test split
- One-hot encoding your complaint text
- Transforming your category labels

1.5 Preprocessing: Generate a Random Sample

Since you have quite a bit of data and training neural networks takes a substantial amount of time and resources, downsample in order to test your initial pipeline. Going forward, these can be interesting areas of investigation: how does your model's performance change as you increase (or decrease) the size of your dataset?

- Generate a random sample of 10,000 observations using seed 123 for consistency of results.
- Split this sample into `X` and `y`

[3]:
```
# Downsample the data
df_sample = df.sample(10000, random_state = 123)

# Split the data into X and y
y = df_sample["Product"]

X = df_sample['Consumer complaint narrative']

### The Following Does Not Work
# X2 = df_sample.drop("Product", axis = 1)
```

1.6 Train-test split

- Split the data into training and test sets
- Assign 1500 obervations to the test set and use 42 as the seed

[4]:
```
# Split data into training and test sets
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size = 1500,
                                                    random_state = 42)
```

1.7 Validation set

As mentioned in the previous lesson, it is good practice to set aside a validation set, which is then used during hyperparameter tuning. Afterwards, when you have decided upon a final model, the test set can then be used to determine an unbiased perforance of the model.

Run the cell below to further divide the training data into training and validation sets.

[5]:
```
# Split the data into training and validation sets
X_train_final, X_val, y_train_final, y_val = train_test_split(X_train,
                                                              y_train,
                                                              test_size=1000,
                                                              random_state=42)
```

1.8 Preprocessing: One-hot Encoding the Complaints

As before, you need to do some preprocessing before building a neural network model.

- Keep the 2,000 most common words and use one-hot encoding to reformat the complaints into a matrix of vectors
- Transform the training, validate, and test sets

[6]:
```
# Use one-hot encoding to reformat the complaints into a matrix of vectors
# Only keep the 2000 most common words

tokenizer = Tokenizer(num_words = 2000)
tokenizer.fit_on_texts(X_train_final)

X_train_tokens = tokenizer.texts_to_matrix(X_train_final, mode = 'binary')
X_val_tokens   = tokenizer.texts_to_matrix(X_val, mode = 'binary')
X_test_tokens  = tokenizer.texts_to_matrix(X_test, mode = 'binary')
```

1.9 Preprocessing: Encoding the Products

Similarly, now transform the descriptive product labels to integers labels. After transforming them to integer labels, retransform them into a matrix of binary flags, one for each of the various product labels.

> **Note**: This is similar to your previous work with dummy variables. Each of the various product categories will be its own column, and each observation will be a row. In turn, each of these observation rows will have a 1 in the column associated with it's label, and all other entries for the row will be zero.

Transform the training, validate, and test sets.

[7]:
```
# Transform the product labels to numerical values
lb = LabelBinarizer()
lb.fit(y_train_final)
```

```
y_train_lb = to_categorical(lb.transform(y_train_final))[:,:,1]
y_val_lb   = to_categorical(lb.transform(y_val))[:,:,1]
y_test_lb  = to_categorical(lb.transform(y_test))[:,:,1]
```

1.10 A Baseline Model

Rebuild a fully connected (Dense) layer network:
- Use 2 hidden layers with 50 units in the first and 25 in the second layer, both with `'relu'` activation functions (since you are dealing with a multiclass problem, classifying the complaints into 7 classes) - Use a `'softmax'` activation function for the output layer

[8]:
```
X_train_tokens.shape[1]
```

[8]: 2000

[9]:
```
# Build a baseline neural network model using Keras
random.seed(123)
from keras import models
from keras import layers
baseline_model = models.Sequential()

baseline_model.add(layers.Dense(50,
                                activation = "relu",
                                input_shape = (2000,)))

baseline_model.add(layers.Dense(25, activation = "relu"))
baseline_model.add(layers.Dense(7, activation = "softmax"))
```

1.10.1 Compile the Model

Compile this model with:

- a stochastic gradient descent optimizer
- `'categorical_crossentropy'` as the loss function
- a focus on `'accuracy'`

[10]:
```
# Compile the model
baseline_model.compile(optimizer = "sgd",
                       loss = "categorical_crossentropy",
                       metrics = ["acc"])
```

1.10.2 Train the Model

- Train the model for 150 epochs in mini-batches of 256 samples
- Include the `validation_data` argument to ensure you keep track of the validation loss

[11]:
```
baseline_model_val = baseline_model.fit(X_train_tokens,
                                        y_train_lb,
```

```
                                        epochs=150,
                                        batch_size=256,
                                        validation_data=(X_val_tokens,␣
↪y_val_lb))
```

```
Epoch 1/150
30/30 [==============================] - 0s 8ms/step - loss: 1.9627 - acc:
0.1489 - val_loss: 1.9482 - val_acc: 0.1450
Epoch 2/150
30/30 [==============================] - 0s 3ms/step - loss: 1.9344 - acc:
0.1731 - val_loss: 1.9308 - val_acc: 0.1980
Epoch 3/150
30/30 [==============================] - 0s 3ms/step - loss: 1.9165 - acc:
0.2145 - val_loss: 1.9151 - val_acc: 0.2280
Epoch 4/150
30/30 [==============================] - 0s 3ms/step - loss: 1.8977 - acc:
0.2491 - val_loss: 1.8968 - val_acc: 0.2450
Epoch 5/150
30/30 [==============================] - 0s 3ms/step - loss: 1.8755 - acc:
0.2728 - val_loss: 1.8739 - val_acc: 0.2720
Epoch 6/150
30/30 [==============================] - 0s 3ms/step - loss: 1.8487 - acc:
0.2971 - val_loss: 1.8460 - val_acc: 0.2980
Epoch 7/150
30/30 [==============================] - 0s 3ms/step - loss: 1.8169 - acc:
0.3212 - val_loss: 1.8125 - val_acc: 0.3170
Epoch 8/150
30/30 [==============================] - 0s 3ms/step - loss: 1.7791 - acc:
0.3440 - val_loss: 1.7737 - val_acc: 0.3420
Epoch 9/150
30/30 [==============================] - 0s 3ms/step - loss: 1.7365 - acc:
0.3712 - val_loss: 1.7322 - val_acc: 0.3600
Epoch 10/150
30/30 [==============================] - 0s 3ms/step - loss: 1.6913 - acc:
0.3961 - val_loss: 1.6882 - val_acc: 0.3840
Epoch 11/150
30/30 [==============================] - 0s 3ms/step - loss: 1.6446 - acc:
0.4181 - val_loss: 1.6428 - val_acc: 0.4120
Epoch 12/150
30/30 [==============================] - 0s 3ms/step - loss: 1.5966 - acc:
0.4479 - val_loss: 1.5961 - val_acc: 0.4410
Epoch 13/150
30/30 [==============================] - 0s 3ms/step - loss: 1.5485 - acc:
0.4792 - val_loss: 1.5487 - val_acc: 0.4680
Epoch 14/150
30/30 [==============================] - 0s 3ms/step - loss: 1.4995 - acc:
0.5061 - val_loss: 1.5003 - val_acc: 0.5040
```

```
Epoch 15/150
30/30 [==============================] - 0s 3ms/step - loss: 1.4509 - acc:
0.5367 - val_loss: 1.4541 - val_acc: 0.5160
Epoch 16/150
30/30 [==============================] - 0s 3ms/step - loss: 1.4029 - acc:
0.5585 - val_loss: 1.4073 - val_acc: 0.5480
Epoch 17/150
30/30 [==============================] - 0s 3ms/step - loss: 1.3558 - acc:
0.5776 - val_loss: 1.3617 - val_acc: 0.5640
Epoch 18/150
30/30 [==============================] - 0s 5ms/step - loss: 1.3102 - acc:
0.5979 - val_loss: 1.3176 - val_acc: 0.5810
Epoch 19/150
30/30 [==============================] - 0s 3ms/step - loss: 1.2660 - acc:
0.6160 - val_loss: 1.2753 - val_acc: 0.5890
Epoch 20/150
30/30 [==============================] - 0s 3ms/step - loss: 1.2240 - acc:
0.6273 - val_loss: 1.2357 - val_acc: 0.6060
Epoch 21/150
30/30 [==============================] - 0s 3ms/step - loss: 1.1840 - acc:
0.6396 - val_loss: 1.1995 - val_acc: 0.6110
Epoch 22/150
30/30 [==============================] - 0s 3ms/step - loss: 1.1464 - acc:
0.6472 - val_loss: 1.1621 - val_acc: 0.6280
Epoch 23/150
30/30 [==============================] - 0s 3ms/step - loss: 1.1109 - acc:
0.6580 - val_loss: 1.1292 - val_acc: 0.6360
Epoch 24/150
30/30 [==============================] - 0s 3ms/step - loss: 1.0775 - acc:
0.6672 - val_loss: 1.0980 - val_acc: 0.6520
Epoch 25/150
30/30 [==============================] - 0s 3ms/step - loss: 1.0459 - acc:
0.6756 - val_loss: 1.0678 - val_acc: 0.6540
Epoch 26/150
30/30 [==============================] - 0s 3ms/step - loss: 1.0164 - acc:
0.6819 - val_loss: 1.0419 - val_acc: 0.6560
Epoch 27/150
30/30 [==============================] - 0s 3ms/step - loss: 0.9891 - acc:
0.6855 - val_loss: 1.0177 - val_acc: 0.6680
Epoch 28/150
30/30 [==============================] - 0s 3ms/step - loss: 0.9635 - acc:
0.6923 - val_loss: 0.9932 - val_acc: 0.6680
Epoch 29/150
30/30 [==============================] - 0s 3ms/step - loss: 0.9395 - acc:
0.6981 - val_loss: 0.9708 - val_acc: 0.6760
Epoch 30/150
30/30 [==============================] - 0s 3ms/step - loss: 0.9171 - acc:
0.7043 - val_loss: 0.9531 - val_acc: 0.6760
```

```
Epoch 31/150
30/30 [==============================] - 0s 3ms/step - loss: 0.8961 - acc:
0.7115 - val_loss: 0.9346 - val_acc: 0.6830
Epoch 32/150
30/30 [==============================] - 0s 3ms/step - loss: 0.8767 - acc:
0.7149 - val_loss: 0.9132 - val_acc: 0.6910
Epoch 33/150
30/30 [==============================] - 0s 3ms/step - loss: 0.8583 - acc:
0.7213 - val_loss: 0.8997 - val_acc: 0.6890
Epoch 34/150
30/30 [==============================] - 0s 3ms/step - loss: 0.8409 - acc:
0.7239 - val_loss: 0.8845 - val_acc: 0.6950
Epoch 35/150
30/30 [==============================] - 0s 3ms/step - loss: 0.8252 - acc:
0.7292 - val_loss: 0.8715 - val_acc: 0.6920
Epoch 36/150
30/30 [==============================] - 0s 3ms/step - loss: 0.8094 - acc:
0.7337 - val_loss: 0.8599 - val_acc: 0.7010
Epoch 37/150
30/30 [==============================] - 0s 3ms/step - loss: 0.7953 - acc:
0.7360 - val_loss: 0.8472 - val_acc: 0.6960
Epoch 38/150
30/30 [==============================] - 0s 3ms/step - loss: 0.7820 - acc:
0.7380 - val_loss: 0.8352 - val_acc: 0.7000
Epoch 39/150
30/30 [==============================] - 0s 3ms/step - loss: 0.7694 - acc:
0.7441 - val_loss: 0.8270 - val_acc: 0.6980
Epoch 40/150
30/30 [==============================] - 0s 3ms/step - loss: 0.7571 - acc:
0.7461 - val_loss: 0.8187 - val_acc: 0.7010
Epoch 41/150
30/30 [==============================] - 0s 3ms/step - loss: 0.7453 - acc:
0.7500 - val_loss: 0.8056 - val_acc: 0.7060
Epoch 42/150
30/30 [==============================] - 0s 3ms/step - loss: 0.7345 - acc:
0.7520 - val_loss: 0.7992 - val_acc: 0.6970
Epoch 43/150
30/30 [==============================] - 0s 3ms/step - loss: 0.7243 - acc:
0.7567 - val_loss: 0.7901 - val_acc: 0.7060
Epoch 44/150
30/30 [==============================] - 0s 3ms/step - loss: 0.7143 - acc:
0.7581 - val_loss: 0.7817 - val_acc: 0.7060
Epoch 45/150
30/30 [==============================] - 0s 4ms/step - loss: 0.7047 - acc:
0.7579 - val_loss: 0.7763 - val_acc: 0.7120
Epoch 46/150
30/30 [==============================] - 0s 3ms/step - loss: 0.6956 - acc:
0.7605 - val_loss: 0.7765 - val_acc: 0.7070
```

```
Epoch 47/150
30/30 [==============================] - 0s 3ms/step - loss: 0.6876 - acc:
0.7629 - val_loss: 0.7630 - val_acc: 0.7080
Epoch 48/150
30/30 [==============================] - 0s 3ms/step - loss: 0.6790 - acc:
0.7667 - val_loss: 0.7590 - val_acc: 0.7160
Epoch 49/150
30/30 [==============================] - 0s 3ms/step - loss: 0.6711 - acc:
0.7685 - val_loss: 0.7507 - val_acc: 0.7130
Epoch 50/150
30/30 [==============================] - 0s 3ms/step - loss: 0.6634 - acc:
0.7725 - val_loss: 0.7453 - val_acc: 0.7180
Epoch 51/150
30/30 [==============================] - 0s 3ms/step - loss: 0.6556 - acc:
0.7741 - val_loss: 0.7428 - val_acc: 0.7150
Epoch 52/150
30/30 [==============================] - 0s 3ms/step - loss: 0.6488 - acc:
0.7764 - val_loss: 0.7354 - val_acc: 0.7180
Epoch 53/150
30/30 [==============================] - 0s 3ms/step - loss: 0.6418 - acc:
0.7779 - val_loss: 0.7304 - val_acc: 0.7180
Epoch 54/150
30/30 [==============================] - 0s 3ms/step - loss: 0.6346 - acc:
0.7801 - val_loss: 0.7337 - val_acc: 0.7180
Epoch 55/150
30/30 [==============================] - 0s 3ms/step - loss: 0.6284 - acc:
0.7857 - val_loss: 0.7318 - val_acc: 0.7220
Epoch 56/150
30/30 [==============================] - 0s 3ms/step - loss: 0.6223 - acc:
0.7856 - val_loss: 0.7194 - val_acc: 0.7240
Epoch 57/150
30/30 [==============================] - 0s 3ms/step - loss: 0.6159 - acc:
0.7879 - val_loss: 0.7185 - val_acc: 0.7200
Epoch 58/150
30/30 [==============================] - 0s 3ms/step - loss: 0.6101 - acc:
0.7909 - val_loss: 0.7165 - val_acc: 0.7300
Epoch 59/150
30/30 [==============================] - 0s 3ms/step - loss: 0.6041 - acc:
0.7924 - val_loss: 0.7091 - val_acc: 0.7270
Epoch 60/150
30/30 [==============================] - 0s 3ms/step - loss: 0.5985 - acc:
0.7963 - val_loss: 0.7108 - val_acc: 0.7290
Epoch 61/150
30/30 [==============================] - 0s 3ms/step - loss: 0.5930 - acc:
0.7959 - val_loss: 0.7043 - val_acc: 0.7280
Epoch 62/150
30/30 [==============================] - 0s 3ms/step - loss: 0.5879 - acc:
0.8001 - val_loss: 0.7017 - val_acc: 0.7330
```

```
Epoch 63/150
30/30 [==============================] - 0s 3ms/step - loss: 0.5826 - acc:
0.7987 - val_loss: 0.7010 - val_acc: 0.7360
Epoch 64/150
30/30 [==============================] - 0s 3ms/step - loss: 0.5777 - acc:
0.8035 - val_loss: 0.6977 - val_acc: 0.7330
Epoch 65/150
30/30 [==============================] - 0s 3ms/step - loss: 0.5724 - acc:
0.8047 - val_loss: 0.6961 - val_acc: 0.7340
Epoch 66/150
30/30 [==============================] - 0s 3ms/step - loss: 0.5677 - acc:
0.8063 - val_loss: 0.6943 - val_acc: 0.7330
Epoch 67/150
30/30 [==============================] - 0s 3ms/step - loss: 0.5625 - acc:
0.8083 - val_loss: 0.6886 - val_acc: 0.7370
Epoch 68/150
30/30 [==============================] - 0s 3ms/step - loss: 0.5577 - acc:
0.8091 - val_loss: 0.6902 - val_acc: 0.7400
Epoch 69/150
30/30 [==============================] - 0s 3ms/step - loss: 0.5534 - acc:
0.8108 - val_loss: 0.6902 - val_acc: 0.7340
Epoch 70/150
30/30 [==============================] - 0s 3ms/step - loss: 0.5491 - acc:
0.8128 - val_loss: 0.6840 - val_acc: 0.7370
Epoch 71/150
30/30 [==============================] - 0s 3ms/step - loss: 0.5443 - acc:
0.8139 - val_loss: 0.6864 - val_acc: 0.7410
Epoch 72/150
30/30 [==============================] - 0s 3ms/step - loss: 0.5398 - acc:
0.8176 - val_loss: 0.6795 - val_acc: 0.7380
Epoch 73/150
30/30 [==============================] - 0s 3ms/step - loss: 0.5354 - acc:
0.8168 - val_loss: 0.6829 - val_acc: 0.7420
Epoch 74/150
30/30 [==============================] - 0s 3ms/step - loss: 0.5310 - acc:
0.8185 - val_loss: 0.6784 - val_acc: 0.7410
Epoch 75/150
30/30 [==============================] - 0s 3ms/step - loss: 0.5272 - acc:
0.8193 - val_loss: 0.6804 - val_acc: 0.7440
Epoch 76/150
30/30 [==============================] - 0s 3ms/step - loss: 0.5228 - acc:
0.8213 - val_loss: 0.6746 - val_acc: 0.7430
Epoch 77/150
30/30 [==============================] - 0s 3ms/step - loss: 0.5188 - acc:
0.8237 - val_loss: 0.6766 - val_acc: 0.7420
Epoch 78/150
30/30 [==============================] - 0s 3ms/step - loss: 0.5146 - acc:
0.8253 - val_loss: 0.6710 - val_acc: 0.7400
```

```
Epoch 79/150
30/30 [==============================] - 0s 3ms/step - loss: 0.5112 - acc:
0.8243 - val_loss: 0.6708 - val_acc: 0.7420
Epoch 80/150
30/30 [==============================] - 0s 3ms/step - loss: 0.5066 - acc:
0.8279 - val_loss: 0.6693 - val_acc: 0.7390
Epoch 81/150
30/30 [==============================] - 0s 3ms/step - loss: 0.5033 - acc:
0.8276 - val_loss: 0.6731 - val_acc: 0.7400
Epoch 82/150
30/30 [==============================] - 0s 3ms/step - loss: 0.4990 - acc:
0.8309 - val_loss: 0.6681 - val_acc: 0.7450
Epoch 83/150
30/30 [==============================] - 0s 3ms/step - loss: 0.4953 - acc:
0.8317 - val_loss: 0.6683 - val_acc: 0.7400
Epoch 84/150
30/30 [==============================] - 0s 3ms/step - loss: 0.4915 - acc:
0.8319 - val_loss: 0.6643 - val_acc: 0.7390
Epoch 85/150
30/30 [==============================] - 0s 3ms/step - loss: 0.4881 - acc:
0.8336 - val_loss: 0.6652 - val_acc: 0.7450
Epoch 86/150
30/30 [==============================] - 0s 3ms/step - loss: 0.4846 - acc:
0.8356 - val_loss: 0.6686 - val_acc: 0.7460
Epoch 87/150
30/30 [==============================] - 0s 3ms/step - loss: 0.4811 - acc:
0.8395 - val_loss: 0.6667 - val_acc: 0.7460
Epoch 88/150
30/30 [==============================] - 0s 3ms/step - loss: 0.4775 - acc:
0.8387 - val_loss: 0.6670 - val_acc: 0.7460
Epoch 89/150
30/30 [==============================] - 0s 3ms/step - loss: 0.4740 - acc:
0.8389 - val_loss: 0.6622 - val_acc: 0.7490
Epoch 90/150
30/30 [==============================] - 0s 3ms/step - loss: 0.4706 - acc:
0.8415 - val_loss: 0.6594 - val_acc: 0.7430
Epoch 91/150
30/30 [==============================] - 0s 3ms/step - loss: 0.4673 - acc:
0.8436 - val_loss: 0.6594 - val_acc: 0.7430
Epoch 92/150
30/30 [==============================] - 0s 3ms/step - loss: 0.4630 - acc:
0.8440 - val_loss: 0.6617 - val_acc: 0.7460
Epoch 93/150
30/30 [==============================] - 0s 3ms/step - loss: 0.4607 - acc:
0.8456 - val_loss: 0.6607 - val_acc: 0.7410
Epoch 94/150
30/30 [==============================] - 0s 3ms/step - loss: 0.4572 - acc:
0.8480 - val_loss: 0.6579 - val_acc: 0.7450
```

```
Epoch 95/150
30/30 [==============================] - 0s 3ms/step - loss: 0.4536 - acc:
0.8489 - val_loss: 0.6593 - val_acc: 0.7490
Epoch 96/150
30/30 [==============================] - 0s 3ms/step - loss: 0.4503 - acc:
0.8495 - val_loss: 0.6566 - val_acc: 0.7490
Epoch 97/150
30/30 [==============================] - 0s 3ms/step - loss: 0.4475 - acc:
0.8507 - val_loss: 0.6567 - val_acc: 0.7530
Epoch 98/150
30/30 [==============================] - 0s 3ms/step - loss: 0.4441 - acc:
0.8529 - val_loss: 0.6576 - val_acc: 0.7480
Epoch 99/150
30/30 [==============================] - 0s 3ms/step - loss: 0.4408 - acc:
0.8544 - val_loss: 0.6570 - val_acc: 0.7430
Epoch 100/150
30/30 [==============================] - 0s 3ms/step - loss: 0.4381 - acc:
0.8531 - val_loss: 0.6546 - val_acc: 0.7440
Epoch 101/150
30/30 [==============================] - 0s 4ms/step - loss: 0.4346 - acc:
0.8557 - val_loss: 0.6599 - val_acc: 0.7480
Epoch 102/150
30/30 [==============================] - 0s 3ms/step - loss: 0.4314 - acc:
0.8580 - val_loss: 0.6538 - val_acc: 0.7530
Epoch 103/150
30/30 [==============================] - 0s 3ms/step - loss: 0.4290 - acc:
0.8599 - val_loss: 0.6558 - val_acc: 0.7480
Epoch 104/150
30/30 [==============================] - 0s 3ms/step - loss: 0.4254 - acc:
0.8616 - val_loss: 0.6580 - val_acc: 0.7390
Epoch 105/150
30/30 [==============================] - 0s 3ms/step - loss: 0.4223 - acc:
0.8625 - val_loss: 0.6568 - val_acc: 0.7410
Epoch 106/150
30/30 [==============================] - 0s 3ms/step - loss: 0.4194 - acc:
0.8629 - val_loss: 0.6529 - val_acc: 0.7510
Epoch 107/150
30/30 [==============================] - 0s 3ms/step - loss: 0.4165 - acc:
0.8643 - val_loss: 0.6539 - val_acc: 0.7490
Epoch 108/150
30/30 [==============================] - 0s 3ms/step - loss: 0.4137 - acc:
0.8655 - val_loss: 0.6546 - val_acc: 0.7530
Epoch 109/150
30/30 [==============================] - 0s 3ms/step - loss: 0.4110 - acc:
0.8663 - val_loss: 0.6592 - val_acc: 0.7470
Epoch 110/150
30/30 [==============================] - 0s 3ms/step - loss: 0.4084 - acc:
0.8684 - val_loss: 0.6583 - val_acc: 0.7440
```

```
Epoch 111/150
30/30 [==============================] - 0s 3ms/step - loss: 0.4050 - acc:
0.8696 - val_loss: 0.6558 - val_acc: 0.7470
Epoch 112/150
30/30 [==============================] - 0s 3ms/step - loss: 0.4023 - acc:
0.8703 - val_loss: 0.6569 - val_acc: 0.7390
Epoch 113/150
30/30 [==============================] - 0s 3ms/step - loss: 0.3996 - acc:
0.8715 - val_loss: 0.6559 - val_acc: 0.7570
Epoch 114/150
30/30 [==============================] - 0s 3ms/step - loss: 0.3965 - acc:
0.8729 - val_loss: 0.6567 - val_acc: 0.7540
Epoch 115/150
30/30 [==============================] - 0s 3ms/step - loss: 0.3941 - acc:
0.8731 - val_loss: 0.6572 - val_acc: 0.7530
Epoch 116/150
30/30 [==============================] - 0s 3ms/step - loss: 0.3914 - acc:
0.8743 - val_loss: 0.6634 - val_acc: 0.7500
Epoch 117/150
30/30 [==============================] - 0s 3ms/step - loss: 0.3889 - acc:
0.8745 - val_loss: 0.6544 - val_acc: 0.7480
Epoch 118/150
30/30 [==============================] - 0s 3ms/step - loss: 0.3857 - acc:
0.8772 - val_loss: 0.6585 - val_acc: 0.7440
Epoch 119/150
30/30 [==============================] - 0s 3ms/step - loss: 0.3831 - acc:
0.8773 - val_loss: 0.6581 - val_acc: 0.7450
Epoch 120/150
30/30 [==============================] - 0s 3ms/step - loss: 0.3803 - acc:
0.8787 - val_loss: 0.6544 - val_acc: 0.7510
Epoch 121/150
30/30 [==============================] - 0s 3ms/step - loss: 0.3780 - acc:
0.8800 - val_loss: 0.6576 - val_acc: 0.7490
Epoch 122/150
30/30 [==============================] - 0s 3ms/step - loss: 0.3752 - acc:
0.8817 - val_loss: 0.6539 - val_acc: 0.7490
Epoch 123/150
30/30 [==============================] - 0s 3ms/step - loss: 0.3733 - acc:
0.8819 - val_loss: 0.6585 - val_acc: 0.7470
Epoch 124/150
30/30 [==============================] - 0s 3ms/step - loss: 0.3703 - acc:
0.8817 - val_loss: 0.6588 - val_acc: 0.7520
Epoch 125/150
30/30 [==============================] - 0s 3ms/step - loss: 0.3677 - acc:
0.8839 - val_loss: 0.6561 - val_acc: 0.7510
Epoch 126/150
30/30 [==============================] - 0s 3ms/step - loss: 0.3651 - acc:
0.8844 - val_loss: 0.6579 - val_acc: 0.7440
```

```
Epoch 127/150
30/30 [==============================] - 0s 3ms/step - loss: 0.3626 - acc:
0.8855 - val_loss: 0.6594 - val_acc: 0.7510
Epoch 128/150
30/30 [==============================] - 0s 3ms/step - loss: 0.3602 - acc:
0.8852 - val_loss: 0.6612 - val_acc: 0.7480
Epoch 129/150
30/30 [==============================] - 0s 3ms/step - loss: 0.3575 - acc:
0.8875 - val_loss: 0.6594 - val_acc: 0.7470
Epoch 130/150
30/30 [==============================] - 0s 3ms/step - loss: 0.3551 - acc:
0.8877 - val_loss: 0.6617 - val_acc: 0.7510
Epoch 131/150
30/30 [==============================] - 0s 3ms/step - loss: 0.3526 - acc:
0.8900 - val_loss: 0.6612 - val_acc: 0.7500
Epoch 132/150
30/30 [==============================] - 0s 3ms/step - loss: 0.3507 - acc:
0.8896 - val_loss: 0.6620 - val_acc: 0.7460
Epoch 133/150
30/30 [==============================] - 0s 3ms/step - loss: 0.3479 - acc:
0.8901 - val_loss: 0.6644 - val_acc: 0.7530
Epoch 134/150
30/30 [==============================] - 0s 3ms/step - loss: 0.3455 - acc:
0.8925 - val_loss: 0.6624 - val_acc: 0.7440
Epoch 135/150
30/30 [==============================] - 0s 3ms/step - loss: 0.3435 - acc:
0.8912 - val_loss: 0.6636 - val_acc: 0.7470
Epoch 136/150
30/30 [==============================] - 0s 3ms/step - loss: 0.3408 - acc:
0.8945 - val_loss: 0.6634 - val_acc: 0.7510
Epoch 137/150
30/30 [==============================] - 0s 3ms/step - loss: 0.3386 - acc:
0.8947 - val_loss: 0.6669 - val_acc: 0.7460
Epoch 138/150
30/30 [==============================] - 0s 3ms/step - loss: 0.3362 - acc:
0.8959 - val_loss: 0.6677 - val_acc: 0.7490
Epoch 139/150
30/30 [==============================] - 0s 3ms/step - loss: 0.3339 - acc:
0.8976 - val_loss: 0.6731 - val_acc: 0.7430
Epoch 140/150
30/30 [==============================] - 0s 3ms/step - loss: 0.3317 - acc:
0.8969 - val_loss: 0.6649 - val_acc: 0.7490
Epoch 141/150
30/30 [==============================] - 0s 3ms/step - loss: 0.3296 - acc:
0.8991 - val_loss: 0.6679 - val_acc: 0.7510
Epoch 142/150
30/30 [==============================] - 0s 3ms/step - loss: 0.3275 - acc:
0.9008 - val_loss: 0.6673 - val_acc: 0.7510
```

```
Epoch 143/150
30/30 [==============================] - 0s 3ms/step - loss: 0.3246 - acc:
0.9008 - val_loss: 0.6690 - val_acc: 0.7490
Epoch 144/150
30/30 [==============================] - 0s 3ms/step - loss: 0.3225 - acc:
0.9011 - val_loss: 0.6724 - val_acc: 0.7540
Epoch 145/150
30/30 [==============================] - 0s 3ms/step - loss: 0.3205 - acc:
0.9032 - val_loss: 0.6680 - val_acc: 0.7500
Epoch 146/150
30/30 [==============================] - 0s 3ms/step - loss: 0.3185 - acc:
0.9035 - val_loss: 0.6727 - val_acc: 0.7500
Epoch 147/150
30/30 [==============================] - 0s 3ms/step - loss: 0.3165 - acc:
0.9037 - val_loss: 0.6710 - val_acc: 0.7500
Epoch 148/150
30/30 [==============================] - 0s 3ms/step - loss: 0.3143 - acc:
0.9055 - val_loss: 0.6789 - val_acc: 0.7460
Epoch 149/150
30/30 [==============================] - 0s 3ms/step - loss: 0.3118 - acc:
0.9053 - val_loss: 0.6690 - val_acc: 0.7540
Epoch 150/150
30/30 [==============================] - 0s 3ms/step - loss: 0.3101 - acc:
0.9081 - val_loss: 0.6763 - val_acc: 0.7480
```

