log_model

April 27, 2023

```
[1]: import ants
     import glob
     import os
     from sklearn.decomposition import PCA
     from sklearn.model_selection import train_test_split
     from sklearn.preprocessing import StandardScaler
     from sklearn.linear_model import LogisticRegression
     from multiprocessing import Pool
     import gc

     import pandas as pd
     import numpy as np
     import matplotlib.pyplot as plt
```

0.1 Read in the data

All data is in one folder, so we need to split the files into white matter and gray matter

```
[2]: def get_ordered_files(directory, prefix):

         # Get a list of all files in the directory
         all_files = os.listdir(directory)

         # Filter files that start with prefix
         files = [f for f in all_files if f.startswith(prefix)]

         # Filter again for wm and gm
         gm_files = [f for f in files if f.endswith('-gm.nii.gz')]
         wm_files = [f for f in files if f.endswith('-wm.nii.gz')]

         # Sort the files list
         sorted_gm_files = sorted(gm_files)
         sorted_wm_files = sorted(wm_files)

         return sorted_gm_files, sorted_wm_files
```

[3]:
```
data_path = '/scratch/users/neuroimage/conda/data'
img_path = os.path.join(data_path, 'preprocessed/imgsss')

smt_files_gm, smt_files_wm = get_ordered_files(img_path, "smt")
snmt_files_gm, snmt_files_wm = get_ordered_files(img_path, "snmt")
nsmt_files_gm, nsmt_files_wm = get_ordered_files(img_path, "nsmt")
```

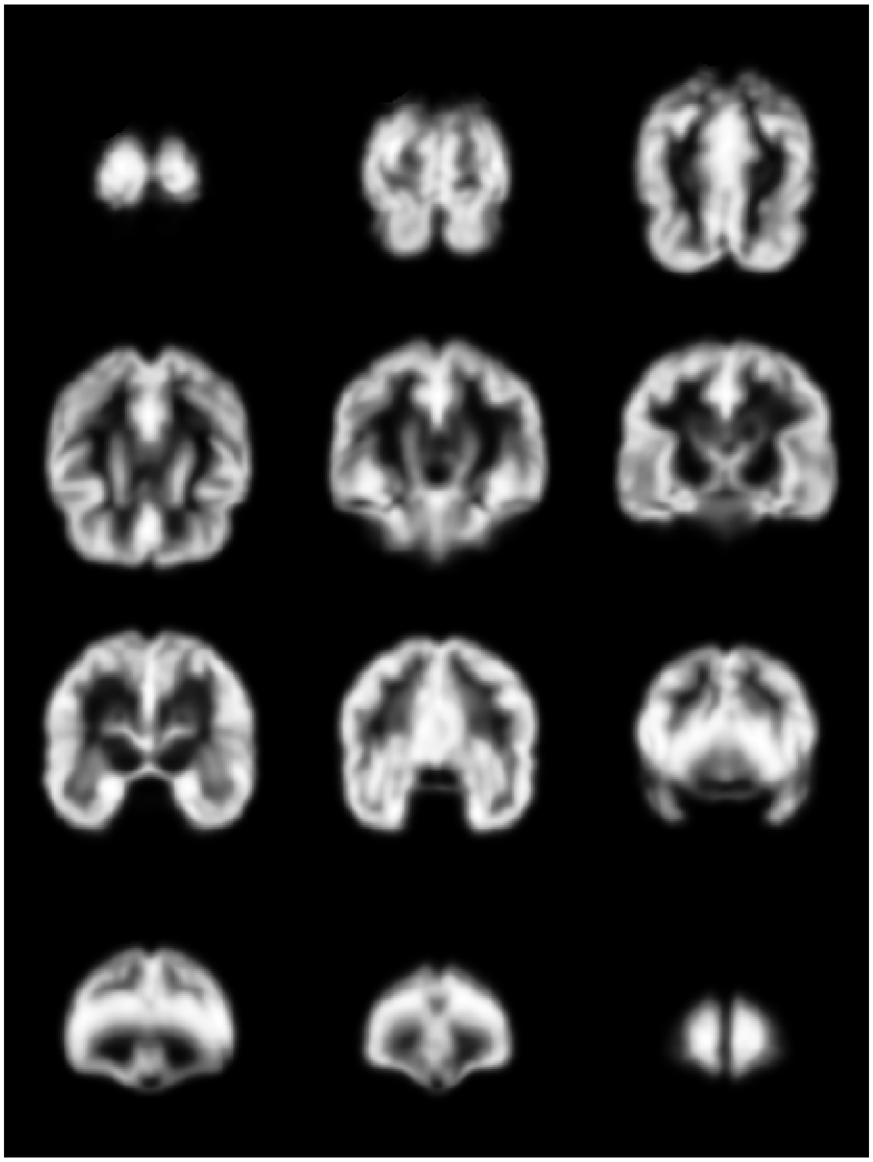
[4]:
```
print(smt_files_gm[0], smt_files_wm[0])
print(snmt_files_gm[0], snmt_files_wm[0])
print(nsmt_files_gm[0], nsmt_files_wm[0])
```

```
smt-002_S_0413-I118675-gm.nii.gz smt-002_S_0413-I118675-wm.nii.gz
snmt-002_S_0413-I118675-gm.nii.gz snmt-002_S_0413-I118675-wm.nii.gz
nsmt-002_S_0413-I118675-gm.nii.gz nsmt-002_S_0413-I118675-wm.nii.gz
```

