Neural Networks image recognition - ConvNet

1. Add random noise (see below on `size parameter` on `np.random.normal`) to the images in training and testing. **Make sure each image gets a different noise feature added to it. Inspect by printing out several images. Note - the `size` parameter should match the data.**
2. Compare the `accuracy` of train and val after N epochs for MLNN with and without noise.
3. Vary the amount of noise by changing the `scale` parameter in `np.random.normal` by a factor. Use `.1, .5, 1.0, 2.0, 4.0` for the `scale` and keep track of the `accuracy` for training and validation and plot these results.
4. Compare these results with the previous week where we used a MultiLayer Perceptron (this week we use a ConvNet).

Neural Networks - Image Recognition

In [30]:
```python
import keras
from keras.datasets import mnist
from keras.models import Sequential
from keras.optimizers import RMSprop
from keras.layers import Dense, Dropout, Flatten
from keras.layers import Conv2D, MaxPooling2D
from keras import backend
```

Conv Net

Trains a simple convnet on the MNIST dataset. Gets to 99.25% test accuracy after 12 epochs (there is still a lot of margin for parameter tuning).

Without Noise

In [31]:
```python
# input image dimensions
img_rows, img_cols = 28, 28

# the data, shuffled and split between train and test sets
(x_train, y_train), (x_test, y_test) = mnist.load_data()

if backend.image_data_format() == 'channels_first':
    x_train = x_train.reshape(x_train.shape[0], 1, img_rows, img_cols)
    x_test = x_test.reshape(x_test.shape[0], 1, img_rows, img_cols)
    input_shape = (1, img_rows, img_cols)
else:
    x_train = x_train.reshape(x_train.shape[0], img_rows, img_cols, 1)
    x_test = x_test.reshape(x_test.shape[0], img_rows, img_cols, 1)
    input_shape = (img_rows, img_cols, 1)

x_train = x_train.astype('float32')
x_test = x_test.astype('float32')
x_train /= 255
x_test /= 255
print('x_train shape:', x_train.shape)
```

```
print(x_train.shape[0], 'train samples')
print(x_test.shape[0], 'test samples')
```

```
x_train shape: (60000, 28, 28, 1)
60000 train samples
10000 test samples
```

In [32]:
```python
batch_size = 128
num_classes = 10
epochs = 20

# convert class vectors to binary class matrices
y_train = keras.utils.to_categorical(y_train, num_classes)
y_test = keras.utils.to_categorical(y_test, num_classes)

model = Sequential()
model.add(Conv2D(32, kernel_size=(3, 3),
                 activation='relu',
                 input_shape=input_shape))
model.add(Conv2D(64, (3, 3), activation='relu'))
model.add(MaxPooling2D(pool_size=(2, 2)))
model.add(Dropout(0.25))
model.add(Flatten())
model.add(Dense(128, activation='relu'))
model.add(Dropout(0.5))
model.add(Dense(num_classes, activation='softmax'))

model.compile(loss=keras.losses.categorical_crossentropy,
              optimizer=keras.optimizers.Adadelta(),
              metrics=['accuracy'])

history = model.fit(x_train, y_train,
          batch_size=batch_size,
          epochs=epochs,
          verbose=1,
          validation_data=(x_test, y_test))
score = model.evaluate(x_test, y_test, verbose=0)
print('Test loss:', score[0])
print('Test accuracy:', score[1])
```

```
Epoch 1/20
2022-11-07 22:55:50.195587: I tensorflow/core/grappler/optimizers/custom_graph_optimizer
_registry.cc:114] Plugin optimizer for device_type GPU is enabled.
469/469 [==============================] - ETA: 0s - loss: 2.2890 - accuracy: 0.1327
2022-11-07 22:56:00.339846: I tensorflow/core/grappler/optimizers/custom_graph_optimizer
_registry.cc:114] Plugin optimizer for device_type GPU is enabled.
```

```
469/469 [==============================] - 11s 23ms/step - loss: 2.2890 - accuracy: 0.13
27 - val_loss: 2.2667 - val_accuracy: 0.2267
Epoch 2/20
469/469 [==============================] - 10s 22ms/step - loss: 2.2508 - accuracy: 0.22
43 - val_loss: 2.2219 - val_accuracy: 0.3756
Epoch 3/20
469/469 [==============================] - 10s 22ms/step - loss: 2.2023 - accuracy: 0.31
22 - val_loss: 2.1608 - val_accuracy: 0.4910
Epoch 4/20
469/469 [==============================] - 10s 21ms/step - loss: 2.1335 - accuracy: 0.39
45 - val_loss: 2.0730 - val_accuracy: 0.5912
Epoch 5/20
469/469 [==============================] - 10s 22ms/step - loss: 2.0359 - accuracy: 0.46
52 - val_loss: 1.9480 - val_accuracy: 0.6617
Epoch 6/20
469/469 [==============================] - 11s 23ms/step - loss: 1.9025 - accuracy: 0.52
21 - val_loss: 1.7782 - val_accuracy: 0.7049
Epoch 7/20
469/469 [==============================] - 10s 22ms/step - loss: 1.7355 - accuracy: 0.56
63 - val_loss: 1.5681 - val_accuracy: 0.7515
Epoch 8/20
469/469 [==============================] - 10s 22ms/step - loss: 1.5438 - accuracy: 0.60
75 - val_loss: 1.3430 - val_accuracy: 0.7794
Epoch 9/20
469/469 [==============================] - 10s 22ms/step - loss: 1.3602 - accuracy: 0.64
20 - val_loss: 1.1391 - val_accuracy: 0.7980
Epoch 10/20
469/469 [==============================] - 11s 22ms/step - loss: 1.2047 - accuracy: 0.67
04 - val_loss: 0.9746 - val_accuracy: 0.8160
Epoch 11/20
469/469 [==============================] - 10s 22ms/step - loss: 1.0799 - accuracy: 0.69
74 - val_loss: 0.8499 - val_accuracy: 0.8282
Epoch 12/20
469/469 [==============================] - 10s 22ms/step - loss: 0.9785 - accuracy: 0.71
95 - val_loss: 0.7555 - val_accuracy: 0.8364
Epoch 13/20
469/469 [==============================] - 10s 22ms/step - loss: 0.9034 - accuracy: 0.73
73 - val_loss: 0.6845 - val_accuracy: 0.8455
Epoch 14/20
469/469 [==============================] - 10s 22ms/step - loss: 0.8405 - accuracy: 0.75
32 - val_loss: 0.6304 - val_accuracy: 0.8514
Epoch 15/20
469/469 [==============================] - 10s 22ms/step - loss: 0.7950 - accuracy: 0.76
41 - val_loss: 0.5867 - val_accuracy: 0.8592
Epoch 16/20
469/469 [==============================] - 10s 22ms/step - loss: 0.7528 - accuracy: 0.77
72 - val_loss: 0.5520 - val_accuracy: 0.8648
Epoch 17/20
469/469 [==============================] - 11s 23ms/step - loss: 0.7115 - accuracy: 0.79
01 - val_loss: 0.5217 - val_accuracy: 0.8701
Epoch 18/20
469/469 [==============================] - 10s 22ms/step - loss: 0.6809 - accuracy: 0.79
78 - val_loss: 0.4971 - val_accuracy: 0.8732
Epoch 19/20
469/469 [==============================] - 11s 22ms/step - loss: 0.6532 - accuracy: 0.80
65 - val_loss: 0.4765 - val_accuracy: 0.8781
Epoch 20/20
469/469 [==============================] - 11s 23ms/step - loss: 0.6288 - accuracy: 0.81
19 - val_loss: 0.4582 - val_accuracy: 0.8805
Test loss: 0.4582493007183075
Test accuracy: 0.8805000185966492
```

With Noise

In [33]:
```python
import numpy as np
import matplotlib.pyplot as plt
```

In [34]:
```python
# input image dimensions
img_rows, img_cols = 28, 28

# the data, shuffled and split between train and test sets
(x_train, y_train), (x_test, y_test) = mnist.load_data()

if backend.image_data_format() == 'channels_first':
    x_train = x_train.reshape(x_train.shape[0], 1, img_rows, img_cols)
    x_test = x_test.reshape(x_test.shape[0], 1, img_rows, img_cols)
    input_shape = (1, img_rows, img_cols)
else:
    x_train = x_train.reshape(x_train.shape[0], img_rows, img_cols, 1)
    x_test = x_test.reshape(x_test.shape[0], img_rows, img_cols, 1)
    input_shape = (img_rows, img_cols, 1)

x_train = x_train.astype('float32')
x_test = x_test.astype('float32')
x_train /= 255
x_test /= 255

x_train_noise = np.random.normal(x_train)
x_test_noise = np.random.normal(x_test)

print('x_train shape:', x_train.shape)
print(x_train.shape[0], 'train samples')
print(x_test.shape[0], 'test samples')
```
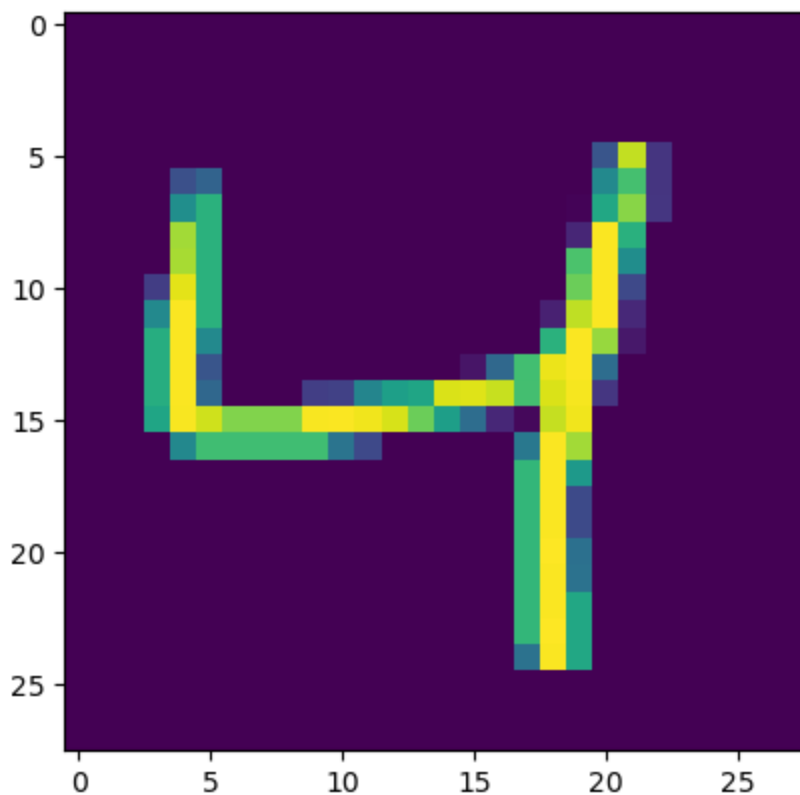
```
x_train shape: (60000, 28, 28, 1)
60000 train samples
10000 test samples
```