1.10.3 Model Performance

The attribute `.history` (stored as a dictionary) contains four entries now: one per metric that was being monitored during training and validation. Print the keys of this dictionary for confirmation:

[12]:
```
# Access the history attribute and store the dictionary
baseline_model_val_dict = baseline_model_val.history

# Print the keys
baseline_model_val_dict.keys()
```

[12]:
```
dict_keys(['loss', 'acc', 'val_loss', 'val_acc'])
```

Evaluate this model on the training data:

[13]:
```
results_train = baseline_model.evaluate(X_train_tokens, y_train_lb)
print('----------')
print(f'Training Loss: {results_train[0]:.3} \nTraining Accuracy:␣
↪{results_train[1]:.3}')
```

```
235/235 [==============================] - 0s 745us/step - loss: 0.3071 - acc:
0.9049
----------
```

```
Training Loss: 0.307
Training Accuracy: 0.905
```

Evaluate this model on the test data:

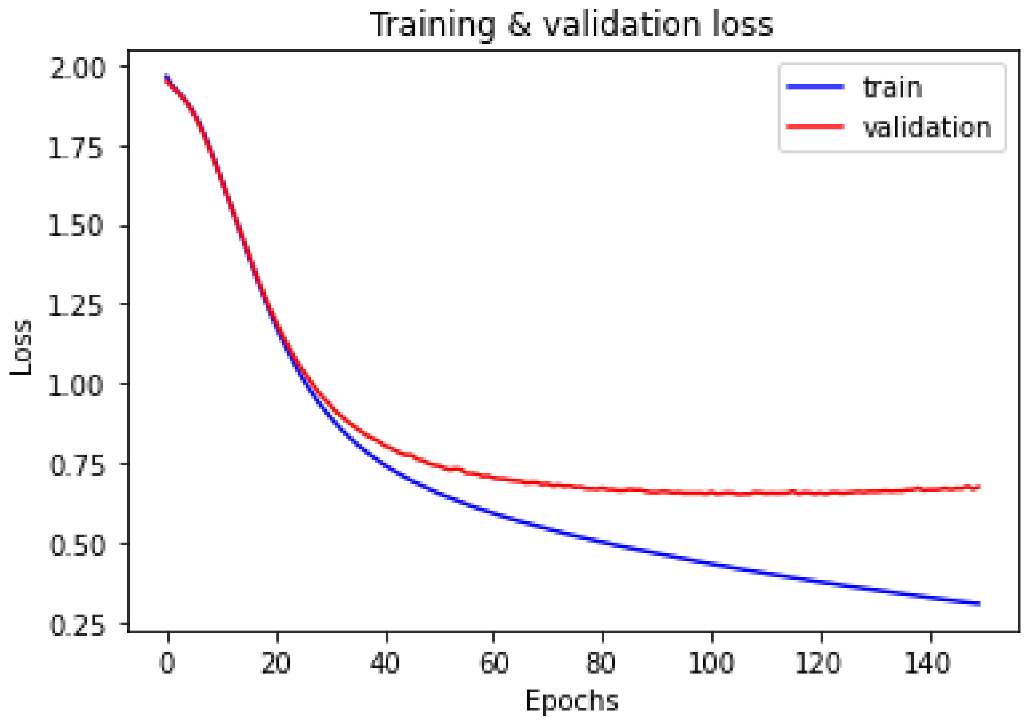
[14]:
```
results_test = baseline_model.evaluate(X_test_tokens, y_test_lb)
print('----------')
print(f'Test Loss: {results_test[0]:.3} \nTest Accuracy: {results_test[1]:.3}')
```

```
47/47 [==============================] - 0s 742us/step - loss: 0.6133 - acc:
0.7907
----------
Test Loss: 0.613
Test Accuracy: 0.791
```

1.10.4 Plot the Results

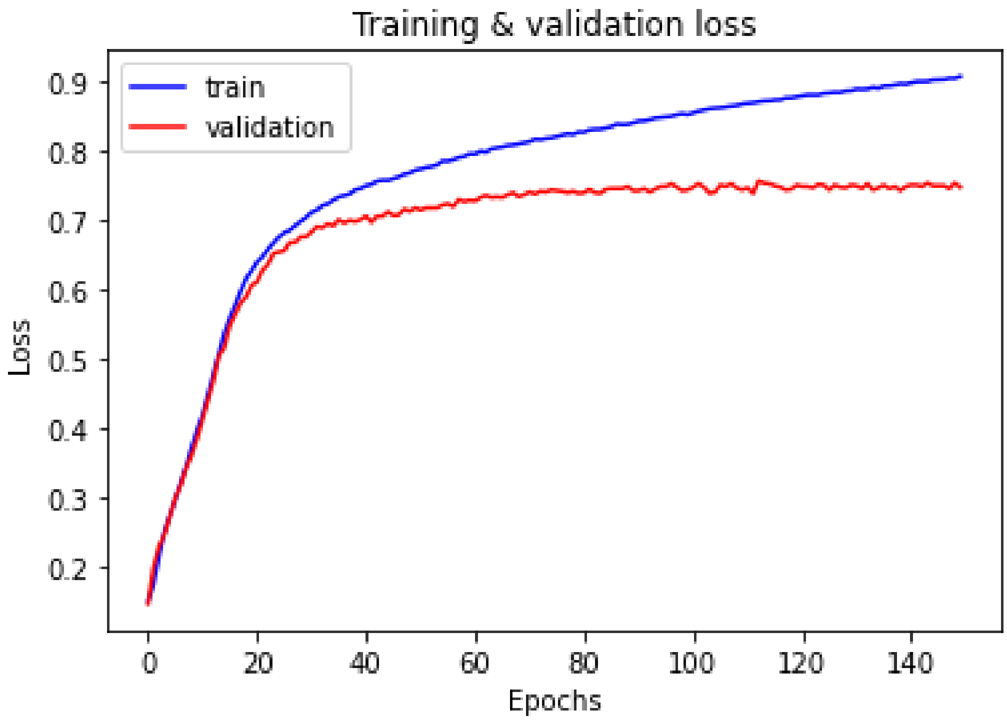
Plot the loss versus the number of epochs. Be sure to include the training and the validation loss in the same plot.

[15]:
```
# Loss vs number of epochs with train and validation sets
plt.plot(baseline_model_val_dict["loss"], color = "blue", label = "train")
plt.plot(baseline_model_val_dict["val_loss"], color = "red", label =␣
 ↪"validation")

plt.title('Training & validation loss')
plt.xlabel('Epochs')
plt.ylabel('Loss')


plt.legend();
```



Create a second plot comparing training and validation accuracy to the number of epochs.

[16]:
```
# Accuracy vs number of epochs with train and validation sets

# Loss vs number of epochs with train and validation sets
plt.plot(baseline_model_val_dict["acc"], color = "blue", label = "train")
plt.plot(baseline_model_val_dict["val_acc"], color = "red", label =␣
 ↪"validation")

plt.title('Training & validation loss')
plt.xlabel('Epochs')
plt.ylabel('Loss')


plt.legend();
```



Did you notice an interesting pattern here? Although the training accuracy keeps increasing when going through more epochs, and the training loss keeps decreasing, the validation accuracy and loss don't necessarily do the same. After a certain point, validation accuracy keeps swinging, which means that you're probably **overfitting** the model to the training data when you train for many epochs past a certain dropoff point. Let's tackle this now. You will now specify an early stopping point when training your model.

1.11 Early Stopping

Overfitting neural networks is something you ***want*** to avoid at all costs. However, it's not possible to know in advance how many *epochs* you need to train your model on, and running the model multiple times with varying number of *epochs* maybe helpful, but is a time-consuming process.

We've defined a model with the same architecture as above. This time specify an early stopping point when training the model.

[17]:
```
random.seed(123)
model_2 = models.Sequential()
model_2.add(layers.Dense(50, activation='relu', input_shape=(2000,)))
model_2.add(layers.Dense(25, activation='relu'))
model_2.add(layers.Dense(7, activation='softmax'))

model_2.compile(optimizer='SGD',
                loss='categorical_crossentropy',
                metrics=['acc'])
```

- Import `EarlyStopping` and `ModelCheckpoint` from `keras.callbacks`
- Define a list, `early_stopping`:
  - Monitor `'val_loss'` and continue training for 10 epochs before stopping
  - Save the best model while monitoring `'val_loss'`

  If you need help, consult documentation.

[20]:
```
# Import EarlyStopping and ModelCheckpoint
from keras.callbacks import EarlyStopping, ModelCheckpoint

# Define the callbacks
early_stopping = [EarlyStopping(monitor = "val_loss", patience = 10),
                  ModelCheckpoint(filepath='best_model.h5',
                                  monitor='val_loss',
                                  save_best_only=True)]
```

Train `model_2`. Make sure you set the `callbacks` argument to `early_stopping`.

