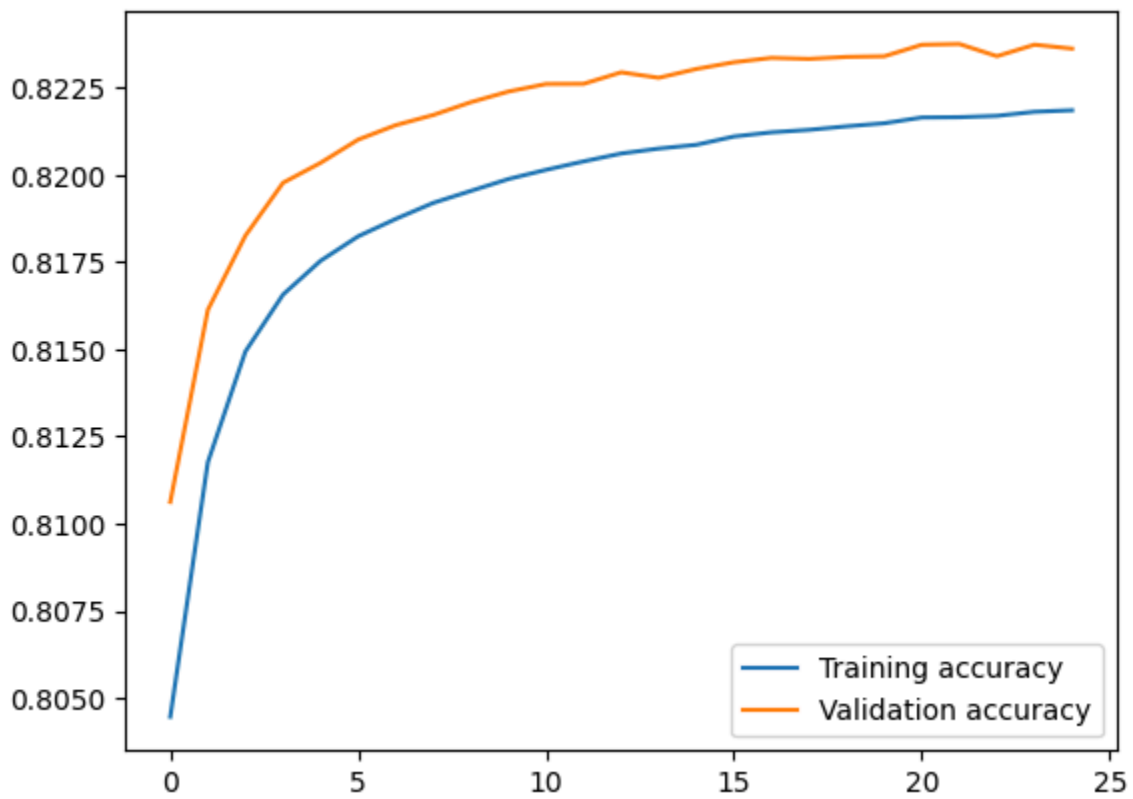
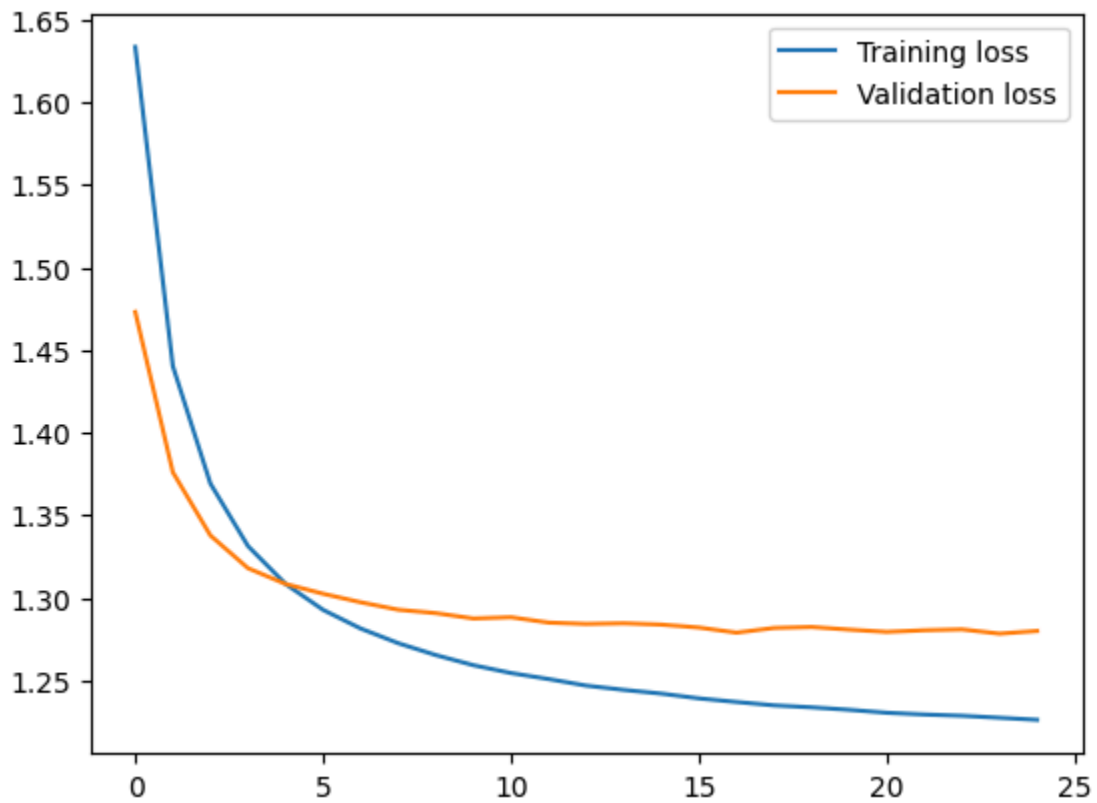
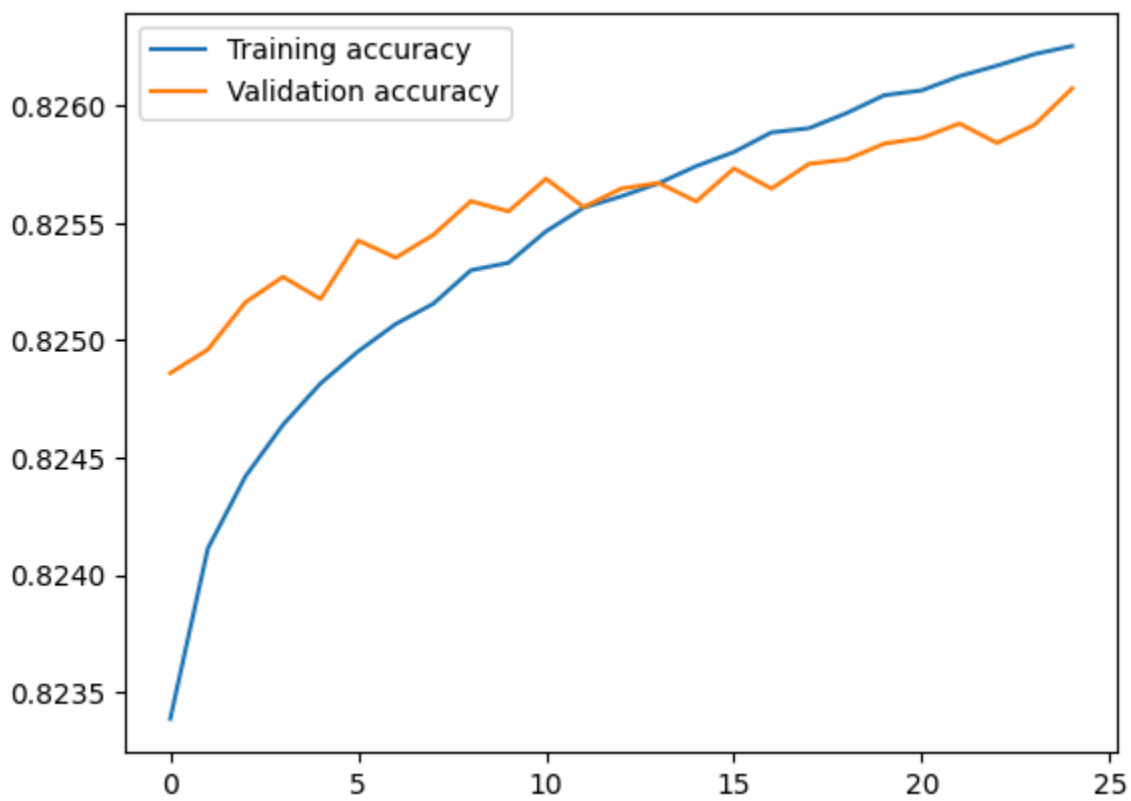
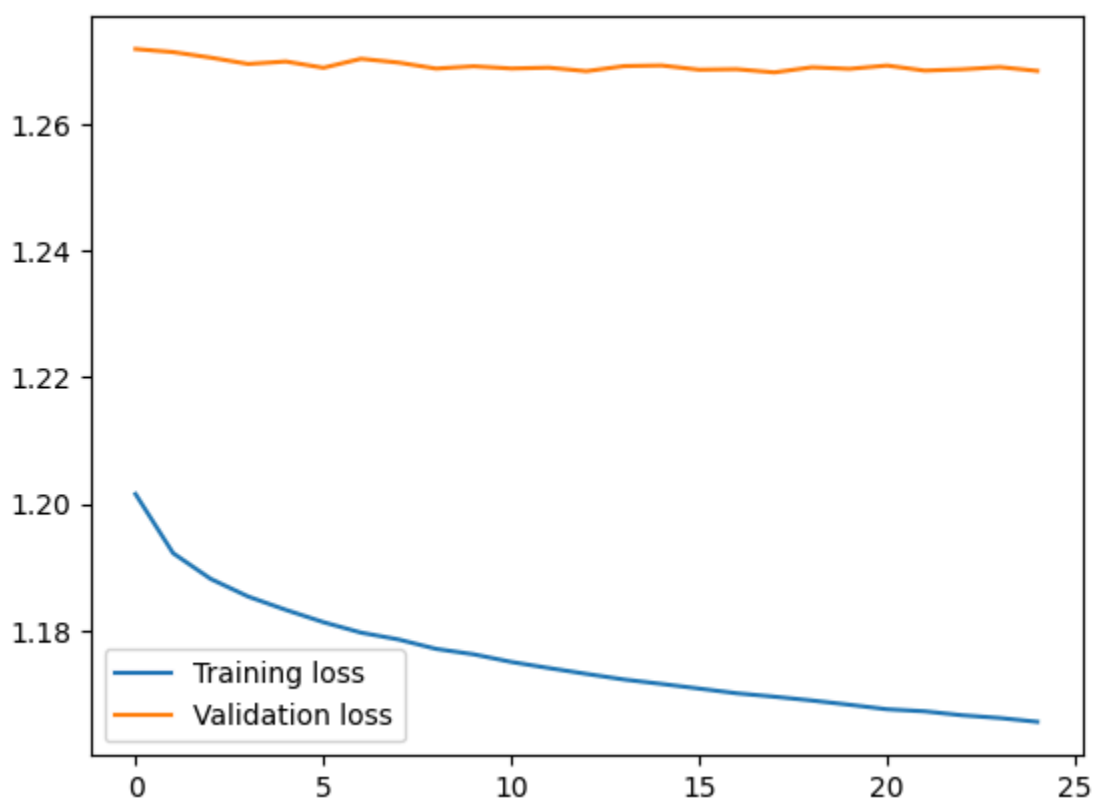
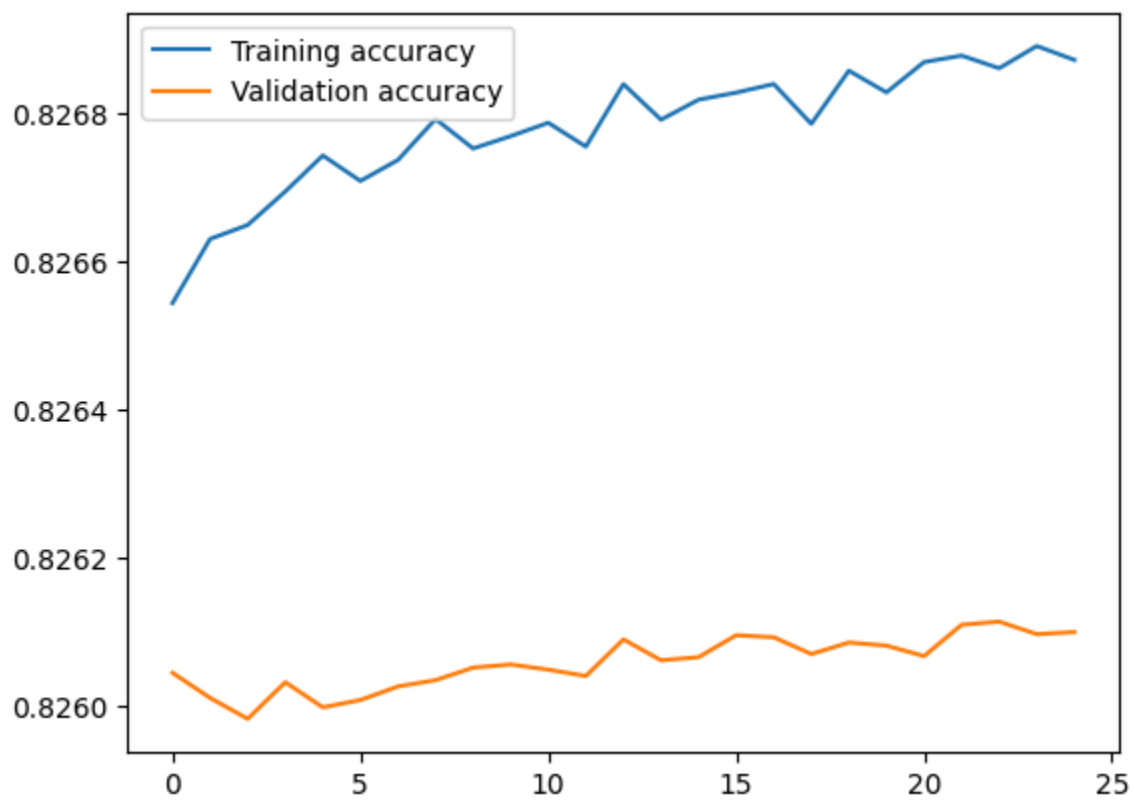
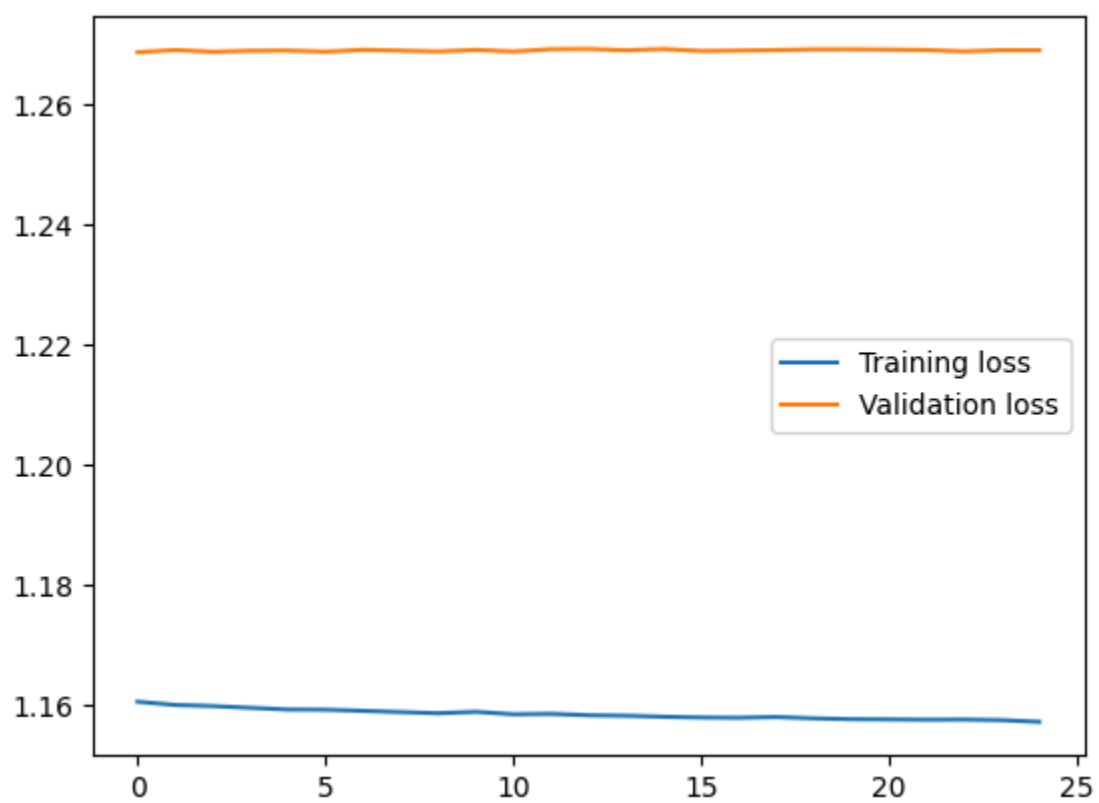
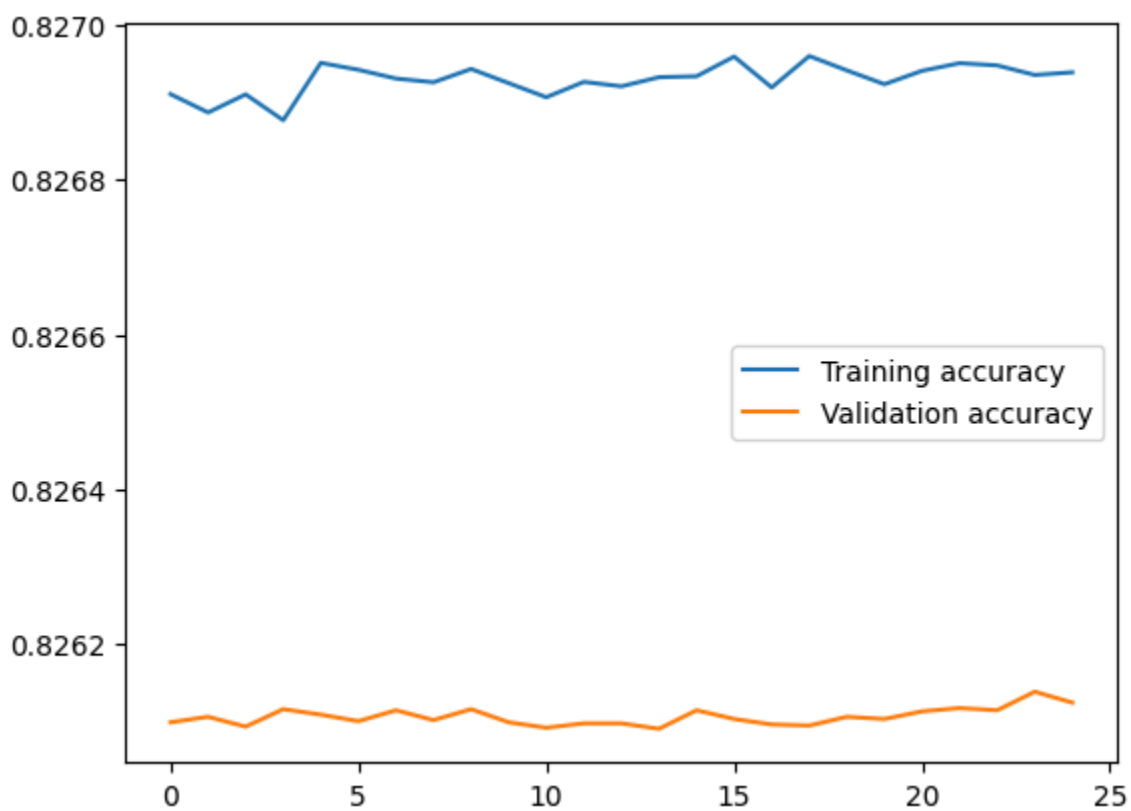
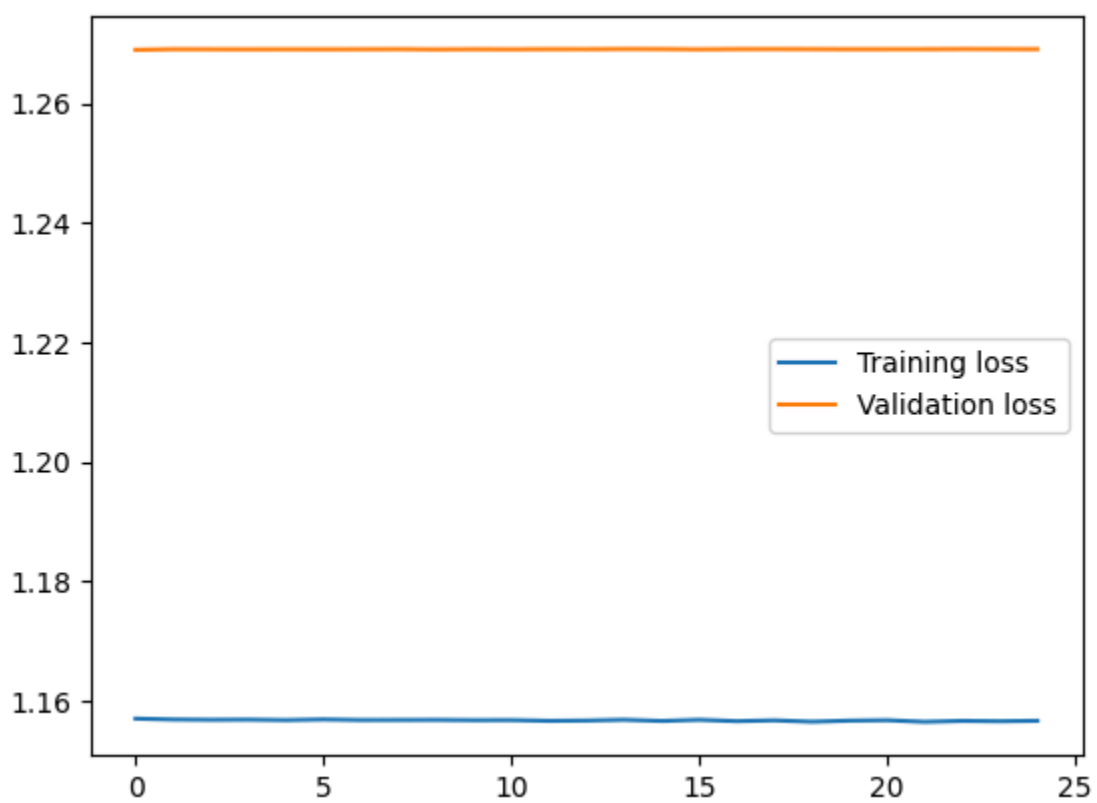