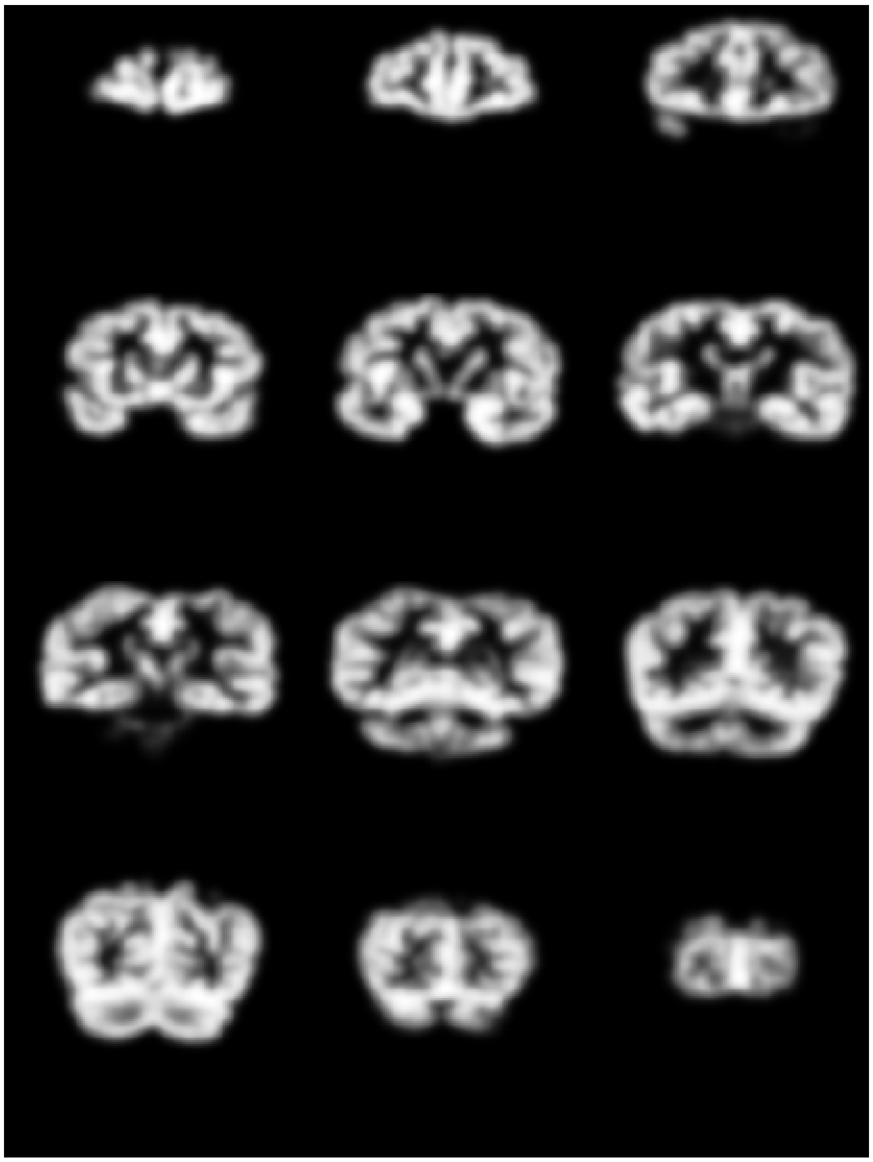
Visualizing the difference in smooth mapped to template, smooth but not mapped to template and not smooth but mappyed to template

[5]:
```
print("SMT")
ants.plot(os.path.join(img_path, smt_files_gm[1]),axis=1)
print("SNMT")
ants.plot(os.path.join(img_path, snmt_files_gm[0]),axis=1)
print("NSMT")
ants.plot(os.path.join(img_path, nsmt_files_gm[0]),axis=1)
print("SMT")
ants.plot(os.path.join(img_path, smt_files_wm[0]),axis=1)
print("SNMT")
ants.plot(os.path.join(img_path, snmt_files_wm[0]),axis=1)
print("NSMT")
ants.plot(os.path.join(img_path, nsmt_files_wm[0]),axis=1)
```