In [35]:
```python
plt.imshow(x_train[2].reshape(28,28))
```

Out[35]: <matplotlib.image.AxesImage at 0x2e3344760>

```
In [36]: plt.imshow(x_train_noise[2].reshape(28,28))
```

Out[36]: <matplotlib.image.AxesImage at 0x310bfe700>


```
In [37]: batch_size = 128
         num_classes = 10
         epochs = 20

         # convert class vectors to binary class matrices
         y_train = keras.utils.to_categorical(y_train, num_classes)
         y_test = keras.utils.to_categorical(y_test, num_classes)
```

```python
model = Sequential()
model.add(Conv2D(32, kernel_size=(3, 3),
                 activation='relu',
                 input_shape=input_shape))
model.add(Conv2D(64, (3, 3), activation='relu'))
model.add(MaxPooling2D(pool_size=(2, 2)))
model.add(Dropout(0.25))
model.add(Flatten())
model.add(Dense(128, activation='relu'))
model.add(Dropout(0.5))
model.add(Dense(num_classes, activation='softmax'))

model.compile(loss=keras.losses.categorical_crossentropy,
              optimizer=keras.optimizers.Adadelta(),
              metrics=['accuracy'])

history_n = model.fit(x_train_noise, y_train,
          batch_size=batch_size,
          epochs=epochs,
          verbose=1,
          validation_data=(x_test_noise, y_test))
score = model.evaluate(x_test_noise, y_test, verbose=0)
print('Test loss:', score[0])
print('Test accuracy:', score[1])
```

Epoch 1/20

2022-11-07 22:59:23.826415: I tensorflow/core/grappler/optimizers/custom_graph_optimizer
_registry.cc:114] Plugin optimizer for device_type GPU is enabled.

469/469 [==============================] - ETA: 0s - loss: 2.3249 - accuracy: 0.1053

2022-11-07 22:59:34.083649: I tensorflow/core/grappler/optimizers/custom_graph_optimizer
_registry.cc:114] Plugin optimizer for device_type GPU is enabled.

```
469/469 [==============================] – 11s 23ms/step – loss: 2.3249 – accuracy: 0.10
53 – val_loss: 2.2904 – val_accuracy: 0.1280
Epoch 2/20
469/469 [==============================] – 11s 24ms/step – loss: 2.3028 – accuracy: 0.11
73 – val_loss: 2.2807 – val_accuracy: 0.1552
Epoch 3/20
469/469 [==============================] – 10s 22ms/step – loss: 2.2921 – accuracy: 0.13
03 – val_loss: 2.2717 – val_accuracy: 0.1792
Epoch 4/20
469/469 [==============================] – 11s 23ms/step – loss: 2.2824 – accuracy: 0.14
01 – val_loss: 2.2614 – val_accuracy: 0.2050
Epoch 5/20
469/469 [==============================] – 11s 23ms/step – loss: 2.2720 – accuracy: 0.15
37 – val_loss: 2.2486 – val_accuracy: 0.2325
Epoch 6/20
469/469 [==============================] – 11s 23ms/step – loss: 2.2609 – accuracy: 0.16
64 – val_loss: 2.2338 – val_accuracy: 0.2661
Epoch 7/20
469/469 [==============================] – 11s 23ms/step – loss: 2.2474 – accuracy: 0.18
06 – val_loss: 2.2156 – val_accuracy: 0.3064
Epoch 8/20
469/469 [==============================] – 11s 24ms/step – loss: 2.2332 – accuracy: 0.19
38 – val_loss: 2.1939 – val_accuracy: 0.3419
Epoch 9/20
469/469 [==============================] – 11s 24ms/step – loss: 2.2129 – accuracy: 0.21
32 – val_loss: 2.1690 – val_accuracy: 0.3724
Epoch 10/20
469/469 [==============================] – 11s 23ms/step – loss: 2.1901 – accuracy: 0.23
17 – val_loss: 2.1401 – val_accuracy: 0.3979
Epoch 11/20
469/469 [==============================] – 11s 23ms/step – loss: 2.1662 – accuracy: 0.24
96 – val_loss: 2.1085 – val_accuracy: 0.4371
Epoch 12/20
469/469 [==============================] – 12s 25ms/step – loss: 2.1375 – accuracy: 0.27
47 – val_loss: 2.0724 – val_accuracy: 0.4569
Epoch 13/20
469/469 [==============================] – 11s 24ms/step – loss: 2.1045 – accuracy: 0.29
47 – val_loss: 2.0325 – val_accuracy: 0.4869
Epoch 14/20
469/469 [==============================] – 11s 24ms/step – loss: 2.0652 – accuracy: 0.31
92 – val_loss: 1.9880 – val_accuracy: 0.5133
Epoch 15/20
469/469 [==============================] – 11s 24ms/step – loss: 2.0264 – accuracy: 0.33
94 – val_loss: 1.9389 – val_accuracy: 0.5312
Epoch 16/20
469/469 [==============================] – 12s 25ms/step – loss: 1.9839 – accuracy: 0.36
19 – val_loss: 1.8867 – val_accuracy: 0.5463
Epoch 17/20
469/469 [==============================] – 11s 23ms/step – loss: 1.9356 – accuracy: 0.38
10 – val_loss: 1.8311 – val_accuracy: 0.5627
Epoch 18/20
469/469 [==============================] – 11s 23ms/step – loss: 1.8881 – accuracy: 0.40
17 – val_loss: 1.7735 – val_accuracy: 0.5725
Epoch 19/20
469/469 [==============================] – 11s 23ms/step – loss: 1.8321 – accuracy: 0.42
56 – val_loss: 1.7139 – val_accuracy: 0.5875
Epoch 20/20
469/469 [==============================] – 11s 24ms/step – loss: 1.7805 – accuracy: 0.44
34 – val_loss: 1.6546 – val_accuracy: 0.6018
Test loss: 1.654606580734253
Test accuracy: 0.6018000245094299
```

```
In [38]: plt.plot(history.history['accuracy'],c='b',label='Original')
         plt.plot(history_n.history['accuracy'],c='red',label='With Noise')
         plt.ylabel('Accuracy')
         plt.xlabel('Epochs')
         plt.xlim(-1,20)
         plt.legend(title='Data')
         plt.show()
```
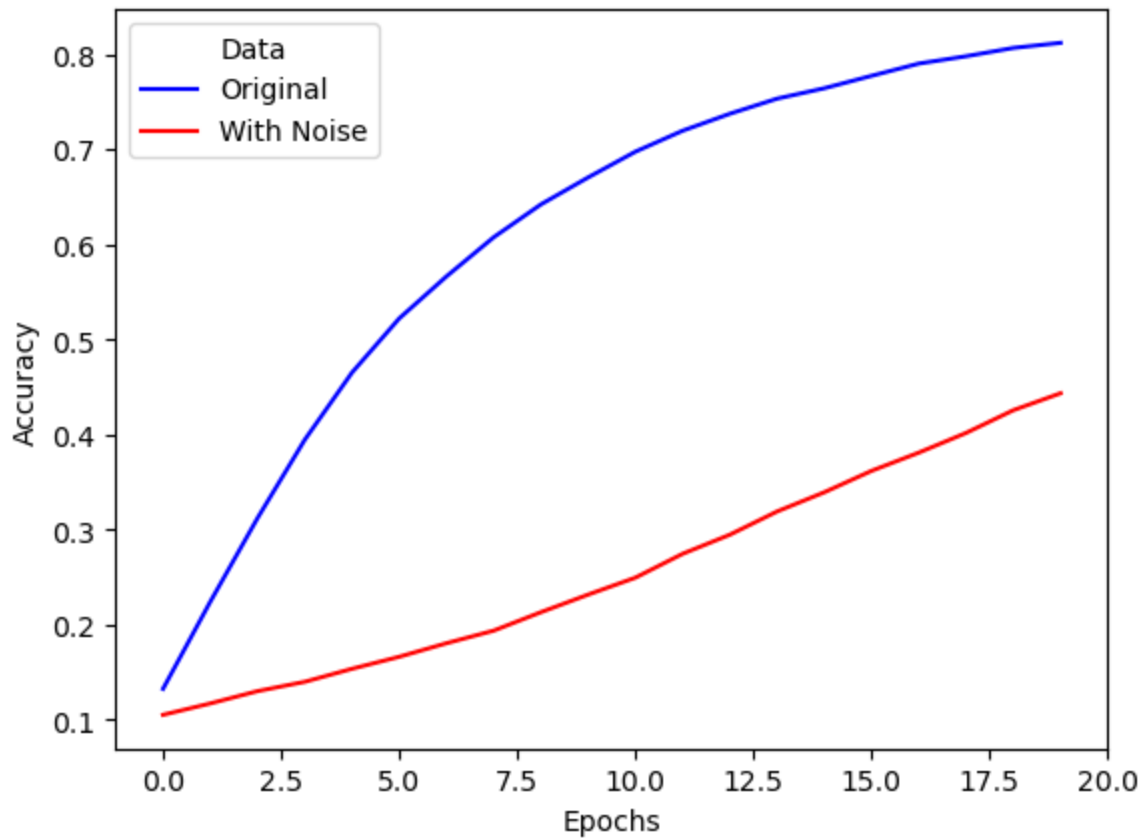


```
In [39]: plt.plot(history.history['val_accuracy'],c='b',label='Original')
         plt.plot(history_n.history['val_accuracy'],c='red',label='With Noise')
         plt.ylabel('Value Accuracy')
         plt.xlabel('Epochs')
         plt.xlim(-1,20)
         plt.legend(title='Data')
         plt.show()
```
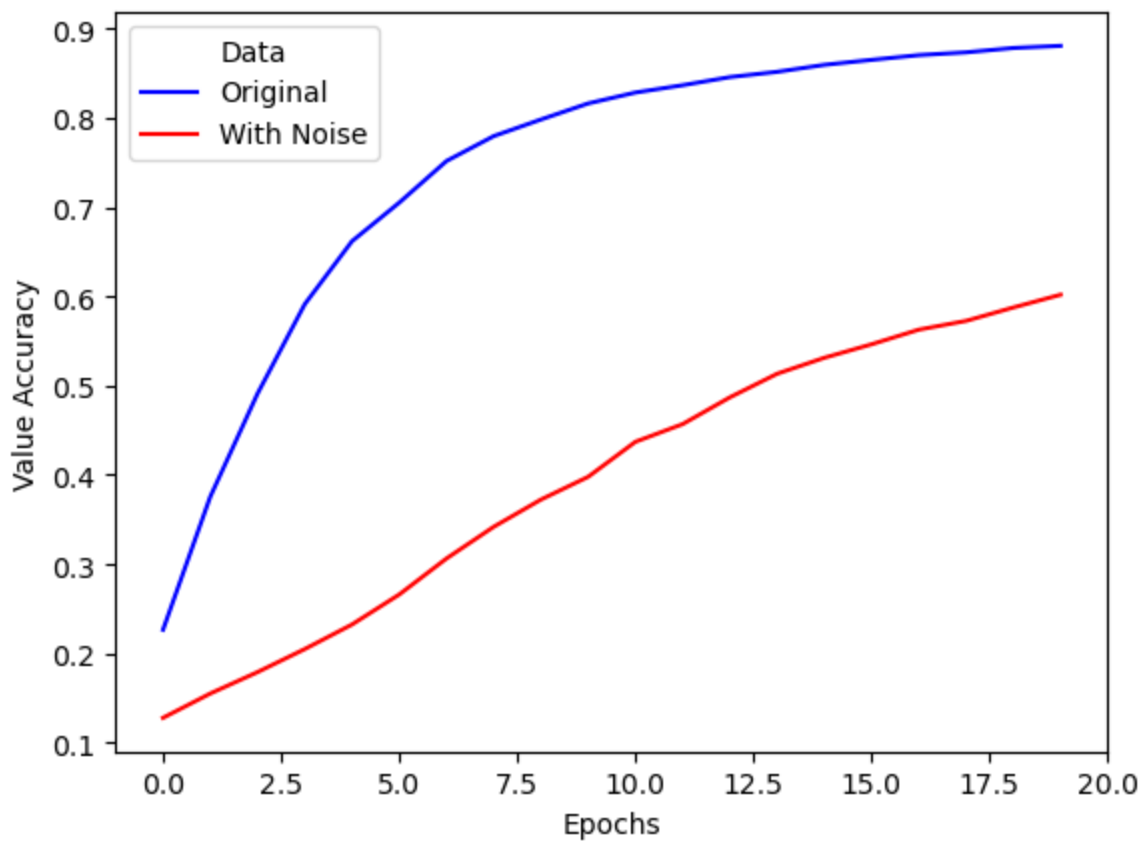
Varying Scales

```
In [40]: scales = [.1, .5, 1.0, 2.0, 4.0]
         accuracies = []
         vals = []

         for scale in scales:
             (x_train, y_train), (x_test, y_test) = mnist.load_data()

             if backend.image_data_format() == 'channels_first':
                 x_train = x_train.reshape(x_train.shape[0], 1, img_rows, img_cols)
                 x_test = x_test.reshape(x_test.shape[0], 1, img_rows, img_cols)
                 input_shape = (1, img_rows, img_cols)
             else:
                 x_train = x_train.reshape(x_train.shape[0], img_rows, img_cols, 1)
                 x_test = x_test.reshape(x_test.shape[0], img_rows, img_cols, 1)
                 input_shape = (img_rows, img_cols, 1)

             x_train = x_train.astype('float32')
             x_test = x_test.astype('float32')
             x_train /= 255
             x_test /= 255

             x_train = np.random.normal(x_train,scale=scale)
             x_test = np.random.normal(x_test,scale=scale)

             batch_size = 128
             num_classes = 10
             epochs = 20

             y_train = keras.utils.to_categorical(y_train, num_classes)
             y_test = keras.utils.to_categorical(y_test, num_classes)

             model = Sequential()
```

```python
    model.add(Conv2D(32, kernel_size=(3, 3),
                     activation='relu',
                     input_shape=input_shape))
    model.add(Conv2D(64, (3, 3), activation='relu'))
    model.add(MaxPooling2D(pool_size=(2, 2)))
    model.add(Dropout(0.25))
    model.add(Flatten())
    model.add(Dense(128, activation='relu'))
    model.add(Dropout(0.5))
    model.add(Dense(num_classes, activation='softmax'))

    model.compile(loss=keras.losses.categorical_crossentropy,
              optimizer=keras.optimizers.Adadelta(),
              metrics=['accuracy'])

    history = model.fit(x_train, y_train,
          batch_size=batch_size,
          epochs=epochs,
          verbose=1,
          validation_data=(x_test, y_test))
    score = model.evaluate(x_test, y_test, verbose=0)

    accuracies.append(history.history['accuracy'])
    vals.append(history.history['val_accuracy'])
```