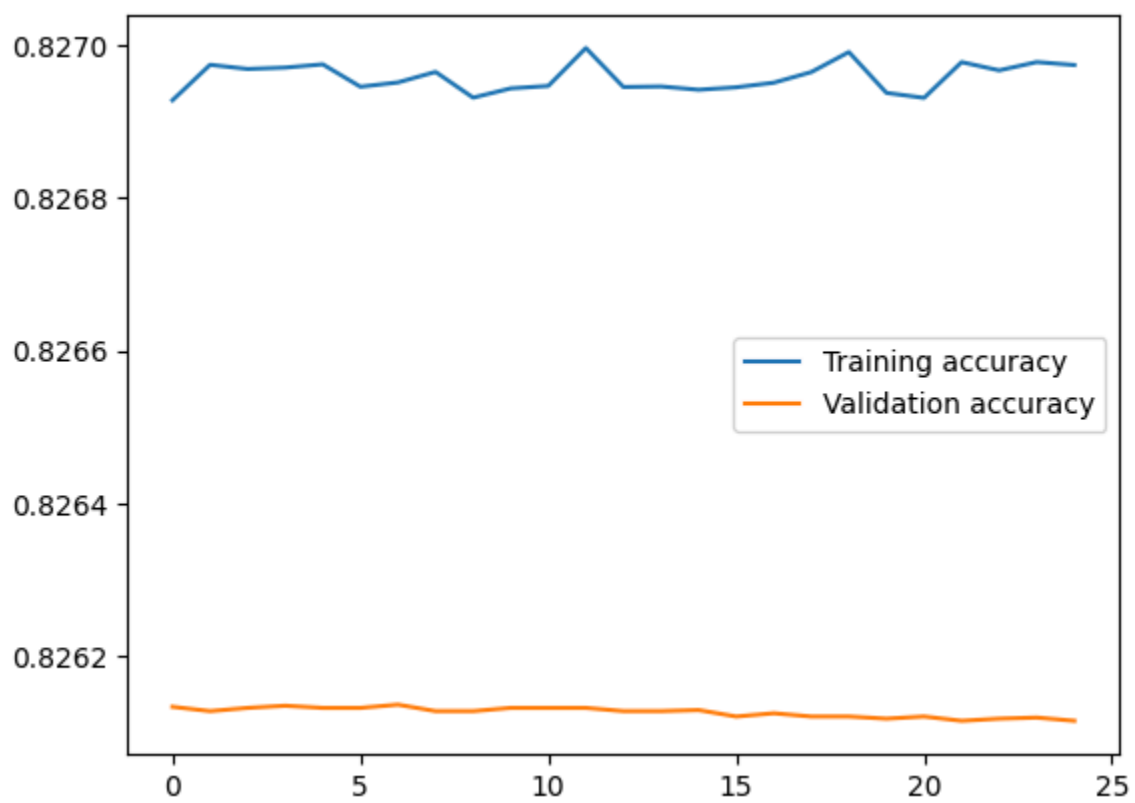
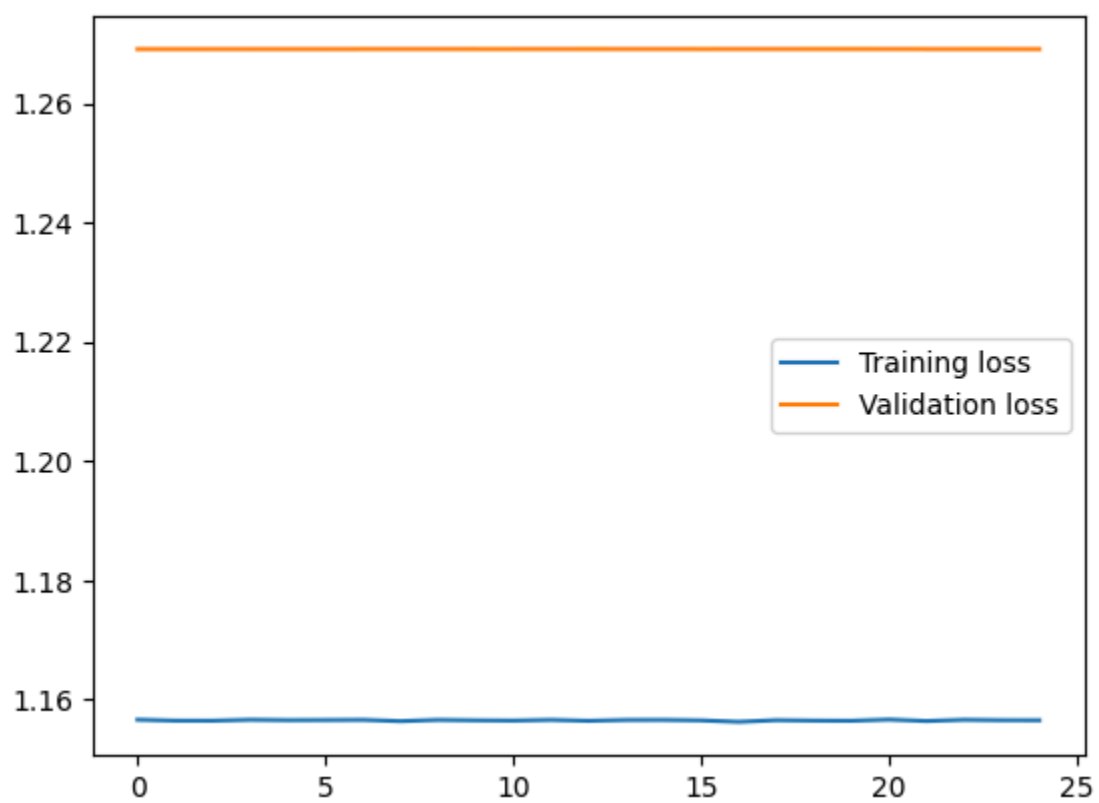
### Pretraining:









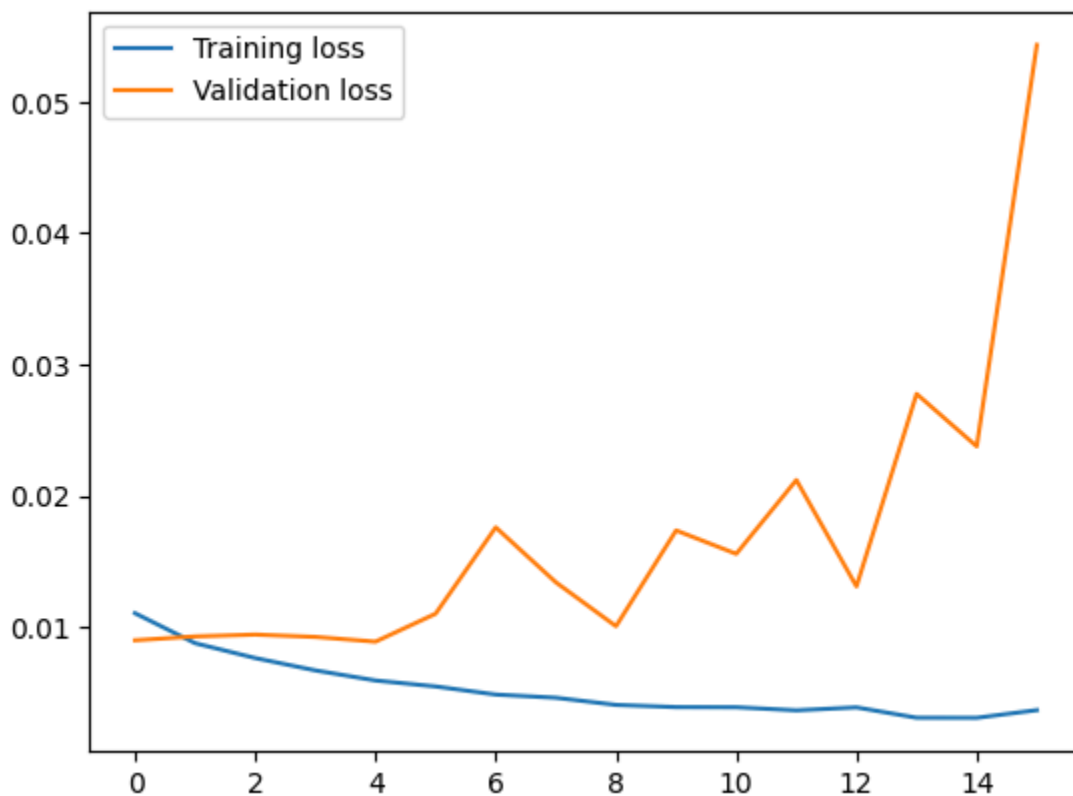


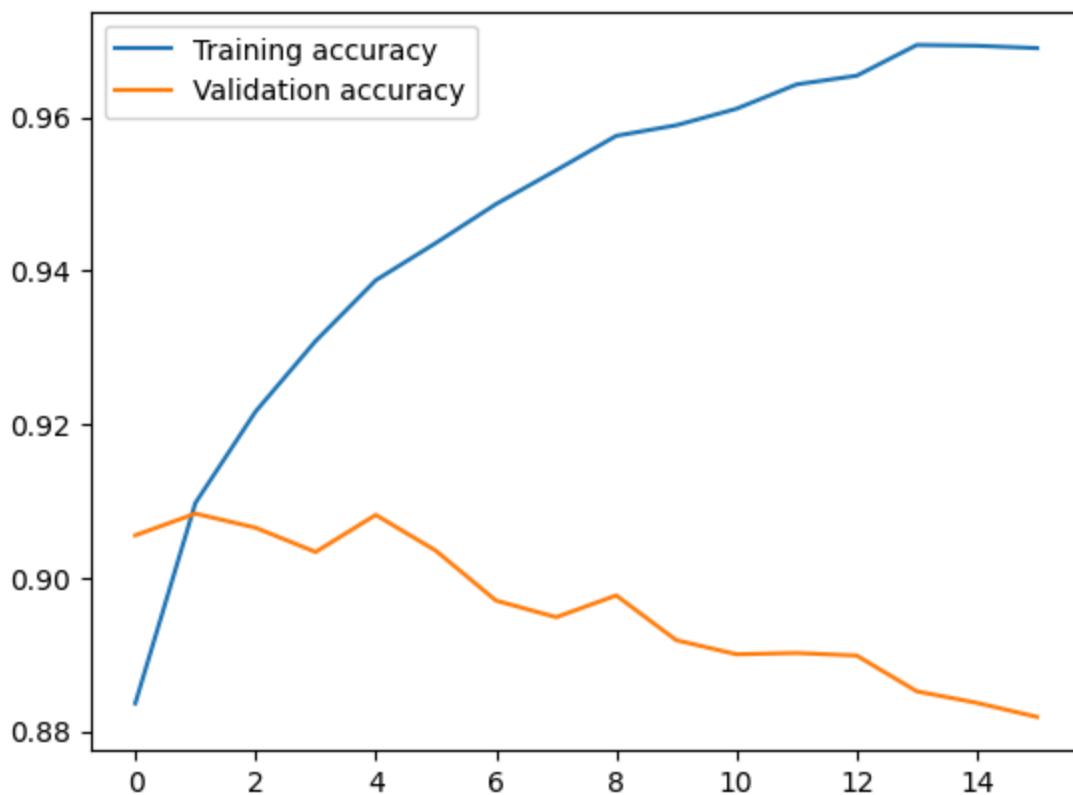
Training Loss: 1.1565209308802797, Validation Loss: 1.269105260676526,  
Training Accuracy: 0.8269350100292974, Validation Accuracy:  
0.8261387712777929 (Saved new best model)

## Downstream Task:

### 1. Normal

```
SentimentalAnalysis(  
    (embedding): Embedding(39976, 100)  
    (lstm1): LSTM(100, 100, num_layers=2, batch_first=True, dropout=0.36)  
    (lstm2): LSTM(100, 100, num_layers=2, batch_first=True, dropout=0.36)  
    (dropout): Dropout(p=0.25, inplace=False)  
    (fc1): Linear(in_features=100, out_features=100, bias=True)  
    (fc2): Linear(in_features=100, out_features=4, bias=True)  
)
```





100% [██████████] 188/188 [00:01<00:00, 115.95it/s]

Accuracy on the valid set: 0.9083333333333333

Classification Report:

	precision	recall	f1-score	support
0	0.92	0.89	0.90	1500
1	0.96	0.98	0.97	1500
2	0.86	0.89	0.87	1500
3	0.90	0.87	0.89	1500
accuracy		0.91		6000
macro avg	0.91	0.91	0.91	6000
weighted avg	0.91	0.91	0.91	6000

Confusion Matrix:

```
[[1333  42  84  41]
 [ 16 1470  10   4]
 [ 52  15 1338  95]
 [ 52   7  132 1309]]
```

Micro Recall: 0.9083333333333333

Macro Recall: 0.9083333333333334

Micro F1 Score: 0.9083333333333333

Macro F1 Score: 0.9082388019266814

100%|██████████| 238/238 [00:02<00:00, 114.77it/s]

Accuracy on the test set: 0.9094736842105263

Classification Report:

	precision	recall	f1-score	support
0	0.92	0.91	0.91	1900
1	0.95	0.97	0.96	1900
2	0.87	0.88	0.88	1900
3	0.90	0.88	0.89	1900
accuracy		0.91		7600
macro avg	0.91	0.91	0.91	7600
weighted avg	0.91	0.91	0.91	7600

Confusion Matrix:

```
[[1725  57  82  36]
 [ 26 1845  17  12]
 [ 68  17 1677 138]
 [ 64  15 156 1665]]
```

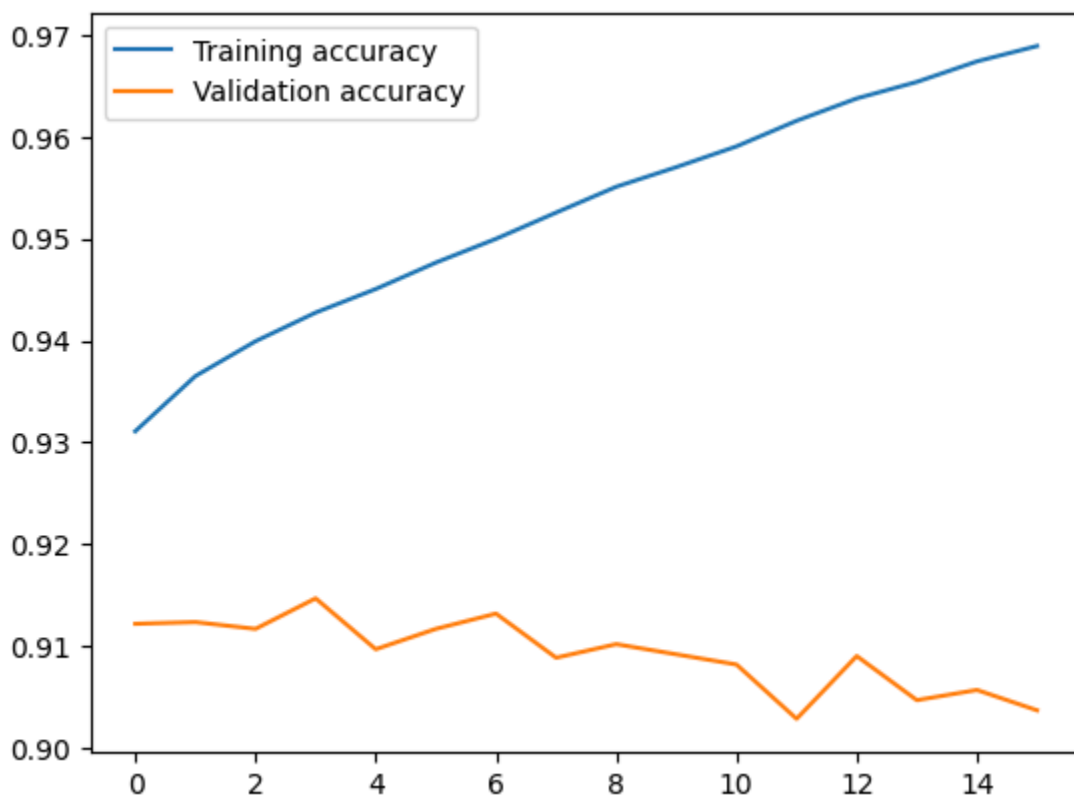
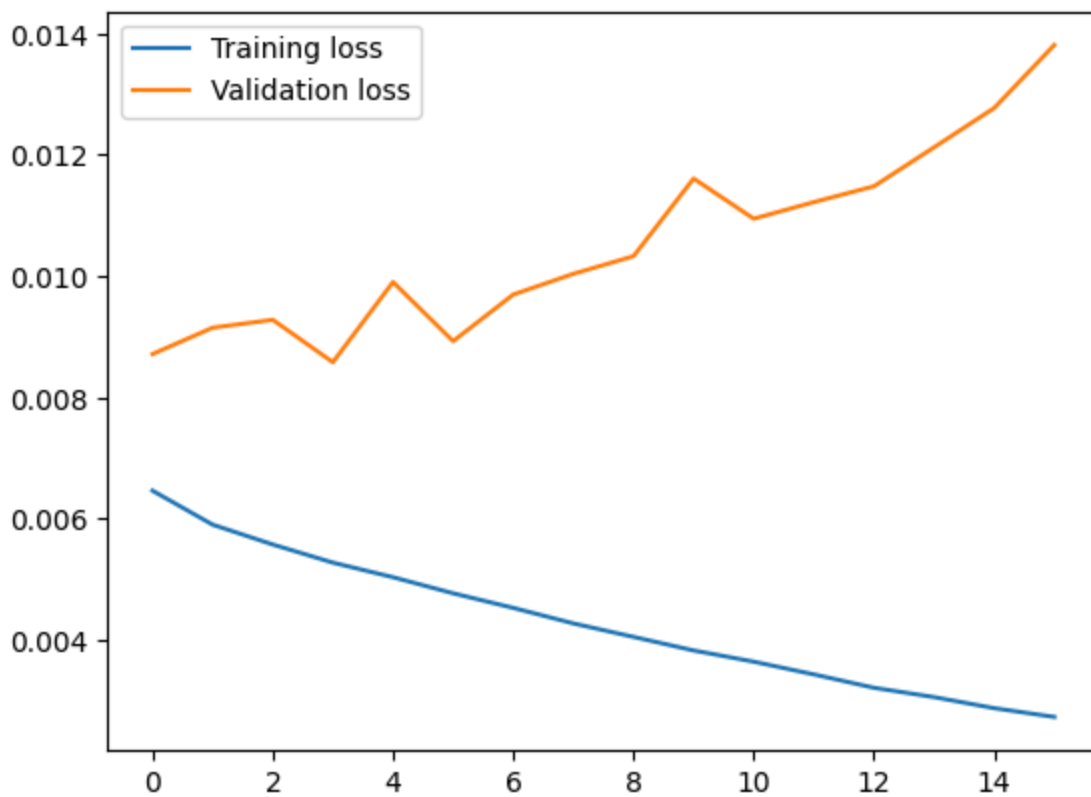
Micro Recall: 0.9094736842105263

Macro Recall: 0.9094736842105263

Micro F1 Score: 0.9094736842105263

Macro F1 Score: 0.9093600403331703





Accuracy on the valid set: 0.9146666666666666

Classification Report:

	precision	recall	f1-score	support
0	0.93	0.89	0.91	1500
1	0.96	0.98	0.97	1500
2	0.88	0.90	0.89	1500
3	0.90	0.90	0.90	1500
accuracy		0.91		6000
macro avg	0.91	0.91	0.91	6000
weighted avg	0.91	0.91	0.91	6000

Confusion Matrix:

[[1334 42 75 49]

[ 22 1466 8 4]

[ 44 12 1344 100]


[ 41 6 109 1344]]

Micro Recall: 0.9146666666666666

Macro Recall: 0.9146666666666666

Micro F1 Score: 0.9146666666666666

Macro F1 Score: 0.9145956775990495

100% 238/238 [00:02<00:00, 117.31it/s]

Accuracy on the test set: 0.9113157894736842

Classification Report:

	precision	recall	f1-score	support
0	0.92	0.91	0.91	1900
1	0.96	0.97	0.96	1900
2	0.88	0.88	0.88	1900
3	0.89	0.89	0.89	1900
accuracy		0.91		7600
macro avg	0.91	0.91	0.91	7600
weighted avg	0.91	0.91	0.91	7600

Confusion Matrix:

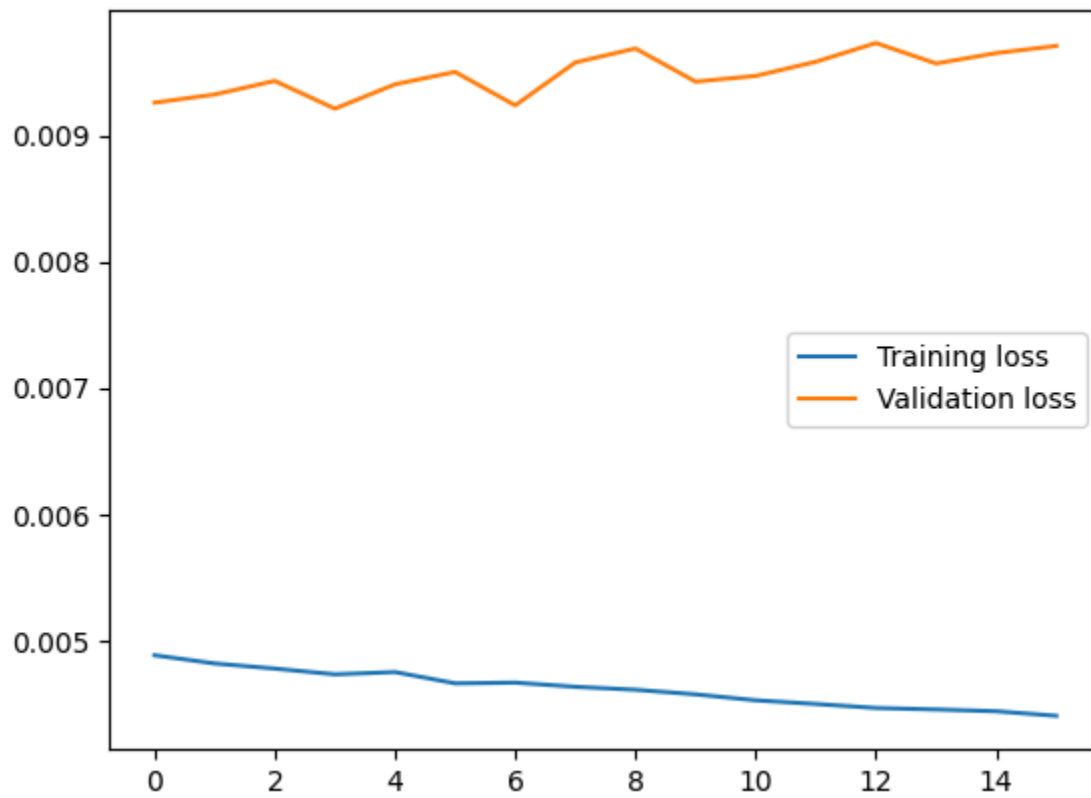
[[1722 50 80 48]

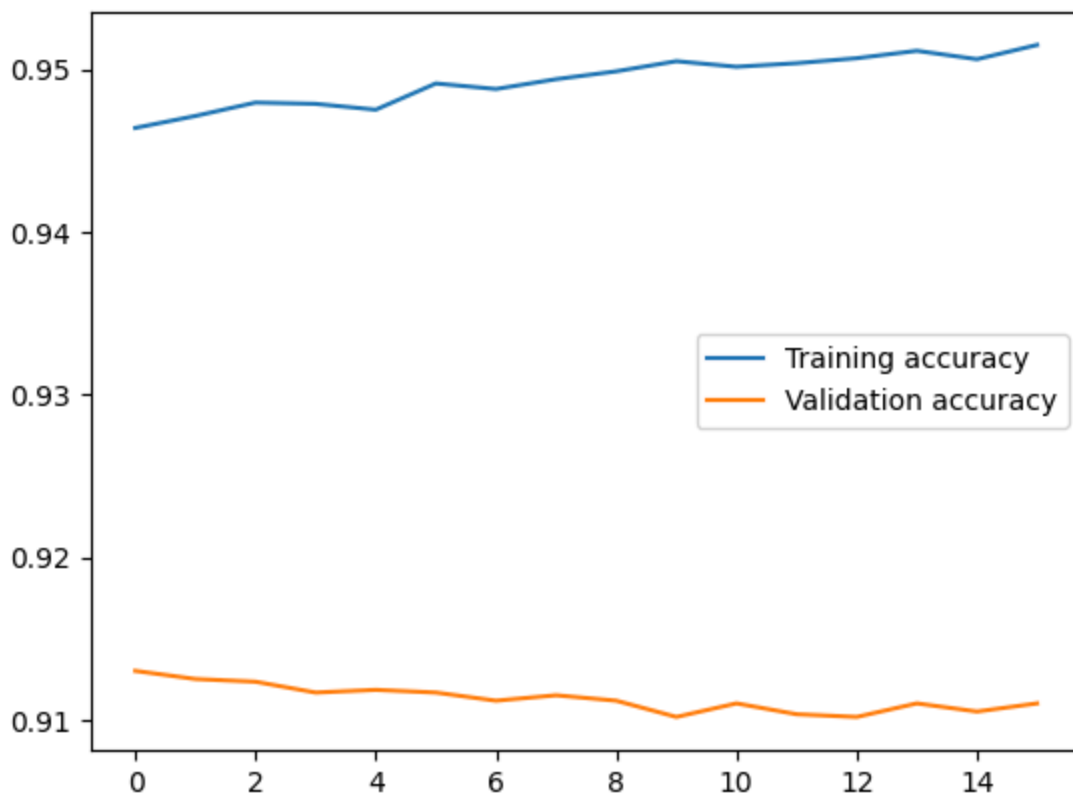
[ 35 1837 17 11]

[ 62 20 1667 151]

[ 57 13 130 1700]]

Micro Recall: 0.9113157894736842  
Macro Recall: 0.9113157894736842  
Micro F1 Score: 0.9113157894736842  
Macro F1 Score: 0.9112501894396248





100% [██████████] 188/188 [00:01<00:00, 114.34it/s]

Accuracy on the valid set: 0.9146666666666666

Classification Report:

	precision	recall	f1-score	support
0	0.93	0.89	0.91	1500
1	0.96	0.98	0.97	1500
2	0.88	0.90	0.89	1500
3	0.90	0.90	0.90	1500
accuracy		0.91		6000
macro avg	0.91	0.91	0.91	6000
weighted avg	0.91	0.91	0.91	6000

Confusion Matrix:

```
[[1334  42  75  49]
 [ 22 1466   8   4]
 [ 44  12 1344 100]
 [ 41   6 109 1344]]
```

Micro Recall: 0.9146666666666666

Macro Recall: 0.9146666666666666

Micro F1 Score: 0.9146666666666666

Macro F1 Score: 0.9145956775990495

100%|██████████| 238/238 [00:02<00:00, 113.69it/s]

Accuracy on the test set: 0.9113157894736842

Classification Report:

	precision	recall	f1-score	support
0	0.92	0.91	0.91	1900
1	0.96	0.97	0.96	1900
2	0.88	0.88	0.88	1900
3	0.89	0.89	0.89	1900
accuracy		0.91		7600
macro avg	0.91	0.91	0.91	7600
weighted avg	0.91	0.91	0.91	7600

Confusion Matrix:

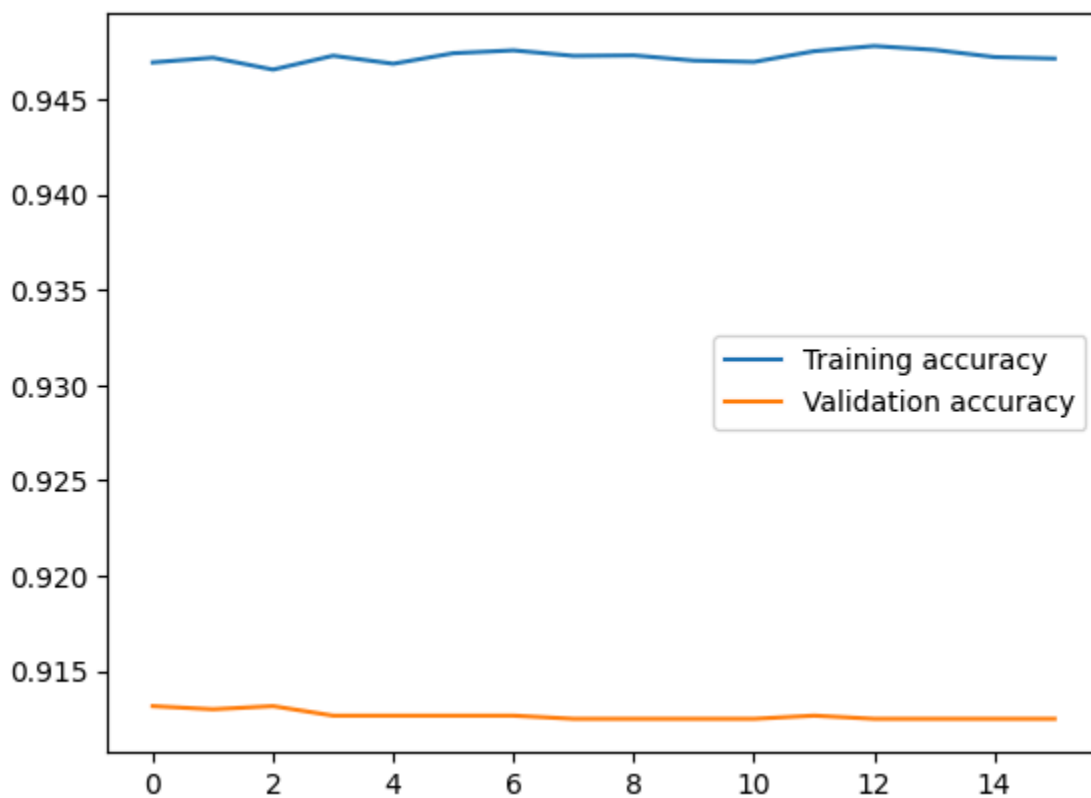
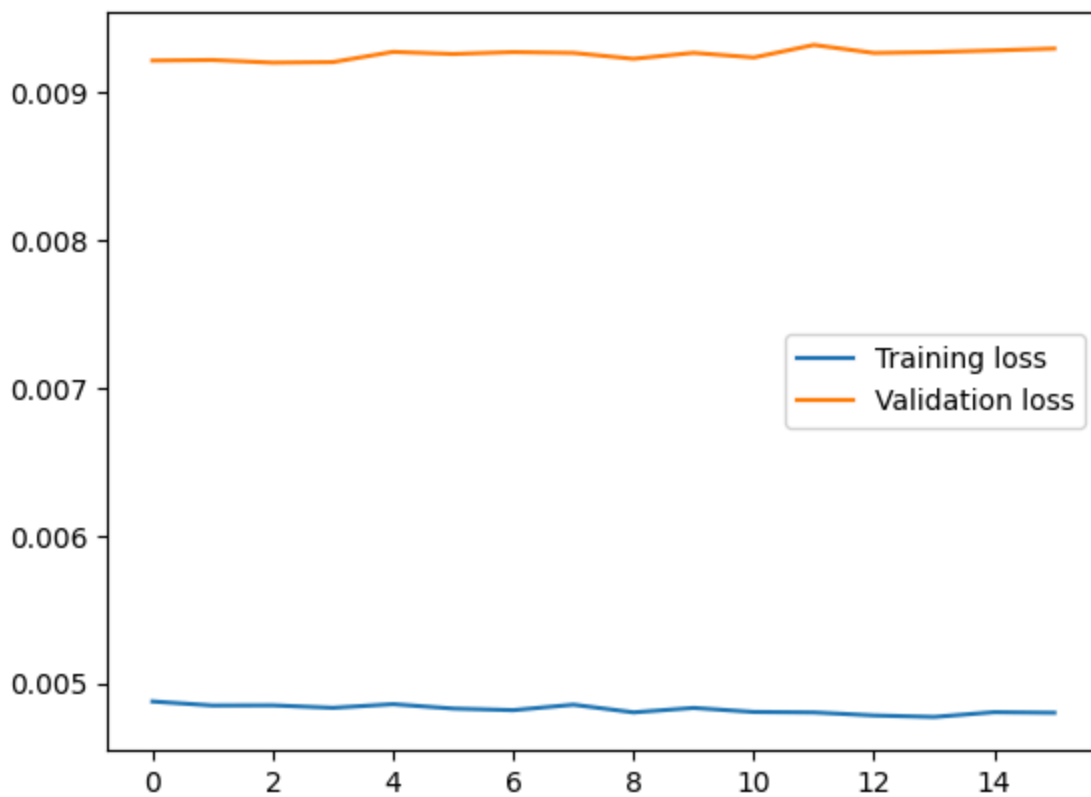
```
[[1722  50  80  48]
 [ 35 1837  17  11]
 [ 62  20 1667 151]
 [ 57  13  130 1700]]
```

Micro Recall: 0.9113157894736842

Macro Recall: 0.9113157894736842

Micro F1 Score: 0.9113157894736842

Macro F1 Score: 0.9112501894396248



Accuracy on the valid set: 0.9146666666666666

Classification Report:

	precision	recall	f1-score	support
0	0.93	0.89	0.91	1500
1	0.96	0.98	0.97	1500
2	0.88	0.90	0.89	1500
3	0.90	0.90	0.90	1500
accuracy		0.91		6000
macro avg	0.91	0.91	0.91	6000
weighted avg	0.91	0.91	0.91	6000

Confusion Matrix:

[[1334 42 75 49]

[ 22 1466 8 4]

[ 44 12 1344 100]

[ 41 6 109 1344]]

Micro Recall: 0.9146666666666666

Macro Recall: 0.9146666666666666

Micro F1 Score: 0.9146666666666666

Macro F1 Score: 0.9145956775990495

100% ██████████ 238/238 [00:02<00:00, 107.92it/s]Accuracy on the test set:

0.9113157894736842

Classification Report:

	precision	recall	f1-score	support
0	0.92	0.91	0.91	1900
1	0.96	0.97	0.96	1900
2	0.88	0.88	0.88	1900
3	0.89	0.89	0.89	1900
accuracy		0.91		7600
macro avg	0.91	0.91	0.91	7600
weighted avg	0.91	0.91	0.91	7600

Confusion Matrix:

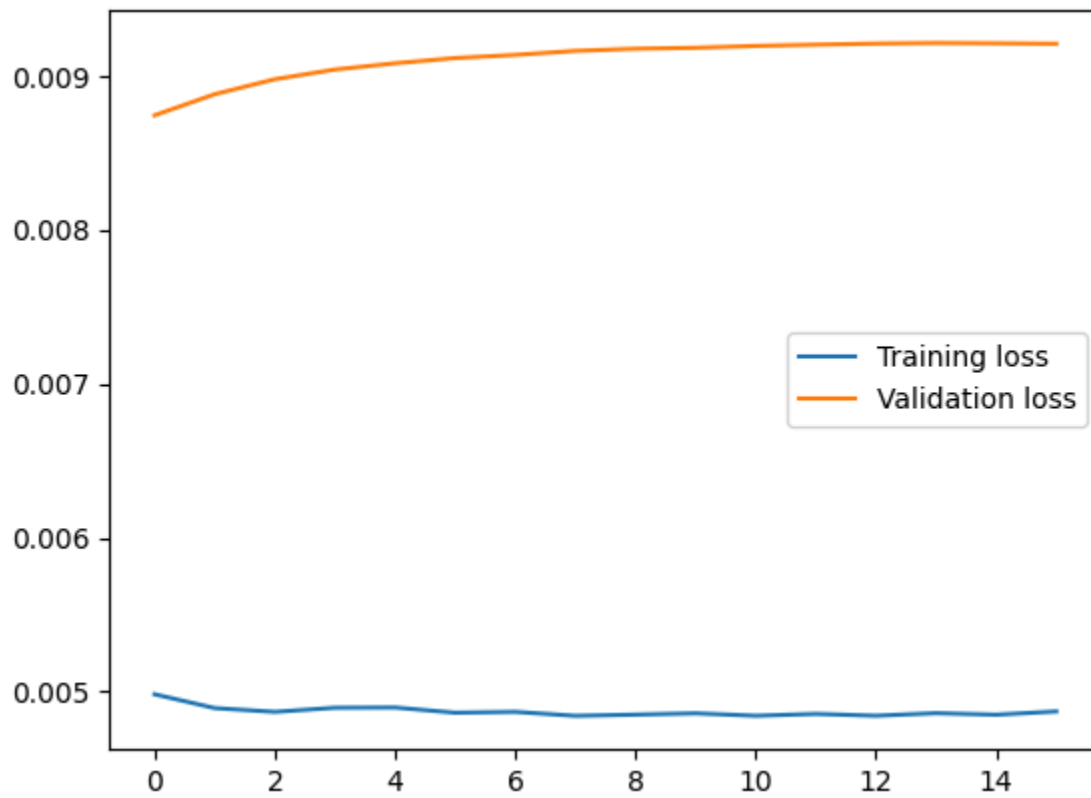
[[1722 50 80 48]

[ 35 1837 17 11]

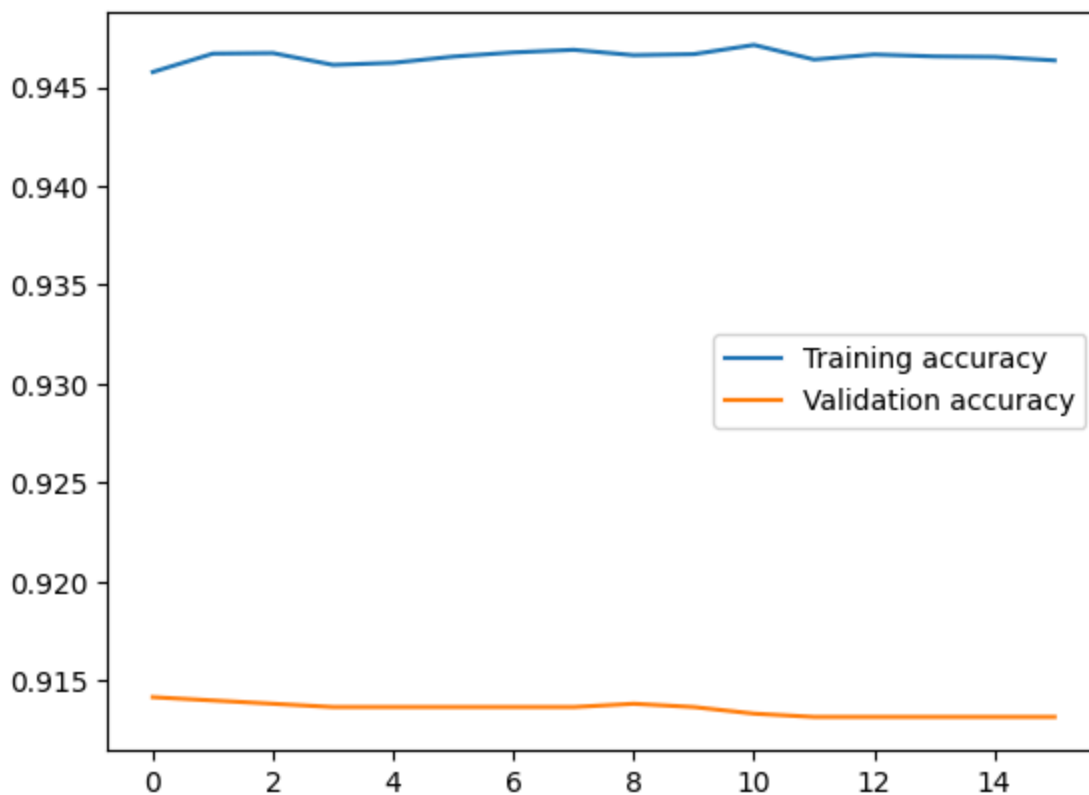
[ 62 20 1667 151]

[ 57 13 130 1700]]

Micro Recall: 0.9113157894736842  
Macro Recall: 0.9113157894736842  
Micro F1 Score: 0.9113157894736842  
Macro F1 Score: 0.9112501894396248







100% [██████████] 188/188 [00:01<00:00, 117.49it/s]

Accuracy on the valid set: 0.9146666666666666

Classification Report:

	precision	recall	f1-score	support
0	0.93	0.89	0.91	1500
1	0.96	0.98	0.97	1500
2	0.88	0.90	0.89	1500
3	0.90	0.90	0.90	1500
accuracy	0.91			6000
macro avg	0.91	0.91	0.91	6000
weighted avg	0.91	0.91	0.91	6000

Confusion Matrix:

```
[[1334  42  75  49]
 [ 22 1466   8   4]
 [ 44  12 1344  100]
 [ 41   6  109 1344]]
```

Micro Recall: 0.9146666666666666

Macro Recall: 0.9146666666666666

Micro F1 Score: 0.9146666666666666

Macro F1 Score: 0.9145956775990495

100%|██████████| 238/238 [00:02<00:00, 114.75it/s]

Accuracy on the test set: **0.9113157894736842**

Classification Report:

	precision	recall	f1-score	support
0	0.92	0.91	0.91	1900
1	0.96	0.97	0.96	1900
2	0.88	0.88	0.88	1900
3	0.89	0.89	0.89	1900
accuracy		0.91		7600
macro avg	0.91	0.91	0.91	7600
weighted avg	0.91	0.91	0.91	7600

Confusion Matrix:

```
[[1722  50  80  48]
 [ 35 1837  17  11]
 [ 62  20 1667 151]
 [ 57  13  130 1700]]
```

Micro Recall: 0.9113157894736842

Macro Recall: 0.9113157894736842

Micro F1 Score: 0.9113157894736842

Macro F1 Score: 0.9112501894396248

## 2. Trainable $\lambda$ s

Overview: In this setting,  $\lambda$ s are parameters within the model that are adjusted during the training process. The weights are applied to the outputs of different layers (e.g., initial embeddings, forward LSTM, backward LSTM) and are optimized along with the rest of the network parameters.

