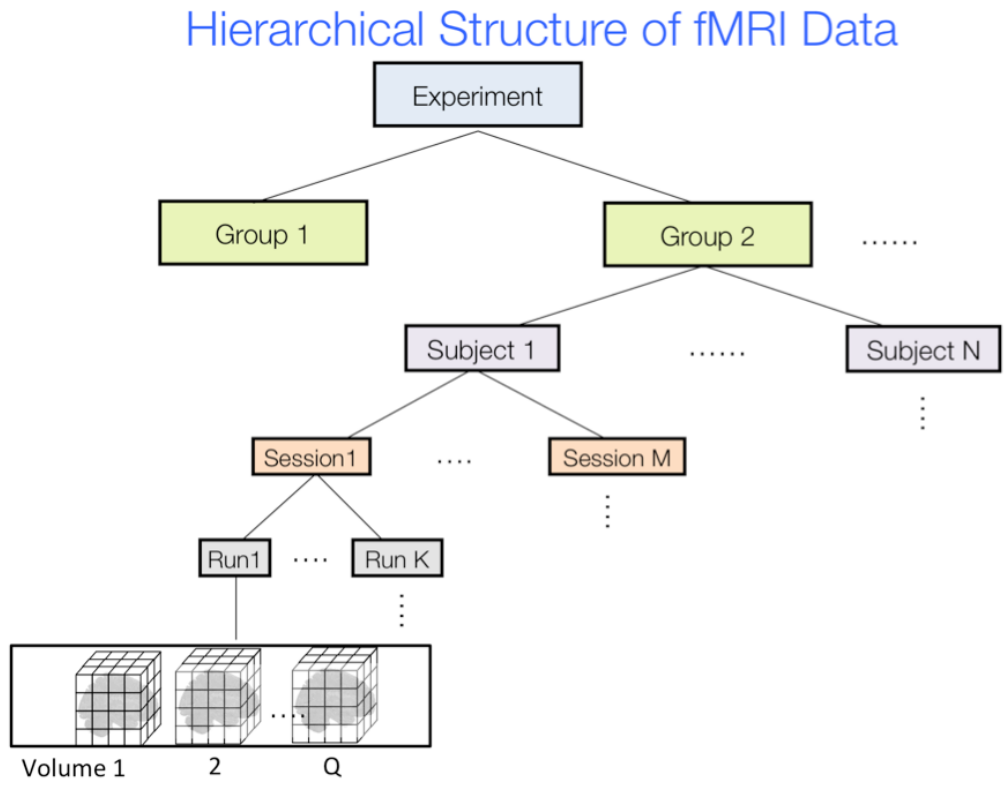
Why is the second-level analysis needed in fMRI?

- The fMRI experiment is hierarchical in nature, with lower-level observations nested within higher levels
- The second-level analysis in fMRI (Group analysis)
  - Summarize multi-subject fMRI results (single-level analysis)
  - Increase the experiment's overall effects
    - Allow you to determine whether observed effects are **common** across subjects
    - Allow your conclusions to be generalized to the entire population from which the subject was drawn



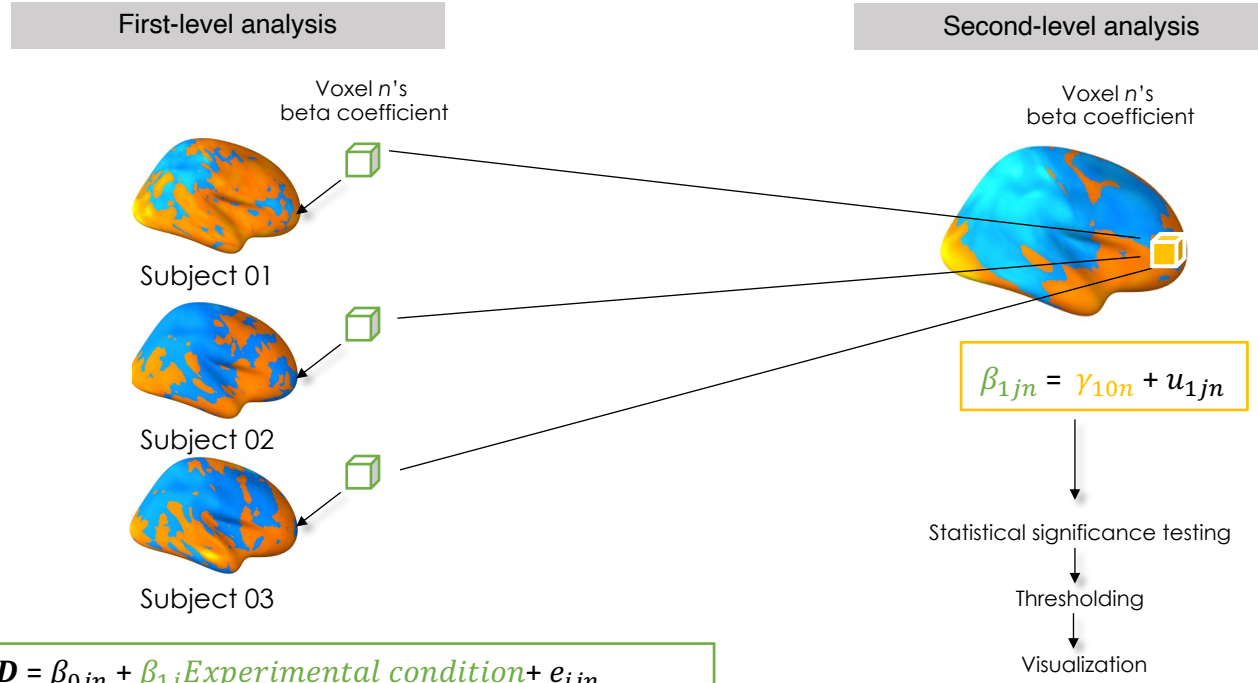
✓ In order to effectively compare data for specific voxels across subjects, it is important that all subjects are normalized to a stereotaxic space prior to comparison (e.g., MNI space)

Figure from Principles of fMRI (Wager and Lindquist)

When is the second-level analysis needed in fMRI?

- First, a first-level GLM is fitted separately to each subject
- In the second level, these beta images are used to perform statistical tests
  - A standard group analysis consists of specifying a second-level GLM model, this time using a set of beta images corresponding to a single beta (one per subject) as the response variable (y)

It's exactly same as multilevel modeling



$Y_{ijn}\boldsymbol{BOLD} = \beta_{0jn} + \beta_{1j}Experimental\ condition + e_{ijn}$

However, these analysis is performed by each voxel, which we called this **univariate analysis**. If you want to consider the patten of regions or multivariate pattern, MVPA or RSA (or machine learning approach) could be appropriate methods

When is the second-level analysis needed in fMRI?

- The second-level analysis refers to the group-level analysis, which means overall effects across subjects
- Therefore, it can be employed across different results such as ANOVA, contrast, or mediation analysis
- Issues:
  - Mixed effect model (Random, or mixed)
  - Estimation methods (OLS, WLS, MLE or REML)
  - This second-level analysis in fMRI can be affected by outliers due to subject number

→ Robust regression is a good method to overcome this limitation