In [1]:
```
import tensorflow as tf
from tensorflow.keras.preprocessing.image import ImageDataGenerator
from tensorflow.keras.models import Model
from tensorflow.keras.layers import Input, Flatten, Dense, Dropout,GlobalAverage
from tensorflow.keras.applications.mobilenet import MobileNet, preprocess_input
import math
import numpy as np
import matplotlib
import matplotlib.pyplot as plt
import matplotlib.image as mpimg
```

In [2]:
```
TRAIN_DATA_DIR = '/Users/jantonchuk/Documents/NU/MSDS-462/fmri-data/training/'
VALIDATION_DATA_DIR = '/Users/jantonchuk/Documents/NU/MSDS-462/fmri-data/testing
TRAIN_SAMPLES = 98
VALIDATION_SAMPLES = 98
NUM_CLASSES = 2
IMG_WIDTH, IMG_HEIGHT = 224, 224
BATCH_SIZE = 14
```

In [3]:
```
train_datagen = ImageDataGenerator(preprocessing_function=preprocess_input,
                                   rotation_range=20,
                                   width_shift_range=0.2,
                                   height_shift_range=0.2,
                                   zoom_range=0.2)
val_datagen = ImageDataGenerator(preprocessing_function=preprocess_input)
```

In [4]:
```
train_generator = train_datagen.flow_from_directory(
                        TRAIN_DATA_DIR,
                        target_size=(IMG_WIDTH, IMG_HEIGHT),
                        batch_size=BATCH_SIZE,
                        shuffle=True,
                        seed=12345,
                        class_mode='categorical')

validation_generator = val_datagen.flow_from_directory(
                        VALIDATION_DATA_DIR,
                        target_size=(IMG_WIDTH, IMG_HEIGHT),
                        batch_size=BATCH_SIZE,
                        shuffle=False,
                        class_mode='categorical')
```

```
Found 98 images belonging to 2 classes.
Found 98 images belonging to 2 classes.
```

In [5]:
```
def model_maker():
    base_model = MobileNet(include_top=False, input_shape=(IMG_WIDTH,IMG_HEIGHT,
    for layer in base_model.layers[:]:
        layer.trainable = False # Freeze the layers
    input = Input(shape=(IMG_WIDTH, IMG_HEIGHT, 3))
    custom_model = base_model(input)
    custom_model = GlobalAveragePooling2D()(custom_model)
    custom_model = Dense(64, activation='relu')(custom_model)
    custom_model = Dropout(0.5)(custom_model)
    predictions = Dense(NUM_CLASSES, activation='softmax')(custom_model)
    return Model(inputs=input, outputs=predictions)
```