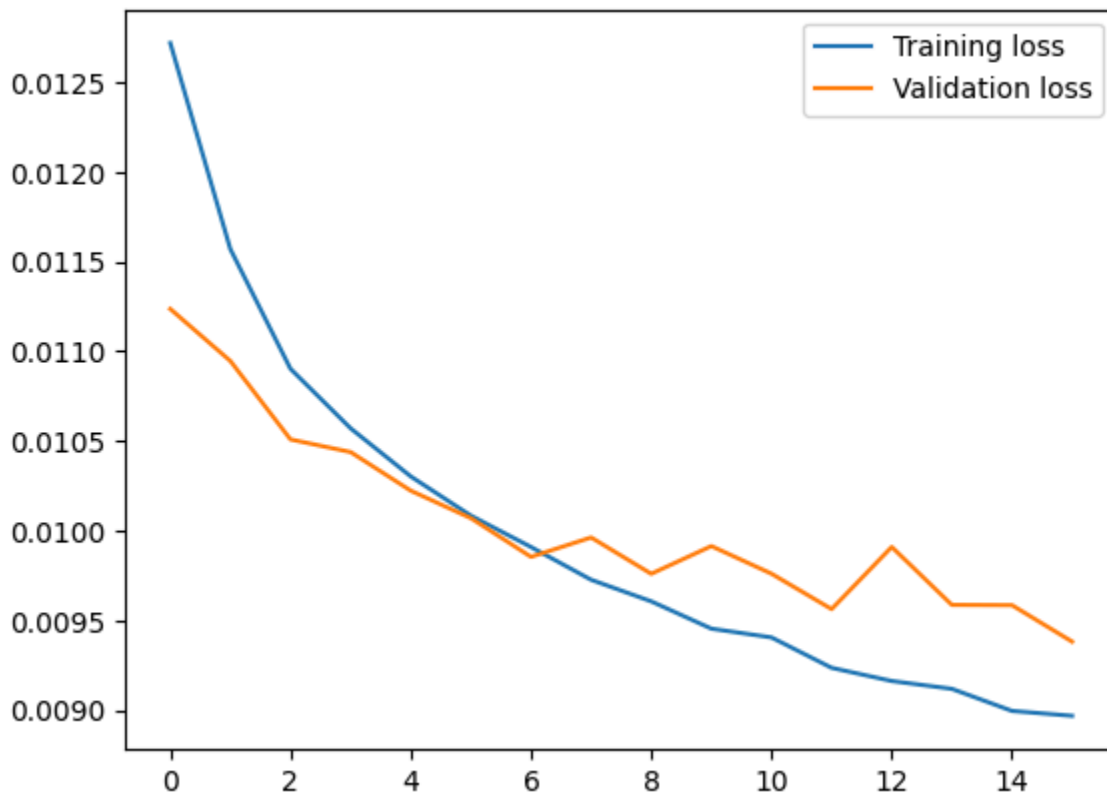
Advantages:

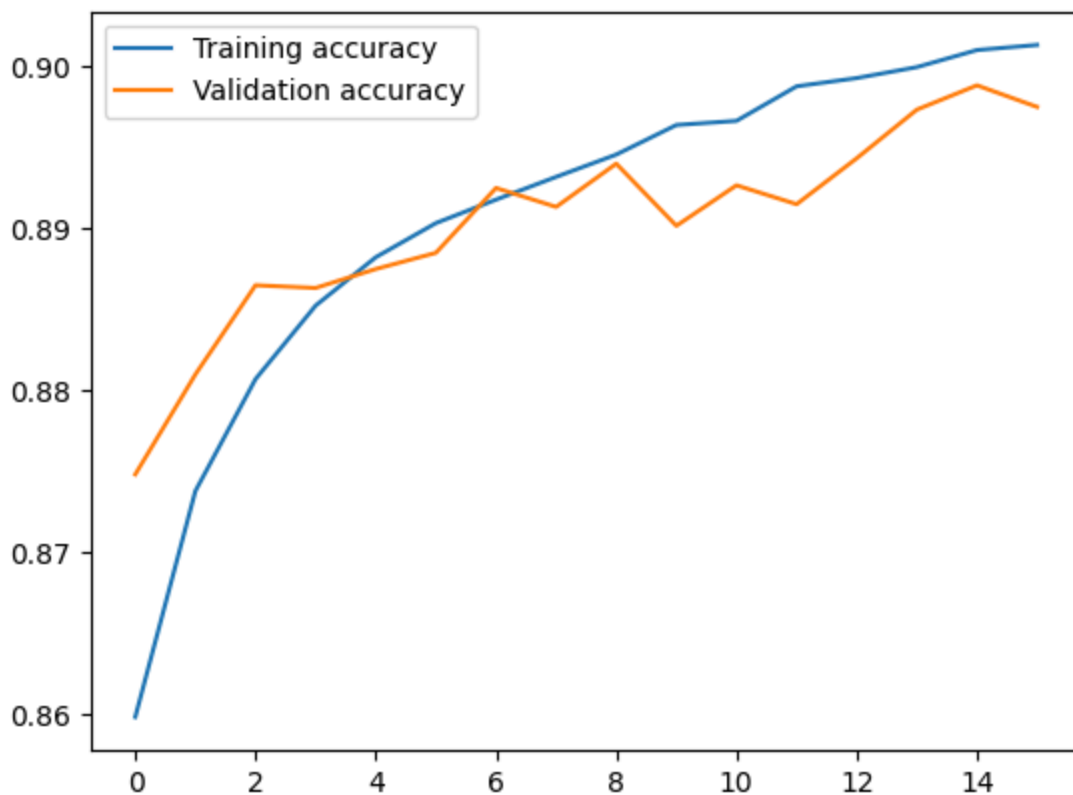
- Flexibility: Allows the model to learn how much to weigh each layer's output based on the training data, potentially improving the ability to capture relevant features for the prediction task.
- Adaptability: Can dynamically adjust the weights during training to better capture the nuances of the data, which may vary across different tasks or datasets.

Disadvantages:

- Overfitting: More parameters to train can lead to overfitting, especially with smaller datasets.
- Complexity: Increases the complexity of the model, requiring more data and potentially longer training times.

```
SentimentalAnalysisFlow(  
    (embedding): Embedding(39976, 100)  
    (lstm1): LSTM(100, 100, num_layers=2, batch_first=True, dropout=0.36)  
    (lstm2): LSTM(100, 100, num_layers=2, batch_first=True, dropout=0.36)  
    (dropout): Dropout(p=0.25, inplace=False)  
    (fc1): Linear(in_features=100, out_features=100, bias=True)  
    (fc2): Linear(in_features=100, out_features=4, bias=True)  
)
```





100% [██████████] 188/188 [00:01<00:00, 117.00it/s]

Accuracy on the valid set: 0.8988333333333334

Classification Report:

	precision	recall	f1-score	support
0	0.91	0.88	0.89	1500
1	0.96	0.97	0.96	1500
2	0.84	0.89	0.86	1500
3	0.89	0.86	0.87	1500
accuracy	0.90			6000
macro avg	0.90	0.90	0.90	6000
weighted avg	0.90	0.90	0.90	6000

Confusion Matrix:

```
[[1313  42  99  46]
 [ 27 1456   9   8]
 [ 44  14 1332 110]
 [ 52   7 149 1292]]
```

Micro Recall: 0.8988333333333334

Macro Recall: 0.8988333333333334

Micro F1 Score: 0.8988333333333334

Macro F1 Score: 0.8988853132732192

100%|██████████| 238/238 [00:02<00:00, 114.29it/s]

Accuracy on the test set: 0.8984210526315789

Classification Report:

	precision	recall	f1-score	support
0	0.91	0.89	0.90	1900
1	0.96	0.96	0.96	1900
2	0.85	0.88	0.86	1900
3	0.88	0.86	0.87	1900
accuracy			0.90	7600
macro avg	0.90	0.90	0.90	7600
weighted avg	0.90	0.90	0.90	7600

Confusion Matrix:

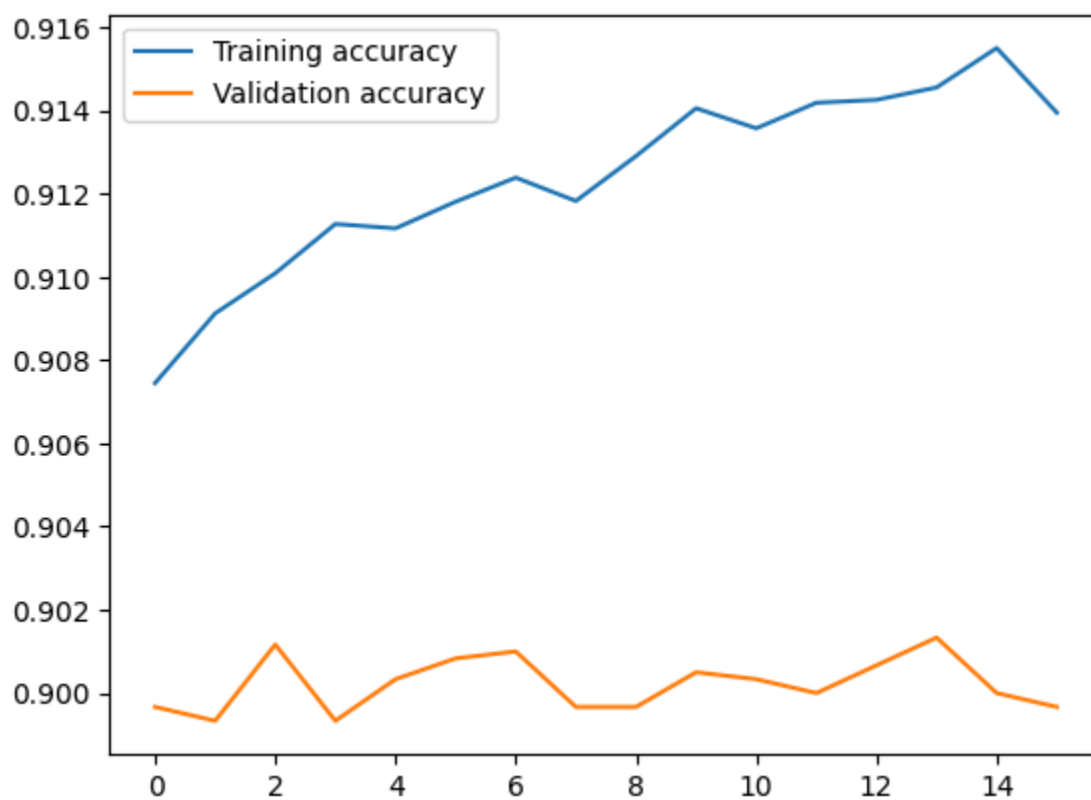
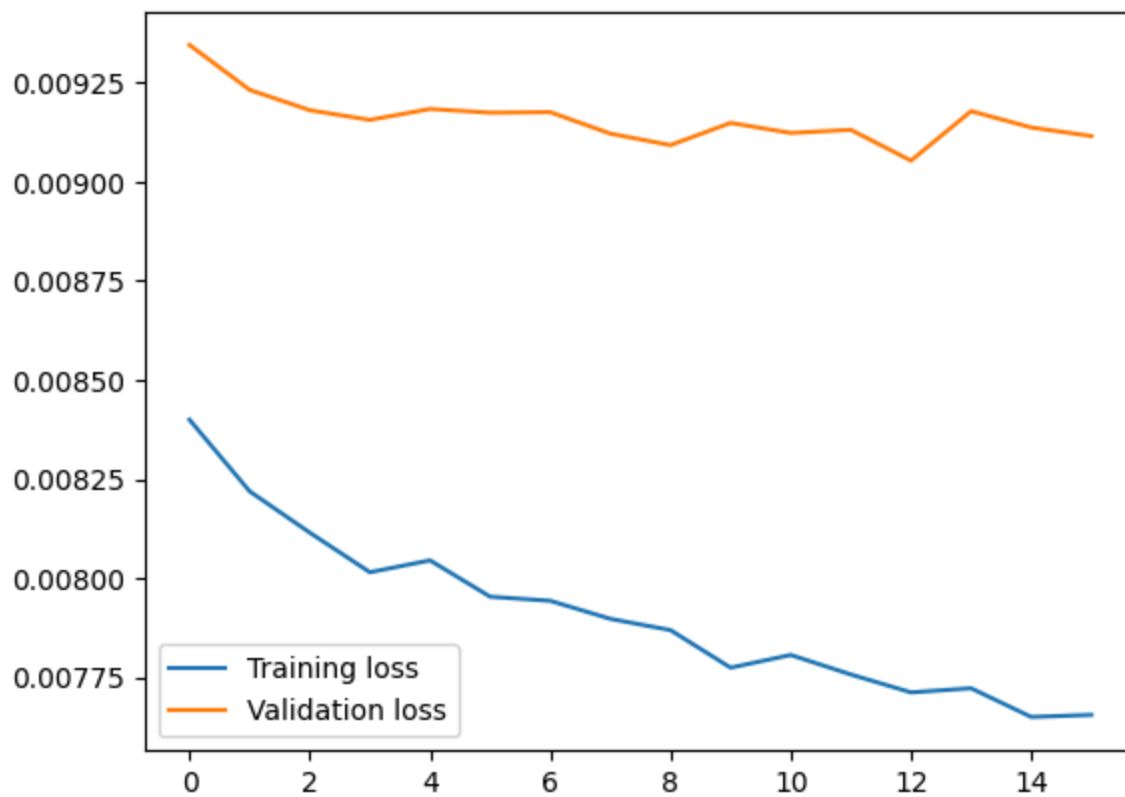
```
[[1692  54  99  55]
 [ 36 1830  21  13]
 [ 60  15 1667 158]
 [ 70  14 177 1639]]
```

Micro Recall: 0.8984210526315789

Macro Recall: 0.898421052631579

Micro F1 Score: 0.8984210526315789

Macro F1 Score: 0.8984600655962866



Accuracy on the valid set: 0.9013333333333333

Classification Report:

	precision	recall	f1-score	support
0	0.92	0.89	0.90	1500
1	0.96	0.97	0.97	1500
2	0.85	0.88	0.87	1500
3	0.88	0.86	0.87	1500
accuracy			0.90	6000
macro avg	0.90	0.90	0.90	6000
weighted avg	0.90	0.90	0.90	6000

Confusion Matrix:


```
[[1328 37 86 49]
 [ 20 1457 8 15]
 [ 48 14 1326 112]
 [ 52 8 143 1297]]
```

Micro Recall: 0.9013333333333333

Macro Recall: 0.9013333333333333

Micro F1 Score: 0.9013333333333333

Macro F1 Score: 0.901366833548382

100% 238/238 [00:02<00:00, 112.36it/s]

Accuracy on the test set: 0.9060526315789473

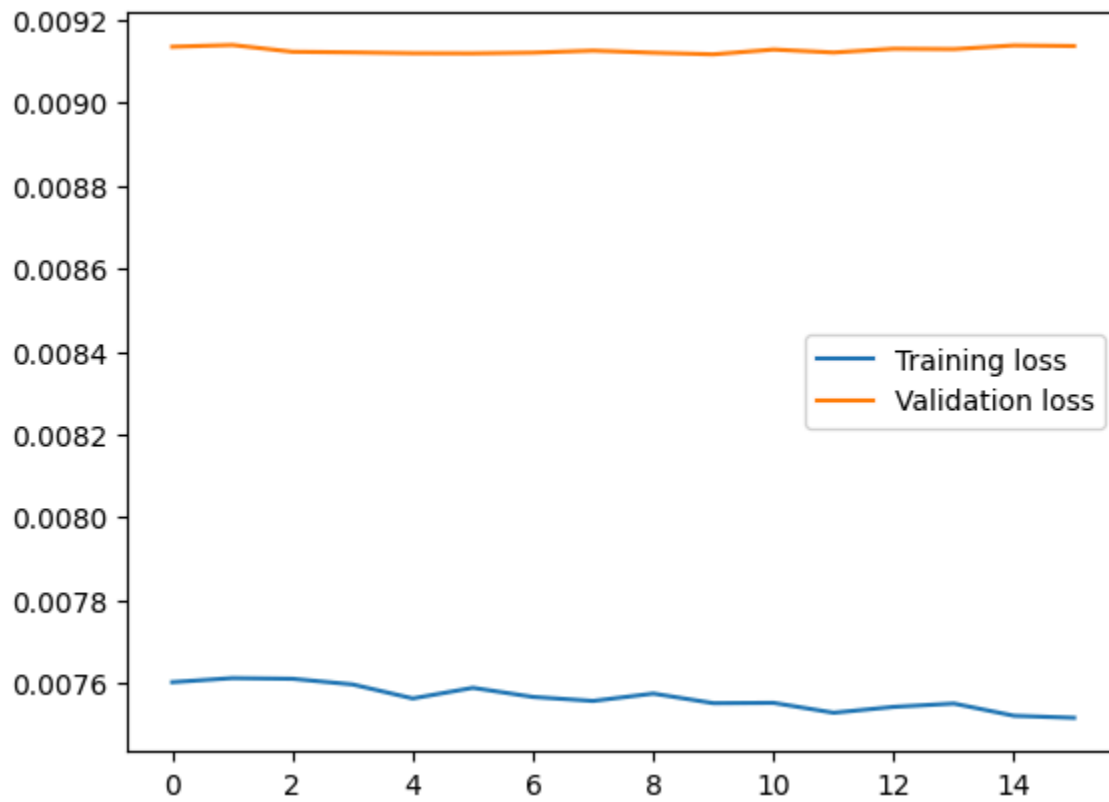
Classification Report:

	precision	recall	f1-score	support
0	0.92	0.90	0.91	1900
1	0.96	0.97	0.96	1900
2	0.86	0.88	0.87	1900
3	0.88	0.88	0.88	1900
accuracy			0.91	7600
macro avg	0.91	0.91	0.91	7600
weighted avg	0.91	0.91	0.91	7600

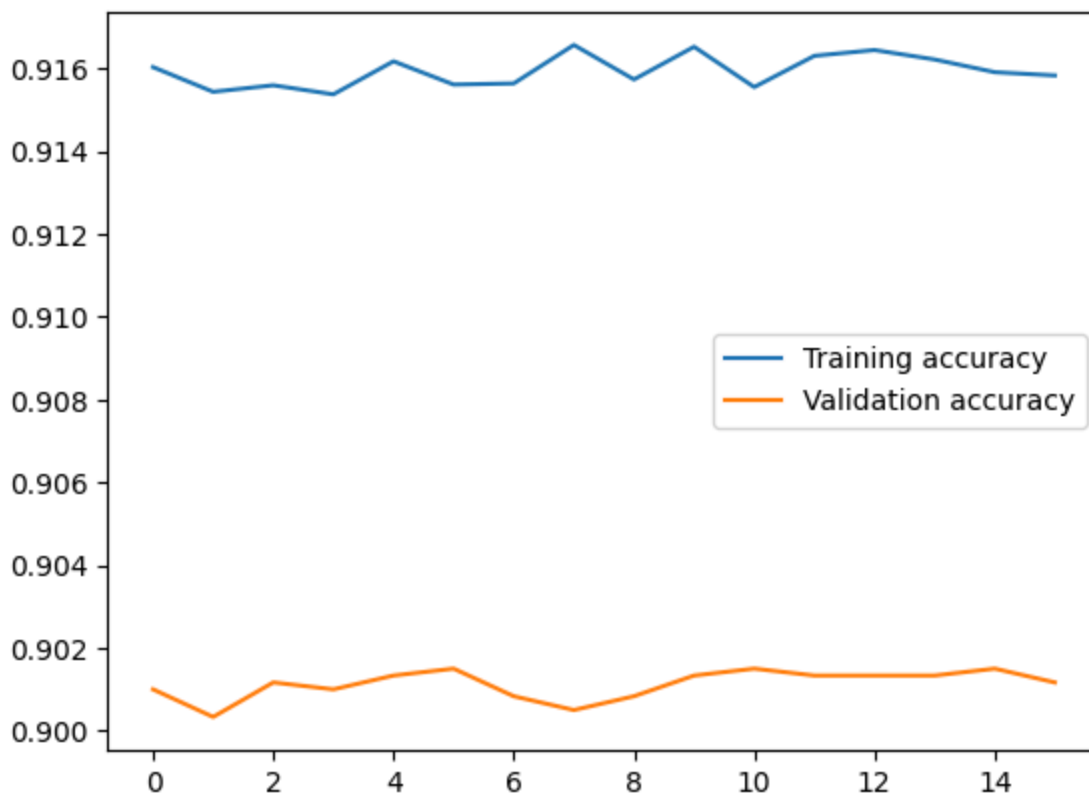
Confusion Matrix:

```
[[1710 55 83 52]
 [ 24 1843 21 12]
 [ 63 14 1669 154]
 [ 59 15 162 1664]]
```

Micro Recall: 0.9060526315789473  
Macro Recall: 0.9060526315789474  
Micro F1 Score: 0.9060526315789473  
Macro F1 Score: 0.9060153792245165







100% ██████████ 188/188 [00:01<00:00, 115.90it/s]

Accuracy on the valid set: 0.9015

Classification Report:

	precision	recall	f1-score	support
0	0.92	0.88	0.90	1500
1	0.96	0.97	0.97	1500
2	0.85	0.88	0.87	1500
3	0.88	0.87	0.87	1500
accuracy	0.90			6000
macro avg	0.90	0.90	0.90	6000
weighted avg	0.90	0.90	0.90	6000

Confusion Matrix:

```
[[1327 37 86 50]
 [ 19 1458 8 15]
 [ 49 14 1316 121]
 [ 52 8 132 1308]]
```

Micro Recall: 0.9015

Macro Recall: 0.9015

Micro F1 Score: 0.9015

Macro F1 Score: 0.9015169096939332

100%|██████████| 238/238 [00:02<00:00, 113.14it/s]

Accuracy on the test set: 0.9067105263157895

Classification Report:

	precision	recall	f1-score	support
0	0.92	0.90	0.91	1900
1	0.96	0.97	0.96	1900
2	0.87	0.87	0.87	1900
3	0.88	0.88	0.88	1900
accuracy			0.91	7600
macro avg	0.91	0.91	0.91	7600
weighted avg	0.91	0.91	0.91	7600

Confusion Matrix:

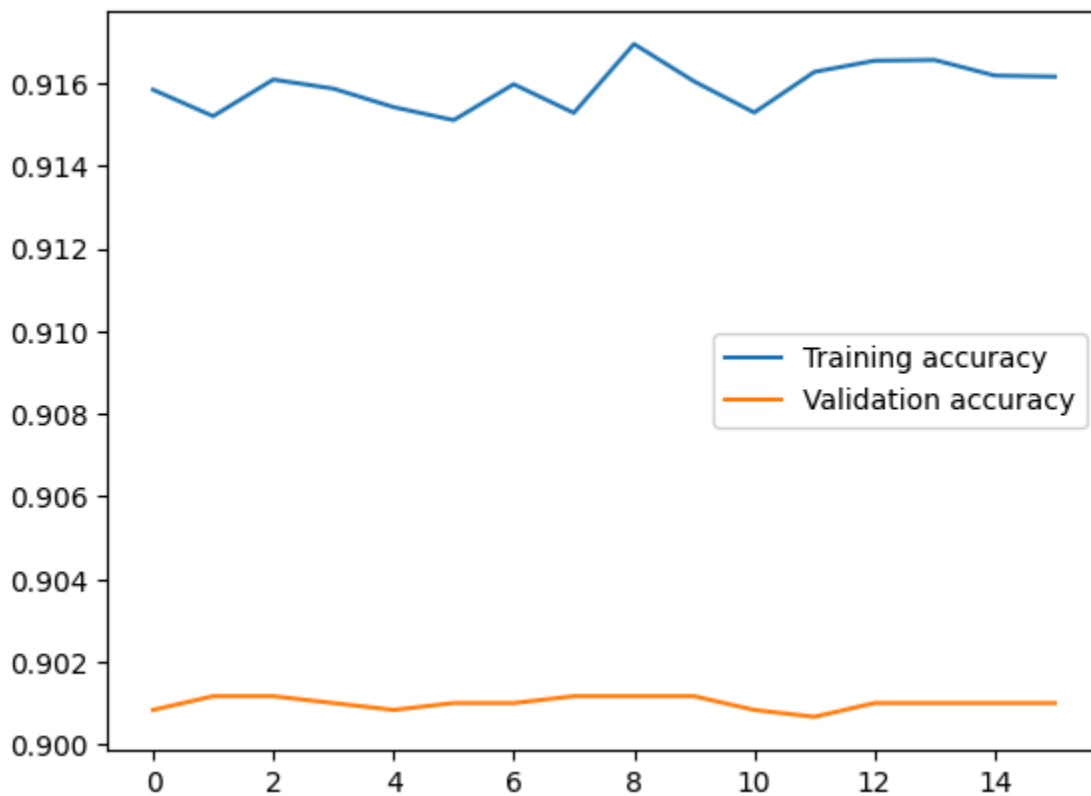
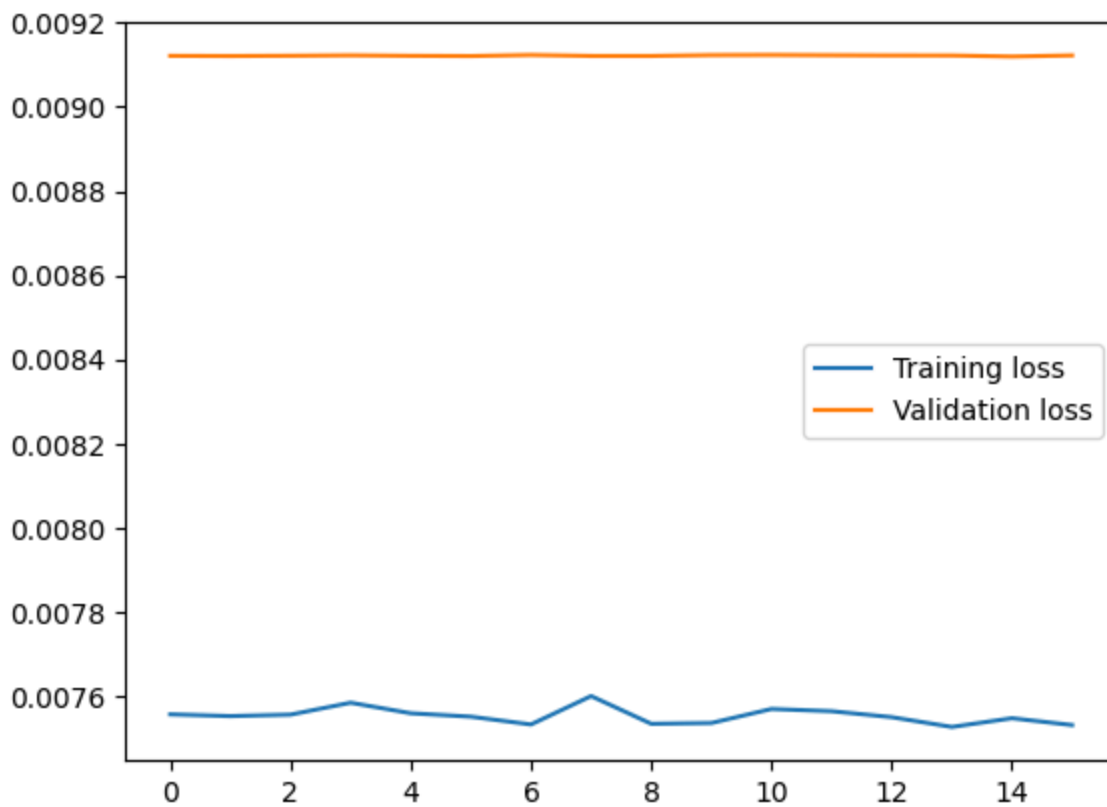
```
[[1710  55  80  55]
 [ 24 1845  19  12]
 [ 66  15 1658 161]
 [ 57  14 151 1678]]
```

Micro Recall: 0.9067105263157895

Macro Recall: 0.9067105263157895

Micro F1 Score: 0.9067105263157895

Macro F1 Score: 0.9066407044819789



100%|██████████| 188/188 [00:01<00:00, 115.74it/s]

Accuracy on the valid set: 0.9015

Classification Report:

	precision	recall	f1-score	support
0	0.92	0.88	0.90	1500
1	0.96	0.97	0.97	1500
2	0.85	0.88	0.87	1500
3	0.88	0.87	0.87	1500
accuracy			0.90	6000
macro avg	0.90	0.90	0.90	6000
weighted avg	0.90	0.90	0.90	6000

Confusion Matrix:

```
[[1327 37 86 50]
 [ 19 1458 8 15]
 [ 49 14 1316 121]
 [ 52 8 132 1308]]
```

Micro Recall: 0.9015

Macro Recall: 0.9015

Micro F1 Score: 0.9015

Macro F1 Score: 0.9015169096939332

100% ██████████ 238/238 [00:02<00:00, 113.95it/s]

Accuracy on the test set: 0.9067105263157895

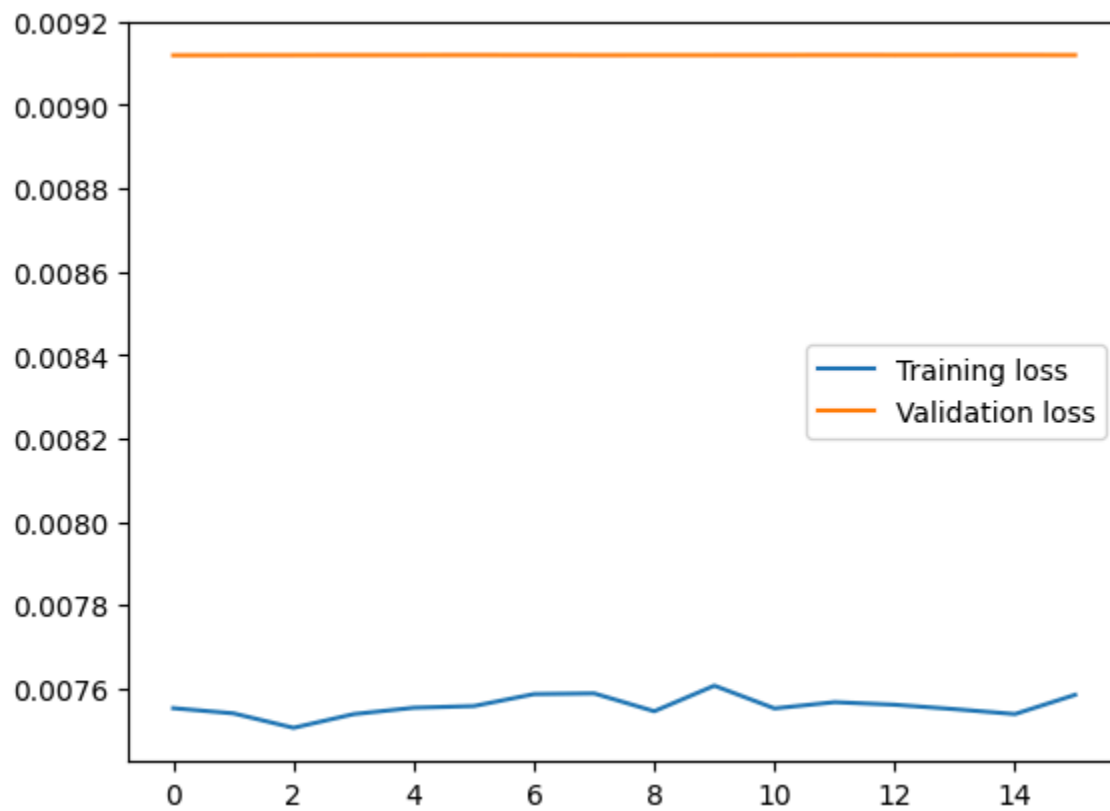
Classification Report:

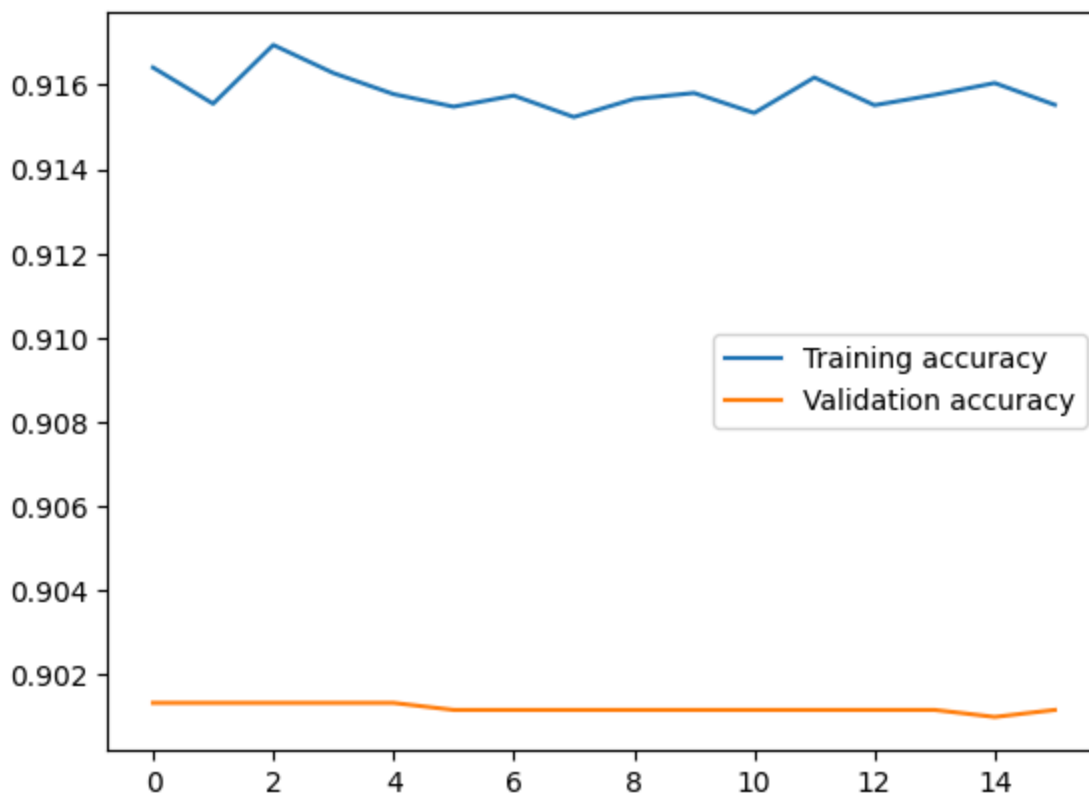
	precision	recall	f1-score	support
0	0.92	0.90	0.91	1900
1	0.96	0.97	0.96	1900
2	0.87	0.87	0.87	1900
3	0.88	0.88	0.88	1900
accuracy			0.91	7600
macro avg	0.91	0.91	0.91	7600
weighted avg	0.91	0.91	0.91	7600

Confusion Matrix:

```
[[1710 55 80 55]
 [ 24 1845 19 12]
 [ 66 15 1658 161]
 [ 57 14 151 1678]]
```

Micro Recall: 0.9067105263157895  
Macro Recall: 0.9067105263157895  
Micro F1 Score: 0.9067105263157895  
Macro F1 Score: 0.9066407044819789





100% [██████████] 188/188 [00:01<00:00, 115.19it/s]

Accuracy on the valid set: 0.9015

Classification Report:

	precision	recall	f1-score	support
0	0.92	0.88	0.90	1500
1	0.96	0.97	0.97	1500
2	0.85	0.88	0.87	1500
3	0.88	0.87	0.87	1500
accuracy			0.90	6000
macro avg	0.90	0.90	0.90	6000
weighted avg	0.90	0.90	0.90	6000

Confusion Matrix:

```
[[1327 37 86 50]
 [ 19 1458 8 15]
 [ 49 14 1316 121]
 [ 52 8 132 1308]]
```

Micro Recall: 0.9015

Macro Recall: 0.9015

Micro F1 Score: 0.9015

Macro F1 Score: 0.9015169096939332

100% ██████████ 238/238 [00:02<00:00, 113.26it/s]

Accuracy on the test set: **0.9067105263157895**

Classification Report:

	precision	recall	f1-score	support
0	0.92	0.90	0.91	1900
1	0.96	0.97	0.96	1900
2	0.87	0.87	0.87	1900
3	0.88	0.88	0.88	1900
accuracy			0.91	7600
macro avg	0.91	0.91	0.91	7600
weighted avg	0.91	0.91	0.91	7600

Confusion Matrix:

```
[[1710 55 80 55]
 [ 24 1845 19 12]
 [ 66 15 1658 161]
 [ 57 14 151 1678]]
```

Micro Recall: 0.9067105263157895

Macro Recall: 0.9067105263157895

Micro F1 Score: 0.9067105263157895

Macro F1 Score: 0.9066407044819789

## 2. Frozen $\lambda$ s

Overview: Here,  $\lambda$ s are initialized randomly (or based on some heuristic) and are kept constant throughout the training process. They do not adjust based on the training data.

Advantages:

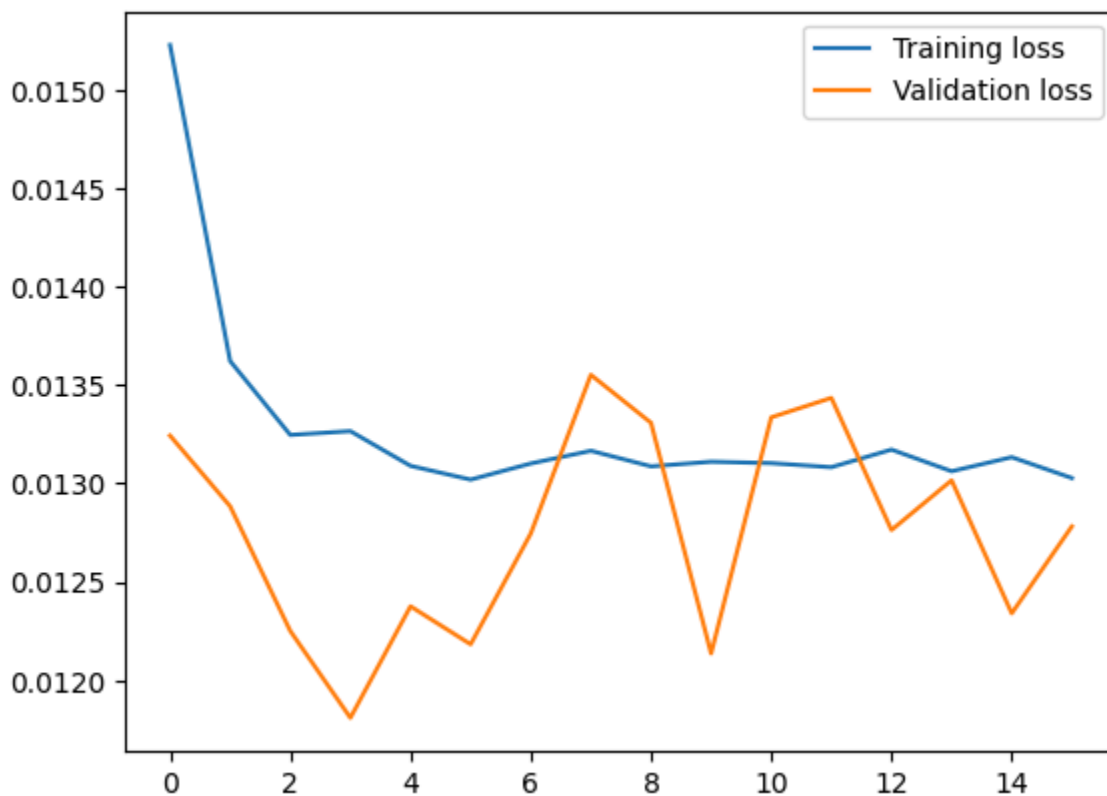
- Simplicity: Reduces the number of parameters that need to be learned, which can speed up training and reduce the computational burden.
- Stability: Fixed weights can lead to more stable predictions across different datasets since they are not tailored to any specific training set.

Disadvantages:

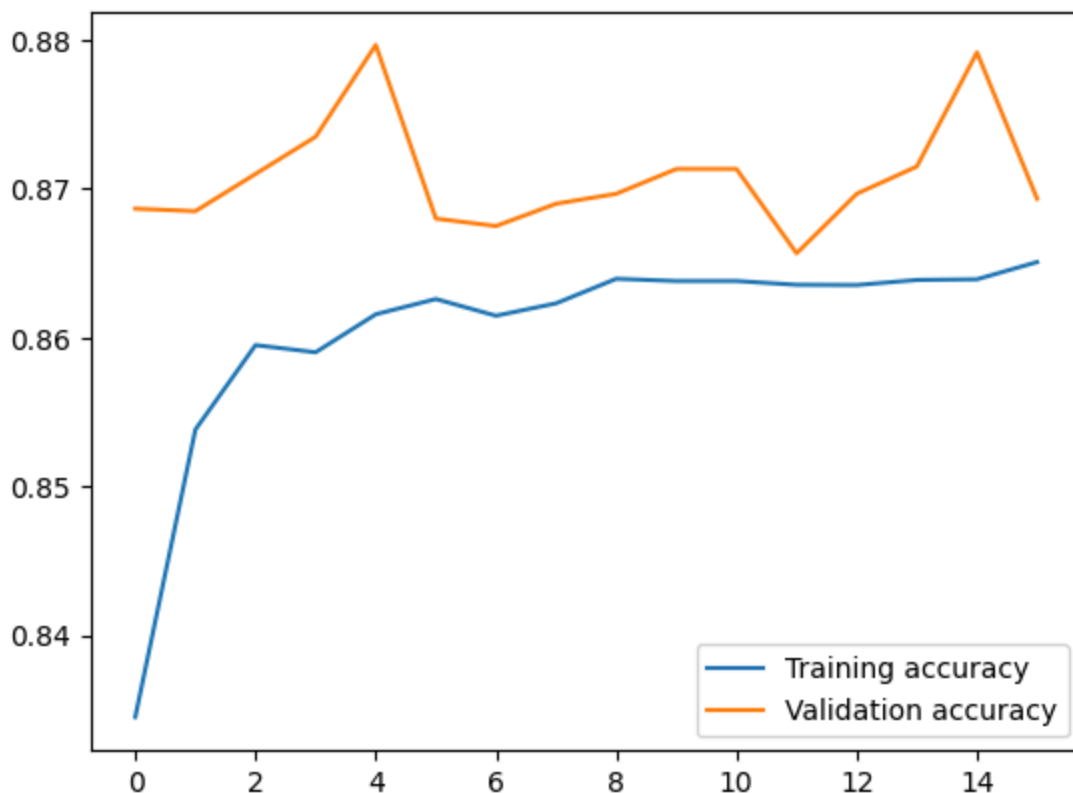
- Inflexibility: Since the weights are not learned, they may not optimally combine the layer outputs for the specific task at hand.