Epoch 1/20

2022-11-07 23:03:09.501590: I tensorflow/core/grappler/optimizers/custom_graph_optimizer
_registry.cc:114] Plugin optimizer for device_type GPU is enabled.

469/469 [==============================] - ETA: 0s - loss: 2.2882 - accuracy: 0.1323

2022-11-07 23:03:20.077842: I tensorflow/core/grappler/optimizers/custom_graph_optimizer
_registry.cc:114] Plugin optimizer for device_type GPU is enabled.

```
469/469 [==============================] – 12s 24ms/step – loss: 2.2882 – accuracy: 0.13
23 – val_loss: 2.2646 – val_accuracy: 0.2250
Epoch 2/20
469/469 [==============================] – 11s 24ms/step – loss: 2.2502 – accuracy: 0.21
85 – val_loss: 2.2213 – val_accuracy: 0.3574
Epoch 3/20
469/469 [==============================] – 11s 24ms/step – loss: 2.2042 – accuracy: 0.29
45 – val_loss: 2.1653 – val_accuracy: 0.4304
Epoch 4/20
469/469 [==============================] – 11s 23ms/step – loss: 2.1419 – accuracy: 0.36
81 – val_loss: 2.0895 – val_accuracy: 0.5121
Epoch 5/20
469/469 [==============================] – 11s 23ms/step – loss: 2.0633 – accuracy: 0.42
77 – val_loss: 1.9872 – val_accuracy: 0.6122
Epoch 6/20
469/469 [==============================] – 11s 24ms/step – loss: 1.9557 – accuracy: 0.48
89 – val_loss: 1.8549 – val_accuracy: 0.6743
Epoch 7/20
469/469 [==============================] – 12s 25ms/step – loss: 1.8247 – accuracy: 0.53
55 – val_loss: 1.6944 – val_accuracy: 0.7106
Epoch 8/20
469/469 [==============================] – 11s 23ms/step – loss: 1.6738 – accuracy: 0.57
27 – val_loss: 1.5144 – val_accuracy: 0.7373
Epoch 9/20
469/469 [==============================] – 12s 27ms/step – loss: 1.5196 – accuracy: 0.60
79 – val_loss: 1.3319 – val_accuracy: 0.7645
Epoch 10/20
469/469 [==============================] – 12s 25ms/step – loss: 1.3698 – accuracy: 0.63
54 – val_loss: 1.1619 – val_accuracy: 0.7850
Epoch 11/20
469/469 [==============================] – 11s 24ms/step – loss: 1.2408 – accuracy: 0.66
02 – val_loss: 1.0183 – val_accuracy: 0.7997
Epoch 12/20
469/469 [==============================] – 11s 24ms/step – loss: 1.1289 – accuracy: 0.68
52 – val_loss: 0.9018 – val_accuracy: 0.8173
Epoch 13/20
469/469 [==============================] – 12s 25ms/step – loss: 1.0354 – accuracy: 0.70
70 – val_loss: 0.8086 – val_accuracy: 0.8311
Epoch 14/20
469/469 [==============================] – 12s 26ms/step – loss: 0.9654 – accuracy: 0.72
03 – val_loss: 0.7358 – val_accuracy: 0.8422
Epoch 15/20
469/469 [==============================] – 13s 27ms/step – loss: 0.8989 – accuracy: 0.73
82 – val_loss: 0.6771 – val_accuracy: 0.8519
Epoch 16/20
469/469 [==============================] – 11s 24ms/step – loss: 0.8514 – accuracy: 0.74
89 – val_loss: 0.6307 – val_accuracy: 0.8574
Epoch 17/20
469/469 [==============================] – 13s 27ms/step – loss: 0.8061 – accuracy: 0.76
17 – val_loss: 0.5924 – val_accuracy: 0.8624
Epoch 18/20
469/469 [==============================] – 12s 26ms/step – loss: 0.7630 – accuracy: 0.77
36 – val_loss: 0.5592 – val_accuracy: 0.8681
Epoch 19/20
469/469 [==============================] – 12s 25ms/step – loss: 0.7288 – accuracy: 0.78
29 – val_loss: 0.5315 – val_accuracy: 0.8720
Epoch 20/20
469/469 [==============================] – 12s 26ms/step – loss: 0.7021 – accuracy: 0.79
12 – val_loss: 0.5077 – val_accuracy: 0.8756
Epoch 1/20
```