In [6]:
```
model = model_maker()
model.compile(loss='categorical_crossentropy',
```

```
              optimizer=tf.optimizers.Adam(lr=0.001),
              metrics=['acc'])
num_steps = math.ceil(float(TRAIN_SAMPLES)/BATCH_SIZE)
print(num_steps)
model.fit(train_generator,
          steps_per_epoch=num_steps,
          epochs=25,
          validation_data=validation_generator,
          validation_steps=num_steps)
```

```
7
WARNING:tensorflow:sample_weight modes were coerced from
  ...
    to
  ['...']
WARNING:tensorflow:sample_weight modes were coerced from
  ...
    to
  ['...']
Train for 7 steps, validate for 7 steps
Epoch 1/25
7/7 [==============================] - 7s 1s/step - loss: 1.2157 - acc: 0.4490 -
val_loss: 0.9269 - val_acc: 0.5000
Epoch 2/25
7/7 [==============================] - 5s 707ms/step - loss: 0.7755 - acc: 0.571
4 - val_loss: 0.7057 - val_acc: 0.5612
Epoch 3/25
7/7 [==============================] - 6s 862ms/step - loss: 0.5291 - acc: 0.673
5 - val_loss: 0.6797 - val_acc: 0.5714
Epoch 4/25
7/7 [==============================] - 6s 875ms/step - loss: 0.5035 - acc: 0.744
9 - val_loss: 0.8630 - val_acc: 0.5306
Epoch 5/25
7/7 [==============================] - 7s 1s/step - loss: 0.4401 - acc: 0.8163 -
val_loss: 0.6345 - val_acc: 0.5918
Epoch 6/25
7/7 [==============================] - 6s 873ms/step - loss: 0.3449 - acc: 0.846
9 - val_loss: 0.7943 - val_acc: 0.5510
Epoch 7/25
7/7 [==============================] - 7s 938ms/step - loss: 0.3468 - acc: 0.826
5 - val_loss: 0.8039 - val_acc: 0.5510
Epoch 8/25
7/7 [==============================] - 6s 822ms/step - loss: 0.3681 - acc: 0.836
7 - val_loss: 0.7045 - val_acc: 0.5816
Epoch 9/25
7/7 [==============================] - 6s 825ms/step - loss: 0.3165 - acc: 0.867
3 - val_loss: 0.5591 - val_acc: 0.6633
Epoch 10/25
7/7 [==============================] - 6s 837ms/step - loss: 0.3841 - acc: 0.795
9 - val_loss: 0.7502 - val_acc: 0.6020
Epoch 11/25
7/7 [==============================] - 6s 808ms/step - loss: 0.2491 - acc: 0.898
0 - val_loss: 0.5988 - val_acc: 0.6327
Epoch 12/25
7/7 [==============================] - 5s 769ms/step - loss: 0.2830 - acc: 0.867
3 - val_loss: 0.7235 - val_acc: 0.6020
Epoch 13/25
7/7 [==============================] - 6s 806ms/step - loss: 0.2336 - acc: 0.887
8 - val_loss: 0.6862 - val_acc: 0.6020
Epoch 14/25
7/7 [==============================] - 5s 686ms/step - loss: 0.1848 - acc: 0.928
6 - val_loss: 0.7370 - val_acc: 0.5918
Epoch 15/25
7/7 [==============================] - 5s 689ms/step - loss: 0.2257 - acc: 0.908
2 - val_loss: 0.5398 - val_acc: 0.7245
```

```
Epoch 16/25
7/7 [==============================] - 5s 684ms/step - loss: 0.2814 - acc: 0.887
8 - val_loss: 0.6682 - val_acc: 0.6224
Epoch 17/25
7/7 [==============================] - 5s 672ms/step - loss: 0.2730 - acc: 0.877
6 - val_loss: 0.9932 - val_acc: 0.5612
Epoch 18/25
7/7 [==============================] - 5s 695ms/step - loss: 0.1961 - acc: 0.928
6 - val_loss: 1.0517 - val_acc: 0.5612
Epoch 19/25
7/7 [==============================] - 5s 691ms/step - loss: 0.1989 - acc: 0.898
0 - val_loss: 0.8958 - val_acc: 0.5918
Epoch 20/25
7/7 [==============================] - 5s 679ms/step - loss: 0.2425 - acc: 0.928
6 - val_loss: 1.0858 - val_acc: 0.5714
Epoch 21/25
7/7 [==============================] - 5s 688ms/step - loss: 0.1980 - acc: 0.938
8 - val_loss: 1.0130 - val_acc: 0.5714
Epoch 22/25
7/7 [==============================] - 5s 687ms/step - loss: 0.2068 - acc: 0.918
4 - val_loss: 0.6647 - val_acc: 0.6429
Epoch 23/25
7/7 [==============================] - 5s 685ms/step - loss: 0.1789 - acc: 0.949
0 - val_loss: 1.0906 - val_acc: 0.5714
Epoch 24/25
7/7 [==============================] - 5s 691ms/step - loss: 0.1591 - acc: 0.928
6 - val_loss: 0.8544 - val_acc: 0.6122
Epoch 25/25
7/7 [==============================] - 5s 696ms/step - loss: 0.1652 - acc: 0.938
8 - val_loss: 0.6579 - val_acc: 0.6837
```

Out[6]:
```
<tensorflow.python.keras.callbacks.History at 0x7f937022fda0>
```

In [7]:
```
model.save('model.h5')
```

In [8]:
```
from tensorflow.keras.models import load_model
model = load_model('model.h5')
```

In [9]:
```
img_path = '/Users/jantonchuk/Documents/NU/MSDS-462/fmri-data/yes/Y250.jpg'
img = tf.keras.preprocessing.image.load_img(img_path, target_size=(224,224))
img_array = tf.keras.preprocessing.image.img_to_array(img)
expanded_img_array = np.expand_dims(img_array, axis=0)
preprocessed_img = preprocess_input(expanded_img_array) # Preprocess the image
prediction = model.predict(preprocessed_img)
print(prediction)
print(validation_generator.class_indices)
```

```
[[0.9910948 0.0089051]]
{'no': 0, 'yes': 1}
```