- Suboptimal: The model may not perform as well because it cannot adapt the integration strategy based on the training data.

```
SentimentalAnalysisFroz(  
    (embedding): Embedding(39976, 100)  
    (lstm1): LSTM(100, 100, num_layers=2, batch_first=True, dropout=0.36)  
    (lstm2): LSTM(100, 100, num_layers=2, batch_first=True, dropout=0.36)  
    (dropout): Dropout(p=0.25, inplace=False)  
    (fc1): Linear(in_features=100, out_features=100, bias=True)  
    (fc2): Linear(in_features=100, out_features=4, bias=True)  
)
```







100% ██████████ 188/188 [00:01<00:00, 118.14it/s]

Accuracy on the valid set: 0.8796666666666667

Classification Report:

	precision	recall	f1-score	support
0	0.91	0.84	0.87	1500
1	0.95	0.96	0.96	1500
2	0.82	0.87	0.84	1500
3	0.85	0.85	0.85	1500
accuracy			0.88	6000
macro avg	0.88	0.88	0.88	6000
weighted avg	0.88	0.88	0.88	6000

Confusion Matrix:

```
[[1255  47 115  83]
 [ 27 1442  13  18]
 [ 51  16 1303 130]
 [ 51  12 159 1278]]
```

Micro Recall: 0.8796666666666667

Macro Recall: 0.8796666666666667

Micro F1 Score: 0.8796666666666667

Macro F1 Score: 0.8797632038906285

100%|██████████| 238/238 [00:02<00:00, 113.63it/s]

Accuracy on the test set: 0.8777631578947368

Classification Report:

	precision	recall	f1-score	support
0	0.90	0.85	0.88	1900
1	0.95	0.95	0.95	1900
2	0.82	0.85	0.84	1900
3	0.84	0.86	0.85	1900
accuracy		0.88		7600
macro avg	0.88	0.88	0.88	7600
weighted avg	0.88	0.88	0.88	7600

Confusion Matrix:

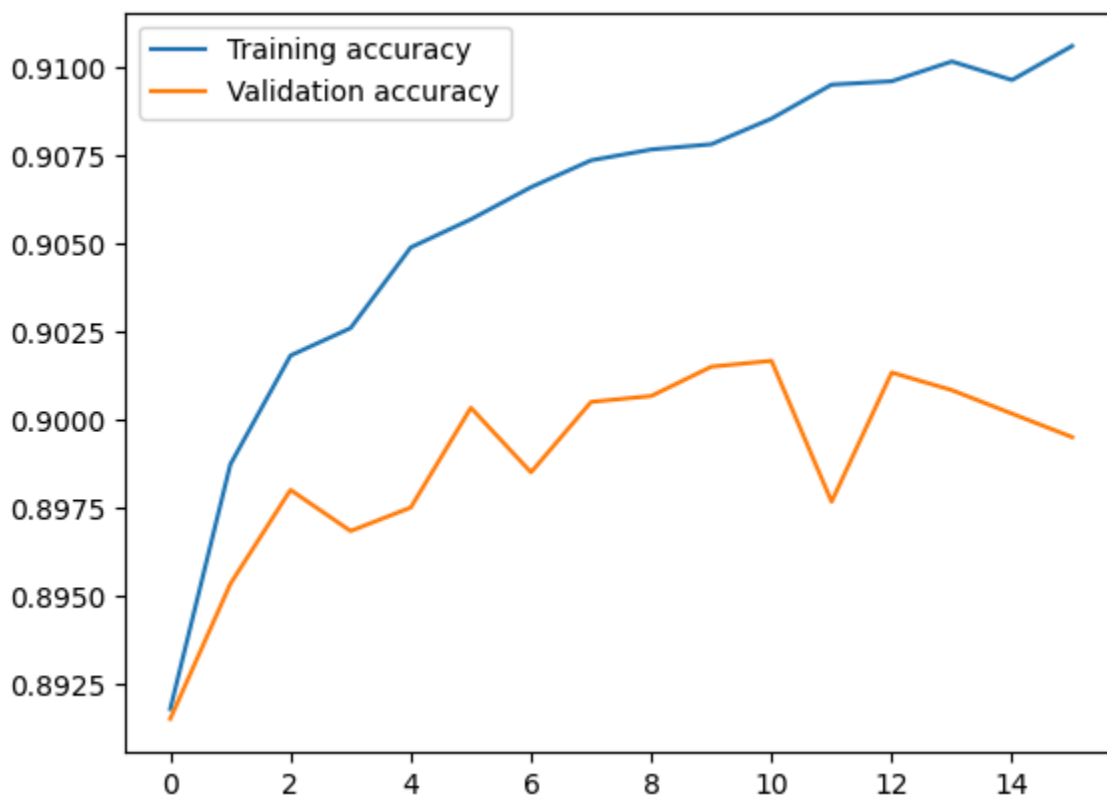
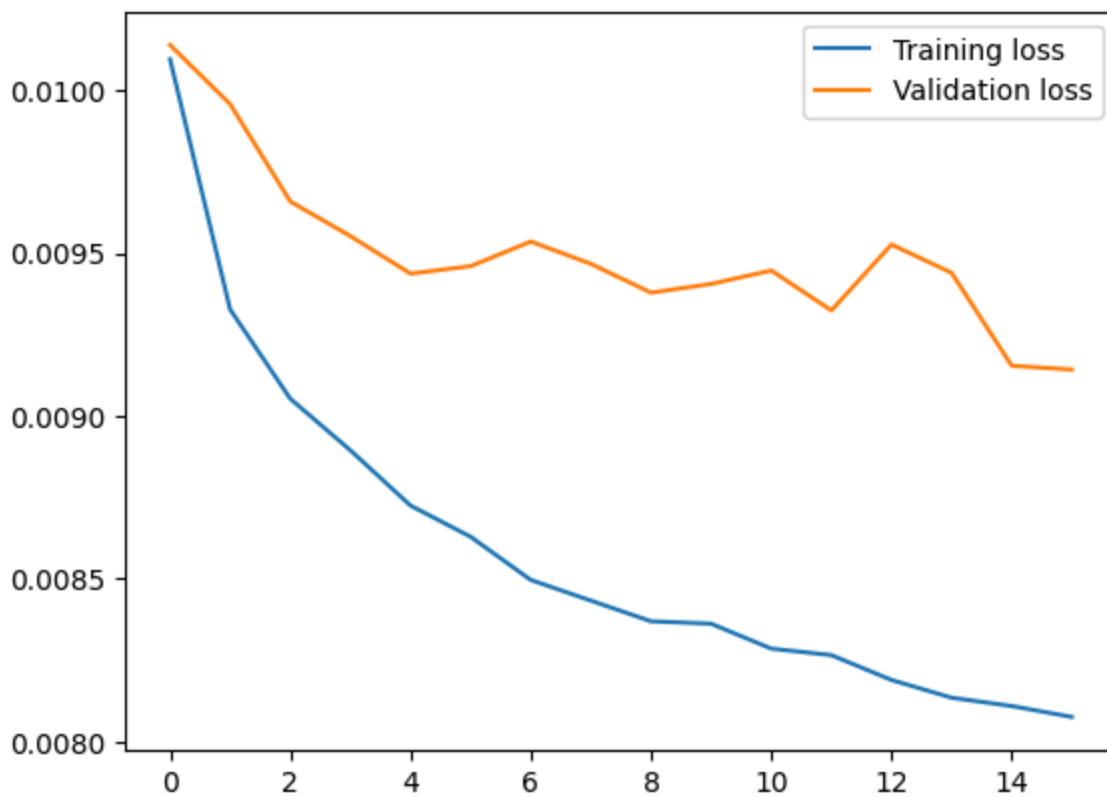
```
[[1620  71 127  82]
 [ 45 1804  28  23]
 [ 69  15 1612 204]
 [ 58  18 189 1635]]
```

Micro Recall: 0.8777631578947368

Macro Recall: 0.8777631578947369

Micro F1 Score: 0.8777631578947368

Macro F1 Score: 0.8779570216313124



Accuracy on the valid set: 0.9016666666666666

Classification Report:

	precision	recall	f1-score	support
0	0.92	0.89	0.90	1500
1	0.95	0.98	0.97	1500
2	0.85	0.88	0.87	1500
3	0.89	0.86	0.87	1500
accuracy		0.90		6000
macro avg	0.90	0.90	0.90	6000
weighted avg	0.90	0.90	0.90	6000

Confusion Matrix:

```
[[1331 39 84 46]
 [ 16 1466 9 9]
 [ 46 18 1325 111]
 [ 57 14 141 1288]]
```

Micro Recall: 0.9016666666666666

Macro Recall: 0.9016666666666667

Micro F1 Score: 0.9016666666666667

Macro F1 Score: 0.9015333447269133

100% ██████████ 238/238 [00:02<00:00, 116.98it/s]

Accuracy on the test set: 0.900921052631579

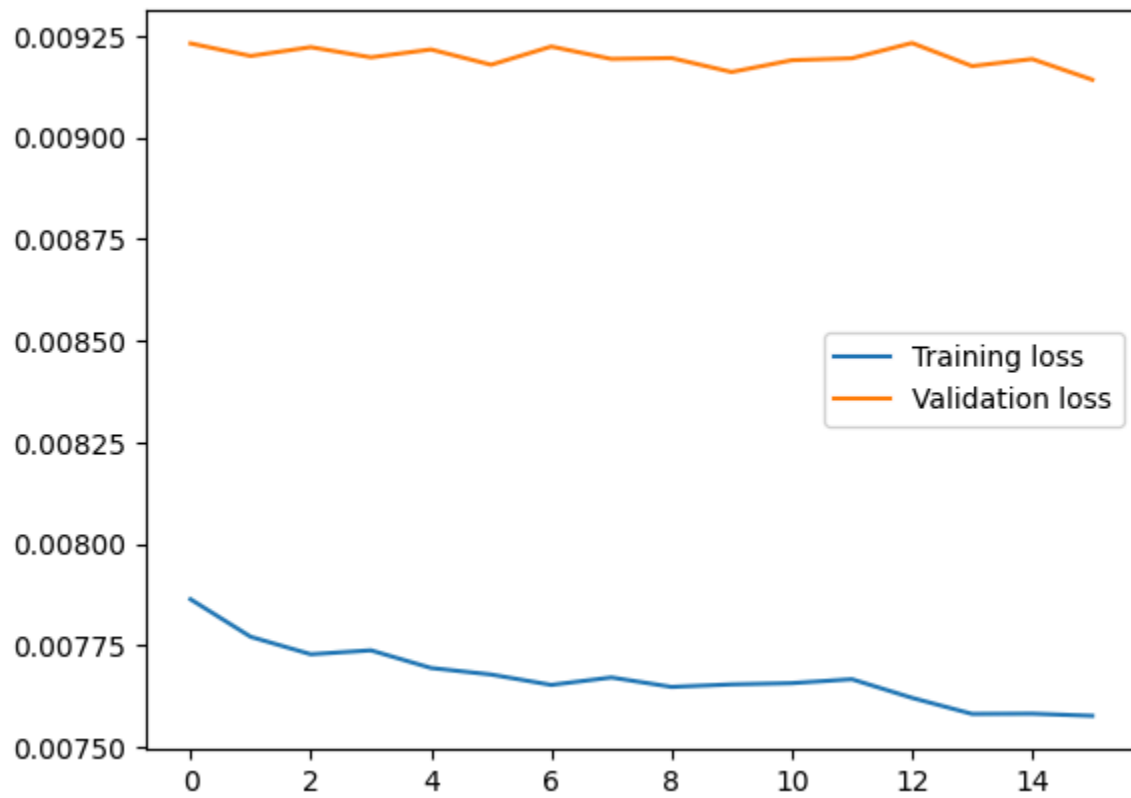
Classification Report:

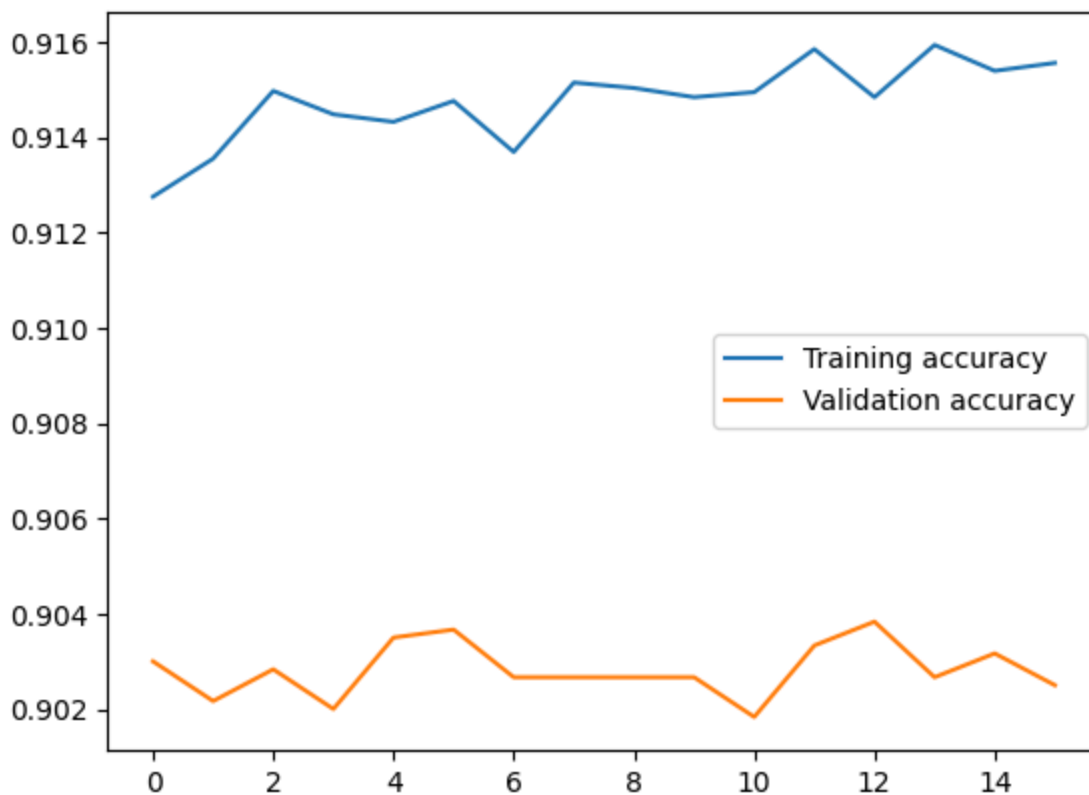
	precision	recall	f1-score	support
0	0.92	0.89	0.91	1900
1	0.95	0.97	0.96	1900
2	0.85	0.88	0.87	1900
3	0.88	0.86	0.87	1900
accuracy		0.90		7600
macro avg	0.90	0.90	0.90	7600
weighted avg	0.90	0.90	0.90	7600

Confusion Matrix:

```
[[1698 61 90 51]
 [ 28 1842 15 15]
 [ 60 15 1673 152]
 [ 60 22 184 1634]]
```

Micro Recall: 0.900921052631579  
Macro Recall: 0.900921052631579  
Micro F1 Score: 0.900921052631579  
Macro F1 Score: 0.9008336520649256





100% [██████████] 188/188 [00:01<00:00, 118.25it/s]

Accuracy on the valid set: 0.9038333333333334

Classification Report:

	precision	recall	f1-score	support
0	0.92	0.88	0.90	1500
1	0.96	0.98	0.97	1500
2	0.86	0.88	0.87	1500
3	0.88	0.87	0.88	1500
accuracy			0.90	6000
macro avg	0.90	0.90	0.90	6000
weighted avg	0.90	0.90	0.90	6000

Confusion Matrix:

```
[[1326  41  82  51]
 [ 15 1465  10  10]
 [ 43  15 1321 121]
 [ 53  12  124 1311]]
```

Micro Recall: 0.9038333333333334

Macro Recall: 0.9038333333333334

Micro F1 Score: 0.9038333333333334

Macro F1 Score: 0.9037459929254198

100%|██████████| 238/238 [00:02<00:00, 117.56it/s]

Accuracy on the test set: 0.9018421052631579

Classification Report:

	precision	recall	f1-score	support
0	0.92	0.90	0.91	1900
1	0.95	0.97	0.96	1900
2	0.86	0.87	0.87	1900
3	0.87	0.87	0.87	1900
accuracy		0.90		7600
macro avg	0.90	0.90	0.90	7600
weighted avg	0.90	0.90	0.90	7600

Confusion Matrix:

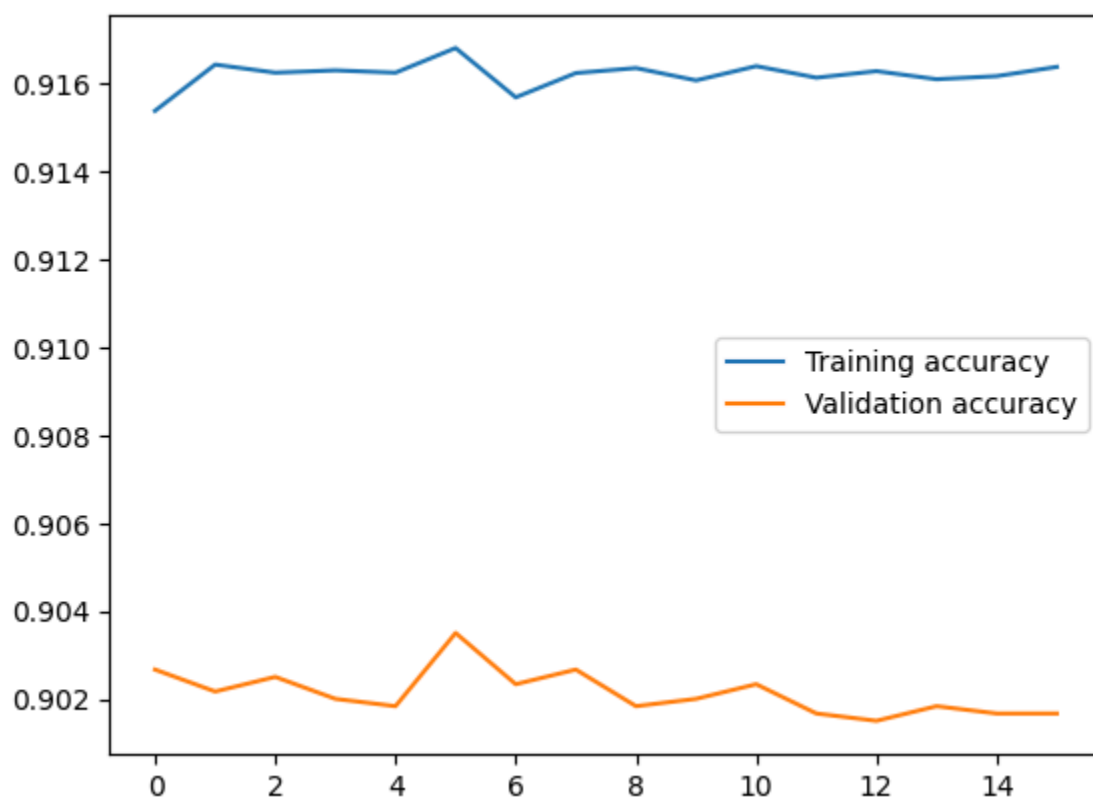
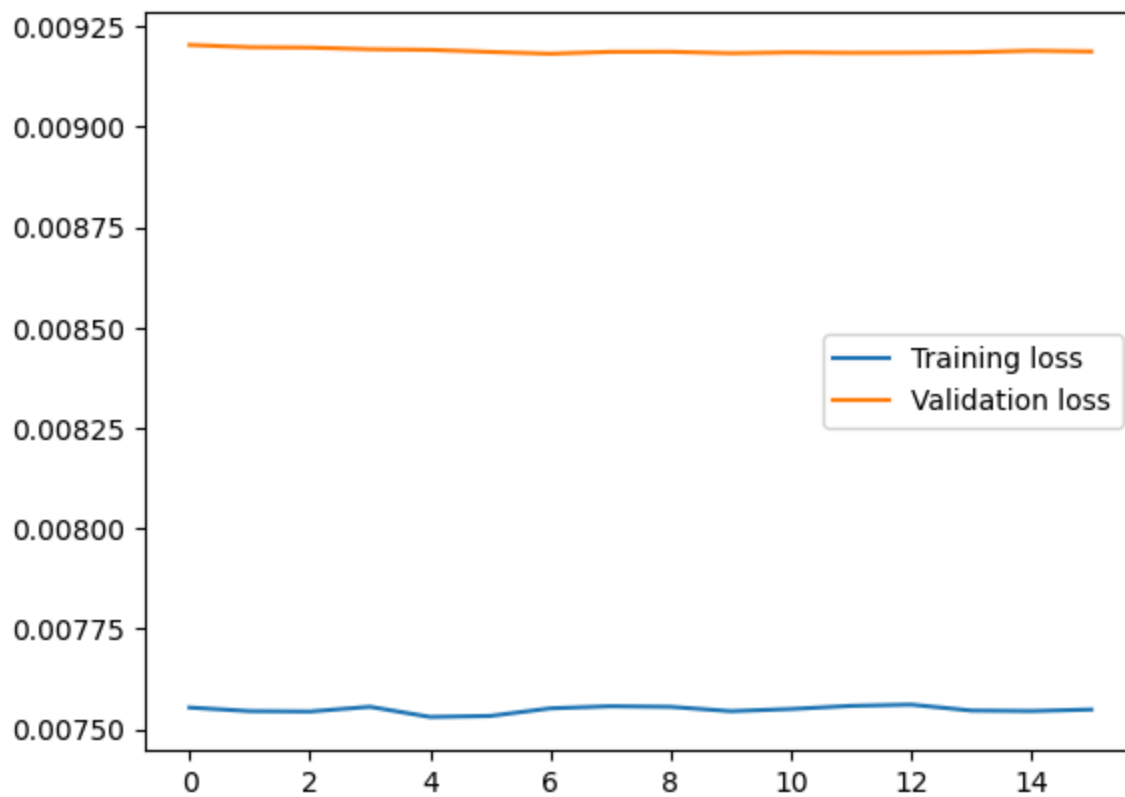
```
[[1703  59  81  57]
 [ 28 1845  12  15]
 [ 60  16 1659 165]
 [ 64  22 167 1647]]
```

Micro Recall: 0.9018421052631579

Macro Recall: 0.9018421052631579

Micro F1 Score: 0.9018421052631579

Macro F1 Score: 0.9017039386076697





Accuracy on the valid set: 0.9038333333333334

Classification Report:

	precision	recall	f1-score	support
0	0.92	0.88	0.90	1500
1	0.96	0.98	0.97	1500
2	0.86	0.88	0.87	1500
3	0.88	0.87	0.88	1500
accuracy			0.90	6000
macro avg	0.90	0.90	0.90	6000
weighted avg	0.90	0.90	0.90	6000

Confusion Matrix:

```
[[1326 41 82 51]
 [ 15 1465 10 10]
 [ 43 15 1321 121]
 [ 53 12 124 1311]]
```

Micro Recall: 0.9038333333333334

Macro Recall: 0.9038333333333334

Micro F1 Score: 0.9038333333333334

Macro F1 Score: 0.9037459929254198

100% ██████████ 238/238 [00:02<00:00, 113.98it/s]