[22]:
```
model_2_val = model_2.fit(X_train_tokens,
                          y_train_lb,
                          callbacks = early_stopping,
                          epochs = 150,
                          batch_size = 125,
                          validation_data = (X_val_tokens, y_val_lb))
```

```
Epoch 1/150
60/60 [==============================] - 0s 2ms/step - loss: 0.3343 - acc:
0.9009 - val_loss: 0.6802 - val_acc: 0.7370
Epoch 2/150
60/60 [==============================] - 0s 2ms/step - loss: 0.3298 - acc:
0.9013 - val_loss: 0.6816 - val_acc: 0.7380
Epoch 3/150
60/60 [==============================] - 0s 2ms/step - loss: 0.3258 - acc:
0.9043 - val_loss: 0.6811 - val_acc: 0.7350
Epoch 4/150
60/60 [==============================] - 0s 2ms/step - loss: 0.3214 - acc:
0.9045 - val_loss: 0.6859 - val_acc: 0.7400
Epoch 5/150
60/60 [==============================] - 0s 2ms/step - loss: 0.3161 - acc:
0.9079 - val_loss: 0.6855 - val_acc: 0.7360
Epoch 6/150
60/60 [==============================] - 0s 2ms/step - loss: 0.3120 - acc:
0.9071 - val_loss: 0.6809 - val_acc: 0.7450
Epoch 7/150
60/60 [==============================] - 0s 2ms/step - loss: 0.3078 - acc:
0.9101 - val_loss: 0.6828 - val_acc: 0.7470
Epoch 8/150
60/60 [==============================] - 0s 2ms/step - loss: 0.3029 - acc:
0.9125 - val_loss: 0.6878 - val_acc: 0.7390
```

```
Epoch 9/150
60/60 [==============================] - 0s 2ms/step - loss: 0.2988 - acc:
0.9148 - val_loss: 0.6838 - val_acc: 0.7450
Epoch 10/150
60/60 [==============================] - 0s 2ms/step - loss: 0.2944 - acc:
0.9167 - val_loss: 0.6841 - val_acc: 0.7390
Epoch 11/150
60/60 [==============================] - 0s 2ms/step - loss: 0.2908 - acc:
0.9172 - val_loss: 0.6890 - val_acc: 0.7390
```

Load the best (saved) model.

[23]:
```
# Load the best (saved) model

saved_model = models.load_model('best_model.h5')
```

Now, use this model to to calculate the training and test accuracy:

[24]:
```
results_train = saved_model.evaluate(X_train_tokens, y_train_lb)
print(f'Training Loss: {results_train[0]:.3} \nTraining Accuracy:␣
 ↪{results_train[1]:.3}')

print('----------')

results_test = saved_model.evaluate(X_test_tokens, y_test_lb)
print(f'Test Loss: {results_test[0]:.3} \nTest Accuracy: {results_test[1]:.3}')
```

```
235/235 [==============================] - 0s 711us/step - loss: 0.3875 - acc:
0.8775
Training Loss: 0.388
Training Accuracy: 0.877
----------
47/47 [==============================] - 0s 1ms/step - loss: 0.6102 - acc:
0.7833
Test Loss: 0.61
Test Accuracy: 0.783
```

Nicely done! Did you notice that the model didn't train for all 150 epochs? You reduced your training time.

Now, take a look at how regularization techniques can further improve your model performance.

1.12 L2 Regularization

First, take a look at L2 regularization. Keras makes L2 regularization easy. Simply add the `kernel_regularizer=keras.regularizers.l2(lambda_coeff)` parameter to any model layer. The `lambda_coeff` parameter determines the strength of the regularization you wish to perform.

- Use 2 hidden layers with 50 units in the first and 25 in the second layer, both with `'relu'` activation functions

- Add L2 regularization to both the hidden layers with 0.005 as the `lambda_coeff`

[26]:
```
# Import regularizers
from keras import regularizers

random.seed(123)
L2_model = models.Sequential()
lambda_coeff = 0.005

# Add the input and first hidden layer
L2_model.add(layers.Dense(50,
                          kernel_regularizer=regularizers.l2(lambda_coeff),
                          activation = "relu",
                          input_shape = (2000,)))

# Add another hidden layer

L2_model.add(layers.Dense(25,
                          kernel_regularizer=regularizers.l2(lambda_coeff),
                          activation = "relu"))

# Add an output layer
L2_model.add(layers.Dense(7, activation='softmax'))

# Compile the model
L2_model.compile(optimizer='SGD',
                 loss='categorical_crossentropy',
                 metrics=['acc'])

# Train the model
L2_model_val = L2_model.fit(X_train_tokens,
                            y_train_lb,
                            epochs=150,
                            batch_size=256,
                            validation_data=(X_val_tokens, y_val_lb))
```

```
Epoch 1/150
30/30 [==============================] - 0s 8ms/step - loss: 2.5806 - acc:
0.1772 - val_loss: 2.5725 - val_acc: 0.1910
Epoch 2/150
30/30 [==============================] - 0s 3ms/step - loss: 2.5522 - acc:
0.1991 - val_loss: 2.5500 - val_acc: 0.2160
Epoch 3/150
30/30 [==============================] - 0s 3ms/step - loss: 2.5270 - acc:
0.2216 - val_loss: 2.5269 - val_acc: 0.2310
Epoch 4/150
30/30 [==============================] - 0s 3ms/step - loss: 2.4990 - acc:
0.2479 - val_loss: 2.4997 - val_acc: 0.2450
```

```
Epoch 5/150
30/30 [==============================] - 0s 3ms/step - loss: 2.4664 - acc:
0.2836 - val_loss: 2.4668 - val_acc: 0.2890
Epoch 6/150
30/30 [==============================] - 0s 3ms/step - loss: 2.4271 - acc:
0.3255 - val_loss: 2.4269 - val_acc: 0.3280
Epoch 7/150
30/30 [==============================] - 0s 3ms/step - loss: 2.3819 - acc:
0.3668 - val_loss: 2.3824 - val_acc: 0.3670
Epoch 8/150
30/30 [==============================] - 0s 3ms/step - loss: 2.3326 - acc:
0.4000 - val_loss: 2.3329 - val_acc: 0.3990
Epoch 9/150
30/30 [==============================] - 0s 3ms/step - loss: 2.2796 - acc:
0.4309 - val_loss: 2.2812 - val_acc: 0.4190
Epoch 10/150
30/30 [==============================] - 0s 3ms/step - loss: 2.2252 - acc:
0.4603 - val_loss: 2.2280 - val_acc: 0.4450
Epoch 11/150
30/30 [==============================] - 0s 3ms/step - loss: 2.1712 - acc:
0.4873 - val_loss: 2.1761 - val_acc: 0.4520
Epoch 12/150
30/30 [==============================] - 0s 3ms/step - loss: 2.1181 - acc:
0.5108 - val_loss: 2.1258 - val_acc: 0.4750
Epoch 13/150
30/30 [==============================] - 0s 3ms/step - loss: 2.0667 - acc:
0.5339 - val_loss: 2.0755 - val_acc: 0.4910
Epoch 14/150
30/30 [==============================] - 0s 3ms/step - loss: 2.0175 - acc:
0.5523 - val_loss: 2.0283 - val_acc: 0.5190
Epoch 15/150
30/30 [==============================] - 0s 3ms/step - loss: 1.9707 - acc:
0.5713 - val_loss: 1.9841 - val_acc: 0.5330
Epoch 16/150
30/30 [==============================] - 0s 3ms/step - loss: 1.9266 - acc:
0.5893 - val_loss: 1.9445 - val_acc: 0.5450
Epoch 17/150
30/30 [==============================] - 0s 3ms/step - loss: 1.8846 - acc:
0.6028 - val_loss: 1.9041 - val_acc: 0.5490
Epoch 18/150
30/30 [==============================] - 0s 3ms/step - loss: 1.8449 - acc:
0.6163 - val_loss: 1.8653 - val_acc: 0.5770
Epoch 19/150
30/30 [==============================] - 0s 3ms/step - loss: 1.8072 - acc:
0.6296 - val_loss: 1.8317 - val_acc: 0.5880
Epoch 20/150
30/30 [==============================] - 0s 3ms/step - loss: 1.7714 - acc:
0.6396 - val_loss: 1.7978 - val_acc: 0.6050
```

```
Epoch 21/150
30/30 [==============================] - 0s 3ms/step - loss: 1.7380 - acc:
0.6492 - val_loss: 1.7721 - val_acc: 0.6030
Epoch 22/150
30/30 [==============================] - 0s 3ms/step - loss: 1.7057 - acc:
0.6564 - val_loss: 1.7395 - val_acc: 0.6100
Epoch 23/150
30/30 [==============================] - 0s 3ms/step - loss: 1.6750 - acc:
0.6699 - val_loss: 1.7116 - val_acc: 0.6300
Epoch 24/150
30/30 [==============================] - 0s 3ms/step - loss: 1.6457 - acc:
0.6761 - val_loss: 1.6821 - val_acc: 0.6390
Epoch 25/150
30/30 [==============================] - 0s 3ms/step - loss: 1.6178 - acc:
0.6865 - val_loss: 1.6561 - val_acc: 0.6450
Epoch 26/150
30/30 [==============================] - 0s 3ms/step - loss: 1.5915 - acc:
0.6933 - val_loss: 1.6335 - val_acc: 0.6500
Epoch 27/150
30/30 [==============================] - 0s 3ms/step - loss: 1.5662 - acc:
0.7000 - val_loss: 1.6109 - val_acc: 0.6570
Epoch 28/150
30/30 [==============================] - 0s 3ms/step - loss: 1.5421 - acc:
0.7065 - val_loss: 1.5922 - val_acc: 0.6570
Epoch 29/150
30/30 [==============================] - 0s 3ms/step - loss: 1.5193 - acc:
0.7111 - val_loss: 1.5693 - val_acc: 0.6530
Epoch 30/150
30/30 [==============================] - 0s 3ms/step - loss: 1.4971 - acc:
0.7157 - val_loss: 1.5495 - val_acc: 0.6620
Epoch 31/150
30/30 [==============================] - 0s 5ms/step - loss: 1.4759 - acc:
0.7196 - val_loss: 1.5395 - val_acc: 0.6770
Epoch 32/150
30/30 [==============================] - 0s 3ms/step - loss: 1.4566 - acc:
0.7236 - val_loss: 1.5153 - val_acc: 0.6770
Epoch 33/150
30/30 [==============================] - 0s 3ms/step - loss: 1.4372 - acc:
0.7281 - val_loss: 1.4953 - val_acc: 0.6850
Epoch 34/150
30/30 [==============================] - 0s 3ms/step - loss: 1.4194 - acc:
0.7312 - val_loss: 1.4807 - val_acc: 0.6850
Epoch 35/150
30/30 [==============================] - 0s 3ms/step - loss: 1.4017 - acc:
0.7349 - val_loss: 1.4661 - val_acc: 0.6900
Epoch 36/150
30/30 [==============================] - 0s 3ms/step - loss: 1.3851 - acc:
0.7399 - val_loss: 1.4520 - val_acc: 0.7000
```

```
Epoch 37/150
30/30 [==============================] - 0s 3ms/step - loss: 1.3697 - acc:
0.7413 - val_loss: 1.4404 - val_acc: 0.7000
Epoch 38/150
30/30 [==============================] - 0s 3ms/step - loss: 1.3544 - acc:
0.7447 - val_loss: 1.4270 - val_acc: 0.6890
Epoch 39/150
30/30 [==============================] - 0s 3ms/step - loss: 1.3405 - acc:
0.7485 - val_loss: 1.4137 - val_acc: 0.7070
Epoch 40/150
30/30 [==============================] - 0s 3ms/step - loss: 1.3262 - acc:
0.7503 - val_loss: 1.4020 - val_acc: 0.7030
Epoch 41/150
30/30 [==============================] - 0s 3ms/step - loss: 1.3132 - acc:
0.7556 - val_loss: 1.3930 - val_acc: 0.7120
Epoch 42/150
30/30 [==============================] - 0s 3ms/step - loss: 1.3005 - acc:
0.7569 - val_loss: 1.3808 - val_acc: 0.7090
Epoch 43/150
30/30 [==============================] - 0s 3ms/step - loss: 1.2886 - acc:
0.7603 - val_loss: 1.3725 - val_acc: 0.7140
Epoch 44/150
30/30 [==============================] - 0s 3ms/step - loss: 1.2767 - acc:
0.7651 - val_loss: 1.3712 - val_acc: 0.7070
Epoch 45/150
30/30 [==============================] - 0s 3ms/step - loss: 1.2659 - acc:
0.7655 - val_loss: 1.3560 - val_acc: 0.7130
Epoch 46/150
30/30 [==============================] - 0s 3ms/step - loss: 1.2546 - acc:
0.7687 - val_loss: 1.3453 - val_acc: 0.7050
Epoch 47/150
30/30 [==============================] - 0s 3ms/step - loss: 1.2448 - acc:
0.7716 - val_loss: 1.3388 - val_acc: 0.7070
Epoch 48/150
30/30 [==============================] - 0s 3ms/step - loss: 1.2343 - acc:
0.7737 - val_loss: 1.3289 - val_acc: 0.7160
Epoch 49/150
30/30 [==============================] - 0s 3ms/step - loss: 1.2247 - acc:
0.7765 - val_loss: 1.3233 - val_acc: 0.7110
Epoch 50/150
30/30 [==============================] - 0s 3ms/step - loss: 1.2154 - acc:
0.7800 - val_loss: 1.3146 - val_acc: 0.7120
Epoch 51/150
30/30 [==============================] - 0s 3ms/step - loss: 1.2060 - acc:
0.7829 - val_loss: 1.3057 - val_acc: 0.7130
Epoch 52/150
30/30 [==============================] - 0s 3ms/step - loss: 1.1978 - acc:
0.7819 - val_loss: 1.2999 - val_acc: 0.7150
```

```
Epoch 53/150
30/30 [==============================] - 0s 3ms/step - loss: 1.1892 - acc:
0.7869 - val_loss: 1.2940 - val_acc: 0.7170
Epoch 54/150
30/30 [==============================] - 0s 3ms/step - loss: 1.1811 - acc:
0.7885 - val_loss: 1.2903 - val_acc: 0.7080
Epoch 55/150
30/30 [==============================] - 0s 3ms/step - loss: 1.1730 - acc:
0.7915 - val_loss: 1.2826 - val_acc: 0.7190
Epoch 56/150
30/30 [==============================] - 0s 3ms/step - loss: 1.1652 - acc:
0.7933 - val_loss: 1.2822 - val_acc: 0.7190
Epoch 57/150
30/30 [==============================] - 0s 3ms/step - loss: 1.1574 - acc:
0.7936 - val_loss: 1.2820 - val_acc: 0.7220
Epoch 58/150
30/30 [==============================] - 0s 3ms/step - loss: 1.1504 - acc:
0.7963 - val_loss: 1.2673 - val_acc: 0.7170
Epoch 59/150
30/30 [==============================] - 0s 3ms/step - loss: 1.1430 - acc:
0.7980 - val_loss: 1.2628 - val_acc: 0.7140
Epoch 60/150
30/30 [==============================] - 0s 3ms/step - loss: 1.1361 - acc:
0.7993 - val_loss: 1.2579 - val_acc: 0.7210
Epoch 61/150
30/30 [==============================] - 0s 3ms/step - loss: 1.1288 - acc:
0.8012 - val_loss: 1.2572 - val_acc: 0.7170
Epoch 62/150
30/30 [==============================] - 0s 3ms/step - loss: 1.1224 - acc:
0.8021 - val_loss: 1.2481 - val_acc: 0.7190
Epoch 63/150
30/30 [==============================] - 0s 3ms/step - loss: 1.1155 - acc:
0.8027 - val_loss: 1.2436 - val_acc: 0.7210
Epoch 64/150
30/30 [==============================] - 0s 3ms/step - loss: 1.1090 - acc:
0.8041 - val_loss: 1.2423 - val_acc: 0.7220
Epoch 65/150
30/30 [==============================] - 0s 3ms/step - loss: 1.1031 - acc:
0.8059 - val_loss: 1.2354 - val_acc: 0.7260
Epoch 66/150
30/30 [==============================] - 0s 3ms/step - loss: 1.0965 - acc:
0.8087 - val_loss: 1.2363 - val_acc: 0.7230
Epoch 67/150
30/30 [==============================] - 0s 3ms/step - loss: 1.0902 - acc:
0.8085 - val_loss: 1.2365 - val_acc: 0.7230
Epoch 68/150
30/30 [==============================] - 0s 3ms/step - loss: 1.0844 - acc:
0.8124 - val_loss: 1.2263 - val_acc: 0.7280
```

```
Epoch 69/150
30/30 [==============================] - 0s 3ms/step - loss: 1.0783 - acc:
0.8121 - val_loss: 1.2183 - val_acc: 0.7260
Epoch 70/150
30/30 [==============================] - 0s 3ms/step - loss: 1.0723 - acc:
0.8155 - val_loss: 1.2176 - val_acc: 0.7270
Epoch 71/150
30/30 [==============================] - 0s 3ms/step - loss: 1.0664 - acc:
0.8168 - val_loss: 1.2143 - val_acc: 0.7260
Epoch 72/150
30/30 [==============================] - 0s 3ms/step - loss: 1.0612 - acc:
0.8161 - val_loss: 1.2108 - val_acc: 0.7320
Epoch 73/150
30/30 [==============================] - 0s 4ms/step - loss: 1.0550 - acc:
0.8204 - val_loss: 1.2088 - val_acc: 0.7270
Epoch 74/150
30/30 [==============================] - 0s 3ms/step - loss: 1.0502 - acc:
0.8217 - val_loss: 1.2061 - val_acc: 0.7330
Epoch 75/150
30/30 [==============================] - 0s 3ms/step - loss: 1.0448 - acc:
0.8213 - val_loss: 1.2000 - val_acc: 0.7290
Epoch 76/150
30/30 [==============================] - 0s 3ms/step - loss: 1.0389 - acc:
0.8233 - val_loss: 1.1990 - val_acc: 0.7300
Epoch 77/150
30/30 [==============================] - 0s 3ms/step - loss: 1.0341 - acc:
0.8245 - val_loss: 1.1945 - val_acc: 0.7290
Epoch 78/150
30/30 [==============================] - 0s 3ms/step - loss: 1.0288 - acc:
0.8259 - val_loss: 1.1946 - val_acc: 0.7310
Epoch 79/150
30/30 [==============================] - 0s 3ms/step - loss: 1.0237 - acc:
0.8265 - val_loss: 1.1880 - val_acc: 0.7270
Epoch 80/150
30/30 [==============================] - 0s 3ms/step - loss: 1.0184 - acc:
0.8308 - val_loss: 1.1863 - val_acc: 0.7290
Epoch 81/150
30/30 [==============================] - 0s 3ms/step - loss: 1.0134 - acc:
0.8303 - val_loss: 1.1838 - val_acc: 0.7310
Epoch 82/150
30/30 [==============================] - 0s 3ms/step - loss: 1.0083 - acc:
0.8321 - val_loss: 1.1835 - val_acc: 0.7290
Epoch 83/150
30/30 [==============================] - 0s 3ms/step - loss: 1.0041 - acc:
0.8313 - val_loss: 1.1765 - val_acc: 0.7280
Epoch 84/150
30/30 [==============================] - 0s 3ms/step - loss: 0.9987 - acc:
0.8347 - val_loss: 1.1786 - val_acc: 0.7270
```

```
Epoch 85/150
30/30 [==============================] - 0s 3ms/step - loss: 0.9940 - acc:
0.8348 - val_loss: 1.1759 - val_acc: 0.7290
Epoch 86/150
30/30 [==============================] - 0s 3ms/step - loss: 0.9894 - acc:
0.8364 - val_loss: 1.1720 - val_acc: 0.7250
Epoch 87/150
30/30 [==============================] - 0s 3ms/step - loss: 0.9846 - acc:
0.8388 - val_loss: 1.1669 - val_acc: 0.7290
Epoch 88/150
30/30 [==============================] - 0s 3ms/step - loss: 0.9799 - acc:
0.8401 - val_loss: 1.1681 - val_acc: 0.7320
Epoch 89/150
30/30 [==============================] - 0s 3ms/step - loss: 0.9757 - acc:
0.8415 - val_loss: 1.1630 - val_acc: 0.7290
Epoch 90/150
30/30 [==============================] - 0s 3ms/step - loss: 0.9702 - acc:
0.8415 - val_loss: 1.1578 - val_acc: 0.7290
Epoch 91/150
30/30 [==============================] - 0s 5ms/step - loss: 0.9658 - acc:
0.8429 - val_loss: 1.1561 - val_acc: 0.7320
Epoch 92/150
30/30 [==============================] - 0s 3ms/step - loss: 0.9621 - acc:
0.8448 - val_loss: 1.1534 - val_acc: 0.7270
Epoch 93/150
30/30 [==============================] - 0s 3ms/step - loss: 0.9575 - acc:
0.8468 - val_loss: 1.1545 - val_acc: 0.7310
Epoch 94/150
30/30 [==============================] - 0s 3ms/step - loss: 0.9534 - acc:
0.8471 - val_loss: 1.1513 - val_acc: 0.7310
Epoch 95/150
30/30 [==============================] - 0s 3ms/step - loss: 0.9490 - acc:
0.8476 - val_loss: 1.1532 - val_acc: 0.7280
Epoch 96/150
30/30 [==============================] - 0s 3ms/step - loss: 0.9445 - acc:
0.8495 - val_loss: 1.1502 - val_acc: 0.7280
Epoch 97/150
30/30 [==============================] - 0s 3ms/step - loss: 0.9403 - acc:
0.8504 - val_loss: 1.1523 - val_acc: 0.7310
Epoch 98/150
30/30 [==============================] - 0s 3ms/step - loss: 0.9362 - acc:
0.8491 - val_loss: 1.1421 - val_acc: 0.7330
Epoch 99/150
30/30 [==============================] - 0s 3ms/step - loss: 0.9321 - acc:
0.8528 - val_loss: 1.1419 - val_acc: 0.7300
Epoch 100/150
30/30 [==============================] - 0s 3ms/step - loss: 0.9279 - acc:
0.8535 - val_loss: 1.1453 - val_acc: 0.7340
```

```
Epoch 101/150
30/30 [==============================] - 0s 3ms/step - loss: 0.9238 - acc:
0.8536 - val_loss: 1.1396 - val_acc: 0.7280
Epoch 102/150
30/30 [==============================] - 0s 3ms/step - loss: 0.9199 - acc:
0.8560 - val_loss: 1.1360 - val_acc: 0.7330
Epoch 103/150
30/30 [==============================] - 0s 3ms/step - loss: 0.9155 - acc:
0.8565 - val_loss: 1.1329 - val_acc: 0.7290
Epoch 104/150
30/30 [==============================] - 0s 3ms/step - loss: 0.9115 - acc:
0.8587 - val_loss: 1.1291 - val_acc: 0.7320
Epoch 105/150
30/30 [==============================] - 0s 3ms/step - loss: 0.9078 - acc:
0.8580 - val_loss: 1.1311 - val_acc: 0.7330
Epoch 106/150
30/30 [==============================] - 0s 3ms/step - loss: 0.9039 - acc:
0.8596 - val_loss: 1.1262 - val_acc: 0.7300
Epoch 107/150
30/30 [==============================] - 0s 3ms/step - loss: 0.9002 - acc:
0.8612 - val_loss: 1.1255 - val_acc: 0.7320
Epoch 108/150
30/30 [==============================] - 0s 3ms/step - loss: 0.8961 - acc:
0.8617 - val_loss: 1.1201 - val_acc: 0.7350
Epoch 109/150
30/30 [==============================] - 0s 4ms/step - loss: 0.8924 - acc:
0.8632 - val_loss: 1.1201 - val_acc: 0.7340
Epoch 110/150
30/30 [==============================] - 0s 3ms/step - loss: 0.8888 - acc:
0.8664 - val_loss: 1.1219 - val_acc: 0.7340
Epoch 111/150
30/30 [==============================] - 0s 3ms/step - loss: 0.8850 - acc:
0.8639 - val_loss: 1.1226 - val_acc: 0.7340
Epoch 112/150
30/30 [==============================] - 0s 3ms/step - loss: 0.8812 - acc:
0.8681 - val_loss: 1.1143 - val_acc: 0.7370
Epoch 113/150
30/30 [==============================] - 0s 3ms/step - loss: 0.8775 - acc:
0.8671 - val_loss: 1.1225 - val_acc: 0.7290
Epoch 114/150
30/30 [==============================] - 0s 3ms/step - loss: 0.8740 - acc:
0.8667 - val_loss: 1.1171 - val_acc: 0.7370
Epoch 115/150
30/30 [==============================] - 0s 3ms/step - loss: 0.8700 - acc:
0.8693 - val_loss: 1.1120 - val_acc: 0.7350
Epoch 116/150
30/30 [==============================] - 0s 3ms/step - loss: 0.8663 - acc:
0.8705 - val_loss: 1.1096 - val_acc: 0.7390
```

```
Epoch 117/150
30/30 [==============================] - 0s 3ms/step - loss: 0.8628 - acc:
0.8720 - val_loss: 1.1090 - val_acc: 0.7360
Epoch 118/150
30/30 [==============================] - 0s 3ms/step - loss: 0.8595 - acc:
0.8732 - val_loss: 1.1054 - val_acc: 0.7340
Epoch 119/150
30/30 [==============================] - 0s 3ms/step - loss: 0.8552 - acc:
0.8731 - val_loss: 1.1178 - val_acc: 0.7310
Epoch 120/150
30/30 [==============================] - 0s 3ms/step - loss: 0.8526 - acc:
0.8737 - val_loss: 1.1053 - val_acc: 0.7330
Epoch 121/150
30/30 [==============================] - 0s 3ms/step - loss: 0.8489 - acc:
0.8773 - val_loss: 1.1026 - val_acc: 0.7350
Epoch 122/150
30/30 [==============================] - 0s 3ms/step - loss: 0.8456 - acc:
0.8776 - val_loss: 1.1096 - val_acc: 0.7360
Epoch 123/150
30/30 [==============================] - 0s 3ms/step - loss: 0.8424 - acc:
0.8780 - val_loss: 1.0963 - val_acc: 0.7360
Epoch 124/150
30/30 [==============================] - 0s 3ms/step - loss: 0.8385 - acc:
0.8795 - val_loss: 1.0970 - val_acc: 0.7360
Epoch 125/150
30/30 [==============================] - 0s 3ms/step - loss: 0.8354 - acc:
0.8788 - val_loss: 1.0949 - val_acc: 0.7400
Epoch 126/150
30/30 [==============================] - 0s 3ms/step - loss: 0.8321 - acc:
0.8804 - val_loss: 1.0927 - val_acc: 0.7360
Epoch 127/150
30/30 [==============================] - 0s 3ms/step - loss: 0.8291 - acc:
0.8820 - val_loss: 1.0959 - val_acc: 0.7430
Epoch 128/150
30/30 [==============================] - 0s 3ms/step - loss: 0.8256 - acc:
0.8831 - val_loss: 1.0938 - val_acc: 0.7380
Epoch 129/150
30/30 [==============================] - 0s 3ms/step - loss: 0.8224 - acc:
0.8828 - val_loss: 1.0914 - val_acc: 0.7350
Epoch 130/150
30/30 [==============================] - 0s 3ms/step - loss: 0.8191 - acc:
0.8839 - val_loss: 1.0906 - val_acc: 0.7370
Epoch 131/150
30/30 [==============================] - 0s 3ms/step - loss: 0.8159 - acc:
0.8848 - val_loss: 1.0870 - val_acc: 0.7340
Epoch 132/150
30/30 [==============================] - 0s 3ms/step - loss: 0.8129 - acc:
0.8848 - val_loss: 1.0922 - val_acc: 0.7400
```

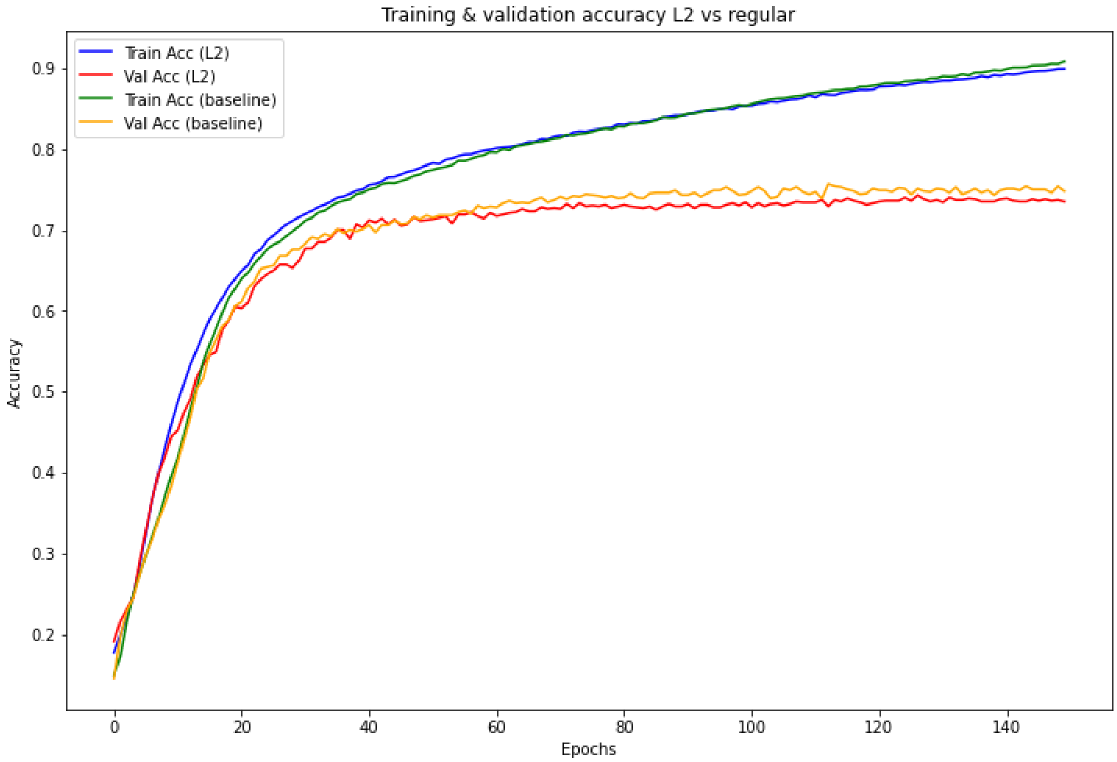
```
Epoch 133/150
30/30 [==============================] - 0s 3ms/step - loss: 0.8096 - acc:
0.8860 - val_loss: 1.0872 - val_acc: 0.7370
Epoch 134/150
30/30 [==============================] - 0s 3ms/step - loss: 0.8065 - acc:
0.8864 - val_loss: 1.0852 - val_acc: 0.7370
Epoch 135/150
30/30 [==============================] - 0s 3ms/step - loss: 0.8036 - acc:
0.8872 - val_loss: 1.0899 - val_acc: 0.7390
Epoch 136/150
30/30 [==============================] - 0s 3ms/step - loss: 0.8004 - acc:
0.8880 - val_loss: 1.0829 - val_acc: 0.7380
Epoch 137/150
30/30 [==============================] - 0s 3ms/step - loss: 0.7972 - acc:
0.8903 - val_loss: 1.0816 - val_acc: 0.7350
Epoch 138/150
30/30 [==============================] - 0s 3ms/step - loss: 0.7945 - acc:
0.8889 - val_loss: 1.0774 - val_acc: 0.7350
Epoch 139/150
30/30 [==============================] - 0s 3ms/step - loss: 0.7907 - acc:
0.8916 - val_loss: 1.0850 - val_acc: 0.7350
Epoch 140/150
30/30 [==============================] - 0s 3ms/step - loss: 0.7881 - acc:
0.8908 - val_loss: 1.0764 - val_acc: 0.7380
Epoch 141/150
30/30 [==============================] - 0s 3ms/step - loss: 0.7853 - acc:
0.8928 - val_loss: 1.0820 - val_acc: 0.7390
Epoch 142/150
30/30 [==============================] - 0s 3ms/step - loss: 0.7825 - acc:
0.8923 - val_loss: 1.0753 - val_acc: 0.7360
Epoch 143/150
30/30 [==============================] - 0s 3ms/step - loss: 0.7799 - acc:
0.8932 - val_loss: 1.0736 - val_acc: 0.7350
Epoch 144/150
30/30 [==============================] - 0s 3ms/step - loss: 0.7770 - acc:
0.8949 - val_loss: 1.0715 - val_acc: 0.7350
Epoch 145/150
30/30 [==============================] - 0s 3ms/step - loss: 0.7740 - acc:
0.8959 - val_loss: 1.0718 - val_acc: 0.7380
Epoch 146/150
30/30 [==============================] - 0s 3ms/step - loss: 0.7711 - acc:
0.8965 - val_loss: 1.0703 - val_acc: 0.7360
Epoch 147/150
30/30 [==============================] - 0s 3ms/step - loss: 0.7683 - acc:
0.8967 - val_loss: 1.0676 - val_acc: 0.7380
Epoch 148/150
30/30 [==============================] - 0s 3ms/step - loss: 0.7651 - acc:
0.8976 - val_loss: 1.0709 - val_acc: 0.7360
```

```
Epoch 149/150
30/30 [==============================] - 0s 3ms/step - loss: 0.7626 - acc:
0.8991 - val_loss: 1.0676 - val_acc: 0.7370
Epoch 150/150
30/30 [==============================] - 0s 4ms/step - loss: 0.7600 - acc:
0.8992 - val_loss: 1.0664 - val_acc: 0.7350
```

Now, look at the training as well as the validation accuracy for both the L2 and the baseline models.

[39]:

```python
# L2 model details
L2_model_dict = L2_model_val.history
L2_acc_values = L2_model_dict['acc']
L2_val_acc_values = L2_model_dict['val_acc']

# Baseline model
baseline_model_acc = baseline_model_val_dict['acc']
baseline_model_val_acc = baseline_model_val_dict['val_acc']

fig, ax = plt.subplots(figsize=(12, 8))

plt.plot(L2_acc_values, color = "blue", label = "Train Acc (L2)")
plt.plot(L2_val_acc_values, color = "red", label = "Val Acc (L2)")

plt.plot(baseline_model_acc, color = "green", label = "Train Acc (baseline)")
plt.plot(baseline_model_val_acc, color = "orange", label = "Val Acc (baseline)")

ax.set_title('Training & validation accuracy L2 vs regular')
ax.set_xlabel('Epochs')
ax.set_ylabel('Accuracy')

plt.legend();
# Plot the accuracy for these models
# fig, ax = plt.subplots(figsize=(12, 8))
# epochs = range(1, len(acc_values) + 1)
# ax.plot(epochs, L2_acc_values, label='Training acc L2')
# ax.plot(epochs, L2_val_acc_values, label='Validation acc L2')
# ax.plot(epochs, baseline_model_acc, label='Training acc')
# ax.plot(epochs, baseline_model_val_acc, label='Validation acc')
# ax.set_title('Training & validation accuracy L2 vs regular')
# ax.set_xlabel('Epochs')
# ax.set_ylabel('Accuracy')
# ax.legend();
```



The results of L2 regularization are quite disappointing here. Notice the discrepancy between validation and training accuracy seems to have decreased slightly, but the end result is definitely not getting better.

1.13 L1 Regularization

Now have a look at L1 regularization. Will this work better?

- Use 2 hidden layers with 50 units in the first and 25 in the second layer, both with `'relu'` activation functions
- Add L1 regularization to both the hidden layers with 0.005 as the `lambda_coeff`