Validation

In [10]:
```
# VARIABLES
IMG_WIDTH, IMG_HEIGHT = 224, 224
VALIDATION_DATA_DIR = '/Users/jantonchuk/Documents/NU/MSDS-462/fmri-data/validat
VALIDATION_BATCH_SIZE = 64

# DATA GENERATORS
validation_datagen = ImageDataGenerator(
        preprocessing_function=preprocess_input)
validation_generator = validation_datagen.flow_from_directory(
        VALIDATION_DATA_DIR,
```

```
        target_size=(IMG_WIDTH, IMG_HEIGHT),
        batch_size=VALIDATION_BATCH_SIZE,
        shuffle=False,
        class_mode='categorical')
ground_truth = validation_generator.classes
```

```
Found 20 images belonging to 2 classes.
```

In [11]:
```
predictions = model.predict(validation_generator)
```

In [12]:
```
# Let's view the names of the files.
filenames = validation_generator.filenames
print(len(filenames))
print(filenames[:10])
```

```
20
['no/25 no.jpg', 'no/26 no.jpg', 'no/27 no.jpg', 'no/28 no.jpg', 'no/29 no.jpg',
'no/30 no.jpg', 'no/31 no.jpg', 'no/32 no.jpg', 'no/33 no.jpg', 'no/34 no.jpg']
```

In [13]:
```
ground_truth = validation_generator.classes
print(ground_truth[:10])
print(len(ground_truth))
```

```
[0 0 0 0 0 0 0 0 0 0]
20
```

In [14]:
```
label_to_index = validation_generator.class_indices
print(label_to_index)
```

```
{'no': 0, 'yes': 1}
```

In [15]:
```
index_to_label = dict((v, k) for k, v in label_to_index.items())
print(index_to_label)
```

```
{0: 'no', 1: 'yes'}
```

In [16]:
```
print(predictions[:10])
```

```
[[9.9759454e-01 2.4054479e-03]
 [9.9932671e-01 6.7331141e-04]
 [9.9705410e-01 2.9458993e-03]
 [8.1740201e-01 1.8259797e-01]
 [9.8511904e-01 1.4880883e-02]
 [9.9567223e-01 4.3277773e-03]
 [9.9107111e-01 8.9289034e-03]
 [9.0196651e-01 9.8033525e-02]
 [6.2941438e-01 3.7058565e-01]
 [9.9158597e-01 8.4140431e-03]]
```

In [17]:
```
prediction_index = []
for prediction in predictions:
    prediction_index.append(np.argmax(prediction))
```

In [18]:
```
prediction_index
```

Out[18]:
```
[0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1]
```

In [19]:
```
def accuracy(predictions, ground_truth):
    total = 0
    for i, j in zip(predictions, ground_truth):
        if i == j:
```

```
            total += 1
    return total * 1.0 / len(predictions)
```

In [20]:
```
print(accuracy(prediction_index, ground_truth))
```

```
0.55
```

In [21]:
```
# prediction_table is a dict with index, prediction, ground truth
prediction_table = {}

for index, val in enumerate(predictions):
    # get argmax index
    index_of_highest_probability = np.argmax(val)
    value_of_highest_probability = val[index_of_highest_probability]
    prediction_table[index] = [value_of_highest_probability,
                               index_of_highest_probability, ground_truth[index]]

assert len(predictions) == len(ground_truth) == len(prediction_table)
```

In [22]:
```
prediction_table
```

Out[22]:
```
{0: [0.99759454, 0, 0],
 1: [0.9993267, 0, 0],
 2: [0.9970541, 0, 0],
 3: [0.817402, 0, 0],
 4: [0.98511904, 0, 0],
 5: [0.9956722, 0, 0],
 6: [0.9910711, 0, 0],
 7: [0.9019665, 0, 0],
 8: [0.6294144, 0, 0],
 9: [0.99158597, 0, 0],
 10: [0.9877315, 0, 1],
 11: [0.9642998, 0, 1],
 12: [0.95570916, 0, 1],
 13: [0.9616493, 0, 1],
 14: [0.56241894, 0, 1],
 15: [0.5782294, 0, 1],
 16: [0.7288066, 0, 1],
 17: [0.64945865, 0, 1],
 18: [0.8098252, 0, 1],
 19: [0.60328424, 1, 1]}
```