Accuracy on the test set: 0.9018421052631579

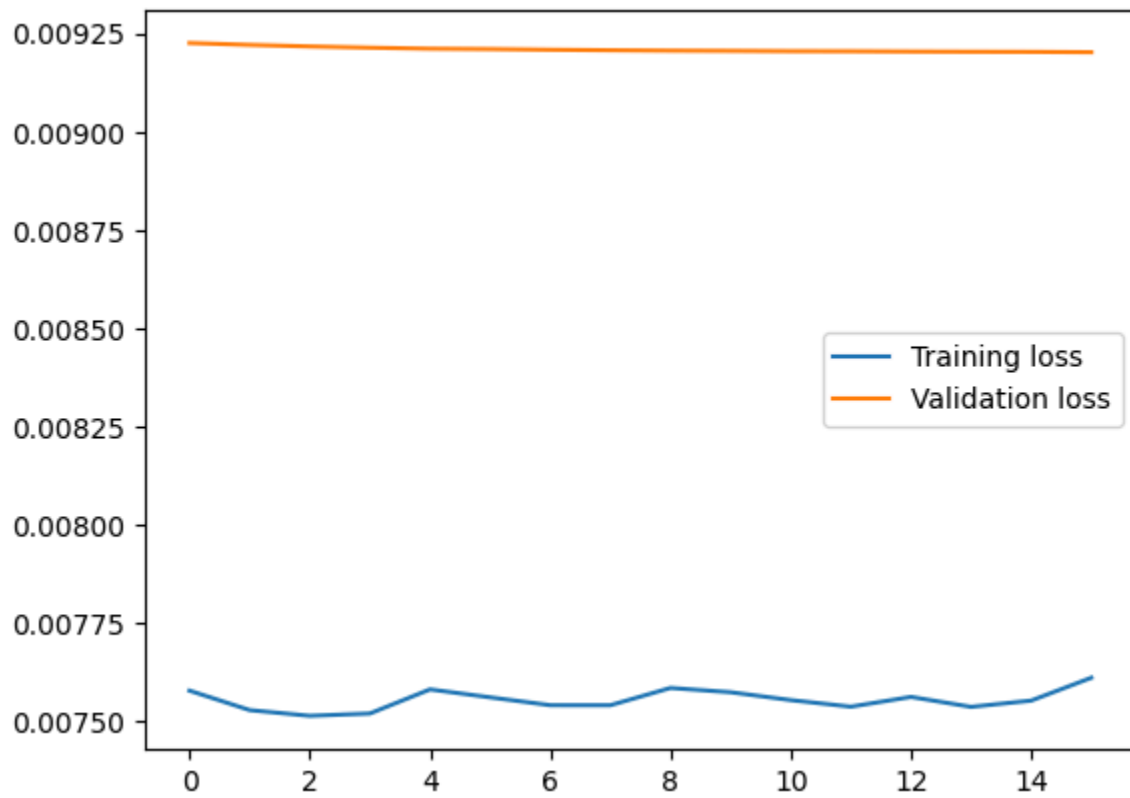
Classification Report:

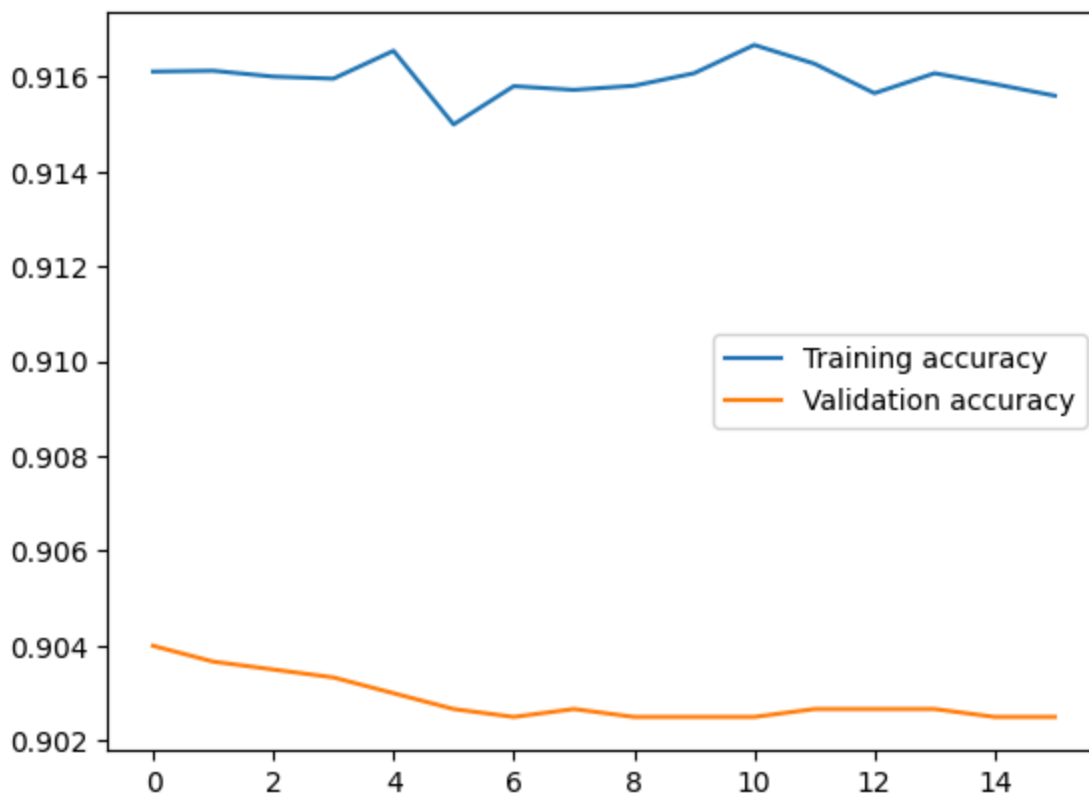
	precision	recall	f1-score	support
0	0.92	0.90	0.91	1900
1	0.95	0.97	0.96	1900
2	0.86	0.87	0.87	1900
3	0.87	0.87	0.87	1900
accuracy			0.90	7600
macro avg	0.90	0.90	0.90	7600
weighted avg	0.90	0.90	0.90	7600

Confusion Matrix:

```
[[1703 59 81 57]
 [ 28 1845 12 15]
 [ 60 16 1659 165]
 [ 64 22 167 1647]]
```

Micro Recall: 0.9018421052631579  
Macro Recall: 0.9018421052631579  
Micro F1 Score: 0.9018421052631579  
Macro F1 Score: 0.9017039386076697





100% [██████████] 188/188 [00:01<00:00, 120.00it/s]

Accuracy on the valid set: 0.904

Classification Report:

	precision	recall	f1-score	support
0	0.92	0.88	0.90	1500
1	0.96	0.98	0.97	1500
2	0.86	0.88	0.87	1500
3	0.88	0.87	0.88	1500
accuracy			0.90	6000
macro avg	0.90	0.90	0.90	6000
weighted avg	0.90	0.90	0.90	6000

Confusion Matrix:

```
[[1327  41  81  51]
 [ 15 1465  10  10]
 [ 44  15 1320 121]
 [ 53  12  123 1312]]
```

Micro Recall: 0.904

Macro Recall: 0.904

Micro F1 Score: 0.904

Macro F1 Score: 0.9039066004726974

100%|██████████| 238/238 [00:02<00:00, 115.15it/s]

Accuracy on the test set: **0.9019736842105263**

Classification Report:

	precision	recall	f1-score	support
0	0.92	0.90	0.91	1900
1	0.95	0.97	0.96	1900
2	0.87	0.87	0.87	1900
3	0.87	0.87	0.87	1900
accuracy		0.90		7600
macro avg	0.90	0.90	0.90	7600
weighted avg	0.90	0.90	0.90	7600

Confusion Matrix:

```
[[1703  59  81  57]
 [ 28 1845  12  15]
 [  60  16 1657 167]
 [  64  22 164 1650]]
```

Micro Recall: 0.9019736842105263

Macro Recall: 0.9019736842105264

Micro F1 Score: 0.9019736842105263

Macro F1 Score: 0.9018351920272057

### 3. Learnable Function

Overview: This method employs a neural network function (or a similar model component) to learn how to best integrate the outputs from different layers. This is the most flexible approach, as the function can potentially learn complex relationships between the layers.

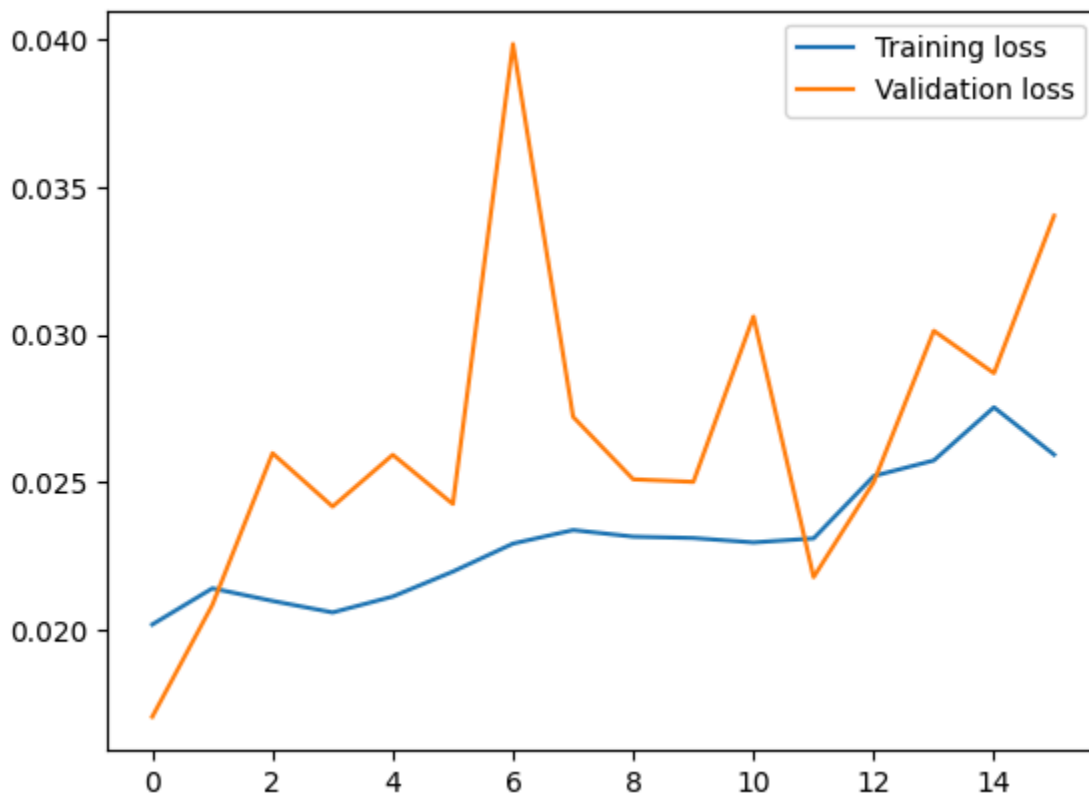
Advantages:

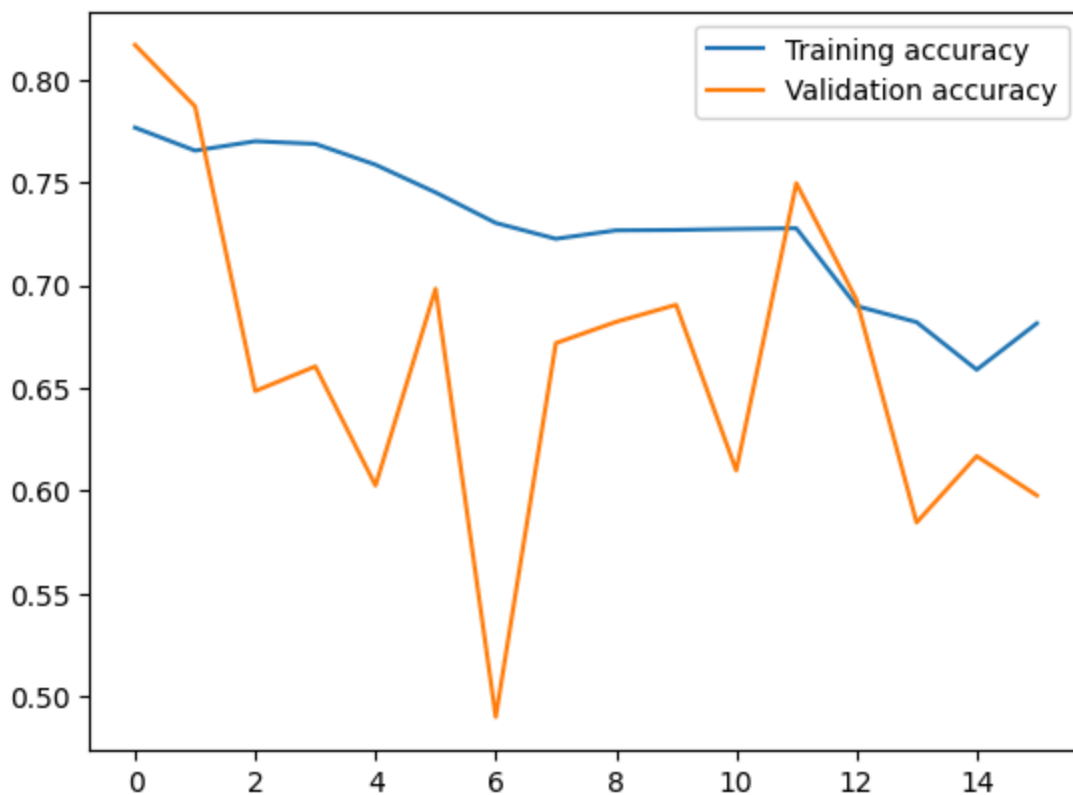
- Capability: Has the potential to learn complex and non-linear combinations of features from different layers, which might be more effective than a simple weighted sum.
- Generalizability: Because the function learns from the data, it can potentially generalize better to new, unseen data if it captures underlying patterns effectively.

Disadvantages:

- Overfitting Risk: With increased model complexity comes a greater risk of overfitting, especially if not managed with techniques like dropout, regularization, or sufficient data.
- Resource Intensive: Requires more computational resources for training due to the additional learnable parameters in the combining function.

```
SentimentalAnalysisLNNF(
    (embedding): Embedding(39976, 100)
    (lstm1): LSTM(100, 100, num_layers=2, batch_first=True, dropout=0.36)
    (lstm2): LSTM(100, 100, num_layers=2, batch_first=True, dropout=0.36)
    (dropout): Dropout(p=0.25, inplace=False)
    (fc1): Linear(in_features=100, out_features=100, bias=True)
    (fc2): Linear(in_features=100, out_features=4, bias=True)
    (combine): Sequential(
      (0): Linear(in_features=300, out_features=100, bias=True)
      (1): Softmax(dim=1)
    )
)
```





100%[██████████] 188/188 [00:01<00:00, 118.32it/s]

Accuracy on the valid set: 0.817

Classification Report:

	precision	recall	f1-score	support
0	0.84	0.80	0.82	1500
1	0.91	0.91	0.91	1500
2	0.77	0.78	0.77	1500
3	0.75	0.78	0.77	1500
accuracy			0.82	6000
macro avg	0.82	0.82	0.82	6000
weighted avg	0.82	0.82	0.82	6000

Confusion Matrix:

```
[[1206  85 106 103]
 [ 53 1358  31  58]
 [ 73  34 1168 225]
 [ 97  20  213 1170]]
```

Micro Recall: 0.817

Macro Recall: 0.817

Micro F1 Score: 0.817

Macro F1 Score: 0.8173645390357585

100%|██████████| 238/238 [00:02<00:00, 118.00it/s]

Accuracy on the test set: 0.8105263157894737

Classification Report:

	precision	recall	f1-score	support
0	0.83	0.82	0.83	1900
1	0.91	0.89	0.90	1900
2	0.76	0.76	0.76	1900
3	0.75	0.77	0.76	1900
accuracy		0.81		7600
macro avg	0.81	0.81	0.81	7600
weighted avg	0.81	0.81	0.81	7600

Confusion Matrix:

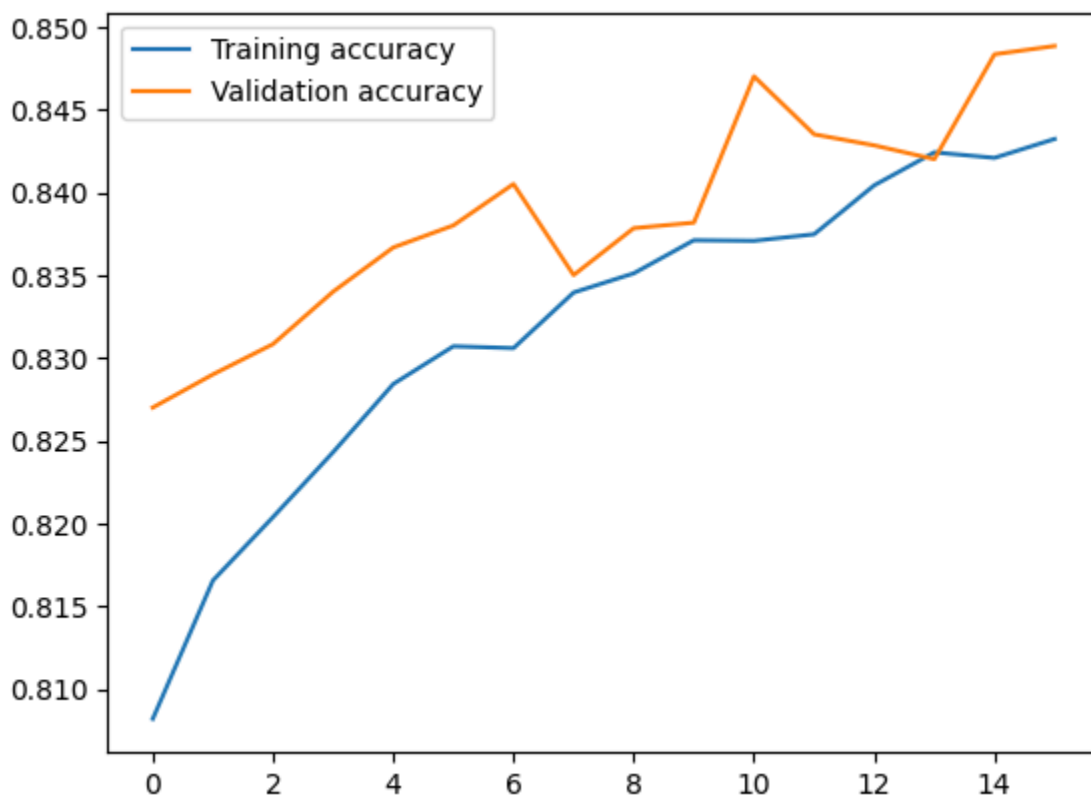
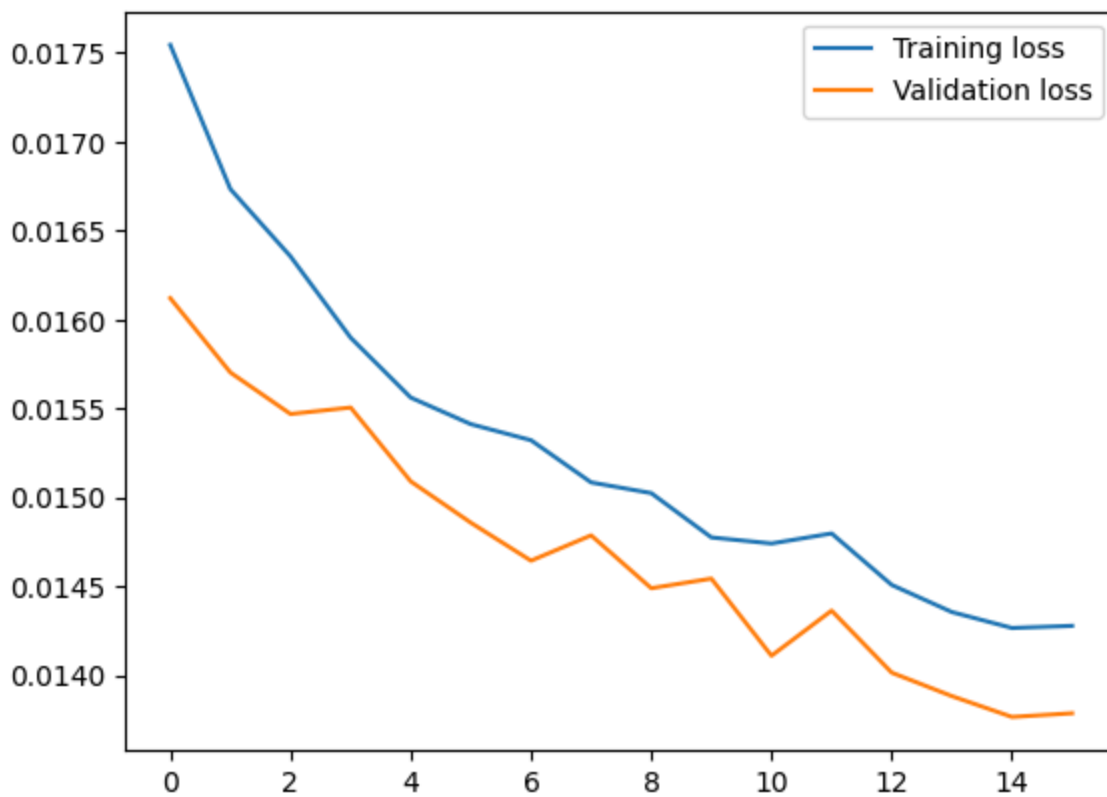
```
[[1559  89 139 113]
 [ 87 1696  49  68]
 [ 122  33 1437 308]
 [ 110  44  278 1468]]
```

Micro Recall: 0.8105263157894737

Macro Recall: 0.8105263157894737

Micro F1 Score: 0.8105263157894737

Macro F1 Score: 0.8109712501880737





Accuracy on the valid set: 0.8488333333333333

Classification Report:

	precision	recall	f1-score	support
0	0.89	0.82	0.85	1500
1	0.92	0.95	0.93	1500
2	0.77	0.84	0.80	1500
3	0.81	0.80	0.80	1500
accuracy		0.85	6000	
macro avg	0.85	0.85	0.85	6000
weighted avg	0.85	0.85	0.85	6000

Confusion Matrix:

```
[[1224 69 136 71]
 [ 25 1422 26 27]
 [ 47 26 1254 173]
 [ 76 26 205 1193]]
```

Micro Recall: 0.8488333333333333

Macro Recall: 0.8488333333333332

Micro F1 Score: 0.8488333333333333

Macro F1 Score: 0.8488883857462387

100% ██████████ 238/238 [00:02<00:00, 112.69it/s]