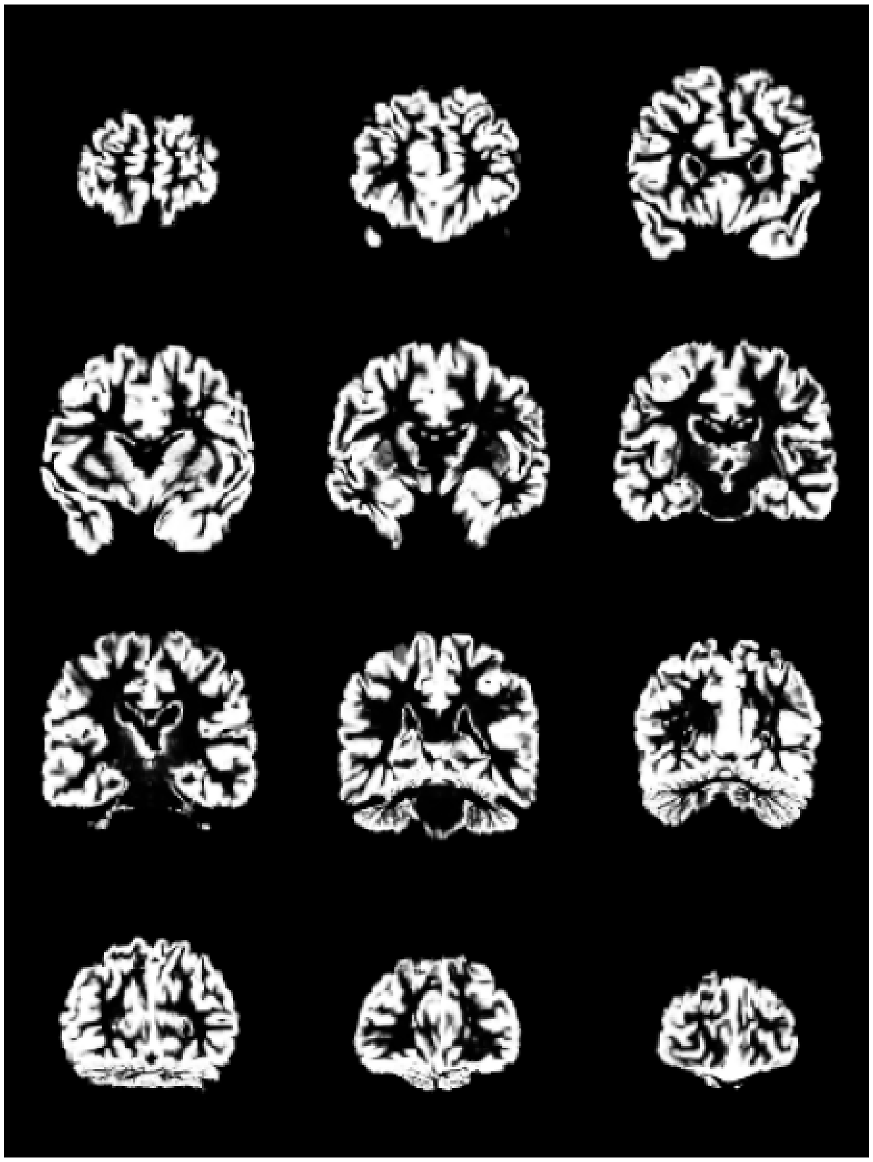
```
SMT
```



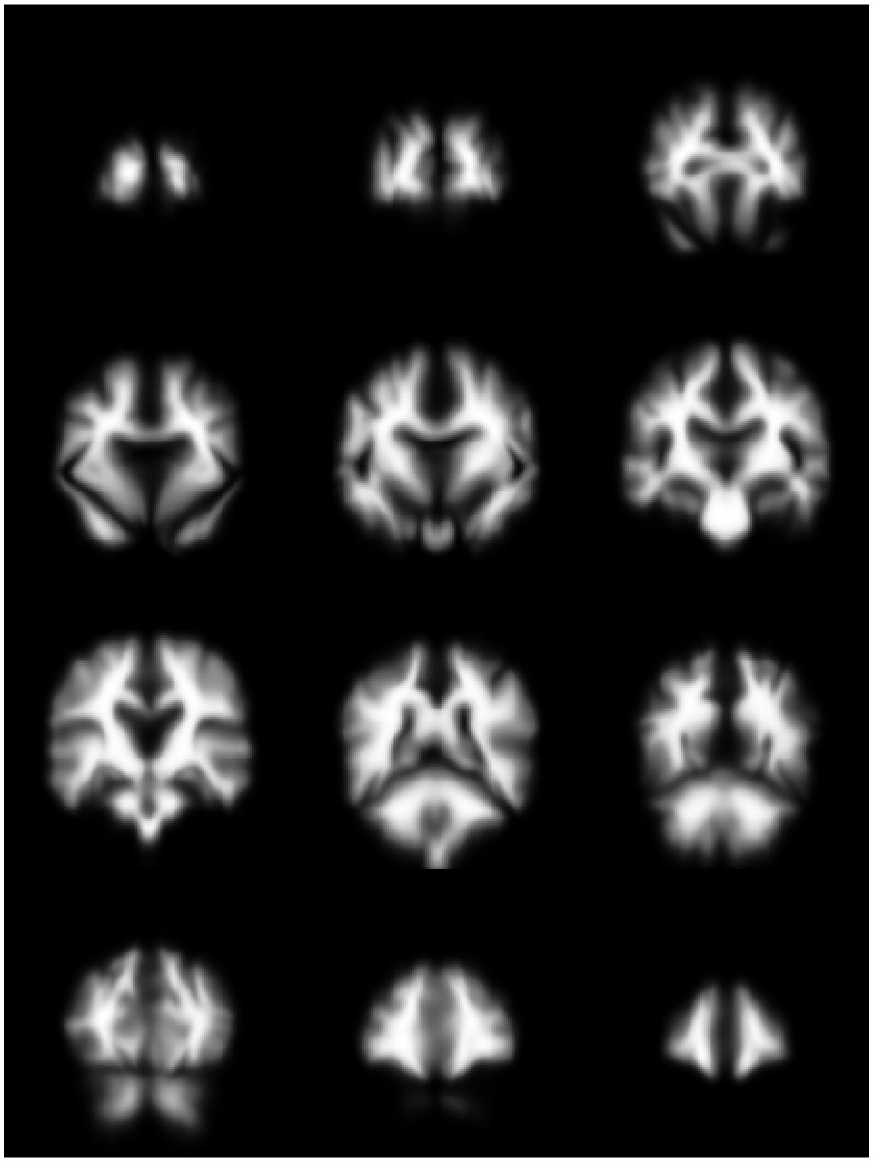
SNMT



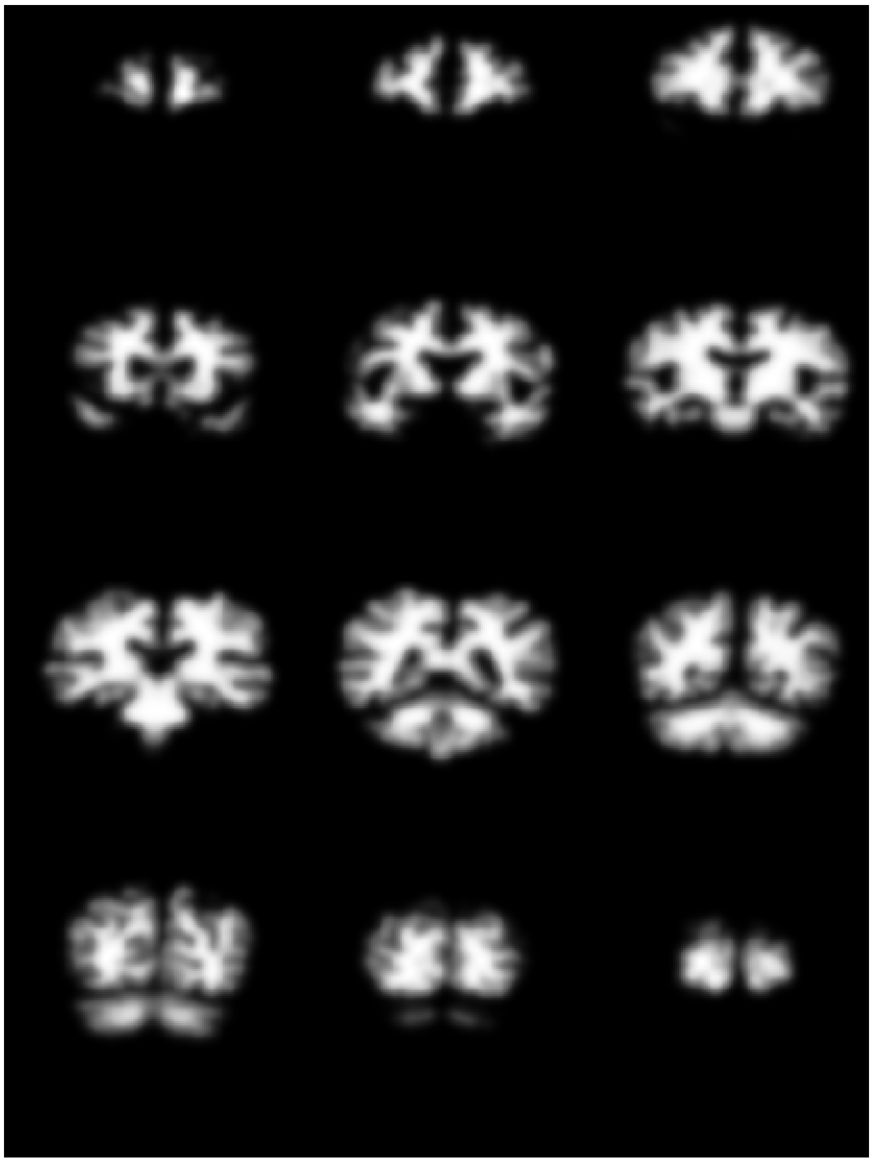
NSMT



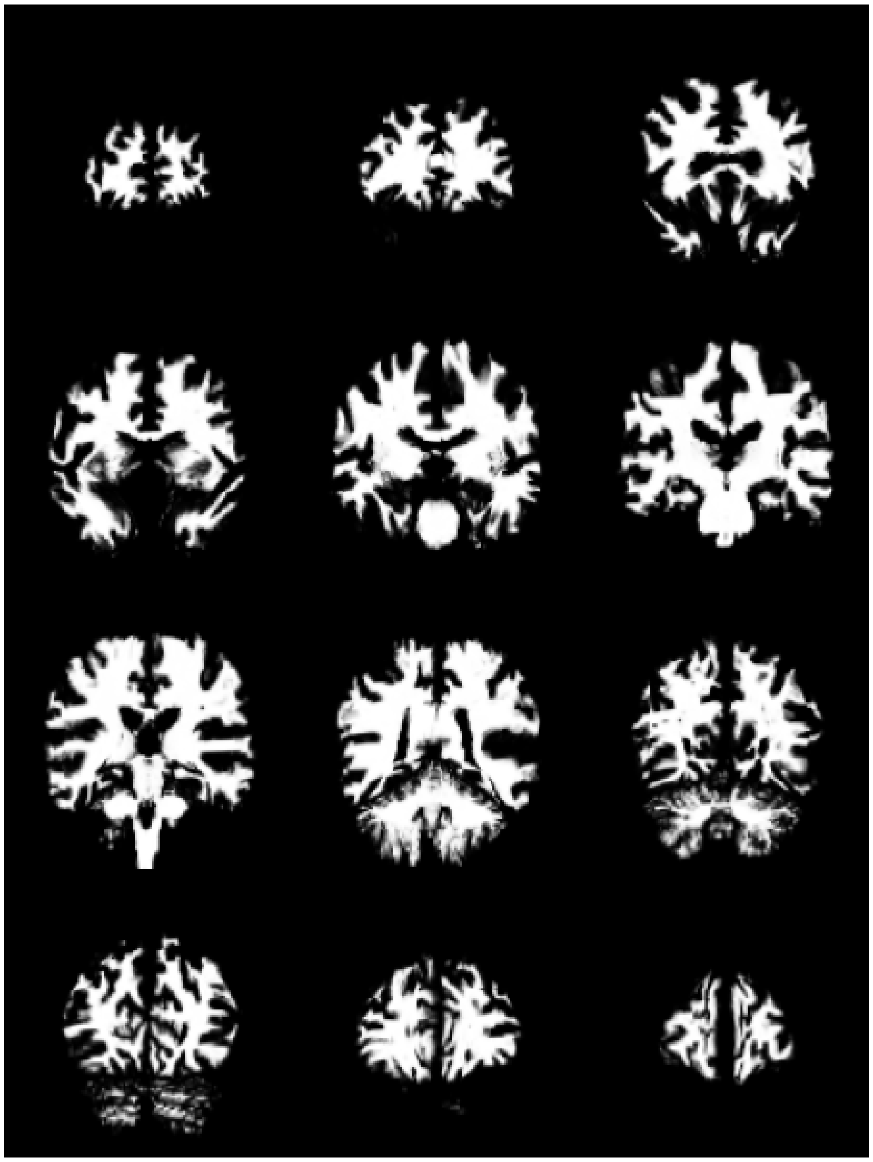
SMT



SNMT



NSMT



0.2 Create Design Matrix

[6]:
```python
def imgs_to_matrix(directory, wm_files=None, gm_files=None, combine=False):
    imgs = []

    if combine:

        for file_grouping in zip(wm_files, gm_files):
            wm_path, gm_path = file_grouping

            wm_img = ants.image_read(os.path.join(directory, wm_path))
            gm_img = ants.image_read(os.path.join(directory, gm_path))

            # Clone the white matter image
            comb_img = ants.image_clone(wm_img)

            # Add the gray matter image to the combined image
            comb_img = comb_img + gm_img

            # grab subject and img info
            sub_id_wm, img_id_wm = wm_path.split('-')[1:3]
            sub_id_gm, img_id_gm = gm_path.split('-')[1:3]

            if sub_id_wm != sub_id_gm:
                raise ValueError(f'wm id:{sub_id_wm} ne to gm id:{sub_id_gm}')

            vector =  comb_img.numpy().ravel()

            # turn to matrix, then to 1D array
            img_vec = np.append([sub_id_wm, img_id_wm], vector)
            imgs.append(img_vec)

        X = np.vstack(imgs)
        return X

    else:
        all_files = [wm_files, gm_files]
        both_Xs = []
        for files in all_files:
            imgs = []
            for path in files:
                img = ants.image_read(os.path.join(directory, path))

                # grab subject and img info
                sub_id, img_id = path.split('-')[1:3]

                vector =  img.numpy().ravel()

                # turn to matrix, then to 1D array
                img_vec = np.append([sub_id, img_id], vector)
                imgs.append(img_vec)

            # stack the vectors into a 2D array
            X = np.vstack(imgs)
            both_Xs.append(X)

        # wm_X, gm_X
        return both_Xs
```

```
[7]: def matrix_to_df(X):
         # V: Voxel intensity
         # turn matrix to dataframe and name columns
         X_cols = ['Subject', 'Img_ID'] + ['V{}'.format(i+1) for i in range(X.
      ↪shape[1]-2)]
         X_df = pd.DataFrame(X, columns=X_cols)

         return X_df

     def clean_data(X_df, md):
         # merge two dfs
         X_cl = md.merge(X_df, on=['Subject', 'Img_ID'])
         X_cl = X_cl.drop(columns=['Img_ID', 'Subject'])

         # create X and y
         y = X_cl['Group'].values
         X = X_cl.drop(columns=['Group'])

         return X, y


     def get_metadata(data_path):
         # Clean metadata dataframe
         md = pd.read_csv(os.path.join(data_path, 'ADNI1_Complete_2Yr_3T_4_18_2023.
      ↪csv'))

         md = md.rename(columns={'Image Data ID': 'Img_ID'})

         md = md.drop(columns=['Visit', 'Modality', 'Description', 'Type', 'Acq␣
      ↪Date', 'Format', 'Downloaded'])

         md['Group'] = md['Group'].map({'CN':0, 'MCI':1, 'AD':2})
         md['Sex'] = md['Sex'].map({'F':0, 'M':1})

         return md
```

Testing out individual functions

```
[8]: X_wm, X_gm = imgs_to_matrix(img_path, smt_files_gm[0:5], smt_files_wm[0:5],␣
      ↪combine=False)
     X_comb = imgs_to_matrix(img_path, smt_files_gm[0:5], smt_files_wm[0:5],␣
      ↪combine=True)
```

```
[9]: md = get_metadata(data_path)
     md.head()
```

```
[9]:      Img_ID     Subject  Group  Sex  Age
     0  I205567  136_S_1227      1    0   66
     1   I166824  136_S_1227      1    0   65
     2   I79080  136_S_1227      1    0   65
     3  I143856  136_S_1227      1    0   67
     4   I99265  136_S_1227      1    0   66
```

```
[10]: df = matrix_to_df(X_comb)
      df.head()
```

```
[10]:       Subject   Img_ID   V1   V2   V3   V4   V5   V6   V7   V8  … V2122936  \
     0  002_S_0413  I118675  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  …      0.0
     1  002_S_0413  I120746  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  …      0.0
     2  002_S_0413  I128346  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  …      0.0
     3  002_S_0413   I40657  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  …      0.0
     4  002_S_0413   I64551  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  …      0.0

       V2122937 V2122938 V2122939 V2122940 V2122941 V2122942 V2122943 V2122944  \
     0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
     1      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
     2      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
     3      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
     4      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0

       V2122945
     0      0.0
     1      0.0
     2      0.0
     3      0.0
     4      0.0

     [5 rows x 2122947 columns]
```

```
[11]: X, y = df.pipe(clean_data, md=md)
```

```
[12]: X.head()
```

```
[12]:    Sex  Age   V1   V2   V3   V4   V5   V6   V7   V8  … V2122936 V2122937  \
     0    0   79  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  …      0.0      0.0
     1    0   76  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  …      0.0      0.0
     2    0   77  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  …      0.0      0.0
     3    0   76  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  …      0.0      0.0
     4    0   77  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  …      0.0      0.0

       V2122938 V2122939 V2122940 V2122941 V2122942 V2122943 V2122944 V2122945
     0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
     1      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
```

```
2       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
3       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
4       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0

[5 rows x 2122947 columns]
```

0.3 PCA and Logistic Regression

[13]:
```
def perform_pca(X, y):
    # Split the data into train and test sets
    X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2,␣
 ↪random_state=10)

    # Preprocess and scale the data
    scaler = StandardScaler()
    X_train_scaled = scaler.fit_transform(X_train)
    X_test_scaled = scaler.transform(X_test)

    # Fit and transform the PCA model on the training set
    pca = PCA(random_state=10)

    X_train_pca = pca.fit_transform(X_train_scaled)

    # calculate cumulative variance
    cumulative_variance = np.cumsum(pca.explained_variance_ratio_)

    # find the index where cumulative variance reaches 95%
    n_components = np.argmax(cumulative_variance >= 0.95) + 1
    print(f'n components:{n_components}')

    # re-fit PCA with the chosen number of components
    pca = PCA(n_components=n_components, random_state=10)
    X_train_pca = pca.fit_transform(X_train_scaled)

    # Transform the test set using the trained PCA model
    X_test_pca = pca.transform(X_test_scaled)

    return X_train_pca, y_train, X_test_pca, y_test


def perform_logreg(X_train_pca, y_train, X_test_pca, y_test):
    clf = LogisticRegression(random_state=10, penalty=None,␣
 ↪multi_class='multinomial', max_iter=1000).fit(X_train_pca, y_train)
    y_preds = clf.predict(X_test_pca)

    acc = sum(y_preds == y_test) / len(y_test)
    return acc


def full_pipeline(X_matrix):

    md = get_metadata(data_path)

    df = matrix_to_df(X_matrix)

    X, y = df.pipe(clean_data, md=md)

    X_train_pca, y_train, X_test_pca, y_test = perform_pca(X, y)

    return X_train_pca, y_train, X_test_pca, y_test
```

0.4 Comparisons

[14]:
```
X_wm, X_gm = imgs_to_matrix(img_path, smt_files_gm, smt_files_wm, combine=False)
X_comb = imgs_to_matrix(img_path, smt_files_gm, smt_files_wm, combine=True)
```

[15]:
```
X_train_wm, y_train_wm, X_test_wm, y_test_wm = full_pipeline(X_wm)
X_train_gm, y_train_gm, X_test_gm, y_test_gm = full_pipeline(X_gm)
X_train_cb, y_train_cb, X_test_cb, y_test_cb = full_pipeline(X_comb)
```

```
n components:147
n components:160
n components:175
```

[16]:
```
base_pca_dir = os.path.join(data_path, 'base_pca_data')
os.makedirs(base_pca_dir, exist_ok=True)

arrs = {'X_train_wm': X_train_wm, 'y_train_wm': y_train_wm,
       'X_test_wm': X_test_wm, 'y_test_wm': y_test_wm,
       'X_train_gm': X_train_gm, 'y_train_gm': y_train_gm,
       'X_test_gm': X_test_gm, 'y_test_gm': y_test_gm,
       'X_train_cb': X_train_cb, 'y_train_cb': y_train_cb,
       'X_test_cb': X_test_cb, 'y_test_cb': y_test_cb,
      }

# loop through the dictionary and save each dataframe to CSV file
for name, arr in arrs.items():
    np.savetxt(os.path.join(base_pca_dir,f'{name}.csv'), arr, delimiter=',')
```

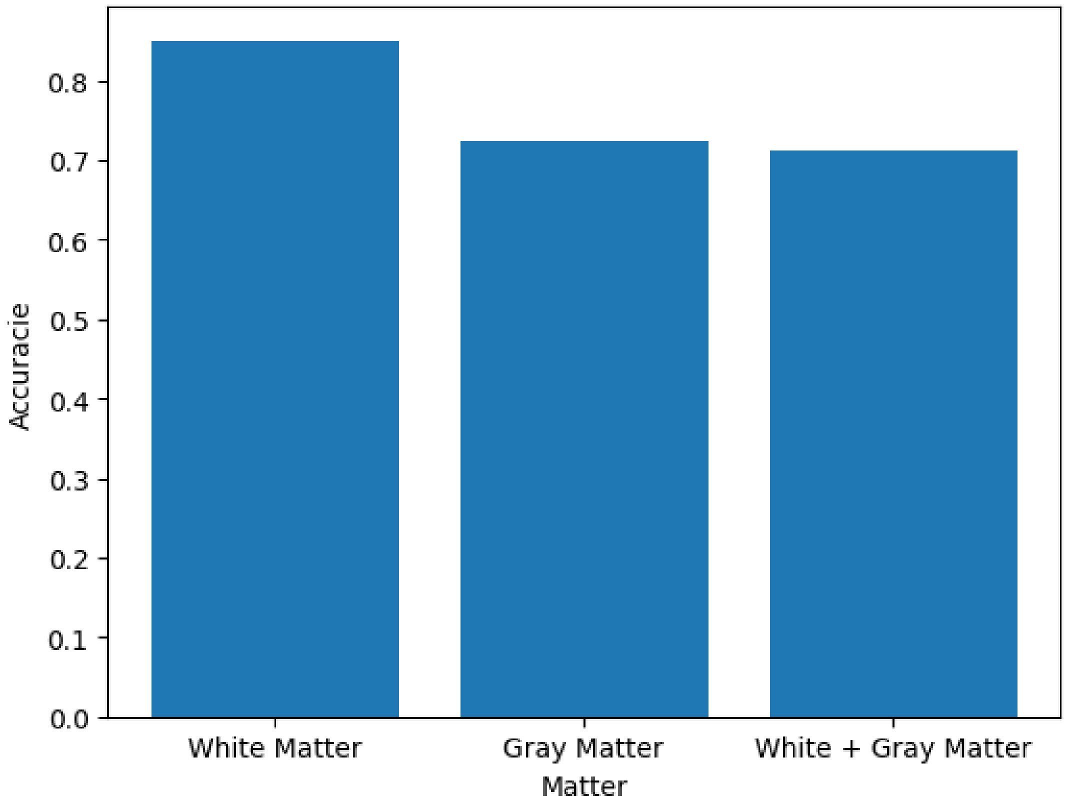
[17]:
```
logreg_wm_acc = perform_logreg(X_train_wm, y_train_wm, X_test_wm, y_test_wm)
logreg_gm_acc = perform_logreg(X_train_gm, y_train_gm, X_test_gm, y_test_gm)
logreg_cb_acc = perform_logreg(X_train_cb, y_train_cb, X_test_cb, y_test_cb)
```

[18]:
```python
print(f"Classification accuracy under WM data: {logreg_wm_acc}")
print(f"Classification accuracy under GM data: {logreg_gm_acc}")
print(f"Classification accuracy under Combined data: {logreg_cb_acc}")
```

```
Classification accuracy under WM data: 0.8505747126436781
Classification accuracy under GM data: 0.7241379310344828
Classification accuracy under Combined data: 0.7126436781609196
```

[19]:
```python
# Create a bar plot
accuracies = [logreg_wm_acc, logreg_gm_acc, logreg_cb_acc]
labels = ['White Matter', 'Gray Matter', 'White + Gray Matter']
plt.bar(labels, accuracies)

# Add labels and title
plt.xlabel('Matter')
plt.ylabel('Accuracie')
# plt.title('Bar plot of 3 values')
# Show the plot
plt.show()
```



Using white matter data for cross validation

[20]:
```python
from sklearn.model_selection import GridSearchCV

# define logistic regression model
lr = LogisticRegression(multi_class='multinomial', random_state=10,␣
 ↪penalty=None, max_iter=1000)

# define solvers to test
solvers = ['lbfgs', 'newton-cg', 'sag', 'saga']

# define grid search parameters
param_grid = {'solver': solvers}

# perform grid search
grid_search = GridSearchCV(lr, param_grid=param_grid, cv=5)
grid_search.fit(X_train_wm, y_train_wm)

# get the best model
best_model = grid_search.best_estimator_
print(best_model)

# use the best model to make predictions on the test set
y_preds = best_model.predict(X_test_wm)

acc = sum(y_preds == y_test_wm) / len(y_test_wm)
print(f"{best_model} has accuracy: {acc}")
```

```
/scratch/users/neuroimage/conda/venv/lib/python3.11/site-
packages/sklearn/linear_model/_sag.py:350: ConvergenceWarning:

The max_iter was reached which means the coef_ did not converge

/scratch/users/neuroimage/conda/venv/lib/python3.11/site-
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/scratch/users/neuroimage/conda/venv/lib/python3.11/site-
```

```
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packages/sklearn/linear_model/_sag.py:350: ConvergenceWarning:

The max_iter was reached which means the coef_ did not converge


LogisticRegression(max_iter=1000, multi_class='multinomial', penalty=None,
                   random_state=10)
LogisticRegression(max_iter=1000, multi_class='multinomial', penalty=None,
                   random_state=10) has accuracy: 0.8505747126436781
```

```
[ ]:
```