In [23]:
```
def get_images_with_sorted_probabilities(prediction_table,
                                         get_highest_probability,
                                         label,
                                         number_of_items,
                                         only_false_predictions=False):
    sorted_prediction_table = [(k, prediction_table[k])
                               for k in sorted(prediction_table,
                                               key=prediction_table.get,
                                               reverse=get_highest_probability)
                               ]
    result = []
    for index, key in enumerate(sorted_prediction_table):
        image_index, [probability, predicted_index, gt] = key
        if predicted_index == label:
            if only_false_predictions == True:
                if predicted_index != gt:
                    result.append(
                        [image_index, [probability, predicted_index, gt]])
            else:
                result.append(
```

```
                    [image_index, [probability, predicted_index, gt]])
    return result[:number_of_items]
```

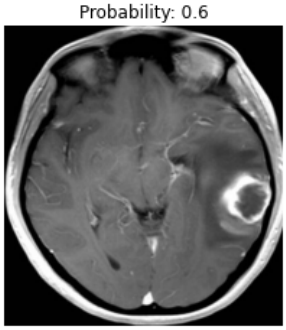
In [24]:
```
def plot_images(filenames, distances, message):
    images = []

    for filename in filenames:
        images.append(mpimg.imread(filename))
    plt.figure(figsize=(20, 15))
    columns = 5
    for i, image in enumerate(images):
        ax = plt.subplot(len(images) / columns + 1, columns, i + 1)
        ax.set_title("\n\n" + filenames[i].split("/")[-1] + "\n" +
                     "\nProbability: " +
                     str(float("{0:.2f}".format(distances[i]))))
        plt.suptitle(message, fontsize=20, fontweight='bold')
        plt.axis('off')
        plt.imshow(image)

def display(sorted_indices, message):
    similar_image_paths = []
    distances = []

    for name, value in sorted_indices:
        [probability, predicted_index, gt] = value
        similar_image_paths.append(VALIDATION_DATA_DIR + filenames[name])
        distances.append(probability)
    plot_images(similar_image_paths, distances, message)
```

In [25]:
```
most_confident_tumor_images = get_images_with_sorted_probabilities(prediction_ta
message = 'Images with highest probability of containing brain tumor'
display(most_confident_tumor_images, message)
```

Images with highest probability of containing brain tumor

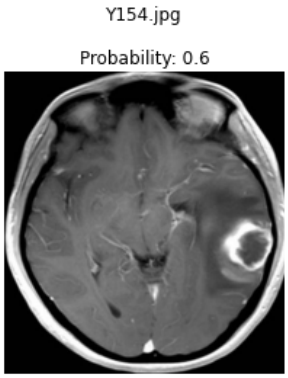
Y154.jpg

Probability: 0.6



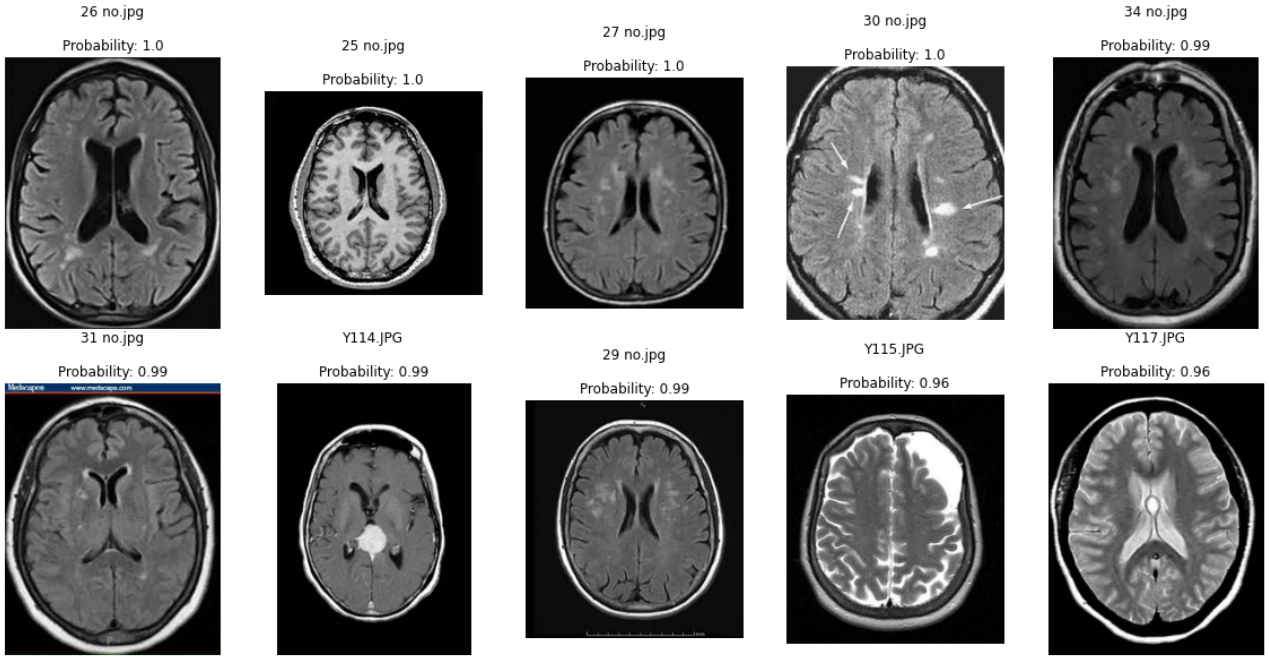
In [26]:
```
least_confident_tumor_images = get_images_with_sorted_probabilities(prediction_t
message = 'Images with lowest probability of containing brain tumor'
display(least_confident_tumor_images, message)
```