Accuracy on the test set: 0.8463157894736842

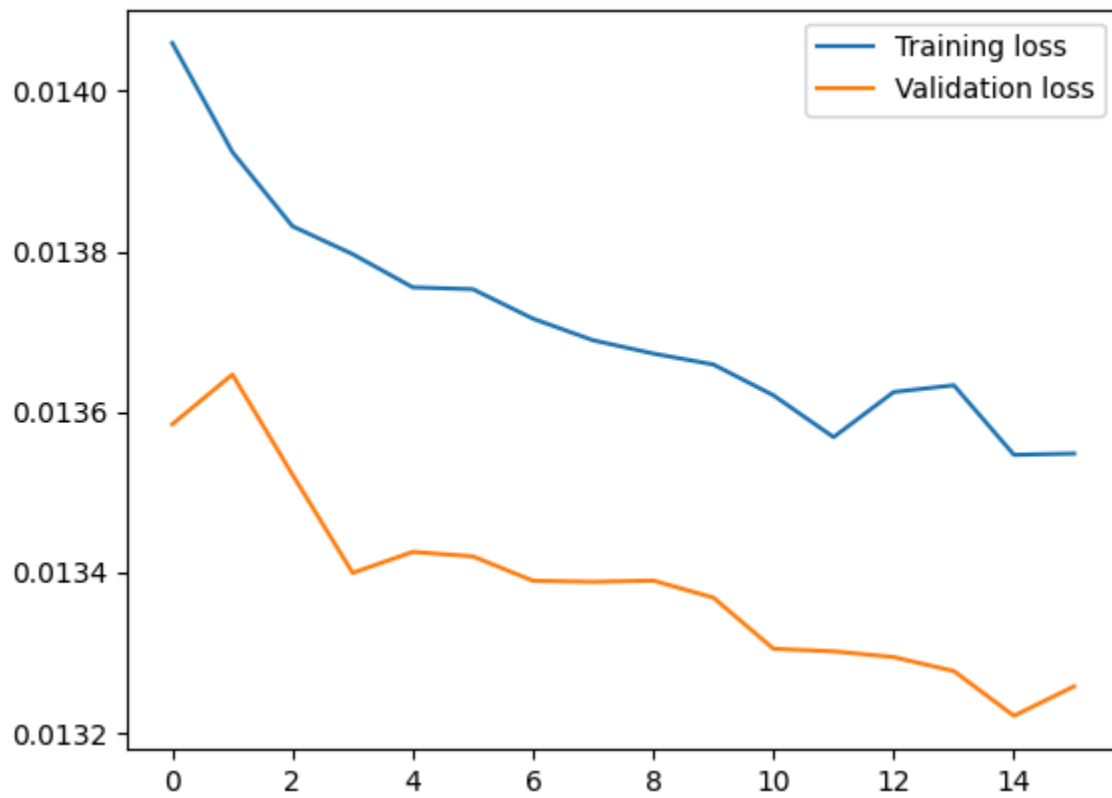
Classification Report:

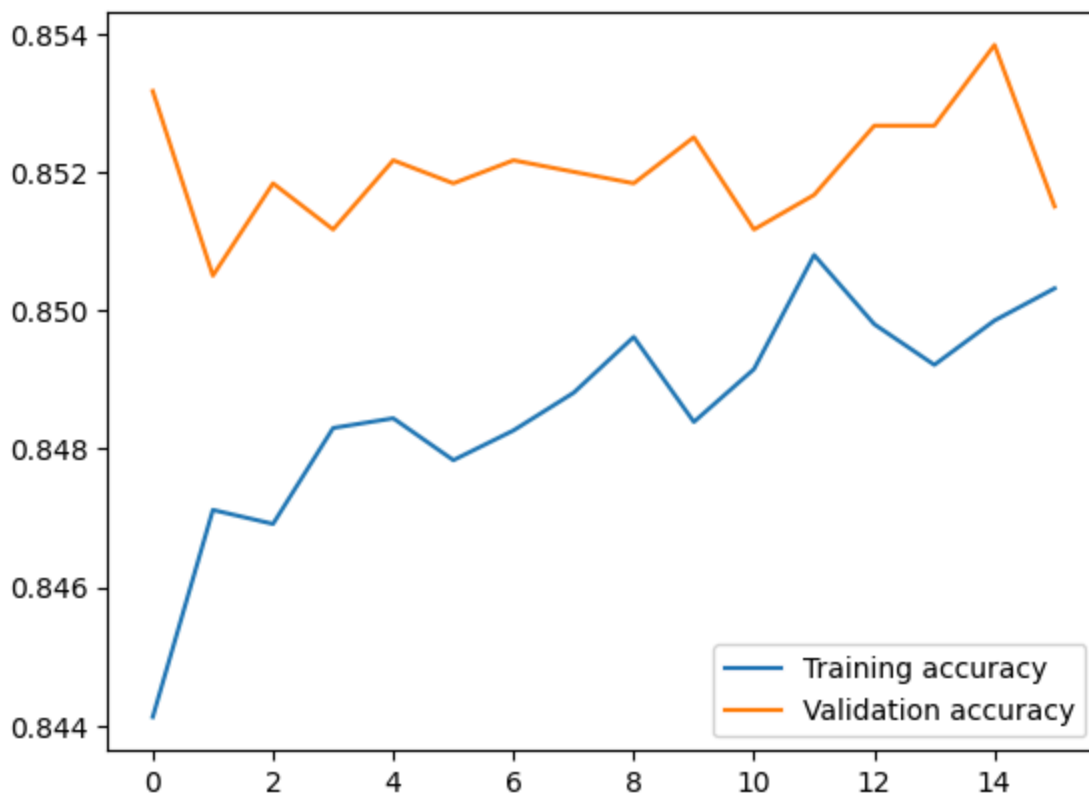
	precision	recall	f1-score	support
0	0.89	0.83	0.86	1900
1	0.92	0.94	0.93	1900
2	0.77	0.83	0.80	1900
3	0.82	0.79	0.80	1900
accuracy		0.85	7600	
macro avg	0.85	0.85	0.85	7600
weighted avg	0.85	0.85	0.85	7600

Confusion Matrix:

```
[[1571 94 153 82]
 [ 34 1790 42 34]
 [ 73 34 1571 222]
 [ 87 36 277 1500]]
```

Micro Recall: 0.8463157894736842  
Macro Recall: 0.8463157894736841  
Micro F1 Score: 0.8463157894736841  
Macro F1 Score: 0.8464068026513003





100% [██████████] 188/188 [00:01<00:00, 117.00it/s]

Accuracy on the valid set: 0.8538333333333333

Classification Report:

	precision	recall	f1-score	support
0	0.88	0.83	0.86	1500
1	0.93	0.95	0.94	1500
2	0.78	0.83	0.81	1500
3	0.82	0.80	0.81	1500
accuracy	0.85			6000
macro avg	0.85	0.85	0.85	6000
weighted avg	0.85	0.85	0.85	6000

Confusion Matrix:


```
[[1249  64 121  66]
 [ 24 1427  25  24]
 [ 63  19 1247 171]
 [ 81  19  200 1200]]
```

Micro Recall: 0.8538333333333333

Macro Recall: 0.8538333333333334

Micro F1 Score: 0.8538333333333333

Macro F1 Score: 0.8538645751360364

100% 238/238 [00:02<00:00, 115.23it/s]

Accuracy on the test set: 0.8561842105263158

Classification Report:

	precision	recall	f1-score	support
0	0.88	0.85	0.86	1900
1	0.93	0.94	0.94	1900
2	0.79	0.82	0.81	1900
3	0.82	0.81	0.82	1900
accuracy			0.86	7600
macro avg	0.86	0.86	0.86	7600
weighted avg	0.86	0.86	0.86	7600

Confusion Matrix:

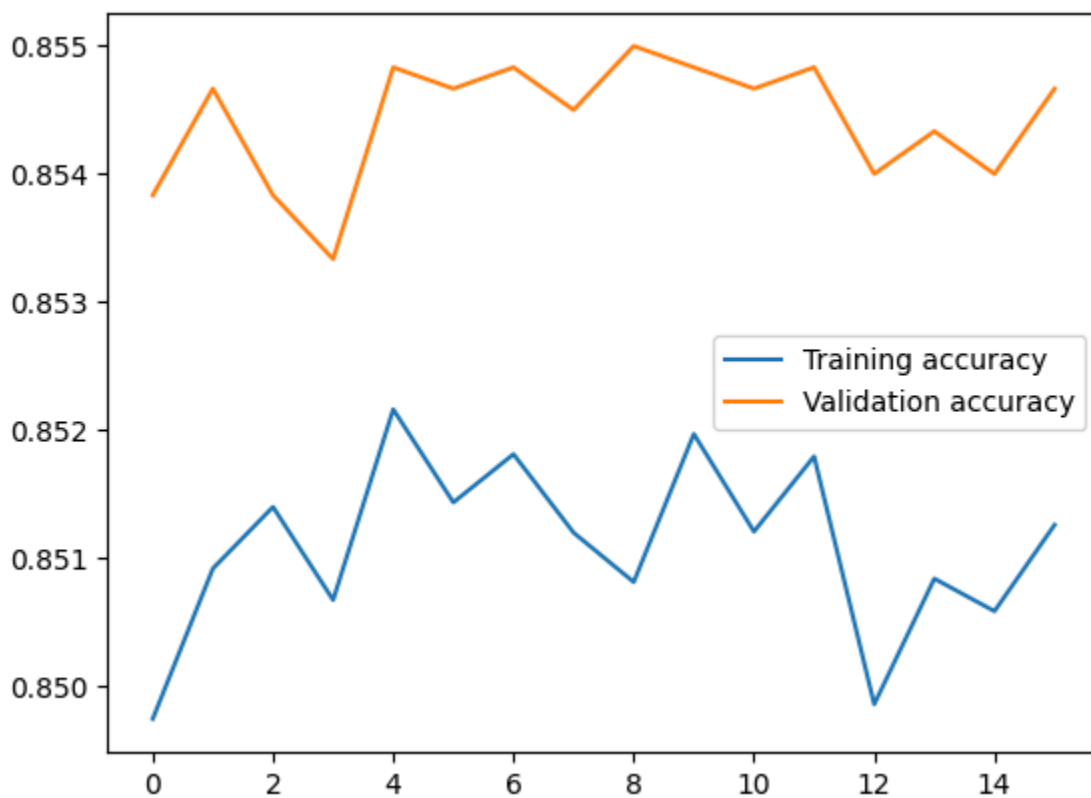
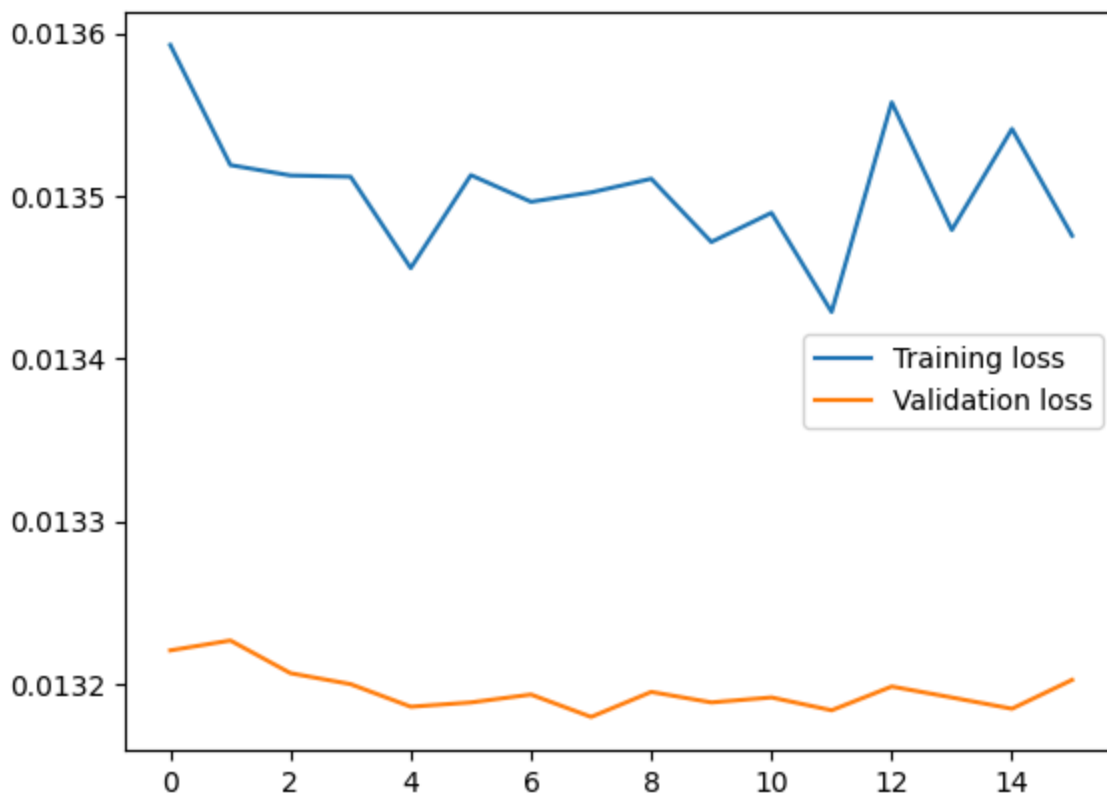
```
[[1614  82 128  76]
 [ 37 1793  39  31]
 [ 88  24 1565 223]
 [ 93  33  239 1535]]
```

Micro Recall: 0.8561842105263158

Macro Recall: 0.8561842105263158

Micro F1 Score: 0.8561842105263158

Macro F1 Score: 0.856184291998335



Accuracy on the valid set: 0.855

Classification Report:

	precision	recall	f1-score	support
0	0.89	0.83	0.86	1500
1	0.93	0.95	0.94	1500
2	0.78	0.83	0.81	1500
3	0.82	0.80	0.81	1500
accuracy		0.85		6000
macro avg	0.86	0.85	0.86	6000
weighted avg	0.86	0.85	0.86	6000

Confusion Matrix:

```
[[1246 63 122 69]
 [ 23 1430 25 22]
 [ 55 22 1249 174]
 [ 76 22 197 1205]]
```

Micro Recall: 0.855

Macro Recall: 0.855

Micro F1 Score: 0.855

Macro F1 Score: 0.8550267725703959

100% ██████████ 238/238 [00:02<00:00, 118.02it/s]Accuracy on the test set:

0.8563157894736843

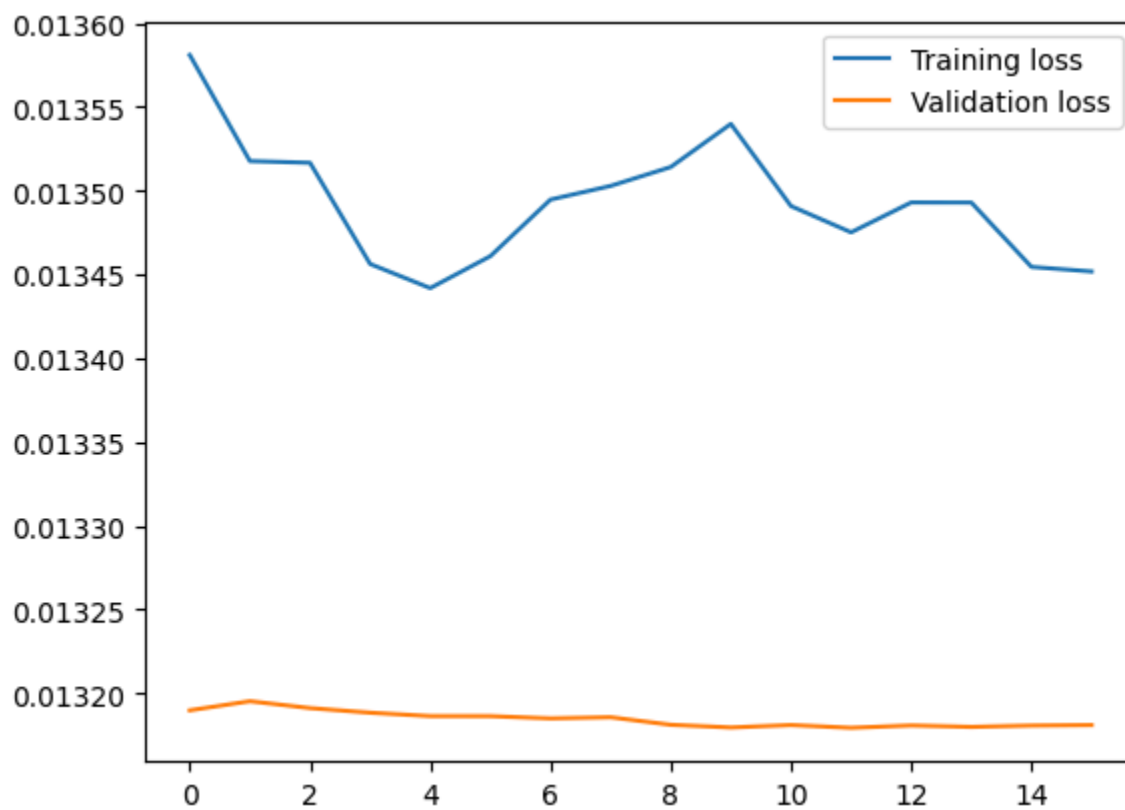
Classification Report:

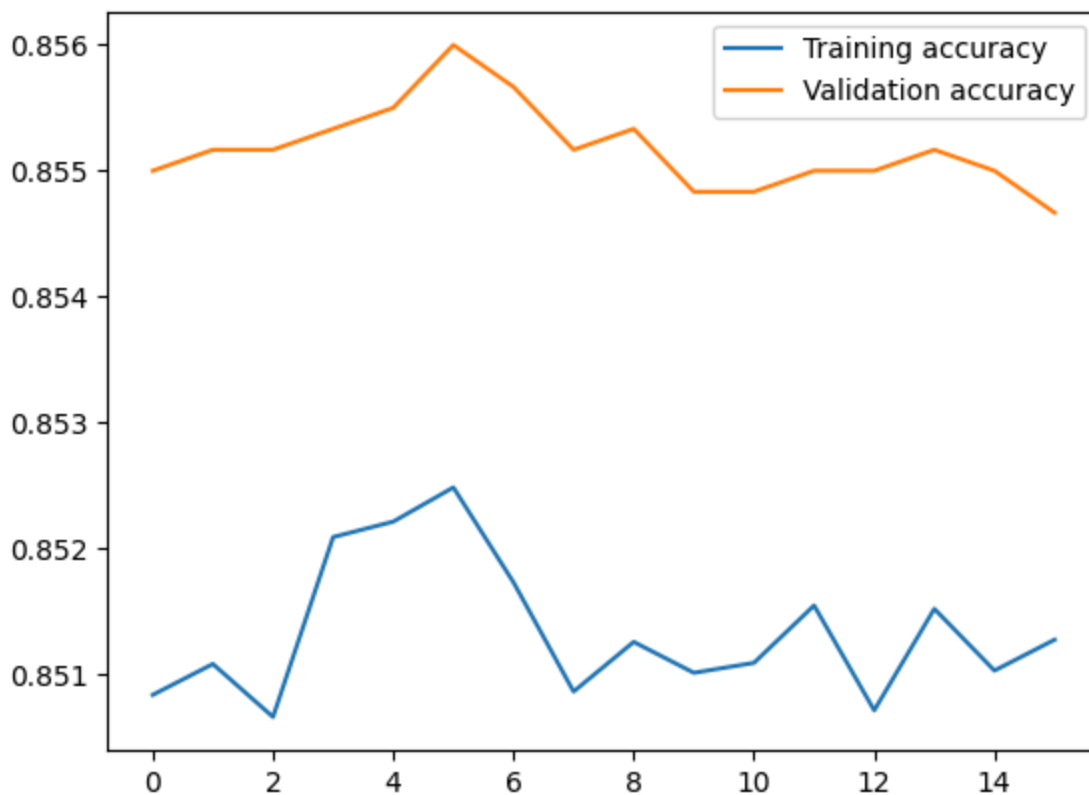
	precision	recall	f1-score	support
0	0.89	0.84	0.87	1900
1	0.92	0.95	0.94	1900
2	0.79	0.82	0.81	1900
3	0.82	0.81	0.82	1900
accuracy		0.86		7600
macro avg	0.86	0.86	0.86	7600
weighted avg	0.86	0.86	0.86	7600

Confusion Matrix:

```
[[1602 85 133 80]
 [ 29 1800 38 33]
 [ 85 26 1564 225]
 [ 85 36 237 1542]]
```

Micro Recall: 0.8563157894736843  
Macro Recall: 0.8563157894736841  
Micro F1 Score: 0.8563157894736843  
Macro F1 Score: 0.8563075876431954





100% [██████████] 188/188 [00:01<00:00, 118.78it/s]

Accuracy on the valid set: 0.856

Classification Report:

	precision	recall	f1-score	support
0	0.89	0.83	0.86	1500
1	0.93	0.95	0.94	1500
2	0.78	0.84	0.81	1500
3	0.82	0.80	0.81	1500
accuracy	0.86			6000
macro avg	0.86	0.86	0.86	6000
weighted avg	0.86	0.86	0.86	6000

Confusion Matrix:

```
[[1247  63 121  69]
 [ 23 1430  25  22]
 [ 54  22 1253 171]
 [ 74  22  198 1206]]
```

Micro Recall: 0.856

Macro Recall: 0.8560000000000001

Micro F1 Score: 0.856



Macro F1 Score: 0.8560377356258941

100%|██████████| 238/238 [00:02<00:00, 117.24it/s]

Accuracy on the test set: **0.8567105263157895**

Classification Report:

	precision	recall	f1-score	support
0	0.89	0.84	0.87	1900
1	0.93	0.95	0.94	1900
2	0.79	0.82	0.81	1900
3	0.82	0.81	0.82	1900
accuracy		0.86		7600
macro avg	0.86	0.86	0.86	7600
weighted avg	0.86	0.86	0.86	7600

Confusion Matrix:

```
[[1603  85 133  79]
 [ 30 1800  38  32]
 [ 84  26 1565 225]
 [ 87  34  236 1543]]
```

Micro Recall: 0.8567105263157895

Macro Recall: 0.8567105263157896

Micro F1 Score: 0.8567105263157895

Macro F1 Score: 0.8567043904375904

## Which Might Perform Best?

- Dataset Size and Complexity: For larger and more complex datasets, the learnable function might perform best as it can capture complex patterns in the data. However, for smaller datasets, the trainable  $\lambda$ s might be advantageous as they offer a balance between flexibility and model complexity.
- Task Specificity: For tasks requiring nuanced understanding of different types of information (such as sentiment analysis across different contexts), a learnable function could potentially perform better by effectively integrating contextual cues from various layers.
- Computational Resources and Training Time: If computational resources and training time are limited, using frozen  $\lambda$ s might be beneficial despite potential performance compromises.