[40]:
```
lambda_coeff = 0.005
random.seed(123)
L1_model = models.Sequential()

# Add the input and first hidden layer
L1_model.add(layers.Dense(50,
                          kernel_regularizer=regularizers.l1(lambda_coeff),
                          activation = "relu",
                          input_shape = (2000,)))

# Add a hidden layer
L1_model.add(layers.Dense(25,
```

```python
                          kernel_regularizer=regularizers.l1(lambda_coeff),
                          activation = "relu"))

# Add an output layer
L1_model.add(layers.Dense(7, activation='softmax'))

# Compile the model
L1_model.compile(optimizer='SGD',
                 loss='categorical_crossentropy',
                 metrics=['acc'])

# Train the model
L1_model_val = L1_model.fit(X_train_tokens,
                            y_train_lb,
                            epochs=150,
                            batch_size=256,
                            validation_data=(X_val_tokens, y_val_lb))
```

```
Epoch 1/150
30/30 [==============================] - 0s 8ms/step - loss: 15.9841 - acc:
0.1525 - val_loss: 15.5799 - val_acc: 0.1660
Epoch 2/150
30/30 [==============================] - 0s 3ms/step - loss: 15.2233 - acc:
0.1759 - val_loss: 14.8352 - val_acc: 0.1820
Epoch 3/150
30/30 [==============================] - 0s 3ms/step - loss: 14.4892 - acc:
0.2048 - val_loss: 14.1141 - val_acc: 0.2070
Epoch 4/150
30/30 [==============================] - 0s 3ms/step - loss: 13.7769 - acc:
0.2312 - val_loss: 13.4143 - val_acc: 0.2360
Epoch 5/150
30/30 [==============================] - 0s 3ms/step - loss: 13.0853 - acc:
0.2572 - val_loss: 12.7343 - val_acc: 0.2560
Epoch 6/150
30/30 [==============================] - 0s 3ms/step - loss: 12.4138 - acc:
0.2821 - val_loss: 12.0733 - val_acc: 0.2780
Epoch 7/150
30/30 [==============================] - 0s 3ms/step - loss: 11.7611 - acc:
0.3108 - val_loss: 11.4308 - val_acc: 0.3070
Epoch 8/150
30/30 [==============================] - 0s 3ms/step - loss: 11.1271 - acc:
0.3384 - val_loss: 10.8063 - val_acc: 0.3400
Epoch 9/150
30/30 [==============================] - 0s 3ms/step - loss: 10.5125 - acc:
0.3729 - val_loss: 10.2028 - val_acc: 0.3790
Epoch 10/150
30/30 [==============================] - 0s 3ms/step - loss: 9.9174 - acc:
```

```
0.4088 - val_loss: 9.6201 - val_acc: 0.3920
Epoch 11/150
30/30 [==============================] - 0s 3ms/step - loss: 9.3430 - acc:
0.4320 - val_loss: 9.0583 - val_acc: 0.4230
Epoch 12/150
30/30 [==============================] - 0s 3ms/step - loss: 8.7899 - acc:
0.4585 - val_loss: 8.5183 - val_acc: 0.4340
Epoch 13/150
30/30 [==============================] - 0s 3ms/step - loss: 8.2587 - acc:
0.4791 - val_loss: 7.9998 - val_acc: 0.4570
Epoch 14/150
30/30 [==============================] - 0s 3ms/step - loss: 7.7501 - acc:
0.5035 - val_loss: 7.5047 - val_acc: 0.4720
Epoch 15/150
30/30 [==============================] - 0s 3ms/step - loss: 7.2639 - acc:
0.5173 - val_loss: 7.0306 - val_acc: 0.4960
Epoch 16/150
30/30 [==============================] - 0s 5ms/step - loss: 6.8001 - acc:
0.5439 - val_loss: 6.5801 - val_acc: 0.5090
Epoch 17/150
30/30 [==============================] - 0s 3ms/step - loss: 6.3582 - acc:
0.5517 - val_loss: 6.1489 - val_acc: 0.5430
Epoch 18/150
30/30 [==============================] - 0s 4ms/step - loss: 5.9374 - acc:
0.5667 - val_loss: 5.7408 - val_acc: 0.5260
Epoch 19/150
30/30 [==============================] - 0s 4ms/step - loss: 5.5380 - acc:
0.5727 - val_loss: 5.3530 - val_acc: 0.5630
Epoch 20/150
30/30 [==============================] - 0s 3ms/step - loss: 5.1607 - acc:
0.5855 - val_loss: 4.9877 - val_acc: 0.5710
Epoch 21/150
30/30 [==============================] - 0s 3ms/step - loss: 4.8065 - acc:
0.5907 - val_loss: 4.6466 - val_acc: 0.5790
Epoch 22/150
30/30 [==============================] - 0s 3ms/step - loss: 4.4751 - acc:
0.6013 - val_loss: 4.3270 - val_acc: 0.6010
Epoch 23/150
30/30 [==============================] - 0s 3ms/step - loss: 4.1659 - acc:
0.6119 - val_loss: 4.0291 - val_acc: 0.6120
Epoch 24/150
30/30 [==============================] - 0s 3ms/step - loss: 3.8788 - acc:
0.6160 - val_loss: 3.7535 - val_acc: 0.6140
Epoch 25/150
30/30 [==============================] - 0s 3ms/step - loss: 3.6147 - acc:
0.6220 - val_loss: 3.5026 - val_acc: 0.6020
Epoch 26/150
30/30 [==============================] - 0s 3ms/step - loss: 3.3728 - acc:
```

```
0.6232 - val_loss: 3.2703 - val_acc: 0.6280
Epoch 27/150
30/30 [==============================] - 0s 3ms/step - loss: 3.1527 - acc:
0.6316 - val_loss: 3.0624 - val_acc: 0.6370
Epoch 28/150
30/30 [==============================] - 0s 3ms/step - loss: 2.9543 - acc:
0.6349 - val_loss: 2.8751 - val_acc: 0.6390
Epoch 29/150
30/30 [==============================] - 0s 3ms/step - loss: 2.7782 - acc:
0.6405 - val_loss: 2.7092 - val_acc: 0.6380
Epoch 30/150
30/30 [==============================] - 0s 3ms/step - loss: 2.6234 - acc:
0.6393 - val_loss: 2.5663 - val_acc: 0.6380
Epoch 31/150
30/30 [==============================] - 0s 3ms/step - loss: 2.4894 - acc:
0.6432 - val_loss: 2.4400 - val_acc: 0.6510
Epoch 32/150
30/30 [==============================] - 0s 3ms/step - loss: 2.3756 - acc:
0.6456 - val_loss: 2.3365 - val_acc: 0.6420
Epoch 33/150
30/30 [==============================] - 0s 3ms/step - loss: 2.2806 - acc:
0.6469 - val_loss: 2.2505 - val_acc: 0.6430
Epoch 34/150
30/30 [==============================] - 0s 3ms/step - loss: 2.2042 - acc:
0.6501 - val_loss: 2.1828 - val_acc: 0.6470
Epoch 35/150
30/30 [==============================] - 0s 3ms/step - loss: 2.1454 - acc:
0.6549 - val_loss: 2.1320 - val_acc: 0.6470
Epoch 36/150
30/30 [==============================] - 0s 3ms/step - loss: 2.1009 - acc:
0.6543 - val_loss: 2.0935 - val_acc: 0.6490
Epoch 37/150
30/30 [==============================] - 0s 3ms/step - loss: 2.0674 - acc:
0.6559 - val_loss: 2.0631 - val_acc: 0.6540
Epoch 38/150
30/30 [==============================] - 0s 3ms/step - loss: 2.0409 - acc:
0.6576 - val_loss: 2.0383 - val_acc: 0.6580
Epoch 39/150
30/30 [==============================] - 0s 4ms/step - loss: 2.0175 - acc:
0.6631 - val_loss: 2.0169 - val_acc: 0.6520
Epoch 40/150
30/30 [==============================] - 0s 3ms/step - loss: 1.9961 - acc:
0.6611 - val_loss: 1.9951 - val_acc: 0.6590
Epoch 41/150
30/30 [==============================] - 0s 4ms/step - loss: 1.9769 - acc:
0.6639 - val_loss: 1.9786 - val_acc: 0.6550
Epoch 42/150
30/30 [==============================] - 0s 3ms/step - loss: 1.9590 - acc:
```

```
0.6660 - val_loss: 1.9594 - val_acc: 0.6560
Epoch 43/150
30/30 [==============================] - 0s 4ms/step - loss: 1.9411 - acc:
0.6675 - val_loss: 1.9434 - val_acc: 0.6580
Epoch 44/150
30/30 [==============================] - 0s 3ms/step - loss: 1.9247 - acc:
0.6675 - val_loss: 1.9265 - val_acc: 0.6630
Epoch 45/150
30/30 [==============================] - 0s 3ms/step - loss: 1.9094 - acc:
0.6679 - val_loss: 1.9104 - val_acc: 0.6680
Epoch 46/150
30/30 [==============================] - 0s 3ms/step - loss: 1.8945 - acc:
0.6716 - val_loss: 1.8959 - val_acc: 0.6710
Epoch 47/150
30/30 [==============================] - 0s 3ms/step - loss: 1.8803 - acc:
0.6728 - val_loss: 1.8833 - val_acc: 0.6710
Epoch 48/150
30/30 [==============================] - 0s 3ms/step - loss: 1.8669 - acc:
0.6743 - val_loss: 1.8733 - val_acc: 0.6640
Epoch 49/150
30/30 [==============================] - 0s 4ms/step - loss: 1.8539 - acc:
0.6721 - val_loss: 1.8590 - val_acc: 0.6720
Epoch 50/150
30/30 [==============================] - 0s 3ms/step - loss: 1.8409 - acc:
0.6741 - val_loss: 1.8431 - val_acc: 0.6690
Epoch 51/150
30/30 [==============================] - 0s 3ms/step - loss: 1.8287 - acc:
0.6763 - val_loss: 1.8321 - val_acc: 0.6720
Epoch 52/150
30/30 [==============================] - 0s 3ms/step - loss: 1.8162 - acc:
0.6777 - val_loss: 1.8180 - val_acc: 0.6700
Epoch 53/150
30/30 [==============================] - 0s 3ms/step - loss: 1.8045 - acc:
0.6783 - val_loss: 1.8089 - val_acc: 0.6730
Epoch 54/150
30/30 [==============================] - 0s 3ms/step - loss: 1.7934 - acc:
0.6787 - val_loss: 1.7982 - val_acc: 0.6740
Epoch 55/150
30/30 [==============================] - 0s 3ms/step - loss: 1.7824 - acc:
0.6807 - val_loss: 1.7858 - val_acc: 0.6740
Epoch 56/150
30/30 [==============================] - 0s 3ms/step - loss: 1.7711 - acc:
0.6816 - val_loss: 1.7757 - val_acc: 0.6730
Epoch 57/150
30/30 [==============================] - 0s 3ms/step - loss: 1.7611 - acc:
0.6832 - val_loss: 1.7693 - val_acc: 0.6720
Epoch 58/150
30/30 [==============================] - 0s 3ms/step - loss: 1.7510 - acc:
```

```
0.6821 - val_loss: 1.7583 - val_acc: 0.6760
Epoch 59/150
30/30 [==============================] - 0s 3ms/step - loss: 1.7412 - acc:
0.6840 - val_loss: 1.7457 - val_acc: 0.6790
Epoch 60/150
30/30 [==============================] - 0s 3ms/step - loss: 1.7311 - acc:
0.6841 - val_loss: 1.7401 - val_acc: 0.6770
Epoch 61/150
30/30 [==============================] - 0s 3ms/step - loss: 1.7222 - acc:
0.6847 - val_loss: 1.7255 - val_acc: 0.6790
Epoch 62/150
30/30 [==============================] - 0s 3ms/step - loss: 1.7123 - acc:
0.6863 - val_loss: 1.7167 - val_acc: 0.6780
Epoch 63/150
30/30 [==============================] - 0s 4ms/step - loss: 1.7027 - acc:
0.6864 - val_loss: 1.7086 - val_acc: 0.6800
Epoch 64/150
30/30 [==============================] - 0s 4ms/step - loss: 1.6941 - acc:
0.6852 - val_loss: 1.7001 - val_acc: 0.6750
Epoch 65/150
30/30 [==============================] - 0s 3ms/step - loss: 1.6852 - acc:
0.6856 - val_loss: 1.6954 - val_acc: 0.6780
Epoch 66/150
30/30 [==============================] - 0s 3ms/step - loss: 1.6771 - acc:
0.6873 - val_loss: 1.6831 - val_acc: 0.6830
Epoch 67/150
30/30 [==============================] - 0s 3ms/step - loss: 1.6681 - acc:
0.6875 - val_loss: 1.6734 - val_acc: 0.6780
Epoch 68/150
30/30 [==============================] - 0s 4ms/step - loss: 1.6599 - acc:
0.6873 - val_loss: 1.6685 - val_acc: 0.6840
Epoch 69/150
30/30 [==============================] - 0s 3ms/step - loss: 1.6518 - acc:
0.6879 - val_loss: 1.6574 - val_acc: 0.6830
Epoch 70/150
30/30 [==============================] - 0s 3ms/step - loss: 1.6435 - acc:
0.6889 - val_loss: 1.6538 - val_acc: 0.6780
Epoch 71/150
30/30 [==============================] - 0s 3ms/step - loss: 1.6362 - acc:
0.6899 - val_loss: 1.6419 - val_acc: 0.6810
Epoch 72/150
30/30 [==============================] - 0s 3ms/step - loss: 1.6273 - acc:
0.6897 - val_loss: 1.6347 - val_acc: 0.6780
Epoch 73/150
30/30 [==============================] - 0s 3ms/step - loss: 1.6194 - acc:
0.6912 - val_loss: 1.6336 - val_acc: 0.6750
Epoch 74/150
30/30 [==============================] - 0s 3ms/step - loss: 1.6123 - acc:
```

```
0.6909 - val_loss: 1.6210 - val_acc: 0.6810
Epoch 75/150
30/30 [==============================] - 0s 3ms/step - loss: 1.6038 - acc:
0.6911 - val_loss: 1.6159 - val_acc: 0.6760
Epoch 76/150
30/30 [==============================] - 0s 3ms/step - loss: 1.5970 - acc:
0.6917 - val_loss: 1.6093 - val_acc: 0.6830
Epoch 77/150
30/30 [==============================] - 0s 3ms/step - loss: 1.5896 - acc:
0.6925 - val_loss: 1.6044 - val_acc: 0.6860
Epoch 78/150
30/30 [==============================] - 0s 3ms/step - loss: 1.5825 - acc:
0.6944 - val_loss: 1.5922 - val_acc: 0.6820
Epoch 79/150
30/30 [==============================] - 0s 3ms/step - loss: 1.5751 - acc:
0.6933 - val_loss: 1.5859 - val_acc: 0.6850
Epoch 80/150
30/30 [==============================] - 0s 3ms/step - loss: 1.5677 - acc:
0.6935 - val_loss: 1.5763 - val_acc: 0.6790
Epoch 81/150
30/30 [==============================] - 0s 3ms/step - loss: 1.5606 - acc:
0.6929 - val_loss: 1.5724 - val_acc: 0.6790
Epoch 82/150
30/30 [==============================] - 0s 4ms/step - loss: 1.5538 - acc:
0.6952 - val_loss: 1.5645 - val_acc: 0.6890
Epoch 83/150
30/30 [==============================] - 0s 3ms/step - loss: 1.5472 - acc:
0.6957 - val_loss: 1.5569 - val_acc: 0.6830
Epoch 84/150
30/30 [==============================] - 0s 3ms/step - loss: 1.5402 - acc:
0.6933 - val_loss: 1.5531 - val_acc: 0.6850
Epoch 85/150
30/30 [==============================] - 0s 3ms/step - loss: 1.5334 - acc:
0.6963 - val_loss: 1.5446 - val_acc: 0.6810
Epoch 86/150
30/30 [==============================] - 0s 3ms/step - loss: 1.5273 - acc:
0.6969 - val_loss: 1.5382 - val_acc: 0.6870
Epoch 87/150
30/30 [==============================] - 0s 3ms/step - loss: 1.5210 - acc:
0.6963 - val_loss: 1.5311 - val_acc: 0.6850
Epoch 88/150
30/30 [==============================] - 0s 3ms/step - loss: 1.5141 - acc:
0.6960 - val_loss: 1.5243 - val_acc: 0.6850
Epoch 89/150
30/30 [==============================] - 0s 3ms/step - loss: 1.5078 - acc:
0.6969 - val_loss: 1.5197 - val_acc: 0.6830
Epoch 90/150
30/30 [==============================] - 0s 3ms/step - loss: 1.5016 - acc:
```

```
0.6984 - val_loss: 1.5133 - val_acc: 0.6830
Epoch 91/150
30/30 [==============================] - 0s 3ms/step - loss: 1.4956 - acc:
0.6991 - val_loss: 1.5084 - val_acc: 0.6820
Epoch 92/150
30/30 [==============================] - 0s 3ms/step - loss: 1.4892 - acc:
0.7000 - val_loss: 1.5025 - val_acc: 0.6790
Epoch 93/150
30/30 [==============================] - 0s 3ms/step - loss: 1.4835 - acc:
0.7007 - val_loss: 1.4947 - val_acc: 0.6840
Epoch 94/150
30/30 [==============================] - 0s 3ms/step - loss: 1.4769 - acc:
0.7003 - val_loss: 1.4887 - val_acc: 0.6860
Epoch 95/150
30/30 [==============================] - 0s 3ms/step - loss: 1.4713 - acc:
0.7001 - val_loss: 1.4834 - val_acc: 0.6870
Epoch 96/150
30/30 [==============================] - 0s 3ms/step - loss: 1.4653 - acc:
0.7013 - val_loss: 1.4777 - val_acc: 0.6900
Epoch 97/150
30/30 [==============================] - 0s 3ms/step - loss: 1.4598 - acc:
0.7025 - val_loss: 1.4724 - val_acc: 0.6890
Epoch 98/150
30/30 [==============================] - 0s 3ms/step - loss: 1.4538 - acc:
0.7027 - val_loss: 1.4711 - val_acc: 0.6810
Epoch 99/150
30/30 [==============================] - 0s 3ms/step - loss: 1.4481 - acc:
0.7044 - val_loss: 1.4599 - val_acc: 0.6860
Epoch 100/150
30/30 [==============================] - 0s 3ms/step - loss: 1.4423 - acc:
0.7031 - val_loss: 1.4585 - val_acc: 0.6870
Epoch 101/150
30/30 [==============================] - 0s 3ms/step - loss: 1.4370 - acc:
0.7041 - val_loss: 1.4515 - val_acc: 0.6890
Epoch 102/150
30/30 [==============================] - 0s 3ms/step - loss: 1.4314 - acc:
0.7032 - val_loss: 1.4441 - val_acc: 0.6860
Epoch 103/150
30/30 [==============================] - 0s 3ms/step - loss: 1.4262 - acc:
0.7055 - val_loss: 1.4392 - val_acc: 0.6880
Epoch 104/150
30/30 [==============================] - 0s 3ms/step - loss: 1.4210 - acc:
0.7043 - val_loss: 1.4367 - val_acc: 0.6930
Epoch 105/150
30/30 [==============================] - 0s 3ms/step - loss: 1.4160 - acc:
0.7052 - val_loss: 1.4278 - val_acc: 0.6900
Epoch 106/150
30/30 [==============================] - 0s 4ms/step - loss: 1.4102 - acc:
```

```
0.7035 - val_loss: 1.4228 - val_acc: 0.6880
Epoch 107/150
30/30 [==============================] - 0s 3ms/step - loss: 1.4042 - acc:
0.7063 - val_loss: 1.4192 - val_acc: 0.6830
Epoch 108/150
30/30 [==============================] - 0s 3ms/step - loss: 1.3994 - acc:
0.7076 - val_loss: 1.4144 - val_acc: 0.6890
Epoch 109/150
30/30 [==============================] - 0s 4ms/step - loss: 1.3947 - acc:
0.7077 - val_loss: 1.4093 - val_acc: 0.6860
Epoch 110/150
30/30 [==============================] - 0s 3ms/step - loss: 1.3891 - acc:
0.7081 - val_loss: 1.4103 - val_acc: 0.6840
Epoch 111/150
30/30 [==============================] - 0s 3ms/step - loss: 1.3843 - acc:
0.7093 - val_loss: 1.3999 - val_acc: 0.6930
Epoch 112/150
30/30 [==============================] - 0s 3ms/step - loss: 1.3794 - acc:
0.7091 - val_loss: 1.3936 - val_acc: 0.6910
Epoch 113/150
30/30 [==============================] - 0s 3ms/step - loss: 1.3749 - acc:
0.7076 - val_loss: 1.3882 - val_acc: 0.6950
Epoch 114/150
30/30 [==============================] - 0s 3ms/step - loss: 1.3699 - acc:
0.7104 - val_loss: 1.3875 - val_acc: 0.6870
Epoch 115/150
30/30 [==============================] - 0s 3ms/step - loss: 1.3653 - acc:
0.7099 - val_loss: 1.3840 - val_acc: 0.6850
Epoch 116/150
30/30 [==============================] - 0s 3ms/step - loss: 1.3602 - acc:
0.7095 - val_loss: 1.3776 - val_acc: 0.6920
Epoch 117/150
30/30 [==============================] - 0s 3ms/step - loss: 1.3553 - acc:
0.7113 - val_loss: 1.3766 - val_acc: 0.6920
Epoch 118/150
30/30 [==============================] - 0s 3ms/step - loss: 1.3510 - acc:
0.7105 - val_loss: 1.3705 - val_acc: 0.6890
Epoch 119/150
30/30 [==============================] - 0s 3ms/step - loss: 1.3465 - acc:
0.7124 - val_loss: 1.3640 - val_acc: 0.6910
Epoch 120/150
30/30 [==============================] - 0s 3ms/step - loss: 1.3418 - acc:
0.7117 - val_loss: 1.3561 - val_acc: 0.6930
Epoch 121/150
30/30 [==============================] - 0s 3ms/step - loss: 1.3377 - acc:
0.7124 - val_loss: 1.3519 - val_acc: 0.6890
Epoch 122/150
30/30 [==============================] - 0s 3ms/step - loss: 1.3325 - acc:
```

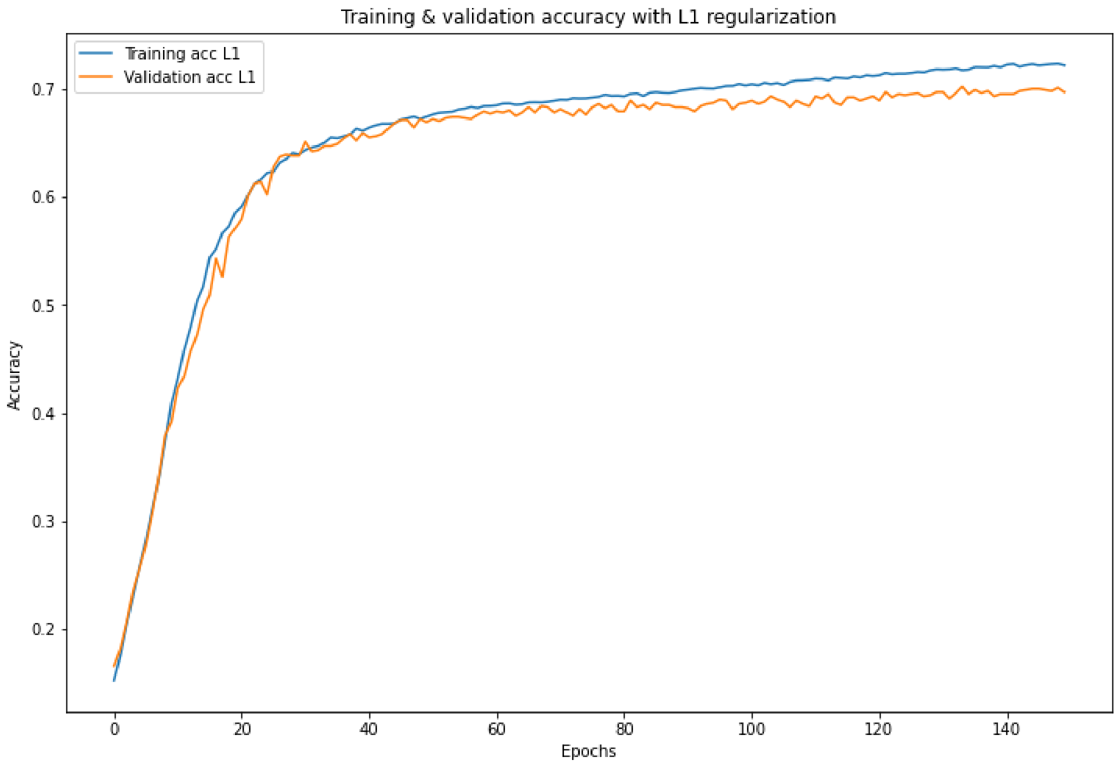
```
0.7145 - val_loss: 1.3507 - val_acc: 0.6970
Epoch 123/150
30/30 [==============================] - 0s 3ms/step - loss: 1.3288 - acc:
0.7133 - val_loss: 1.3465 - val_acc: 0.6920
Epoch 124/150
30/30 [==============================] - 0s 3ms/step - loss: 1.3244 - acc:
0.7139 - val_loss: 1.3400 - val_acc: 0.6950
Epoch 125/150
30/30 [==============================] - 0s 3ms/step - loss: 1.3204 - acc:
0.7139 - val_loss: 1.3366 - val_acc: 0.6940
Epoch 126/150
30/30 [==============================] - 0s 3ms/step - loss: 1.3153 - acc:
0.7145 - val_loss: 1.3324 - val_acc: 0.6950
Epoch 127/150
30/30 [==============================] - 0s 3ms/step - loss: 1.3114 - acc:
0.7155 - val_loss: 1.3287 - val_acc: 0.6960
Epoch 128/150
30/30 [==============================] - 0s 3ms/step - loss: 1.3076 - acc:
0.7151 - val_loss: 1.3251 - val_acc: 0.6930
Epoch 129/150
30/30 [==============================] - 0s 3ms/step - loss: 1.3031 - acc:
0.7169 - val_loss: 1.3209 - val_acc: 0.6940
Epoch 130/150
30/30 [==============================] - 0s 3ms/step - loss: 1.2993 - acc:
0.7179 - val_loss: 1.3211 - val_acc: 0.6970
Epoch 131/150
30/30 [==============================] - 0s 3ms/step - loss: 1.2954 - acc:
0.7176 - val_loss: 1.3128 - val_acc: 0.6970
Epoch 132/150
30/30 [==============================] - 0s 3ms/step - loss: 1.2913 - acc:
0.7179 - val_loss: 1.3137 - val_acc: 0.6910
Epoch 133/150
30/30 [==============================] - 0s 3ms/step - loss: 1.2876 - acc:
0.7188 - val_loss: 1.3119 - val_acc: 0.6960
Epoch 134/150
30/30 [==============================] - 0s 3ms/step - loss: 1.2835 - acc:
0.7171 - val_loss: 1.3039 - val_acc: 0.7020
Epoch 135/150
30/30 [==============================] - 0s 3ms/step - loss: 1.2798 - acc:
0.7176 - val_loss: 1.2972 - val_acc: 0.6950
Epoch 136/150
30/30 [==============================] - 0s 3ms/step - loss: 1.2761 - acc:
0.7200 - val_loss: 1.2937 - val_acc: 0.6990
Epoch 137/150
30/30 [==============================] - 0s 3ms/step - loss: 1.2720 - acc:
0.7199 - val_loss: 1.2970 - val_acc: 0.6960
Epoch 138/150
30/30 [==============================] - 0s 3ms/step - loss: 1.2691 - acc:
```

```
0.7197 - val_loss: 1.2881 - val_acc: 0.6980
Epoch 139/150
30/30 [==============================] - 0s 3ms/step - loss: 1.2650 - acc:
0.7211 - val_loss: 1.2841 - val_acc: 0.6930
Epoch 140/150
30/30 [==============================] - 0s 3ms/step - loss: 1.2623 - acc:
0.7199 - val_loss: 1.2855 - val_acc: 0.6950
Epoch 141/150
30/30 [==============================] - 0s 3ms/step - loss: 1.2587 - acc:
0.7223 - val_loss: 1.2778 - val_acc: 0.6950
Epoch 142/150
30/30 [==============================] - 0s 3ms/step - loss: 1.2547 - acc:
0.7229 - val_loss: 1.2758 - val_acc: 0.6950
Epoch 143/150
30/30 [==============================] - 0s 3ms/step - loss: 1.2511 - acc:
0.7204 - val_loss: 1.2692 - val_acc: 0.6980
Epoch 144/150
30/30 [==============================] - 0s 3ms/step - loss: 1.2479 - acc:
0.7219 - val_loss: 1.2661 - val_acc: 0.6990
Epoch 145/150
30/30 [==============================] - 0s 3ms/step - loss: 1.2441 - acc:
0.7228 - val_loss: 1.2648 - val_acc: 0.7000
Epoch 146/150
30/30 [==============================] - 0s 3ms/step - loss: 1.2409 - acc:
0.7216 - val_loss: 1.2601 - val_acc: 0.7000
Epoch 147/150
30/30 [==============================] - 0s 3ms/step - loss: 1.2377 - acc:
0.7223 - val_loss: 1.2588 - val_acc: 0.6990
Epoch 148/150
30/30 [==============================] - 0s 3ms/step - loss: 1.2347 - acc:
0.7228 - val_loss: 1.2536 - val_acc: 0.6980
Epoch 149/150
30/30 [==============================] - 0s 3ms/step - loss: 1.2314 - acc:
0.7232 - val_loss: 1.2507 - val_acc: 0.7010
Epoch 150/150
30/30 [==============================] - 0s 3ms/step - loss: 1.2286 - acc:
0.7217 - val_loss: 1.2503 - val_acc: 0.6970
```

Plot the training as well as the validation accuracy for the L1 model:

[41]:
```
fig, ax = plt.subplots(figsize=(12, 8))

L1_model_dict = L1_model_val.history

acc_values = L1_model_dict['acc']
val_acc_values = L1_model_dict['val_acc']

# epochs = range(1, len(acc_values) + 1)
```

```
ax.plot(acc_values, label='Training acc L1')
ax.plot(val_acc_values, label='Validation acc L1')
ax.set_title('Training & validation accuracy with L1 regularization')
ax.set_xlabel('Epochs')
ax.set_ylabel('Accuracy')
ax.legend();
```



Notice how the training and validation accuracy don't diverge as much as before. Unfortunately, the validation accuracy isn't still that good. Next, experiment with dropout regularization to see if it offers any advantages.

1.14 Dropout Regularization

It's time to try another technique: applying dropout to layers. As discussed in the earlier lesson, this involves setting a certain proportion of units in each layer to zero. In the following cell:

- Apply a dropout rate of 30% to the input layer
- Add a first hidden layer with 50 units and `'relu'` activation
- Apply a dropout rate of 30% to the first hidden layer
- Add a second hidden layer with 25 units and `'relu'` activation
- Apply a dropout rate of 30% to the second hidden layer

[42]:
```python
#  This cell may take about a minute to run
random.seed(123)
dropout_model = models.Sequential()

# Implement dropout to the input layer
# NOTE: This is where you define the number of units in the input layer
dropout_model.add(layers.Dropout(0.3, input_shape = (2000,)))

# Add the first hidden layer
dropout_model.add(layers.Dense(50, activation = "relu"))

# Implement dropout to the first hidden layer
dropout_model.add(layers.Dropout(0.3))

# Add the second hidden layer
dropout_model.add(layers.Dense(25, activation = "relu"))

# Implement dropout to the second hidden layer
dropout_model.add(layers.Dropout(0.3))


# Add the output layer
dropout_model.add(layers.Dense(7, activation='softmax'))


# Compile the model
dropout_model.compile(optimizer='SGD',
                      loss='categorical_crossentropy',
                      metrics=['acc'])

# Train the model
dropout_model_val = dropout_model.fit(X_train_tokens,
                                      y_train_lb,
                                      epochs=150,
                                      batch_size=256,
                                      validation_data=(X_val_tokens, y_val_lb))
```

```
Epoch 1/150
30/30 [==============================] - 0s 10ms/step - loss: 1.9750 - acc:
0.1613 - val_loss: 1.9361 - val_acc: 0.1550
Epoch 2/150
30/30 [==============================] - 0s 5ms/step - loss: 1.9484 - acc:
0.1675 - val_loss: 1.9274 - val_acc: 0.1750
Epoch 3/150
30/30 [==============================] - 0s 5ms/step - loss: 1.9445 - acc:
0.1688 - val_loss: 1.9204 - val_acc: 0.1820
Epoch 4/150
```

```
30/30 [==============================] - 0s 5ms/step - loss: 1.9261 - acc:
0.1840 - val_loss: 1.9126 - val_acc: 0.1910
Epoch 5/150
30/30 [==============================] - 0s 5ms/step - loss: 1.9200 - acc:
0.1833 - val_loss: 1.9041 - val_acc: 0.1960
Epoch 6/150
30/30 [==============================] - 0s 5ms/step - loss: 1.9076 - acc:
0.2045 - val_loss: 1.8946 - val_acc: 0.2020
Epoch 7/150
30/30 [==============================] - 0s 5ms/step - loss: 1.8989 - acc:
0.1987 - val_loss: 1.8847 - val_acc: 0.2130
Epoch 8/150
30/30 [==============================] - 0s 5ms/step - loss: 1.8994 - acc:
0.2029 - val_loss: 1.8746 - val_acc: 0.2240
Epoch 9/150
30/30 [==============================] - 0s 5ms/step - loss: 1.8852 - acc:
0.2155 - val_loss: 1.8618 - val_acc: 0.2310
Epoch 10/150
30/30 [==============================] - 0s 6ms/step - loss: 1.8770 - acc:
0.2220 - val_loss: 1.8493 - val_acc: 0.2460
Epoch 11/150
30/30 [==============================] - 0s 5ms/step - loss: 1.8596 - acc:
0.2405 - val_loss: 1.8348 - val_acc: 0.2630
Epoch 12/150
30/30 [==============================] - 0s 5ms/step - loss: 1.8564 - acc:
0.2417 - val_loss: 1.8198 - val_acc: 0.2800
Epoch 13/150
30/30 [==============================] - 0s 5ms/step - loss: 1.8393 - acc:
0.2452 - val_loss: 1.8007 - val_acc: 0.2900
Epoch 14/150
30/30 [==============================] - 0s 5ms/step - loss: 1.8226 - acc:
0.2596 - val_loss: 1.7805 - val_acc: 0.3120
Epoch 15/150
30/30 [==============================] - 0s 5ms/step - loss: 1.8106 - acc:
0.2631 - val_loss: 1.7593 - val_acc: 0.3200
Epoch 16/150
30/30 [==============================] - 0s 5ms/step - loss: 1.7929 - acc:
0.2757 - val_loss: 1.7374 - val_acc: 0.3290
Epoch 17/150
30/30 [==============================] - 0s 5ms/step - loss: 1.7801 - acc:
0.2853 - val_loss: 1.7161 - val_acc: 0.3550
Epoch 18/150
30/30 [==============================] - 0s 5ms/step - loss: 1.7505 - acc:
0.3065 - val_loss: 1.6903 - val_acc: 0.3610
Epoch 19/150
30/30 [==============================] - 0s 5ms/step - loss: 1.7443 - acc:
0.3095 - val_loss: 1.6662 - val_acc: 0.3940
Epoch 20/150
```

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30/30 [==============================] - 0s 5ms/step - loss: 1.7237 - acc:
0.3217 - val_loss: 1.6403 - val_acc: 0.4220
Epoch 21/150
30/30 [==============================] - 0s 5ms/step - loss: 1.6996 - acc:
0.3308 - val_loss: 1.6120 - val_acc: 0.4340
Epoch 22/150
30/30 [==============================] - 0s 5ms/step - loss: 1.6874 - acc:
0.3339 - val_loss: 1.5859 - val_acc: 0.4480
Epoch 23/150
30/30 [==============================] - 0s 5ms/step - loss: 1.6592 - acc:
0.3453 - val_loss: 1.5582 - val_acc: 0.4680
Epoch 24/150
30/30 [==============================] - 0s 5ms/step - loss: 1.6515 - acc:
0.3464 - val_loss: 1.5328 - val_acc: 0.4950
Epoch 25/150
30/30 [==============================] - 0s 5ms/step - loss: 1.6278 - acc:
0.3580 - val_loss: 1.5065 - val_acc: 0.5110
Epoch 26/150
30/30 [==============================] - 0s 5ms/step - loss: 1.6068 - acc:
0.3801 - val_loss: 1.4802 - val_acc: 0.5290
Epoch 27/150
30/30 [==============================] - 0s 6ms/step - loss: 1.5929 - acc:
0.3824 - val_loss: 1.4552 - val_acc: 0.5400
Epoch 28/150
30/30 [==============================] - 0s 5ms/step - loss: 1.5691 - acc:
0.4055 - val_loss: 1.4295 - val_acc: 0.5470
Epoch 29/150
30/30 [==============================] - 0s 5ms/step - loss: 1.5551 - acc:
0.4039 - val_loss: 1.4052 - val_acc: 0.5570
Epoch 30/150
30/30 [==============================] - 0s 5ms/step - loss: 1.5302 - acc:
0.4092 - val_loss: 1.3798 - val_acc: 0.5710
Epoch 31/150
30/30 [==============================] - 0s 5ms/step - loss: 1.5116 - acc:
0.4233 - val_loss: 1.3570 - val_acc: 0.5760
Epoch 32/150
30/30 [==============================] - 0s 5ms/step - loss: 1.5025 - acc:
0.4275 - val_loss: 1.3369 - val_acc: 0.5790
Epoch 33/150
30/30 [==============================] - 0s 5ms/step - loss: 1.4827 - acc:
0.4427 - val_loss: 1.3152 - val_acc: 0.5970
Epoch 34/150
30/30 [==============================] - 0s 5ms/step - loss: 1.4581 - acc:
0.4489 - val_loss: 1.2919 - val_acc: 0.5950
Epoch 35/150
30/30 [==============================] - 0s 5ms/step - loss: 1.4433 - acc:
0.4460 - val_loss: 1.2709 - val_acc: 0.6030
Epoch 36/150
```

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30/30 [==============================] - 0s 5ms/step - loss: 1.4345 - acc:
0.4548 - val_loss: 1.2519 - val_acc: 0.6080
Epoch 37/150
30/30 [==============================] - 0s 5ms/step - loss: 1.4245 - acc:
0.4572 - val_loss: 1.2358 - val_acc: 0.6220
Epoch 38/150
30/30 [==============================] - 0s 5ms/step - loss: 1.4017 - acc:
0.4756 - val_loss: 1.2144 - val_acc: 0.6130
Epoch 39/150
30/30 [==============================] - 0s 4ms/step - loss: 1.3942 - acc:
0.4692 - val_loss: 1.2012 - val_acc: 0.6240
Epoch 40/150
30/30 [==============================] - 0s 5ms/step - loss: 1.3807 - acc:
0.4840 - val_loss: 1.1854 - val_acc: 0.6280
Epoch 41/150
30/30 [==============================] - 0s 5ms/step - loss: 1.3689 - acc:
0.4807 - val_loss: 1.1656 - val_acc: 0.6340
Epoch 42/150
30/30 [==============================] - 0s 5ms/step - loss: 1.3520 - acc:
0.4985 - val_loss: 1.1520 - val_acc: 0.6410
Epoch 43/150
30/30 [==============================] - 0s 5ms/step - loss: 1.3355 - acc:
0.4976 - val_loss: 1.1352 - val_acc: 0.6470
Epoch 44/150
30/30 [==============================] - 0s 5ms/step - loss: 1.3287 - acc:
0.4992 - val_loss: 1.1205 - val_acc: 0.6440
Epoch 45/150
30/30 [==============================] - 0s 5ms/step - loss: 1.3285 - acc:
0.4948 - val_loss: 1.1094 - val_acc: 0.6530
Epoch 46/150
30/30 [==============================] - 0s 5ms/step - loss: 1.3112 - acc:
0.5019 - val_loss: 1.0997 - val_acc: 0.6580
Epoch 47/150
30/30 [==============================] - 0s 5ms/step - loss: 1.3007 - acc:
0.5081 - val_loss: 1.0835 - val_acc: 0.6630
Epoch 48/150
30/30 [==============================] - 0s 5ms/step - loss: 1.2842 - acc:
0.5177 - val_loss: 1.0714 - val_acc: 0.6560
Epoch 49/150
30/30 [==============================] - 0s 5ms/step - loss: 1.2766 - acc:
0.5163 - val_loss: 1.0576 - val_acc: 0.6700
Epoch 50/150
30/30 [==============================] - 0s 5ms/step - loss: 1.2800 - acc:
0.5152 - val_loss: 1.0484 - val_acc: 0.6720
Epoch 51/150
30/30 [==============================] - 0s 5ms/step - loss: 1.2605 - acc:
0.5296 - val_loss: 1.0386 - val_acc: 0.6670
Epoch 52/150
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30/30 [==============================] - 0s 5ms/step - loss: 1.2476 - acc:
0.5347 - val_loss: 1.0270 - val_acc: 0.6800
Epoch 53/150
30/30 [==============================] - 0s 5ms/step - loss: 1.2346 - acc:
0.5383 - val_loss: 1.0151 - val_acc: 0.6770
Epoch 54/150
30/30 [==============================] - 0s 5ms/step - loss: 1.2268 - acc:
0.5411 - val_loss: 1.0066 - val_acc: 0.6820
Epoch 55/150
30/30 [==============================] - 0s 5ms/step - loss: 1.2304 - acc:
0.5415 - val_loss: 1.0003 - val_acc: 0.6940
Epoch 56/150
30/30 [==============================] - 0s 5ms/step - loss: 1.2172 - acc:
0.5443 - val_loss: 0.9896 - val_acc: 0.6880
Epoch 57/150
30/30 [==============================] - 0s 5ms/step - loss: 1.2062 - acc:
0.5465 - val_loss: 0.9813 - val_acc: 0.6930
Epoch 58/150
30/30 [==============================] - 0s 5ms/step - loss: 1.2022 - acc:
0.5544 - val_loss: 0.9742 - val_acc: 0.6870
Epoch 59/150
30/30 [==============================] - 0s 5ms/step - loss: 1.1891 - acc:
0.5571 - val_loss: 0.9649 - val_acc: 0.6930
Epoch 60/150
30/30 [==============================] - 0s 5ms/step - loss: 1.1723 - acc:
0.5641 - val_loss: 0.9549 - val_acc: 0.6970
Epoch 61/150
30/30 [==============================] - 0s 5ms/step - loss: 1.1822 - acc:
0.5603 - val_loss: 0.9481 - val_acc: 0.6940
Epoch 62/150
30/30 [==============================] - 0s 5ms/step - loss: 1.1729 - acc:
0.5653 - val_loss: 0.9421 - val_acc: 0.6920
Epoch 63/150
30/30 [==============================] - 0s 5ms/step - loss: 1.1712 - acc:
0.5629 - val_loss: 0.9352 - val_acc: 0.6990
Epoch 64/150
30/30 [==============================] - 0s 5ms/step - loss: 1.1659 - acc:
0.5651 - val_loss: 0.9320 - val_acc: 0.6930
Epoch 65/150
30/30 [==============================] - 0s 5ms/step - loss: 1.1450 - acc:
0.5727 - val_loss: 0.9216 - val_acc: 0.6960
Epoch 66/150
30/30 [==============================] - 0s 5ms/step - loss: 1.1448 - acc:
0.5688 - val_loss: 0.9172 - val_acc: 0.7020
Epoch 67/150
30/30 [==============================] - 0s 5ms/step - loss: 1.1411 - acc:
0.5689 - val_loss: 0.9106 - val_acc: 0.7050
Epoch 68/150
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30/30 [==============================] - 0s 5ms/step - loss: 1.1158 - acc:
0.5844 - val_loss: 0.8996 - val_acc: 0.6990
Epoch 69/150
30/30 [==============================] - 0s 5ms/step - loss: 1.1232 - acc:
0.5857 - val_loss: 0.8949 - val_acc: 0.7010
Epoch 70/150
30/30 [==============================] - 0s 5ms/step - loss: 1.1174 - acc:
0.5809 - val_loss: 0.8906 - val_acc: 0.7060
Epoch 71/150
30/30 [==============================] - 0s 5ms/step - loss: 1.1285 - acc:
0.5833 - val_loss: 0.8831 - val_acc: 0.7080
Epoch 72/150
30/30 [==============================] - 0s 5ms/step - loss: 1.1142 - acc:
0.5793 - val_loss: 0.8780 - val_acc: 0.7070
Epoch 73/150
30/30 [==============================] - 0s 5ms/step - loss: 1.1207 - acc:
0.5800 - val_loss: 0.8737 - val_acc: 0.7070
Epoch 74/150
30/30 [==============================] - 0s 5ms/step - loss: 1.1040 - acc:
0.5901 - val_loss: 0.8706 - val_acc: 0.7120
Epoch 75/150
30/30 [==============================] - 0s 5ms/step - loss: 1.0915 - acc:
0.5920 - val_loss: 0.8664 - val_acc: 0.7110
Epoch 76/150
30/30 [==============================] - 0s 5ms/step - loss: 1.0996 - acc:
0.5891 - val_loss: 0.8626 - val_acc: 0.7080
Epoch 77/150
30/30 [==============================] - 0s 5ms/step - loss: 1.0963 - acc:
0.5923 - val_loss: 0.8578 - val_acc: 0.7130
Epoch 78/150
30/30 [==============================] - 0s 5ms/step - loss: 1.0832 - acc:
0.5989 - val_loss: 0.8531 - val_acc: 0.7130
Epoch 79/150
30/30 [==============================] - 0s 5ms/step - loss: 1.0753 - acc:
0.5987 - val_loss: 0.8451 - val_acc: 0.7140
Epoch 80/150
30/30 [==============================] - 0s 5ms/step - loss: 1.0677 - acc:
0.6003 - val_loss: 0.8406 - val_acc: 0.7130
Epoch 81/150
30/30 [==============================] - 0s 5ms/step - loss: 1.0751 - acc:
0.6059 - val_loss: 0.8370 - val_acc: 0.7120
Epoch 82/150
30/30 [==============================] - 0s 5ms/step - loss: 1.0796 - acc:
0.6009 - val_loss: 0.8342 - val_acc: 0.7140
Epoch 83/150
30/30 [==============================] - 0s 5ms/step - loss: 1.0607 - acc:
0.5983 - val_loss: 0.8303 - val_acc: 0.7140
Epoch 84/150
```

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30/30 [==============================] - 0s 5ms/step - loss: 1.0581 - acc:
0.6069 - val_loss: 0.8239 - val_acc: 0.7150
Epoch 85/150
30/30 [==============================] - 0s 5ms/step - loss: 1.0442 - acc:
0.6109 - val_loss: 0.8191 - val_acc: 0.7180
Epoch 86/150
30/30 [==============================] - 0s 5ms/step - loss: 1.0455 - acc:
0.6143 - val_loss: 0.8170 - val_acc: 0.7210
Epoch 87/150
30/30 [==============================] - 0s 5ms/step - loss: 1.0326 - acc:
0.6137 - val_loss: 0.8109 - val_acc: 0.7210
Epoch 88/150
30/30 [==============================] - 0s 5ms/step - loss: 1.0251 - acc:
0.6233 - val_loss: 0.8048 - val_acc: 0.7210
Epoch 89/150
30/30 [==============================] - 0s 5ms/step - loss: 1.0234 - acc:
0.6115 - val_loss: 0.7988 - val_acc: 0.7220
Epoch 90/150
30/30 [==============================] - 0s 5ms/step - loss: 1.0215 - acc:
0.6172 - val_loss: 0.7984 - val_acc: 0.7180
Epoch 91/150
30/30 [==============================] - 0s 4ms/step - loss: 1.0273 - acc:
0.6191 - val_loss: 0.7957 - val_acc: 0.7180
Epoch 92/150
30/30 [==============================] - 0s 5ms/step - loss: 1.0207 - acc:
0.6225 - val_loss: 0.7939 - val_acc: 0.7180
Epoch 93/150
30/30 [==============================] - 0s 5ms/step - loss: 1.0263 - acc:
0.6163 - val_loss: 0.7880 - val_acc: 0.7220
Epoch 94/150
30/30 [==============================] - 0s 5ms/step - loss: 1.0008 - acc:
0.6332 - val_loss: 0.7861 - val_acc: 0.7240
Epoch 95/150
30/30 [==============================] - 0s 5ms/step - loss: 1.0048 - acc:
0.6236 - val_loss: 0.7833 - val_acc: 0.7230
Epoch 96/150
30/30 [==============================] - 0s 5ms/step - loss: 1.0075 - acc:
0.6273 - val_loss: 0.7812 - val_acc: 0.7250
Epoch 97/150
30/30 [==============================] - 0s 5ms/step - loss: 1.0018 - acc:
0.6300 - val_loss: 0.7784 - val_acc: 0.7250
Epoch 98/150
30/30 [==============================] - 0s 5ms/step - loss: 1.0024 - acc:
0.6312 - val_loss: 0.7761 - val_acc: 0.7270
Epoch 99/150
30/30 [==============================] - 0s 5ms/step - loss: 1.0035 - acc:
0.6292 - val_loss: 0.7736 - val_acc: 0.7290
Epoch 100/150
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30/30 [==============================] - 0s 5ms/step - loss: 0.9866 - acc:
0.6355 - val_loss: 0.7675 - val_acc: 0.7250
Epoch 101/150
30/30 [==============================] - 0s 5ms/step - loss: 0.9754 - acc:
0.6376 - val_loss: 0.7651 - val_acc: 0.7260
Epoch 102/150
30/30 [==============================] - 0s 5ms/step - loss: 0.9828 - acc:
0.6360 - val_loss: 0.7598 - val_acc: 0.7270
Epoch 103/150
30/30 [==============================] - 0s 5ms/step - loss: 0.9796 - acc:
0.6360 - val_loss: 0.7569 - val_acc: 0.7280
Epoch 104/150
30/30 [==============================] - 0s 5ms/step - loss: 0.9732 - acc:
0.6425 - val_loss: 0.7548 - val_acc: 0.7290
Epoch 105/150
30/30 [==============================] - 0s 5ms/step - loss: 0.9702 - acc:
0.6376 - val_loss: 0.7526 - val_acc: 0.7310
Epoch 106/150
30/30 [==============================] - 0s 5ms/step - loss: 0.9754 - acc:
0.6369 - val_loss: 0.7528 - val_acc: 0.7310
Epoch 107/150
30/30 [==============================] - 0s 5ms/step - loss: 0.9754 - acc:
0.6437 - val_loss: 0.7508 - val_acc: 0.7300
Epoch 108/150
30/30 [==============================] - 0s 5ms/step - loss: 0.9663 - acc:
0.6379 - val_loss: 0.7471 - val_acc: 0.7310
Epoch 109/150
30/30 [==============================] - 0s 5ms/step - loss: 0.9656 - acc:
0.6404 - val_loss: 0.7450 - val_acc: 0.7310
Epoch 110/150
30/30 [==============================] - 0s 4ms/step - loss: 0.9566 - acc:
0.6465 - val_loss: 0.7415 - val_acc: 0.7320
Epoch 111/150
30/30 [==============================] - 0s 5ms/step - loss: 0.9599 - acc:
0.6468 - val_loss: 0.7389 - val_acc: 0.7320
Epoch 112/150
30/30 [==============================] - 0s 5ms/step - loss: 0.9398 - acc:
0.6521 - val_loss: 0.7371 - val_acc: 0.7310
Epoch 113/150
30/30 [==============================] - 0s 5ms/step - loss: 0.9501 - acc:
0.6479 - val_loss: 0.7333 - val_acc: 0.7290
Epoch 114/150
30/30 [==============================] - 0s 5ms/step - loss: 0.9643 - acc:
0.6444 - val_loss: 0.7347 - val_acc: 0.7330
Epoch 115/150
30/30 [==============================] - 0s 5ms/step - loss: 0.9486 - acc:
0.6533 - val_loss: 0.7335 - val_acc: 0.7350
Epoch 116/150
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30/30 [==============================] - 0s 5ms/step - loss: 0.9397 - acc:
0.6528 - val_loss: 0.7273 - val_acc: 0.7310
Epoch 117/150
30/30 [==============================] - 0s 5ms/step - loss: 0.9488 - acc:
0.6499 - val_loss: 0.7272 - val_acc: 0.7360
Epoch 118/150
30/30 [==============================] - 0s 5ms/step - loss: 0.9339 - acc:
0.6563 - val_loss: 0.7250 - val_acc: 0.7330
Epoch 119/150
30/30 [==============================] - 0s 5ms/step - loss: 0.9390 - acc:
0.6476 - val_loss: 0.7224 - val_acc: 0.7370
Epoch 120/150
30/30 [==============================] - 0s 5ms/step - loss: 0.9238 - acc:
0.6575 - val_loss: 0.7162 - val_acc: 0.7340
Epoch 121/150
30/30 [==============================] - 0s 5ms/step - loss: 0.9243 - acc:
0.6549 - val_loss: 0.7173 - val_acc: 0.7340
Epoch 122/150
30/30 [==============================] - 0s 5ms/step - loss: 0.9162 - acc:
0.6669 - val_loss: 0.7179 - val_acc: 0.7360
Epoch 123/150
30/30 [==============================] - 0s 4ms/step - loss: 0.9259 - acc:
0.6521 - val_loss: 0.7143 - val_acc: 0.7370
Epoch 124/150
30/30 [==============================] - 0s 5ms/step - loss: 0.9224 - acc:
0.6639 - val_loss: 0.7139 - val_acc: 0.7380
Epoch 125/150
30/30 [==============================] - 0s 5ms/step - loss: 0.9304 - acc:
0.6588 - val_loss: 0.7127 - val_acc: 0.7380
Epoch 126/150
30/30 [==============================] - 0s 5ms/step - loss: 0.9201 - acc:
0.6573 - val_loss: 0.7098 - val_acc: 0.7390
Epoch 127/150
30/30 [==============================] - 0s 5ms/step - loss: 0.9133 - acc:
0.6572 - val_loss: 0.7057 - val_acc: 0.7370
Epoch 128/150
30/30 [==============================] - 0s 5ms/step - loss: 0.9115 - acc:
0.6661 - val_loss: 0.7037 - val_acc: 0.7350
Epoch 129/150
30/30 [==============================] - 0s 5ms/step - loss: 0.9038 - acc:
0.6693 - val_loss: 0.7003 - val_acc: 0.7390
Epoch 130/150
30/30 [==============================] - 0s 5ms/step - loss: 0.9082 - acc:
0.6613 - val_loss: 0.6974 - val_acc: 0.7390
Epoch 131/150
30/30 [==============================] - 0s 5ms/step - loss: 0.9101 - acc:
0.6668 - val_loss: 0.7000 - val_acc: 0.7420
Epoch 132/150
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30/30 [==============================] - 0s 5ms/step - loss: 0.9035 - acc:
0.6689 - val_loss: 0.7001 - val_acc: 0.7400
Epoch 133/150
30/30 [==============================] - 0s 5ms/step - loss: 0.8971 - acc:
0.6677 - val_loss: 0.6978 - val_acc: 0.7400
Epoch 134/150
30/30 [==============================] - 0s 5ms/step - loss: 0.8933 - acc:
0.6691 - val_loss: 0.6967 - val_acc: 0.7450
Epoch 135/150
30/30 [==============================] - 0s 5ms/step - loss: 0.8951 - acc:
0.6673 - val_loss: 0.6929 - val_acc: 0.7440
Epoch 136/150
30/30 [==============================] - 0s 5ms/step - loss: 0.8872 - acc:
0.6697 - val_loss: 0.6911 - val_acc: 0.7420
Epoch 137/150
30/30 [==============================] - 0s 5ms/step - loss: 0.8827 - acc:
0.6696 - val_loss: 0.6892 - val_acc: 0.7390
Epoch 138/150
30/30 [==============================] - 0s 5ms/step - loss: 0.8842 - acc:
0.6756 - val_loss: 0.6871 - val_acc: 0.7390
Epoch 139/150
30/30 [==============================] - 0s 5ms/step - loss: 0.8875 - acc:
0.6752 - val_loss: 0.6860 - val_acc: 0.7400
Epoch 140/150
30/30 [==============================] - 0s 5ms/step - loss: 0.8797 - acc:
0.6777 - val_loss: 0.6829 - val_acc: 0.7430
Epoch 141/150
30/30 [==============================] - 0s 5ms/step - loss: 0.8841 - acc:
0.6747 - val_loss: 0.6855 - val_acc: 0.7450
Epoch 142/150
30/30 [==============================] - 0s 5ms/step - loss: 0.8913 - acc:
0.6760 - val_loss: 0.6852 - val_acc: 0.7410
Epoch 143/150
30/30 [==============================] - 0s 5ms/step - loss: 0.8705 - acc:
0.6804 - val_loss: 0.6834 - val_acc: 0.7450
Epoch 144/150
30/30 [==============================] - 0s 5ms/step - loss: 0.8646 - acc:
0.6749 - val_loss: 0.6795 - val_acc: 0.7460
Epoch 145/150
30/30 [==============================] - 0s 5ms/step - loss: 0.8655 - acc:
0.6780 - val_loss: 0.6771 - val_acc: 0.7450
Epoch 146/150
30/30 [==============================] - 0s 5ms/step - loss: 0.8586 - acc:
0.6875 - val_loss: 0.6774 - val_acc: 0.7470
Epoch 147/150
30/30 [==============================] - 0s 5ms/step - loss: 0.8570 - acc:
0.6864 - val_loss: 0.6759 - val_acc: 0.7450
Epoch 148/150
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30/30 [==============================] - 0s 5ms/step - loss: 0.8655 - acc:
0.6815 - val_loss: 0.6757 - val_acc: 0.7470
Epoch 149/150
30/30 [==============================] - 0s 5ms/step - loss: 0.8580 - acc:
0.6776 - val_loss: 0.6700 - val_acc: 0.7480
Epoch 150/150
30/30 [==============================] - 0s 5ms/step - loss: 0.8610 - acc:
0.6824 - val_loss: 0.6749 - val_acc: 0.7460
```

[45]:
```
results_train = dropout_model.evaluate(X_train_tokens, y_train_lb)
print(f'Training Loss: {results_train[0]:.3} \nTraining Accuracy:␣
↪{results_train[1]:.3}')

print('----------')

results_test = dropout_model.evaluate(X_test_tokens, y_test_lb)
print(f'Test Loss: {results_test[0]:.3} \nTest Accuracy: {results_test[1]:.3}')
```

```
235/235 [==============================] - 0s 707us/step - loss: 0.5701 - acc:
0.8060
Training Loss: 0.57
Training Accuracy: 0.806
----------
47/47 [==============================] - 0s 896us/step - loss: 0.6416 - acc:
0.7753
Test Loss: 0.642
Test Accuracy: 0.775
```

You can see here that the validation performance has improved again, and the training and test accuracy are very close!

1.15 Bigger Data?

Finally, let's examine if we can improve the model's performance just by adding more data. We've quadrapled the sample dataset from 10,000 to 40,000 observations, and all you need to do is run the code!

[46]:
```
df_bigger_sample = df.sample(40000, random_state=123)

X = df['Consumer complaint narrative']
y = df['Product']

# Train-test split
X_train_bigger, X_test_bigger, y_train_bigger, y_test_bigger =␣
↪train_test_split(X,
                                                                            ␣
↪y,
```

```
↪test_size=6000,
↪random_state=42)

# Validation set
X_train_final_bigger, X_val_bigger, y_train_final_bigger, y_val_bigger = 
↪train_test_split(X_train_bigger,
↪          y_train_bigger,
↪          test_size=4000,
↪          random_state=42)


# One-hot encoding of the complaints
tokenizer = Tokenizer(num_words=2000)
tokenizer.fit_on_texts(X_train_final_bigger)

X_train_tokens_bigger = tokenizer.texts_to_matrix(X_train_final_bigger, 
↪mode='binary')
X_val_tokens_bigger = tokenizer.texts_to_matrix(X_val_bigger, mode='binary')
X_test_tokens_bigger = tokenizer.texts_to_matrix(X_test_bigger, mode='binary')

# One-hot encoding of products
lb = LabelBinarizer()
lb.fit(y_train_final_bigger)

y_train_lb_bigger = to_categorical(lb.transform(y_train_final_bigger))[:, :, 1]
y_val_lb_bigger = to_categorical(lb.transform(y_val_bigger))[:, :, 1]
y_test_lb_bigger = to_categorical(lb.transform(y_test_bigger))[:, :, 1]
```

[47]:
```
#  This cell may take several minutes to run
random.seed(123)
bigger_data_model = models.Sequential()
bigger_data_model.add(layers.Dense(50, activation='relu', input_shape=(2000,)))
bigger_data_model.add(layers.Dense(25, activation='relu'))
bigger_data_model.add(layers.Dense(7, activation='softmax'))

bigger_data_model.compile(optimizer='SGD',
                          loss='categorical_crossentropy',
                          metrics=['acc'])

bigger_data_model_val = bigger_data_model.fit(X_train_tokens_bigger,
                                              y_train_lb_bigger,
```

```
                                              epochs=150,
                                              batch_size=256,
                                            ␣
↪validation_data=(X_val_tokens_bigger, y_val_lb_bigger))
```

```
Epoch 1/150
196/196 [==============================] - 1s 3ms/step - loss: 1.9060 - acc:
0.2189 - val_loss: 1.8419 - val_acc: 0.2767
Epoch 2/150
196/196 [==============================] - 0s 3ms/step - loss: 1.7150 - acc:
0.3603 - val_loss: 1.5798 - val_acc: 0.4322
Epoch 3/150
196/196 [==============================] - 1s 3ms/step - loss: 1.4135 - acc:
0.5080 - val_loss: 1.2865 - val_acc: 0.5673
Epoch 4/150
196/196 [==============================] - 0s 3ms/step - loss: 1.1481 - acc:
0.6249 - val_loss: 1.0664 - val_acc: 0.6547
Epoch 5/150
196/196 [==============================] - 1s 3ms/step - loss: 0.9670 - acc:
0.6805 - val_loss: 0.9251 - val_acc: 0.6913
Epoch 6/150
196/196 [==============================] - 0s 2ms/step - loss: 0.8508 - acc:
0.7081 - val_loss: 0.8356 - val_acc: 0.7088
Epoch 7/150
196/196 [==============================] - 0s 3ms/step - loss: 0.7755 - acc:
0.7264 - val_loss: 0.7777 - val_acc: 0.7232
Epoch 8/150
196/196 [==============================] - 0s 2ms/step - loss: 0.7244 - acc:
0.7389 - val_loss: 0.7356 - val_acc: 0.7352
Epoch 9/150
196/196 [==============================] - 0s 2ms/step - loss: 0.6882 - acc:
0.7495 - val_loss: 0.7061 - val_acc: 0.7415
Epoch 10/150
196/196 [==============================] - 0s 2ms/step - loss: 0.6606 - acc:
0.7575 - val_loss: 0.6844 - val_acc: 0.7490
Epoch 11/150
196/196 [==============================] - 0s 3ms/step - loss: 0.6385 - acc:
0.7650 - val_loss: 0.6674 - val_acc: 0.7558
Epoch 12/150
196/196 [==============================] - 0s 2ms/step - loss: 0.6204 - acc:
0.7713 - val_loss: 0.6556 - val_acc: 0.7600
Epoch 13/150
196/196 [==============================] - 0s 3ms/step - loss: 0.6048 - acc:
0.7765 - val_loss: 0.6427 - val_acc: 0.7590
Epoch 14/150
196/196 [==============================] - 0s 2ms/step - loss: 0.5916 - acc:
0.7807 - val_loss: 0.6314 - val_acc: 0.7660
```

```
Epoch 15/150
196/196 [==============================] - 0s 3ms/step - loss: 0.5795 - acc:
0.7858 - val_loss: 0.6228 - val_acc: 0.7700
Epoch 16/150
196/196 [==============================] - 0s 3ms/step - loss: 0.5690 - acc:
0.7908 - val_loss: 0.6155 - val_acc: 0.7747
Epoch 17/150
196/196 [==============================] - 0s 2ms/step - loss: 0.5590 - acc:
0.7946 - val_loss: 0.6103 - val_acc: 0.7795
Epoch 18/150
196/196 [==============================] - 0s 3ms/step - loss: 0.5500 - acc:
0.7979 - val_loss: 0.6003 - val_acc: 0.7835
Epoch 19/150
196/196 [==============================] - 0s 2ms/step - loss: 0.5419 - acc:
0.8012 - val_loss: 0.5995 - val_acc: 0.7835
Epoch 20/150
196/196 [==============================] - 0s 3ms/step - loss: 0.5343 - acc:
0.8047 - val_loss: 0.5938 - val_acc: 0.7887
Epoch 21/150
196/196 [==============================] - 0s 2ms/step - loss: 0.5268 - acc:
0.8077 - val_loss: 0.5911 - val_acc: 0.7837
Epoch 22/150
196/196 [==============================] - 0s 2ms/step - loss: 0.5202 - acc:
0.8102 - val_loss: 0.5820 - val_acc: 0.7915
Epoch 23/150
196/196 [==============================] - 0s 2ms/step - loss: 0.5136 - acc:
0.8134 - val_loss: 0.5848 - val_acc: 0.7875
Epoch 24/150
196/196 [==============================] - 1s 3ms/step - loss: 0.5078 - acc:
0.8157 - val_loss: 0.5750 - val_acc: 0.7928
Epoch 25/150
196/196 [==============================] - 0s 2ms/step - loss: 0.5020 - acc:
0.8186 - val_loss: 0.5718 - val_acc: 0.7952
Epoch 26/150
196/196 [==============================] - 0s 3ms/step - loss: 0.4967 - acc:
0.8211 - val_loss: 0.5723 - val_acc: 0.7983
Epoch 27/150
196/196 [==============================] - 0s 2ms/step - loss: 0.4916 - acc:
0.8228 - val_loss: 0.5696 - val_acc: 0.7937
Epoch 28/150
196/196 [==============================] - 1s 3ms/step - loss: 0.4864 - acc:
0.8248 - val_loss: 0.5692 - val_acc: 0.7972
Epoch 29/150
196/196 [==============================] - 1s 3ms/step - loss: 0.4819 - acc:
0.8273 - val_loss: 0.5644 - val_acc: 0.8025
Epoch 30/150
196/196 [==============================] - 0s 2ms/step - loss: 0.4774 - acc:
0.8278 - val_loss: 0.5610 - val_acc: 0.8018
```

```
Epoch 31/150
196/196 [==============================] - 0s 2ms/step - loss: 0.4732 - acc:
0.8291 - val_loss: 0.5620 - val_acc: 0.7925
Epoch 32/150
196/196 [==============================] - 0s 3ms/step - loss: 0.4689 - acc:
0.8313 - val_loss: 0.5574 - val_acc: 0.8010
Epoch 33/150
196/196 [==============================] - 0s 3ms/step - loss: 0.4650 - acc:
0.8330 - val_loss: 0.5541 - val_acc: 0.8035
Epoch 34/150
196/196 [==============================] - 1s 3ms/step - loss: 0.4614 - acc:
0.8348 - val_loss: 0.5538 - val_acc: 0.8027
Epoch 35/150
196/196 [==============================] - 1s 3ms/step - loss: 0.4576 - acc:
0.8365 - val_loss: 0.5565 - val_acc: 0.7983
Epoch 36/150
196/196 [==============================] - 1s 3ms/step - loss: 0.4543 - acc:
0.8376 - val_loss: 0.5500 - val_acc: 0.8048
Epoch 37/150
196/196 [==============================] - 1s 3ms/step - loss: 0.4511 - acc:
0.8391 - val_loss: 0.5517 - val_acc: 0.8060
Epoch 38/150
196/196 [==============================] - 0s 2ms/step - loss: 0.4474 - acc:
0.8409 - val_loss: 0.5502 - val_acc: 0.8060
Epoch 39/150
196/196 [==============================] - 0s 3ms/step - loss: 0.4445 - acc:
0.8419 - val_loss: 0.5482 - val_acc: 0.8075
Epoch 40/150
196/196 [==============================] - 0s 2ms/step - loss: 0.4413 - acc:
0.8441 - val_loss: 0.5479 - val_acc: 0.8070
Epoch 41/150
196/196 [==============================] - 0s 2ms/step - loss: 0.4386 - acc:
0.8447 - val_loss: 0.5504 - val_acc: 0.8075
Epoch 42/150
196/196 [==============================] - 0s 2ms/step - loss: 0.4357 - acc:
0.8454 - val_loss: 0.5471 - val_acc: 0.8070
Epoch 43/150
196/196 [==============================] - 0s 3ms/step - loss: 0.4328 - acc:
0.8464 - val_loss: 0.5483 - val_acc: 0.8058
Epoch 44/150
196/196 [==============================] - 0s 2ms/step - loss: 0.4302 - acc:
0.8486 - val_loss: 0.5451 - val_acc: 0.8108
Epoch 45/150
196/196 [==============================] - 0s 2ms/step - loss: 0.4278 - acc:
0.8494 - val_loss: 0.5448 - val_acc: 0.8083
Epoch 46/150
196/196 [==============================] - 0s 2ms/step - loss: 0.4253 - acc:
0.8504 - val_loss: 0.5476 - val_acc: 0.8115
```

```
Epoch 47/150
196/196 [==============================] - 0s 2ms/step - loss: 0.4231 - acc:
0.8512 - val_loss: 0.5445 - val_acc: 0.8080
Epoch 48/150
196/196 [==============================] - 1s 3ms/step - loss: 0.4205 - acc:
0.8532 - val_loss: 0.5452 - val_acc: 0.8085
Epoch 49/150
196/196 [==============================] - 0s 2ms/step - loss: 0.4182 - acc:
0.8533 - val_loss: 0.5491 - val_acc: 0.8095
Epoch 50/150
196/196 [==============================] - 0s 2ms/step - loss: 0.4161 - acc:
0.8548 - val_loss: 0.5464 - val_acc: 0.8080
Epoch 51/150
196/196 [==============================] - 0s 2ms/step - loss: 0.4139 - acc:
0.8548 - val_loss: 0.5436 - val_acc: 0.8077
Epoch 52/150
196/196 [==============================] - 0s 3ms/step - loss: 0.4117 - acc:
0.8558 - val_loss: 0.5519 - val_acc: 0.8065
Epoch 53/150
196/196 [==============================] - 0s 2ms/step - loss: 0.4098 - acc:
0.8562 - val_loss: 0.5449 - val_acc: 0.8112
Epoch 54/150
196/196 [==============================] - 0s 2ms/step - loss: 0.4079 - acc:
0.8571 - val_loss: 0.5461 - val_acc: 0.8105
Epoch 55/150
196/196 [==============================] - 0s 2ms/step - loss: 0.4057 - acc:
0.8584 - val_loss: 0.5441 - val_acc: 0.8073
Epoch 56/150
196/196 [==============================] - 0s 3ms/step - loss: 0.4035 - acc:
0.8593 - val_loss: 0.5458 - val_acc: 0.8115
Epoch 57/150
196/196 [==============================] - 0s 2ms/step - loss: 0.4015 - acc:
0.8591 - val_loss: 0.5478 - val_acc: 0.8073
Epoch 58/150
196/196 [==============================] - 1s 3ms/step - loss: 0.3998 - acc:
0.8602 - val_loss: 0.5484 - val_acc: 0.8077
Epoch 59/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3981 - acc:
0.8612 - val_loss: 0.5461 - val_acc: 0.8110
Epoch 60/150
196/196 [==============================] - 1s 3ms/step - loss: 0.3961 - acc:
0.8618 - val_loss: 0.5441 - val_acc: 0.8112
Epoch 61/150
196/196 [==============================] - 0s 3ms/step - loss: 0.3947 - acc:
0.8618 - val_loss: 0.5476 - val_acc: 0.8090
Epoch 62/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3930 - acc:
0.8631 - val_loss: 0.5461 - val_acc: 0.8127
```

```
Epoch 63/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3914 - acc:
0.8646 - val_loss: 0.5457 - val_acc: 0.8112
Epoch 64/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3898 - acc:
0.8639 - val_loss: 0.5450 - val_acc: 0.8112
Epoch 65/150
196/196 [==============================] - 0s 3ms/step - loss: 0.3882 - acc:
0.8641 - val_loss: 0.5484 - val_acc: 0.8090
Epoch 66/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3865 - acc:
0.8650 - val_loss: 0.5536 - val_acc: 0.8073
Epoch 67/150
196/196 [==============================] - 0s 3ms/step - loss: 0.3849 - acc:
0.8659 - val_loss: 0.5505 - val_acc: 0.8110
Epoch 68/150
196/196 [==============================] - 0s 3ms/step - loss: 0.3834 - acc:
0.8657 - val_loss: 0.5505 - val_acc: 0.8083
Epoch 69/150
196/196 [==============================] - 0s 3ms/step - loss: 0.3818 - acc:
0.8680 - val_loss: 0.5461 - val_acc: 0.8112
Epoch 70/150
196/196 [==============================] - 0s 3ms/step - loss: 0.3803 - acc:
0.8676 - val_loss: 0.5463 - val_acc: 0.8112
Epoch 71/150
196/196 [==============================] - 0s 3ms/step - loss: 0.3789 - acc:
0.8688 - val_loss: 0.5498 - val_acc: 0.8098
Epoch 72/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3775 - acc:
0.8682 - val_loss: 0.5471 - val_acc: 0.8090
Epoch 73/150
196/196 [==============================] - 0s 3ms/step - loss: 0.3763 - acc:
0.8685 - val_loss: 0.5489 - val_acc: 0.8100
Epoch 74/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3752 - acc:
0.8693 - val_loss: 0.5493 - val_acc: 0.8110
Epoch 75/150
196/196 [==============================] - 1s 3ms/step - loss: 0.3734 - acc:
0.8697 - val_loss: 0.5498 - val_acc: 0.8098
Epoch 76/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3720 - acc:
0.8702 - val_loss: 0.5530 - val_acc: 0.8115
Epoch 77/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3712 - acc:
0.8703 - val_loss: 0.5503 - val_acc: 0.8102
Epoch 78/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3697 - acc:
0.8715 - val_loss: 0.5502 - val_acc: 0.8120
```

```
Epoch 79/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3684 - acc:
0.8723 - val_loss: 0.5524 - val_acc: 0.8098
Epoch 80/150
196/196 [==============================] - 0s 3ms/step - loss: 0.3671 - acc:
0.8722 - val_loss: 0.5556 - val_acc: 0.8077
Epoch 81/150
196/196 [==============================] - 0s 3ms/step - loss: 0.3660 - acc:
0.8725 - val_loss: 0.5551 - val_acc: 0.8083
Epoch 82/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3649 - acc:
0.8726 - val_loss: 0.5531 - val_acc: 0.8110
Epoch 83/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3635 - acc:
0.8738 - val_loss: 0.5552 - val_acc: 0.8108
Epoch 84/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3623 - acc:
0.8735 - val_loss: 0.5535 - val_acc: 0.8117
Epoch 85/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3615 - acc:
0.8742 - val_loss: 0.5540 - val_acc: 0.8100
Epoch 86/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3599 - acc:
0.8747 - val_loss: 0.5639 - val_acc: 0.8055
Epoch 87/150
196/196 [==============================] - 0s 3ms/step - loss: 0.3589 - acc:
0.8753 - val_loss: 0.5534 - val_acc: 0.8085
Epoch 88/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3578 - acc:
0.8756 - val_loss: 0.5593 - val_acc: 0.8073
Epoch 89/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3564 - acc:
0.8759 - val_loss: 0.5604 - val_acc: 0.8108
Epoch 90/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3556 - acc:
0.8766 - val_loss: 0.5542 - val_acc: 0.8110
Epoch 91/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3543 - acc:
0.8771 - val_loss: 0.5608 - val_acc: 0.8067
Epoch 92/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3534 - acc:
0.8773 - val_loss: 0.5571 - val_acc: 0.8098
Epoch 93/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3521 - acc:
0.8773 - val_loss: 0.5604 - val_acc: 0.8070
Epoch 94/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3509 - acc:
0.8786 - val_loss: 0.5575 - val_acc: 0.8095
```

```
Epoch 95/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3500 - acc:
0.8784 - val_loss: 0.5581 - val_acc: 0.8092
Epoch 96/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3492 - acc:
0.8781 - val_loss: 0.5612 - val_acc: 0.8120
Epoch 97/150
196/196 [==============================] - 0s 3ms/step - loss: 0.3480 - acc:
0.8788 - val_loss: 0.5741 - val_acc: 0.8008
Epoch 98/150
196/196 [==============================] - 0s 3ms/step - loss: 0.3471 - acc:
0.8793 - val_loss: 0.5612 - val_acc: 0.8090
Epoch 99/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3461 - acc:
0.8799 - val_loss: 0.5682 - val_acc: 0.8035
Epoch 100/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3449 - acc:
0.8801 - val_loss: 0.5620 - val_acc: 0.8108
Epoch 101/150
196/196 [==============================] - 0s 3ms/step - loss: 0.3440 - acc:
0.8808 - val_loss: 0.5687 - val_acc: 0.8062
Epoch 102/150
196/196 [==============================] - 1s 3ms/step - loss: 0.3431 - acc:
0.8809 - val_loss: 0.5630 - val_acc: 0.8090
Epoch 103/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3421 - acc:
0.8807 - val_loss: 0.5625 - val_acc: 0.8100
Epoch 104/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3408 - acc:
0.8813 - val_loss: 0.5669 - val_acc: 0.8102
Epoch 105/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3400 - acc:
0.8823 - val_loss: 0.5654 - val_acc: 0.8083
Epoch 106/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3393 - acc:
0.8822 - val_loss: 0.5637 - val_acc: 0.8098
Epoch 107/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3382 - acc:
0.8821 - val_loss: 0.5646 - val_acc: 0.8083
Epoch 108/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3374 - acc:
0.8834 - val_loss: 0.5734 - val_acc: 0.8048
Epoch 109/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3365 - acc:
0.8839 - val_loss: 0.5678 - val_acc: 0.8060
Epoch 110/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3351 - acc:
0.8840 - val_loss: 0.5718 - val_acc: 0.8080
```

```
Epoch 111/150
196/196 [==============================] - 0s 3ms/step - loss: 0.3344 - acc:
0.8845 - val_loss: 0.5700 - val_acc: 0.8060
Epoch 112/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3335 - acc:
0.8846 - val_loss: 0.5711 - val_acc: 0.8077
Epoch 113/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3328 - acc:
0.8848 - val_loss: 0.5724 - val_acc: 0.8067
Epoch 114/150
196/196 [==============================] - 0s 3ms/step - loss: 0.3316 - acc:
0.8848 - val_loss: 0.5689 - val_acc: 0.8083
Epoch 115/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3308 - acc:
0.8852 - val_loss: 0.5735 - val_acc: 0.8055
Epoch 116/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3300 - acc:
0.8853 - val_loss: 0.5696 - val_acc: 0.8105
Epoch 117/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3286 - acc:
0.8866 - val_loss: 0.5818 - val_acc: 0.8040
Epoch 118/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3279 - acc:
0.8862 - val_loss: 0.5778 - val_acc: 0.8052
Epoch 119/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3273 - acc:
0.8867 - val_loss: 0.5721 - val_acc: 0.8105
Epoch 120/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3263 - acc:
0.8866 - val_loss: 0.5769 - val_acc: 0.8052
Epoch 121/150
196/196 [==============================] - 1s 3ms/step - loss: 0.3254 - acc:
0.8874 - val_loss: 0.5811 - val_acc: 0.8085
Epoch 122/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3244 - acc:
0.8871 - val_loss: 0.5749 - val_acc: 0.8083
Epoch 123/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3236 - acc:
0.8881 - val_loss: 0.5763 - val_acc: 0.8080
Epoch 124/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3226 - acc:
0.8883 - val_loss: 0.5814 - val_acc: 0.8060
Epoch 125/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3217 - acc:
0.8890 - val_loss: 0.5847 - val_acc: 0.8043
Epoch 126/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3210 - acc:
0.8891 - val_loss: 0.5768 - val_acc: 0.8087
```

```
Epoch 127/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3197 - acc:
0.8895 - val_loss: 0.5774 - val_acc: 0.8108
Epoch 128/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3193 - acc:
0.8891 - val_loss: 0.5791 - val_acc: 0.8095
Epoch 129/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3181 - acc:
0.8902 - val_loss: 0.5840 - val_acc: 0.8087
Epoch 130/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3172 - acc:
0.8909 - val_loss: 0.5795 - val_acc: 0.8095
Epoch 131/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3168 - acc:
0.8910 - val_loss: 0.5859 - val_acc: 0.8062
Epoch 132/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3154 - acc:
0.8908 - val_loss: 0.5973 - val_acc: 0.8025
Epoch 133/150
196/196 [==============================] - 0s 3ms/step - loss: 0.3147 - acc:
0.8906 - val_loss: 0.5858 - val_acc: 0.8070
Epoch 134/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3139 - acc:
0.8919 - val_loss: 0.5837 - val_acc: 0.8077
Epoch 135/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3132 - acc:
0.8921 - val_loss: 0.5864 - val_acc: 0.8067
Epoch 136/150
196/196 [==============================] - 0s 3ms/step - loss: 0.3121 - acc:
0.8925 - val_loss: 0.5872 - val_acc: 0.8087
Epoch 137/150
196/196 [==============================] - 1s 3ms/step - loss: 0.3114 - acc:
0.8926 - val_loss: 0.5862 - val_acc: 0.8092
Epoch 138/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3105 - acc:
0.8923 - val_loss: 0.5968 - val_acc: 0.8037
Epoch 139/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3095 - acc:
0.8933 - val_loss: 0.5884 - val_acc: 0.8077
Epoch 140/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3090 - acc:
0.8932 - val_loss: 0.5880 - val_acc: 0.8083
Epoch 141/150
196/196 [==============================] - 0s 3ms/step - loss: 0.3077 - acc:
0.8933 - val_loss: 0.5925 - val_acc: 0.8090
Epoch 142/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3070 - acc:
0.8941 - val_loss: 0.5917 - val_acc: 0.8077
```

```
Epoch 143/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3060 - acc:
0.8941 - val_loss: 0.5878 - val_acc: 0.8105
Epoch 144/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3051 - acc:
0.8946 - val_loss: 0.5966 - val_acc: 0.8010
Epoch 145/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3042 - acc:
0.8959 - val_loss: 0.5984 - val_acc: 0.7997
Epoch 146/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3029 - acc:
0.8960 - val_loss: 0.5967 - val_acc: 0.8033
Epoch 147/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3028 - acc:
0.8950 - val_loss: 0.5987 - val_acc: 0.8052
Epoch 148/150
196/196 [==============================] - 0s 2ms/step - loss: 0.3018 - acc:
0.8959 - val_loss: 0.6024 - val_acc: 0.8020
Epoch 149/150
196/196 [==============================] - 1s 3ms/step - loss: 0.3008 - acc:
0.8968 - val_loss: 0.6021 - val_acc: 0.8005
Epoch 150/150
196/196 [==============================] - 0s 2ms/step - loss: 0.2997 - acc:
0.8965 - val_loss: 0.5982 - val_acc: 0.8085
```

[48]:

```
results_train = bigger_data_model.evaluate(X_train_tokens_bigger,␣
↪y_train_lb_bigger)
print(f'Training Loss: {results_train[0]:.3} \nTraining Accuracy:␣
↪{results_train[1]:.3}')

print('----------')

results_test = bigger_data_model.evaluate(X_val_tokens_bigger, y_val_lb_bigger)
print(f'Test Loss: {results_test[0]:.3} \nTest Accuracy: {results_test[1]:.3}')
```

```
1563/1563 [==============================] - 1s 728us/step - loss: 0.2929 - acc:
0.9011
Training Loss: 0.293
Training Accuracy: 0.901
----------
125/125 [==============================] - 0s 1ms/step - loss: 0.5982 - acc:
0.8085
Test Loss: 0.598
Test Accuracy: 0.808
```

With the same amount of epochs and no regularization technique, you were able to get both better test accuracy and loss. You can still consider early stopping, L1, L2 and dropout here. It's clear that having more data has a strong impact on model performance!

1.16 Additional Resources

- https://github.com/susanli2016/Machine-Learning-with-Python/blob/master/Consumer_complaints.ipynb
- https://machinelearningmastery.com/dropout-regularization-deep-learning-models-keras/
- https://catalog.data.gov/dataset/consumer-complaint-database

1.17 Summary

In this lesson, you built deep learning models using a validation set and used several techniques such as L2 and L1 regularization, dropout regularization, and early stopping to improve the accuracy of your models.