2022-11-07 23:07:09.459645: I tensorflow/core/grappler/optimizers/custom_graph_optimizer_registry.cc:114] Plugin optimizer for device_type GPU is enabled.
469/469 [==============================] - ETA: 0s - loss: 2.3019 - accuracy: 0.1146
2022-11-07 23:07:21.489565: I tensorflow/core/grappler/optimizers/custom_graph_optimizer_registry.cc:114] Plugin optimizer for device_type GPU is enabled.

```
469/469 [==============================] – 13s 27ms/step – loss: 2.3019 – accuracy: 0.11
46 – val_loss: 2.2755 – val_accuracy: 0.1961
Epoch 2/20
469/469 [==============================] – 11s 23ms/step – loss: 2.2746 – accuracy: 0.15
22 – val_loss: 2.2465 – val_accuracy: 0.3222
Epoch 3/20
469/469 [==============================] – 12s 26ms/step – loss: 2.2476 – accuracy: 0.19
03 – val_loss: 2.2113 – val_accuracy: 0.4216
Epoch 4/20
469/469 [==============================] – 11s 24ms/step – loss: 2.2142 – accuracy: 0.22
88 – val_loss: 2.1671 – val_accuracy: 0.4954
Epoch 5/20
469/469 [==============================] – 11s 24ms/step – loss: 2.1708 – accuracy: 0.27
54 – val_loss: 2.1123 – val_accuracy: 0.5457
Epoch 6/20
469/469 [==============================] – 13s 27ms/step – loss: 2.1176 – accuracy: 0.32
70 – val_loss: 2.0465 – val_accuracy: 0.5969
Epoch 7/20
469/469 [==============================] – 12s 26ms/step – loss: 2.0554 – accuracy: 0.37
09 – val_loss: 1.9674 – val_accuracy: 0.6314
Epoch 8/20
469/469 [==============================] – 11s 24ms/step – loss: 1.9787 – accuracy: 0.41
91 – val_loss: 1.8746 – val_accuracy: 0.6630
Epoch 9/20
469/469 [==============================] – 12s 25ms/step – loss: 1.8937 – accuracy: 0.45
76 – val_loss: 1.7683 – val_accuracy: 0.6894
Epoch 10/20
469/469 [==============================] – 12s 26ms/step – loss: 1.7950 – accuracy: 0.49
88 – val_loss: 1.6521 – val_accuracy: 0.7069
Epoch 11/20
469/469 [==============================] – 12s 25ms/step – loss: 1.6868 – accuracy: 0.53
48 – val_loss: 1.5287 – val_accuracy: 0.7240
Epoch 12/20
469/469 [==============================] – 11s 24ms/step – loss: 1.5821 – accuracy: 0.56
48 – val_loss: 1.4052 – val_accuracy: 0.7375
Epoch 13/20
469/469 [==============================] – 11s 23ms/step – loss: 1.4752 – accuracy: 0.59
06 – val_loss: 1.2862 – val_accuracy: 0.7509
Epoch 14/20
469/469 [==============================] – 12s 25ms/step – loss: 1.3789 – accuracy: 0.61
43 – val_loss: 1.1790 – val_accuracy: 0.7604
Epoch 15/20
469/469 [==============================] – 12s 25ms/step – loss: 1.2889 – accuracy: 0.63
71 – val_loss: 1.0838 – val_accuracy: 0.7731
Epoch 16/20
469/469 [==============================] – 12s 25ms/step – loss: 1.2075 – accuracy: 0.65
44 – val_loss: 1.0011 – val_accuracy: 0.7808
Epoch 17/20
469/469 [==============================] – 11s 24ms/step – loss: 1.1373 – accuracy: 0.67
25 – val_loss: 0.9299 – val_accuracy: 0.7871
Epoch 18/20
469/469 [==============================] – 11s 24ms/step – loss: 1.0715 – accuracy: 0.68
81 – val_loss: 0.8681 – val_accuracy: 0.7970
Epoch 19/20
469/469 [==============================] – 11s 23ms/step – loss: 1.0187 – accuracy: 0.70
18 – val_loss: 0.8169 – val_accuracy: 0.8046
Epoch 20/20
469/469 [==============================] – 11s 23ms/step – loss: 0.9741 – accuracy: 0.71
13 – val_loss: 0.7734 – val_accuracy: 0.8102
Epoch 1/20
```

```
2022-11-07 23:11:06.865854: I tensorflow/core/grappler/optimizers/custom_graph_optimizer
_registry.cc:114] Plugin optimizer for device_type GPU is enabled.
469/469 [==============================] - ETA: 0s - loss: 2.3293 - accuracy: 0.1027
2022-11-07 23:11:17.134230: I tensorflow/core/grappler/optimizers/custom_graph_optimizer
_registry.cc:114] Plugin optimizer for device_type GPU is enabled.
```

```
469/469 [==============================] – 11s 24ms/step – loss: 2.3293 – accuracy: 0.10
27 – val_loss: 2.2890 – val_accuracy: 0.1409
Epoch 2/20
469/469 [==============================] – 11s 23ms/step – loss: 2.2984 – accuracy: 0.12
18 – val_loss: 2.2719 – val_accuracy: 0.1892
Epoch 3/20
469/469 [==============================] – 11s 24ms/step – loss: 2.2802 – accuracy: 0.13
72 – val_loss: 2.2548 – val_accuracy: 0.2369
Epoch 4/20
469/469 [==============================] – 11s 23ms/step – loss: 2.2635 – accuracy: 0.15
81 – val_loss: 2.2343 – val_accuracy: 0.2875
Epoch 5/20
469/469 [==============================] – 11s 23ms/step – loss: 2.2454 – accuracy: 0.17
92 – val_loss: 2.2090 – val_accuracy: 0.3386
Epoch 6/20
469/469 [==============================] – 11s 24ms/step – loss: 2.2222 – accuracy: 0.19
74 – val_loss: 2.1769 – val_accuracy: 0.3826
Epoch 7/20
469/469 [==============================] – 11s 24ms/step – loss: 2.1947 – accuracy: 0.22
22 – val_loss: 2.1392 – val_accuracy: 0.4161
Epoch 8/20
469/469 [==============================] – 11s 24ms/step – loss: 2.1600 – accuracy: 0.25
11 – val_loss: 2.0937 – val_accuracy: 0.4579
Epoch 9/20
469/469 [==============================] – 12s 26ms/step – loss: 2.1225 – accuracy: 0.27
59 – val_loss: 2.0426 – val_accuracy: 0.4894
Epoch 10/20
469/469 [==============================] – 11s 24ms/step – loss: 2.0760 – accuracy: 0.30
38 – val_loss: 1.9860 – val_accuracy: 0.5201
Epoch 11/20
469/469 [==============================] – 11s 24ms/step – loss: 2.0260 – accuracy: 0.33
35 – val_loss: 1.9242 – val_accuracy: 0.5474
Epoch 12/20
469/469 [==============================] – 11s 24ms/step – loss: 1.9660 – accuracy: 0.36
45 – val_loss: 1.8557 – val_accuracy: 0.5687
Epoch 13/20
469/469 [==============================] – 11s 23ms/step – loss: 1.9067 – accuracy: 0.39
10 – val_loss: 1.7851 – val_accuracy: 0.5937
Epoch 14/20
469/469 [==============================] – 11s 24ms/step – loss: 1.8448 – accuracy: 0.41
70 – val_loss: 1.7115 – val_accuracy: 0.6131
Epoch 15/20
469/469 [==============================] – 11s 24ms/step – loss: 1.7781 – accuracy: 0.44
19 – val_loss: 1.6367 – val_accuracy: 0.6240
Epoch 16/20
469/469 [==============================] – 11s 24ms/step – loss: 1.7154 – accuracy: 0.46
07 – val_loss: 1.5643 – val_accuracy: 0.6344
Epoch 17/20
469/469 [==============================] – 12s 25ms/step – loss: 1.6503 – accuracy: 0.48
16 – val_loss: 1.4928 – val_accuracy: 0.6451
Epoch 18/20
469/469 [==============================] – 12s 25ms/step – loss: 1.5895 – accuracy: 0.50
12 – val_loss: 1.4254 – val_accuracy: 0.6533
Epoch 19/20
469/469 [==============================] – 12s 25ms/step – loss: 1.5342 – accuracy: 0.51
88 – val_loss: 1.3638 – val_accuracy: 0.6645
Epoch 20/20
469/469 [==============================] – 11s 24ms/step – loss: 1.4779 – accuracy: 0.53
47 – val_loss: 1.3076 – val_accuracy: 0.6702
Epoch 1/20
```

```
2022-11-07 23:14:58.668909: I tensorflow/core/grappler/optimizers/custom_graph_optimizer
_registry.cc:114] Plugin optimizer for device_type GPU is enabled.
469/469 [==============================] - ETA: 0s - loss: 2.4057 - accuracy: 0.1022
2022-11-07 23:15:10.360470: I tensorflow/core/grappler/optimizers/custom_graph_optimizer
_registry.cc:114] Plugin optimizer for device_type GPU is enabled.
```

```
469/469 [==============================] – 13s 27ms/step – loss: 2.4057 – accuracy: 0.10
22 – val_loss: 2.3007 – val_accuracy: 0.1217
Epoch 2/20
469/469 [==============================] – 13s 27ms/step – loss: 2.3371 – accuracy: 0.10
71 – val_loss: 2.2929 – val_accuracy: 0.1367
Epoch 3/20
469/469 [==============================] – 13s 27ms/step – loss: 2.3142 – accuracy: 0.11
18 – val_loss: 2.2919 – val_accuracy: 0.1413
Epoch 4/20
469/469 [==============================] – 13s 27ms/step – loss: 2.3039 – accuracy: 0.11
62 – val_loss: 2.2918 – val_accuracy: 0.1421
Epoch 5/20
469/469 [==============================] – 12s 25ms/step – loss: 2.3004 – accuracy: 0.11
91 – val_loss: 2.2903 – val_accuracy: 0.1505
Epoch 6/20
469/469 [==============================] – 12s 26ms/step – loss: 2.2960 – accuracy: 0.12
03 – val_loss: 2.2875 – val_accuracy: 0.1524
Epoch 7/20
469/469 [==============================] – 12s 25ms/step – loss: 2.2922 – accuracy: 0.12
47 – val_loss: 2.2840 – val_accuracy: 0.1669
Epoch 8/20
469/469 [==============================] – 11s 24ms/step – loss: 2.2903 – accuracy: 0.12
97 – val_loss: 2.2799 – val_accuracy: 0.1731
Epoch 9/20
469/469 [==============================] – 12s 26ms/step – loss: 2.2872 – accuracy: 0.13
16 – val_loss: 2.2753 – val_accuracy: 0.1787
Epoch 10/20
469/469 [==============================] – 12s 26ms/step – loss: 2.2833 – accuracy: 0.13
53 – val_loss: 2.2692 – val_accuracy: 0.1868
Epoch 11/20
469/469 [==============================] – 12s 26ms/step – loss: 2.2794 – accuracy: 0.13
99 – val_loss: 2.2629 – val_accuracy: 0.1958
Epoch 12/20
469/469 [==============================] – 13s 28ms/step – loss: 2.2740 – accuracy: 0.14
64 – val_loss: 2.2553 – val_accuracy: 0.2105
Epoch 13/20
469/469 [==============================] – 14s 30ms/step – loss: 2.2692 – accuracy: 0.14
89 – val_loss: 2.2459 – val_accuracy: 0.2197
Epoch 14/20
469/469 [==============================] – 11s 24ms/step – loss: 2.2632 – accuracy: 0.15
47 – val_loss: 2.2364 – val_accuracy: 0.2299
Epoch 15/20
469/469 [==============================] – 11s 24ms/step – loss: 2.2541 – accuracy: 0.16
49 – val_loss: 2.2238 – val_accuracy: 0.2476
Epoch 16/20
469/469 [==============================] – 11s 23ms/step – loss: 2.2477 – accuracy: 0.16
71 – val_loss: 2.2134 – val_accuracy: 0.2603
Epoch 17/20
469/469 [==============================] – 11s 24ms/step – loss: 2.2385 – accuracy: 0.17
53 – val_loss: 2.1990 – val_accuracy: 0.2745
Epoch 18/20
469/469 [==============================] – 11s 24ms/step – loss: 2.2277 – accuracy: 0.18
12 – val_loss: 2.1839 – val_accuracy: 0.2878
Epoch 19/20
469/469 [==============================] – 12s 25ms/step – loss: 2.2171 – accuracy: 0.18
96 – val_loss: 2.1679 – val_accuracy: 0.2947
Epoch 20/20
469/469 [==============================] – 11s 24ms/step – loss: 2.2044 – accuracy: 0.19
64 – val_loss: 2.1494 – val_accuracy: 0.3080
Epoch 1/20
```

```
2022-11-07 23:19:05.124882: I tensorflow/core/grappler/optimizers/custom_graph_optimizer
_registry.cc:114] Plugin optimizer for device_type GPU is enabled.
469/469 [==============================] - ETA: 0s - loss: 2.6343 - accuracy: 0.1008
2022-11-07 23:19:16.524050: I tensorflow/core/grappler/optimizers/custom_graph_optimizer
_registry.cc:114] Plugin optimizer for device_type GPU is enabled.
```

```
469/469 [==============================] - 13s 26ms/step - loss: 2.6343 - accuracy: 0.10
08 - val_loss: 2.3219 - val_accuracy: 0.1016
Epoch 2/20
469/469 [==============================] - 12s 26ms/step - loss: 2.3849 - accuracy: 0.10
06 - val_loss: 2.3044 - val_accuracy: 0.1061
Epoch 3/20
469/469 [==============================] - 12s 25ms/step - loss: 2.3308 - accuracy: 0.10
26 - val_loss: 2.3025 - val_accuracy: 0.1066
Epoch 4/20
469/469 [==============================] - 12s 25ms/step - loss: 2.3149 - accuracy: 0.10
28 - val_loss: 2.3023 - val_accuracy: 0.1037
Epoch 5/20
469/469 [==============================] - 12s 25ms/step - loss: 2.3091 - accuracy: 0.10
15 - val_loss: 2.3022 - val_accuracy: 0.1077
Epoch 6/20
469/469 [==============================] - 12s 25ms/step - loss: 2.3060 - accuracy: 0.10
45 - val_loss: 2.3023 - val_accuracy: 0.1098
Epoch 7/20
469/469 [==============================] - 11s 24ms/step - loss: 2.3051 - accuracy: 0.10
45 - val_loss: 2.3023 - val_accuracy: 0.1127
Epoch 8/20
469/469 [==============================] - 12s 25ms/step - loss: 2.3045 - accuracy: 0.10
49 - val_loss: 2.3024 - val_accuracy: 0.1113
Epoch 9/20
469/469 [==============================] - 11s 24ms/step - loss: 2.3033 - accuracy: 0.10
58 - val_loss: 2.3024 - val_accuracy: 0.1108
Epoch 10/20
469/469 [==============================] - 12s 25ms/step - loss: 2.3032 - accuracy: 0.10
68 - val_loss: 2.3024 - val_accuracy: 0.1115
Epoch 11/20
469/469 [==============================] - 12s 25ms/step - loss: 2.3029 - accuracy: 0.10
69 - val_loss: 2.3024 - val_accuracy: 0.1119
Epoch 12/20
469/469 [==============================] - 12s 25ms/step - loss: 2.3030 - accuracy: 0.10
66 - val_loss: 2.3023 - val_accuracy: 0.1107
Epoch 13/20
469/469 [==============================] - 11s 24ms/step - loss: 2.3029 - accuracy: 0.10
81 - val_loss: 2.3023 - val_accuracy: 0.1102
Epoch 14/20
469/469 [==============================] - 12s 25ms/step - loss: 2.3029 - accuracy: 0.10
67 - val_loss: 2.3023 - val_accuracy: 0.1104
Epoch 15/20
469/469 [==============================] - 12s 26ms/step - loss: 2.3029 - accuracy: 0.10
75 - val_loss: 2.3023 - val_accuracy: 0.1110
Epoch 16/20
469/469 [==============================] - 11s 24ms/step - loss: 2.3025 - accuracy: 0.10
83 - val_loss: 2.3023 - val_accuracy: 0.1098
Epoch 17/20
469/469 [==============================] - 11s 24ms/step - loss: 2.3019 - accuracy: 0.10
84 - val_loss: 2.3022 - val_accuracy: 0.1112
Epoch 18/20
469/469 [==============================] - 11s 24ms/step - loss: 2.3023 - accuracy: 0.10
94 - val_loss: 2.3022 - val_accuracy: 0.1102
Epoch 19/20
469/469 [==============================] - 11s 24ms/step - loss: 2.3025 - accuracy: 0.10
88 - val_loss: 2.3022 - val_accuracy: 0.1103
Epoch 20/20
469/469 [==============================] - 11s 24ms/step - loss: 2.3021 - accuracy: 0.10
95 - val_loss: 2.3021 - val_accuracy: 0.1077
```

```python
In [41]:  for i in range(0,len(accuracies)):
              plt.plot(accuracies[i],label=scales[i])
```

```
plt.ylabel('Accuracy')
plt.xlabel('Epochs')
plt.xlim(-1,20)
plt.legend(title='np.random.normal scale')
plt.show()
```
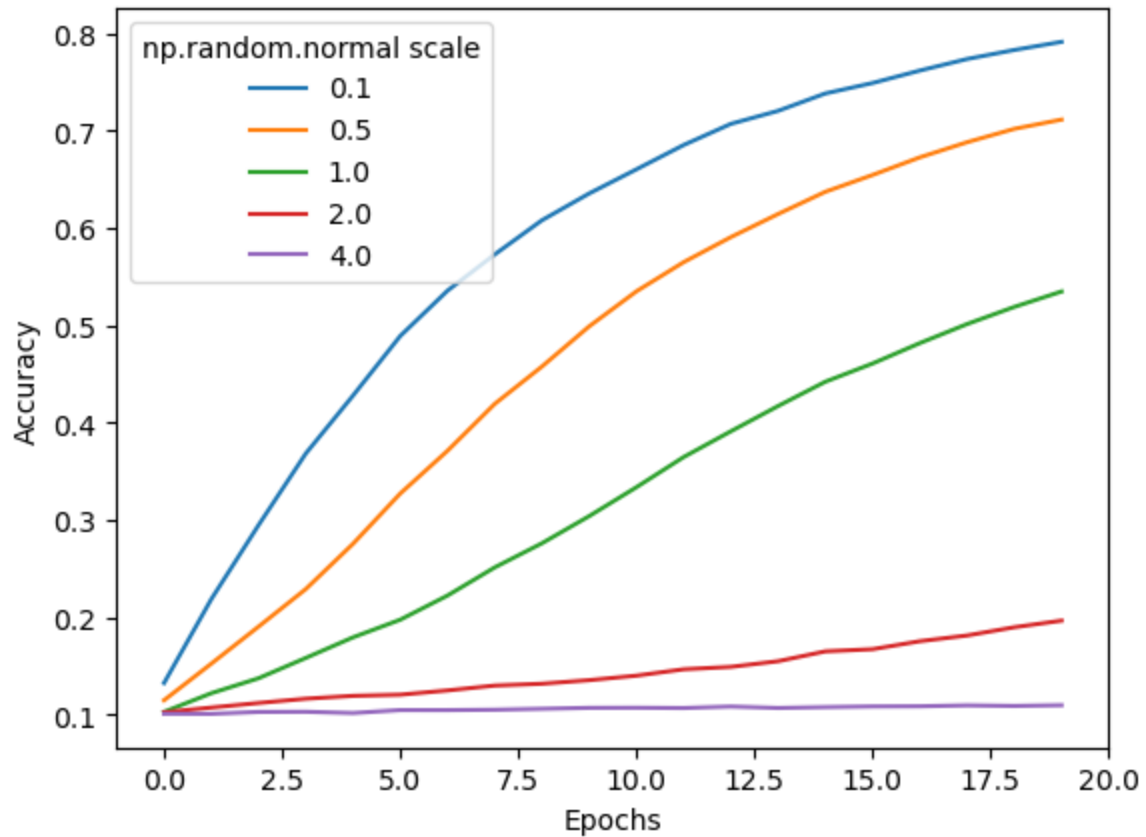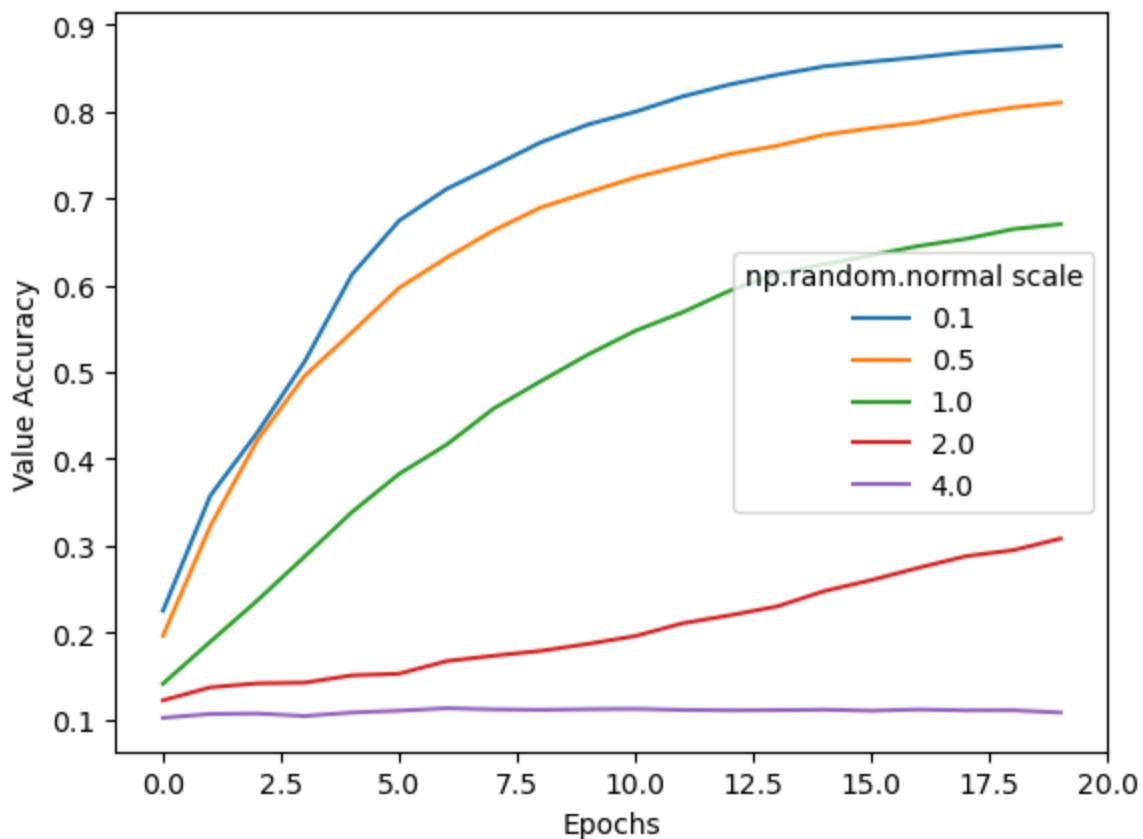

In [42]:
```
for i in range(0,len(vals)):
    plt.plot(vals[i],label=scales[i])
plt.ylabel('Value Accuracy')
plt.xlabel('Epochs')
plt.xlim(-1,20)
plt.legend(title='np.random.normal scale')
plt.show()
```

Comparison with Last Week

```
In [43]:  scales = [.1, .5, 1.0, 2.0, 4.0]
          accuracies_mlp = []
          vals_mlp = []

          for scale in scales:
              (x_train, y_train), (x_test, y_test) = mnist.load_data()

              x_train = x_train.reshape(60000, 784)
              x_test = x_test.reshape(10000, 784)
              x_train = x_train.astype('float32')
              x_test = x_test.astype('float32')
              x_train /= 255
              x_test /= 255

              x_train = np.random.normal(x_train,scale=scale)
              x_test = np.random.normal(x_test,scale=scale)

              batch_size = 128
              num_classes = 10
              epochs = 20
              # convert class vectors to binary class matrices
              y_train = keras.utils.to_categorical(y_train, num_classes)
              y_test = keras.utils.to_categorical(y_test, num_classes)

              model = Sequential()
              model.add(Dense(512, activation='relu', input_shape=(784,)))
              model.add(Dropout(0.2))
              model.add(Dense(512, activation='relu'))
              model.add(Dropout(0.2))
              model.add(Dense(10, activation='softmax'))

              model.summary()
```

```python
    model.compile(loss='categorical_crossentropy',
              optimizer=RMSprop(),
              metrics=['accuracy'])

    history = model.fit(x_train, y_train,
                    batch_size=batch_size,
                    epochs=epochs,
                    verbose=1,
                    validation_data=(x_test, y_test))
    score = model.evaluate(x_test, y_test, verbose=0)

    accuracies_mlp.append(history.history['accuracy'])
    vals_mlp.append(history.history['val_accuracy'])
```

Model: "sequential_24"

Layer (type)	Output Shape	Param #
dense_51 (Dense)	(None, 512)	401920
dropout_48 (Dropout)	(None, 512)	0
dense_52 (Dense)	(None, 512)	262656
dropout_49 (Dropout)	(None, 512)	0
dense_53 (Dense)	(None, 10)	5130

Total params: 669,706
Trainable params: 669,706
Non-trainable params: 0

Epoch 1/20
2022-11-07 23:23:01.951566: I tensorflow/core/grappler/optimizers/custom_graph_optimizer_registry.cc:114] Plugin optimizer for device_type GPU is enabled.
469/469 [==============================] - ETA: 0s - loss: 0.2631 - accuracy: 0.9179
2022-11-07 23:23:08.847260: I tensorflow/core/grappler/optimizers/custom_graph_optimizer_registry.cc:114] Plugin optimizer for device_type GPU is enabled.

```
469/469 [==============================] – 8s 16ms/step – loss: 0.2631 – accuracy: 0.917
9 – val_loss: 0.1266 – val_accuracy: 0.9594
Epoch 2/20
469/469 [==============================] – 7s 15ms/step – loss: 0.0968 – accuracy: 0.970
8 – val_loss: 0.1004 – val_accuracy: 0.9696
Epoch 3/20
469/469 [==============================] – 7s 15ms/step – loss: 0.0608 – accuracy: 0.981
5 – val_loss: 0.0902 – val_accuracy: 0.9736
Epoch 4/20
469/469 [==============================] – 7s 15ms/step – loss: 0.0402 – accuracy: 0.987
5 – val_loss: 0.0965 – val_accuracy: 0.9759
Epoch 5/20
469/469 [==============================] – 7s 14ms/step – loss: 0.0297 – accuracy: 0.990
2 – val_loss: 0.1147 – val_accuracy: 0.9742
Epoch 6/20
469/469 [==============================] – 7s 14ms/step – loss: 0.0236 – accuracy: 0.992
5 – val_loss: 0.1138 – val_accuracy: 0.9757
Epoch 7/20
469/469 [==============================] – 7s 14ms/step – loss: 0.0199 – accuracy: 0.993
4 – val_loss: 0.1179 – val_accuracy: 0.9766
Epoch 8/20
469/469 [==============================] – 7s 14ms/step – loss: 0.0158 – accuracy: 0.994
9 – val_loss: 0.1428 – val_accuracy: 0.9748
Epoch 9/20
469/469 [==============================] – 7s 14ms/step – loss: 0.0153 – accuracy: 0.995
5 – val_loss: 0.1507 – val_accuracy: 0.9765
Epoch 10/20
469/469 [==============================] – 7s 14ms/step – loss: 0.0144 – accuracy: 0.995
6 – val_loss: 0.1592 – val_accuracy: 0.9746
Epoch 11/20
469/469 [==============================] – 7s 14ms/step – loss: 0.0127 – accuracy: 0.996
3 – val_loss: 0.1788 – val_accuracy: 0.9734
Epoch 12/20
469/469 [==============================] – 7s 14ms/step – loss: 0.0101 – accuracy: 0.997
0 – val_loss: 0.1720 – val_accuracy: 0.9759
Epoch 13/20
469/469 [==============================] – 7s 14ms/step – loss: 0.0104 – accuracy: 0.997
0 – val_loss: 0.1658 – val_accuracy: 0.9758
Epoch 14/20
469/469 [==============================] – 7s 14ms/step – loss: 0.0096 – accuracy: 0.997
3 – val_loss: 0.1666 – val_accuracy: 0.9789
Epoch 15/20
469/469 [==============================] – 7s 15ms/step – loss: 0.0085 – accuracy: 0.997
2 – val_loss: 0.1835 – val_accuracy: 0.9772
Epoch 16/20
469/469 [==============================] – 7s 15ms/step – loss: 0.0088 – accuracy: 0.997
6 – val_loss: 0.2134 – val_accuracy: 0.9756
Epoch 17/20
469/469 [==============================] – 7s 15ms/step – loss: 0.0096 – accuracy: 0.997
5 – val_loss: 0.2349 – val_accuracy: 0.9758
Epoch 18/20
469/469 [==============================] – 7s 15ms/step – loss: 0.0095 – accuracy: 0.997
4 – val_loss: 0.2668 – val_accuracy: 0.9748
Epoch 19/20
469/469 [==============================] – 7s 15ms/step – loss: 0.0091 – accuracy: 0.998
0 – val_loss: 0.2242 – val_accuracy: 0.9771
Epoch 20/20
469/469 [==============================] – 7s 15ms/step – loss: 0.0071 – accuracy: 0.997
9 – val_loss: 0.2571 – val_accuracy: 0.9751
Model: "sequential_25"
_____
 Layer (type)                Output Shape              Param #
```

```
=================================================================
 dense_54 (Dense)            (None, 512)              401920

 dropout_50 (Dropout)        (None, 512)              0

 dense_55 (Dense)            (None, 512)              262656

 dropout_51 (Dropout)        (None, 512)              0

 dense_56 (Dense)            (None, 10)               5130

=================================================================
Total params: 669,706
Trainable params: 669,706
Non-trainable params: 0

_____
Epoch 1/20
```

2022-11-07 23:25:24.247061: I tensorflow/core/grappler/optimizers/custom_graph_optimizer_registry.cc:114] Plugin optimizer for device_type GPU is enabled.

```
469/469 [==============================] - ETA: 0s - loss: 0.5475 - accuracy: 0.8229
```

2022-11-07 23:25:31.279292: I tensorflow/core/grappler/optimizers/custom_graph_optimizer_registry.cc:114] Plugin optimizer for device_type GPU is enabled.

```
469/469 [==============================] – 8s 16ms/step – loss: 0.5475 – accuracy: 0.822
9 – val_loss: 0.3112 – val_accuracy: 0.8982
Epoch 2/20
469/469 [==============================] – 7s 15ms/step – loss: 0.2410 – accuracy: 0.923
0 – val_loss: 0.2823 – val_accuracy: 0.9132
Epoch 3/20
469/469 [==============================] – 7s 15ms/step – loss: 0.1218 – accuracy: 0.960
5 – val_loss: 0.3116 – val_accuracy: 0.9134
Epoch 4/20
469/469 [==============================] – 7s 15ms/step – loss: 0.0692 – accuracy: 0.976
4 – val_loss: 0.3580 – val_accuracy: 0.9150
Epoch 5/20
469/469 [==============================] – 7s 15ms/step – loss: 0.0489 – accuracy: 0.983
6 – val_loss: 0.4122 – val_accuracy: 0.9158
Epoch 6/20
469/469 [==============================] – 7s 15ms/step – loss: 0.0384 – accuracy: 0.987
0 – val_loss: 0.5030 – val_accuracy: 0.9141
Epoch 7/20
469/469 [==============================] – 7s 15ms/step – loss: 0.0337 – accuracy: 0.988
8 – val_loss: 0.4966 – val_accuracy: 0.9149
Epoch 8/20
469/469 [==============================] – 7s 15ms/step – loss: 0.0289 – accuracy: 0.990
6 – val_loss: 0.5807 – val_accuracy: 0.9115
Epoch 9/20
469/469 [==============================] – 7s 15ms/step – loss: 0.0286 – accuracy: 0.991
5 – val_loss: 0.5900 – val_accuracy: 0.9154
Epoch 10/20
469/469 [==============================] – 7s 15ms/step – loss: 0.0243 – accuracy: 0.992
4 – val_loss: 0.6067 – val_accuracy: 0.9146
Epoch 11/20
469/469 [==============================] – 7s 15ms/step – loss: 0.0244 – accuracy: 0.992
5 – val_loss: 0.6333 – val_accuracy: 0.9158
Epoch 12/20
469/469 [==============================] – 7s 15ms/step – loss: 0.0227 – accuracy: 0.993
3 – val_loss: 0.6518 – val_accuracy: 0.9180
Epoch 13/20
469/469 [==============================] – 7s 15ms/step – loss: 0.0183 – accuracy: 0.994
5 – val_loss: 0.7053 – val_accuracy: 0.9175
Epoch 14/20
469/469 [==============================] – 7s 15ms/step – loss: 0.0199 – accuracy: 0.994
4 – val_loss: 0.7296 – val_accuracy: 0.9185
Epoch 15/20
469/469 [==============================] – 7s 15ms/step – loss: 0.0184 – accuracy: 0.994
4 – val_loss: 0.7612 – val_accuracy: 0.9163
Epoch 16/20
469/469 [==============================] – 7s 16ms/step – loss: 0.0197 – accuracy: 0.994
1 – val_loss: 0.8203 – val_accuracy: 0.9163
Epoch 17/20
469/469 [==============================] – 7s 15ms/step – loss: 0.0196 – accuracy: 0.995
0 – val_loss: 0.7901 – val_accuracy: 0.9203
Epoch 18/20
469/469 [==============================] – 7s 15ms/step – loss: 0.0181 – accuracy: 0.994
6 – val_loss: 0.8086 – val_accuracy: 0.9185
Epoch 19/20
469/469 [==============================] – 8s 15ms/step – loss: 0.0180 – accuracy: 0.995
3 – val_loss: 0.8272 – val_accuracy: 0.9199
Epoch 20/20
469/469 [==============================] – 7s 15ms/step – loss: 0.0161 – accuracy: 0.995
5 – val_loss: 0.8516 – val_accuracy: 0.9183
Model: "sequential_26"
_____
 Layer (type)                Output Shape              Param #
```

```
================================================================
 dense_57 (Dense)            (None, 512)            401920

 dropout_52 (Dropout)        (None, 512)            0

 dense_58 (Dense)            (None, 512)            262656

 dropout_53 (Dropout)        (None, 512)            0

 dense_59 (Dense)            (None, 10)             5130

================================================================
Total params: 669,706
Trainable params: 669,706
Non-trainable params: 0

_____
Epoch 1/20
```

2022-11-07 23:27:49.411050: I tensorflow/core/grappler/optimizers/custom_graph_optimizer
_registry.cc:114] Plugin optimizer for device_type GPU is enabled.

```
469/469 [==============================] - ETA: 0s - loss: 1.0816 - accuracy: 0.6326
```

2022-11-07 23:27:56.427196: I tensorflow/core/grappler/optimizers/custom_graph_optimizer
_registry.cc:114] Plugin optimizer for device_type GPU is enabled.

```
469/469 [==============================] – 8s 16ms/step – loss: 1.0816 – accuracy: 0.632
6 – val_loss: 0.8133 – val_accuracy: 0.7293
Epoch 2/20
469/469 [==============================] – 7s 15ms/step – loss: 0.6620 – accuracy: 0.777
4 – val_loss: 0.7507 – val_accuracy: 0.7514
Epoch 3/20
469/469 [==============================] – 7s 15ms/step – loss: 0.4488 – accuracy: 0.851
6 – val_loss: 0.7742 – val_accuracy: 0.7595
Epoch 4/20
469/469 [==============================] – 7s 15ms/step – loss: 0.2942 – accuracy: 0.901
7 – val_loss: 0.8913 – val_accuracy: 0.7513
Epoch 5/20
469/469 [==============================] – 7s 15ms/step – loss: 0.2027 – accuracy: 0.929
8 – val_loss: 1.0578 – val_accuracy: 0.7514
Epoch 6/20
469/469 [==============================] – 7s 15ms/step – loss: 0.1577 – accuracy: 0.946
0 – val_loss: 1.1620 – val_accuracy: 0.7501
Epoch 7/20
469/469 [==============================] – 7s 15ms/step – loss: 0.1331 – accuracy: 0.954
6 – val_loss: 1.2956 – val_accuracy: 0.7450
Epoch 8/20
469/469 [==============================] – 7s 15ms/step – loss: 0.1200 – accuracy: 0.959
5 – val_loss: 1.3440 – val_accuracy: 0.7491
Epoch 9/20
469/469 [==============================] – 7s 15ms/step – loss: 0.1101 – accuracy: 0.963
7 – val_loss: 1.4488 – val_accuracy: 0.7497
Epoch 10/20
469/469 [==============================] – 7s 15ms/step – loss: 0.1027 – accuracy: 0.965
4 – val_loss: 1.5095 – val_accuracy: 0.7524
Epoch 11/20
469/469 [==============================] – 7s 14ms/step – loss: 0.0948 – accuracy: 0.969
9 – val_loss: 1.6218 – val_accuracy: 0.7443
Epoch 12/20
469/469 [==============================] – 7s 15ms/step – loss: 0.0869 – accuracy: 0.972
5 – val_loss: 1.7003 – val_accuracy: 0.7512
Epoch 13/20
469/469 [==============================] – 7s 15ms/step – loss: 0.0866 – accuracy: 0.972
4 – val_loss: 1.7594 – val_accuracy: 0.7509
Epoch 14/20
469/469 [==============================] – 7s 15ms/step – loss: 0.0796 – accuracy: 0.975
2 – val_loss: 1.8679 – val_accuracy: 0.7520
Epoch 15/20
469/469 [==============================] – 7s 15ms/step – loss: 0.0820 – accuracy: 0.975
3 – val_loss: 1.9190 – val_accuracy: 0.7487
Epoch 16/20
469/469 [==============================] – 7s 15ms/step – loss: 0.0790 – accuracy: 0.976
1 – val_loss: 1.9345 – val_accuracy: 0.7524
Epoch 17/20
469/469 [==============================] – 7s 15ms/step – loss: 0.0757 – accuracy: 0.977
4 – val_loss: 1.9330 – val_accuracy: 0.7523
Epoch 18/20
469/469 [==============================] – 7s 14ms/step – loss: 0.0720 – accuracy: 0.979
3 – val_loss: 2.0733 – val_accuracy: 0.7487
Epoch 19/20
469/469 [==============================] – 7s 15ms/step – loss: 0.0698 – accuracy: 0.979
2 – val_loss: 2.1146 – val_accuracy: 0.7483
Epoch 20/20
469/469 [==============================] – 7s 15ms/step – loss: 0.0709 – accuracy: 0.980
2 – val_loss: 2.1357 – val_accuracy: 0.7481
Model: "sequential_27"
```

```
_____
 Layer (type)                Output Shape              Param #
```

```
================================================================
 dense_60 (Dense)              (None, 512)              401920

 dropout_54 (Dropout)          (None, 512)              0

 dense_61 (Dense)              (None, 512)              262656

 dropout_55 (Dropout)          (None, 512)              0

 dense_62 (Dense)              (None, 10)               5130

================================================================
Total params: 669,706
Trainable params: 669,706
Non-trainable params: 0
_____
Epoch 1/20
```

2022-11-07 23:30:12.687158: I tensorflow/core/grappler/optimizers/custom_graph_optimizer _registry.cc:114] Plugin optimizer for device_type GPU is enabled.

```
469/469 [==============================] - ETA: 0s - loss: 1.8603 - accuracy: 0.3614
```

2022-11-07 23:30:19.768056: I tensorflow/core/grappler/optimizers/custom_graph_optimizer _registry.cc:114] Plugin optimizer for device_type GPU is enabled.

```
469/469 [==============================] – 8s 16ms/step – loss: 1.8603 – accuracy: 0.361
4 – val_loss: 1.6038 – val_accuracy: 0.4473
Epoch 2/20
469/469 [==============================] – 7s 15ms/step – loss: 1.4565 – accuracy: 0.498
8 – val_loss: 1.5946 – val_accuracy: 0.4511
Epoch 3/20
469/469 [==============================] – 7s 15ms/step – loss: 1.2472 – accuracy: 0.571
0 – val_loss: 1.6408 – val_accuracy: 0.4396
Epoch 4/20
469/469 [==============================] – 7s 15ms/step – loss: 1.0495 – accuracy: 0.637
1 – val_loss: 1.7151 – val_accuracy: 0.4431
Epoch 5/20
469/469 [==============================] – 7s 15ms/step – loss: 0.8812 – accuracy: 0.694
8 – val_loss: 1.8254 – val_accuracy: 0.4318
Epoch 6/20
469/469 [==============================] – 7s 15ms/step – loss: 0.7393 – accuracy: 0.743
5 – val_loss: 1.9954 – val_accuracy: 0.4224
Epoch 7/20
469/469 [==============================] – 7s 15ms/step – loss: 0.6411 – accuracy: 0.778
2 – val_loss: 2.1551 – val_accuracy: 0.4127
Epoch 8/20
469/469 [==============================] – 7s 15ms/step – loss: 0.5639 – accuracy: 0.802
8 – val_loss: 2.3279 – val_accuracy: 0.4129
Epoch 9/20
469/469 [==============================] – 7s 16ms/step – loss: 0.5101 – accuracy: 0.825
3 – val_loss: 2.4836 – val_accuracy: 0.4100
Epoch 10/20
469/469 [==============================] – 7s 15ms/step – loss: 0.4717 – accuracy: 0.838
8 – val_loss: 2.5922 – val_accuracy: 0.4008
Epoch 11/20
469/469 [==============================] – 7s 15ms/step – loss: 0.4321 – accuracy: 0.852
8 – val_loss: 2.6784 – val_accuracy: 0.4051
Epoch 12/20
469/469 [==============================] – 7s 15ms/step – loss: 0.4073 – accuracy: 0.862
3 – val_loss: 2.8651 – val_accuracy: 0.4047
Epoch 13/20
469/469 [==============================] – 7s 15ms/step – loss: 0.3854 – accuracy: 0.870
4 – val_loss: 2.9021 – val_accuracy: 0.4071
Epoch 14/20
469/469 [==============================] – 7s 15ms/step – loss: 0.3646 – accuracy: 0.878
5 – val_loss: 3.0700 – val_accuracy: 0.4013
Epoch 15/20
469/469 [==============================] – 7s 15ms/step – loss: 0.3497 – accuracy: 0.884
1 – val_loss: 3.1603 – val_accuracy: 0.4037
Epoch 16/20
469/469 [==============================] – 7s 15ms/step – loss: 0.3458 – accuracy: 0.888
5 – val_loss: 3.2852 – val_accuracy: 0.4016
Epoch 17/20
469/469 [==============================] – 7s 15ms/step – loss: 0.3341 – accuracy: 0.892
1 – val_loss: 3.3663 – val_accuracy: 0.4024
Epoch 18/20
469/469 [==============================] – 7s 15ms/step – loss: 0.3186 – accuracy: 0.897
3 – val_loss: 3.4679 – val_accuracy: 0.3993
Epoch 19/20
469/469 [==============================] – 7s 15ms/step – loss: 0.3137 – accuracy: 0.898
8 – val_loss: 3.5579 – val_accuracy: 0.4073
Epoch 20/20
469/469 [==============================] – 7s 15ms/step – loss: 0.2989 – accuracy: 0.906
1 – val_loss: 3.7185 – val_accuracy: 0.4007
Model: "sequential_28"
```

| Layer (type) | Output Shape | Param # |

```
================================================================
 dense_63 (Dense)              (None, 512)              401920

 dropout_56 (Dropout)          (None, 512)              0

 dense_64 (Dense)              (None, 512)              262656

 dropout_57 (Dropout)          (None, 512)              0

 dense_65 (Dense)              (None, 10)               5130

================================================================
Total params: 669,706
Trainable params: 669,706
Non-trainable params: 0
_____
Epoch 1/20
```

2022-11-07 23:32:37.766116: I tensorflow/core/grappler/optimizers/custom_graph_optimizer
_registry.cc:114] Plugin optimizer for device_type GPU is enabled.

```
469/469 [==============================] - ETA: 0s - loss: 2.4530 - accuracy: 0.1565
```

2022-11-07 23:32:44.823995: I tensorflow/core/grappler/optimizers/custom_graph_optimizer
_registry.cc:114] Plugin optimizer for device_type GPU is enabled.

```
469/469 [==============================] – 8s 16ms/step – loss: 2.4530 – accuracy: 0.156
5 – val_loss: 2.1534 – val_accuracy: 0.2218
Epoch 2/20
469/469 [==============================] – 7s 15ms/step – loss: 2.0762 – accuracy: 0.258
9 – val_loss: 2.1221 – val_accuracy: 0.2342
Epoch 3/20
469/469 [==============================] – 7s 15ms/step – loss: 1.9378 – accuracy: 0.313
9 – val_loss: 2.1441 – val_accuracy: 0.2360
Epoch 4/20
469/469 [==============================] – 7s 15ms/step – loss: 1.8056 – accuracy: 0.364
7 – val_loss: 2.1898 – val_accuracy: 0.2231
Epoch 5/20
469/469 [==============================] – 7s 15ms/step – loss: 1.6791 – accuracy: 0.407
7 – val_loss: 2.2536 – val_accuracy: 0.2165
Epoch 6/20
469/469 [==============================] – 7s 15ms/step – loss: 1.5643 – accuracy: 0.452
1 – val_loss: 2.3255 – val_accuracy: 0.2146
Epoch 7/20
469/469 [==============================] – 7s 15ms/step – loss: 1.4621 – accuracy: 0.487
3 – val_loss: 2.3843 – val_accuracy: 0.2108
Epoch 8/20
469/469 [==============================] – 7s 15ms/step – loss: 1.3740 – accuracy: 0.522
9 – val_loss: 2.4861 – val_accuracy: 0.2066
Epoch 9/20
469/469 [==============================] – 7s 15ms/step – loss: 1.3026 – accuracy: 0.547
5 – val_loss: 2.5691 – val_accuracy: 0.1930
Epoch 10/20
469/469 [==============================] – 7s 15ms/step – loss: 1.2283 – accuracy: 0.575
3 – val_loss: 2.6509 – val_accuracy: 0.1986
Epoch 11/20
469/469 [==============================] – 7s 15ms/step – loss: 1.1726 – accuracy: 0.596
5 – val_loss: 2.7287 – val_accuracy: 0.1971
Epoch 12/20
469/469 [==============================] – 7s 15ms/step – loss: 1.1260 – accuracy: 0.613
5 – val_loss: 2.8089 – val_accuracy: 0.2009
Epoch 13/20
469/469 [==============================] – 7s 15ms/step – loss: 1.0873 – accuracy: 0.630
5 – val_loss: 2.8739 – val_accuracy: 0.1912
Epoch 14/20
469/469 [==============================] – 7s 15ms/step – loss: 1.0508 – accuracy: 0.642
0 – val_loss: 2.9547 – val_accuracy: 0.1932
Epoch 15/20
469/469 [==============================] – 7s 15ms/step – loss: 1.0152 – accuracy: 0.654
5 – val_loss: 3.0944 – val_accuracy: 0.1938
Epoch 16/20
469/469 [==============================] – 7s 15ms/step – loss: 0.9867 – accuracy: 0.667
1 – val_loss: 3.1741 – val_accuracy: 0.1943
Epoch 17/20
469/469 [==============================] – 7s 15ms/step – loss: 0.9590 – accuracy: 0.677
5 – val_loss: 3.1709 – val_accuracy: 0.1864
Epoch 18/20
469/469 [==============================] – 7s 15ms/step – loss: 0.9355 – accuracy: 0.687
6 – val_loss: 3.2842 – val_accuracy: 0.1918
Epoch 19/20
469/469 [==============================] – 7s 15ms/step – loss: 0.9109 – accuracy: 0.695
3 – val_loss: 3.3182 – val_accuracy: 0.1892
Epoch 20/20
469/469 [==============================] – 7s 15ms/step – loss: 0.8890 – accuracy: 0.704
4 – val_loss: 3.3872 – val_accuracy: 0.1904
```

```python
In [57]: fig, ax = plt.subplots(1,2,sharey=True)
         fig.subplots_adjust(wspace=0)
```
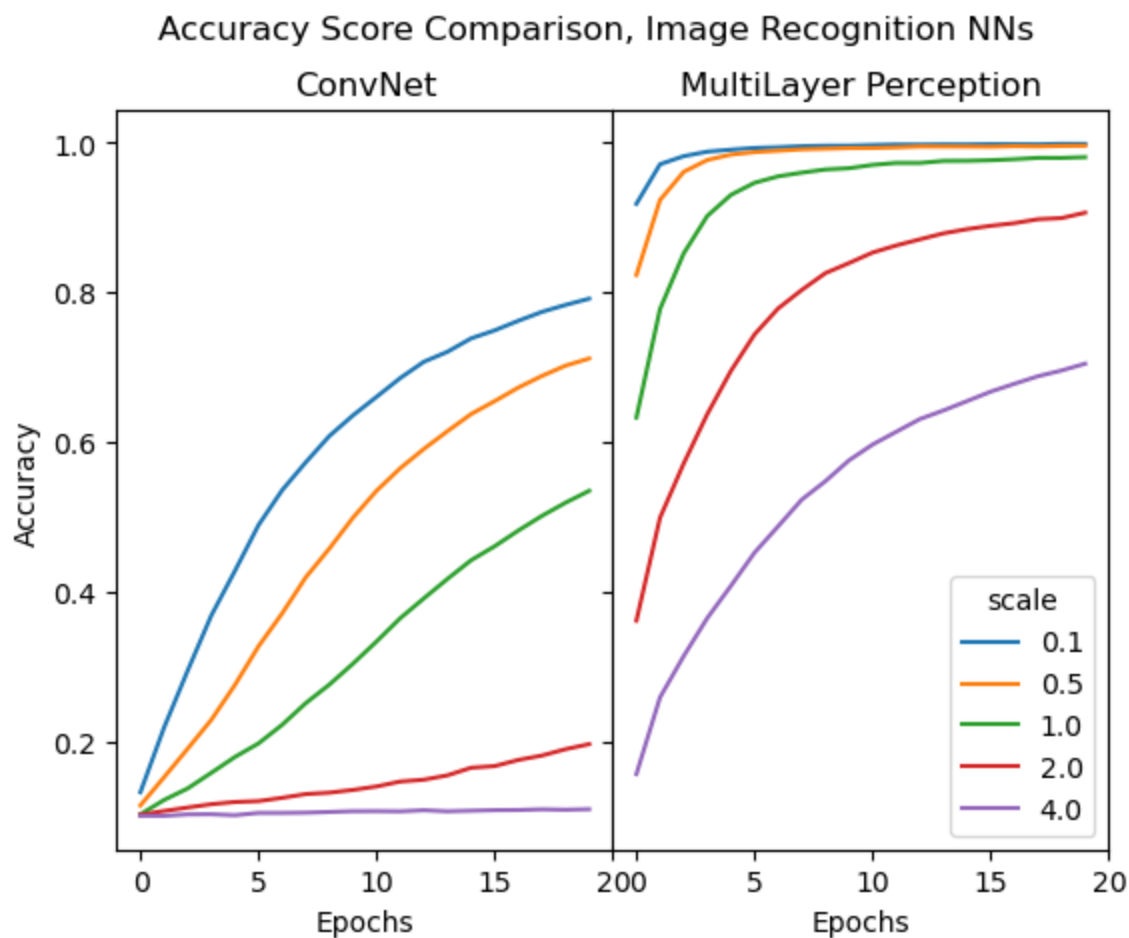
```python
for i in range(0,len(accuracies)):
    ax[0].plot(accuracies[i],label=scales[i])
ax[0].set_ylabel('Accuracy')
ax[0].set_xlabel('Epochs')
ax[0].set_xlim(-1,20)
ax[0].set_title('ConvNet')

for i in range(0,len(accuracies)):
    ax[1].plot(accuracies_mlp[i],label=scales[i])
ax[1].set_xlabel('Epochs')
ax[1].set_xlim(-1,20)
ax[1].legend(title='scale')
ax[1].set_title('MultiLayer Perception')
fig.suptitle('Accuracy Score Comparison, Image Recognition NNs')
plt.show()
```


In [58]:
```python
fig, ax = plt.subplots(1,2,sharey=True)
fig.subplots_adjust(wspace=0)

for i in range(0,len(accuracies)):
    ax[0].plot(vals[i],label=scales[i])
ax[0].set_ylabel('Value Accuracy')
ax[0].set_xlabel('Epochs')
ax[0].set_xlim(-1,20)
ax[0].set_title('ConvNet')

for i in range(0,len(accuracies)):
    ax[1].plot(vals_mlp[i],label=scales[i])
ax[1].set_xlabel('Epochs')
ax[1].set_xlim(-1,20)
ax[1].legend(title='scale')
ax[1].set_title('MultiLayer Perception')
```
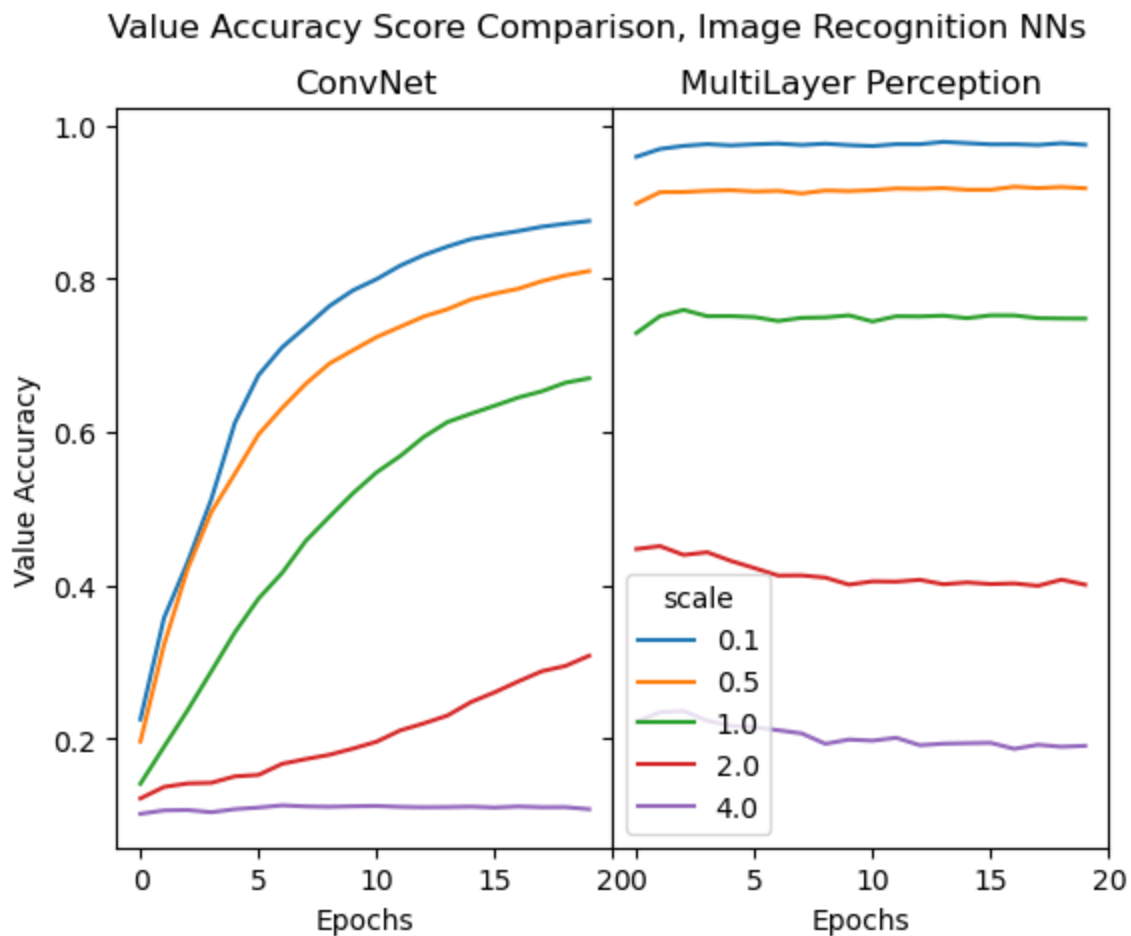
```
fig.suptitle('Value Accuracy Score Comparison, Image Recognition NNs')
plt.show()
```


Value Accuracy Score Comparison, Image Recognition NNs

As visible in the above graphs, the MultiLayer Perception (MLP) Neural Networks from last week were significantly more effective at accurately predicting the numbers in each image in the MNist dataset. MLP accuracy scores for four out of the five scale variations of the MNist dataset were higher than 80% after 20 epochs, while the ConvNet accuracy scores topped out at 80% for only one scale.