Images with lowest probability of containing brain tumor



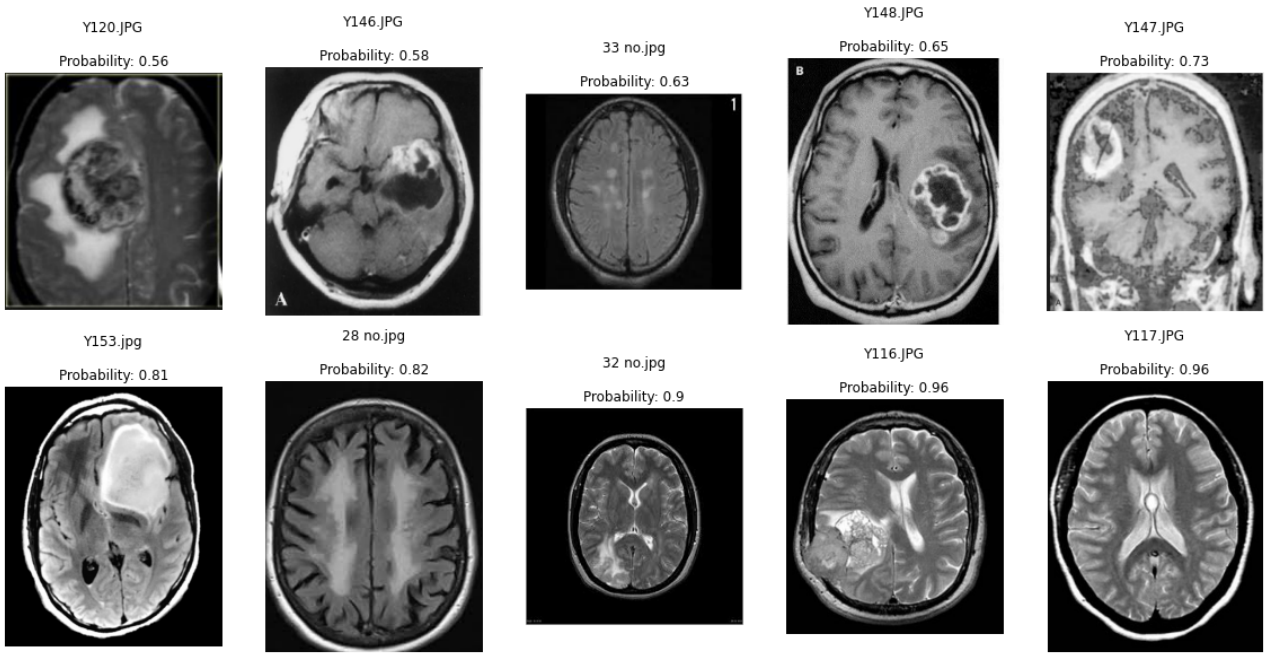
In [27]:
```
most_confident_no_tumor_images = get_images_with_sorted_probabilities(prediction
message = 'Images with highest probability of not containing any tumor'
display(most_confident_no_tumor_images, message)
```

Images with highest probability of not containing any tumor



In [28]:
```
least_confident_no_tumor_images = get_images_with_sorted_probabilities(predictio
                                                                        False)
```

```
message = 'Images with lowest probability of not containing any tumor'
display(least_confident_no_tumor_images, message)
```



In [ ]: