MRC | Cognition and Brain Sciences Unit

Group analysis using GLM

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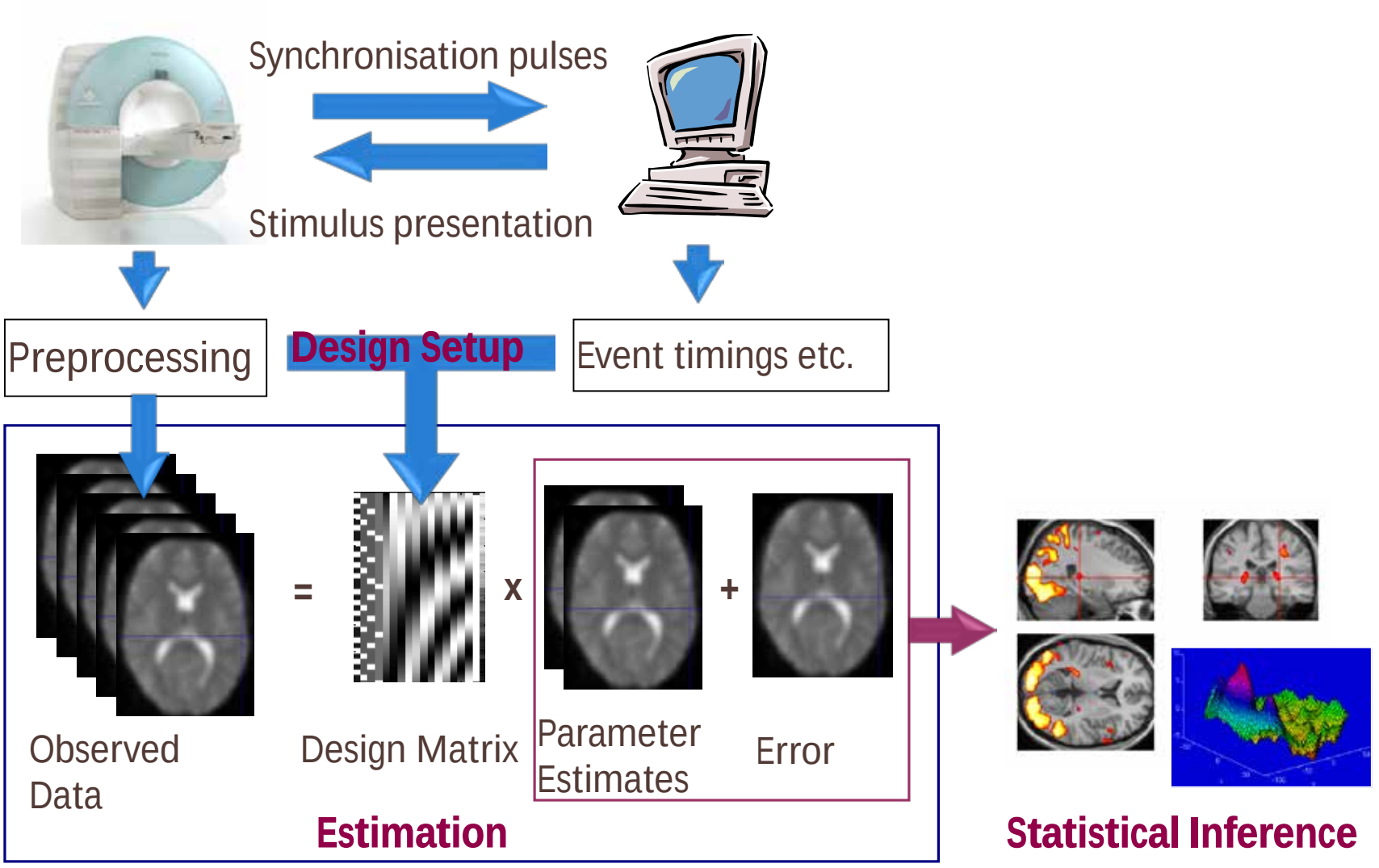
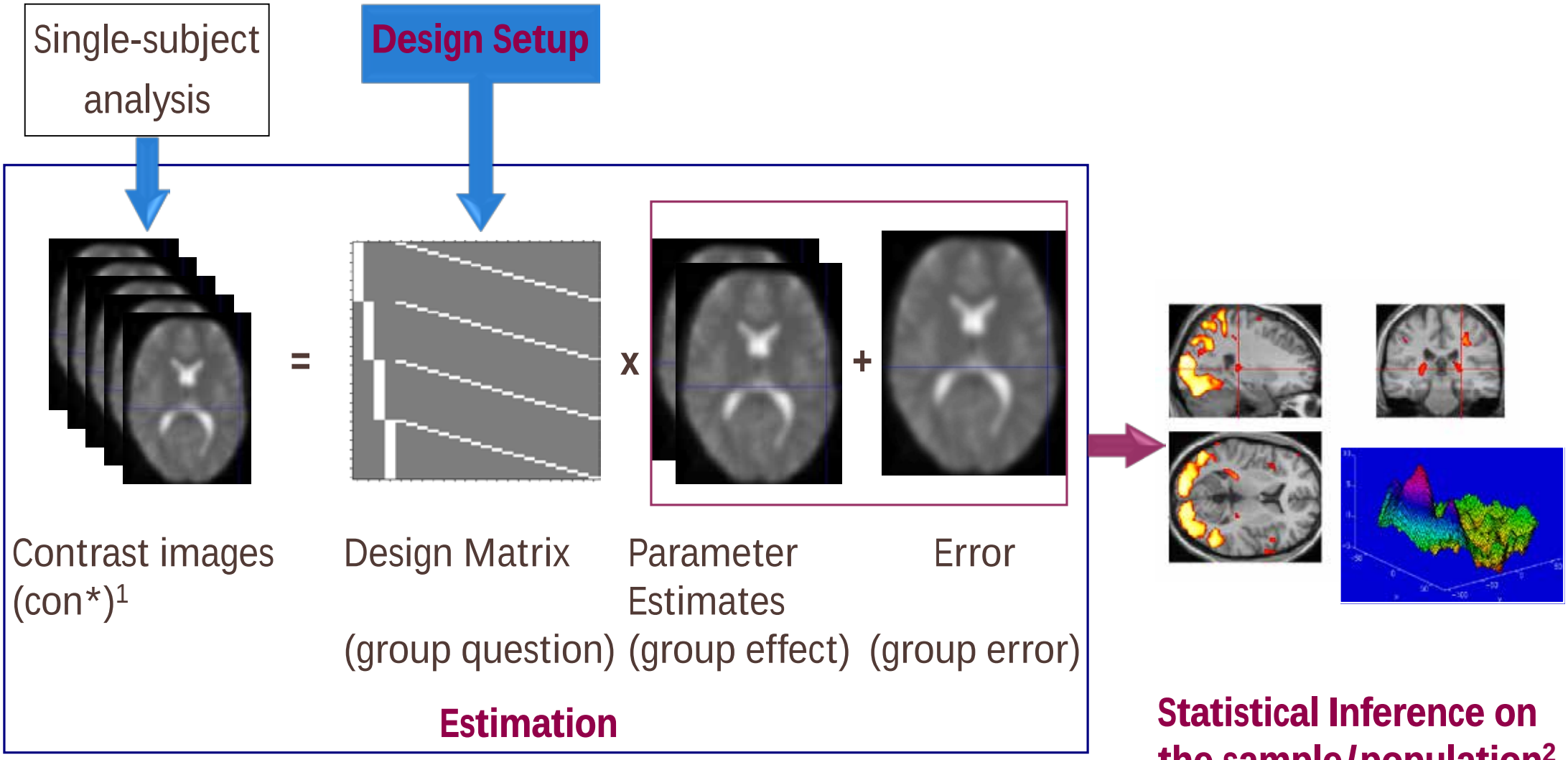
With thanks to Russell Thompson, Rik Henson, Matthew Brett and the authors of the HBF

A single-subject analysis



A group study



General Linear Model – Theory (rep.)

GLM

- models observed data (dependent variable) – **Y**
- as a linear combination (parameter estimate – **β**) of
- regressors/predictor variables/explanatory variables (EV) (independent variables) – **X**

$$Y = \beta X + \varepsilon$$

- AN(C)OVA, t-test, (multiple) regression, LDA, CCA are also GLMs.

- **Relationship between a dependent variable and one or more independent variables**

General Linear Model – Application in group

Mass univariate approach:

- Model **X** estimated for each voxel independently (multiple tests)
- For each voxel:
  - **Y**: **single-subject's "effect size"** at a single voxel
  - One **β** for each predictor

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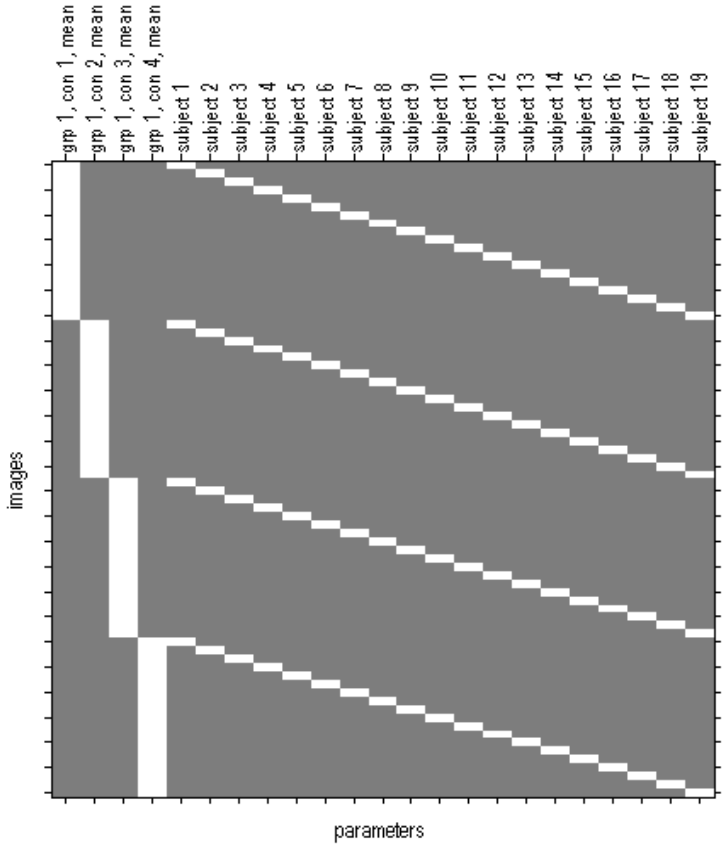
- Series of **β** images (betaXXXX)

General Linear Model – Application in group

Model:

- Contains all known source of variance:
  - Controlled factors (e.g. **groups, timepoints**)[1]
  - All nuisance variables
    - Repetition
    - Confounding factors (gender, age, IQ)

      à ANCOVA



Fixed vs. Random Effects

Fixed Effects (FFX) Analysis:

- Within-subject analysis:
  - Group effect / Within-subject variance

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- Inference:
  - only about the sample

(a new sample may not fit)

Random Effects (RFX) Analysis:

- Between-subject analysis:
  - Group effect / Between-subject variance

↓

- Inference:
  - about the population

(a new sample would fit)

Fixed vs. Random Effects

Fixed Effects (FFX) Analysis:

- Implementation:
  - **Multiple sessions of the same subject**
  - Temporal concatenation on the first-level
- aa:
  - *aas_addsession*
  - *aas_addcontrast* with "uniquebysession" – specifying the same contrast for every session in one vector

Random Effects (RFX) Analysis:

- Implementation:
  - **Multiple subjects**
  - Higher-level analysis
- aa:
  - *aamod_secondlevel_model*
    - Only for one-sample t-test
  - Manually (Rik's *batch_spm_anova*)

Sample dataset

Lexical Decision

Subjects:

- **19 subjects**
  - F/M: 12/7
  - Age:
    - Mean: 27.2
    - Range: 19-36

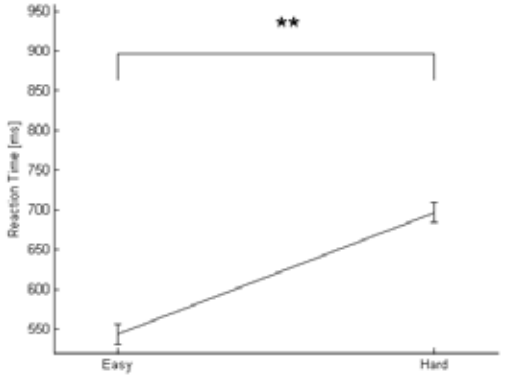
Task

- **Lexical decision: press a button for non-word**
  - Easy: words vs. consonants
  - Hard: words vs. pseudowords

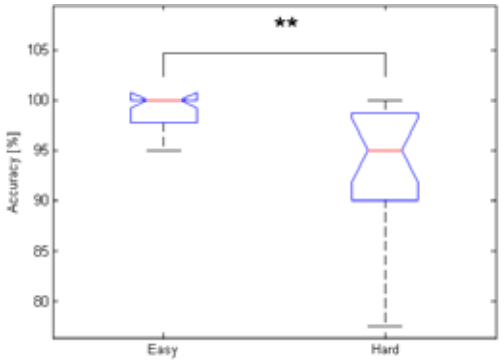
Sample dataset – Behaviour

Lexical Decision

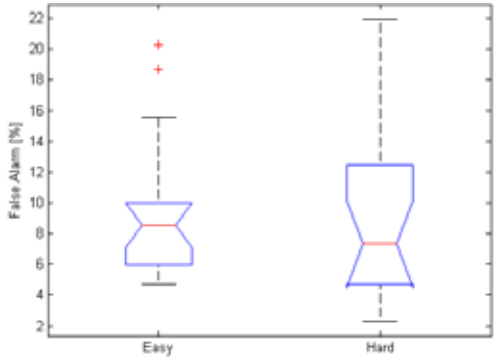
- **Reaction Time:**
  - Easy (Mean, SD): 544 ms, 55 ms
  - Hard (Mean, SD): 697 ms, 54 ms



- **Accuracy:**
  - Easy (Median, Q1-Q3): 100%, 98%-100%
  - Hard (Median, Q1-Q3): 95%, 90%-99%



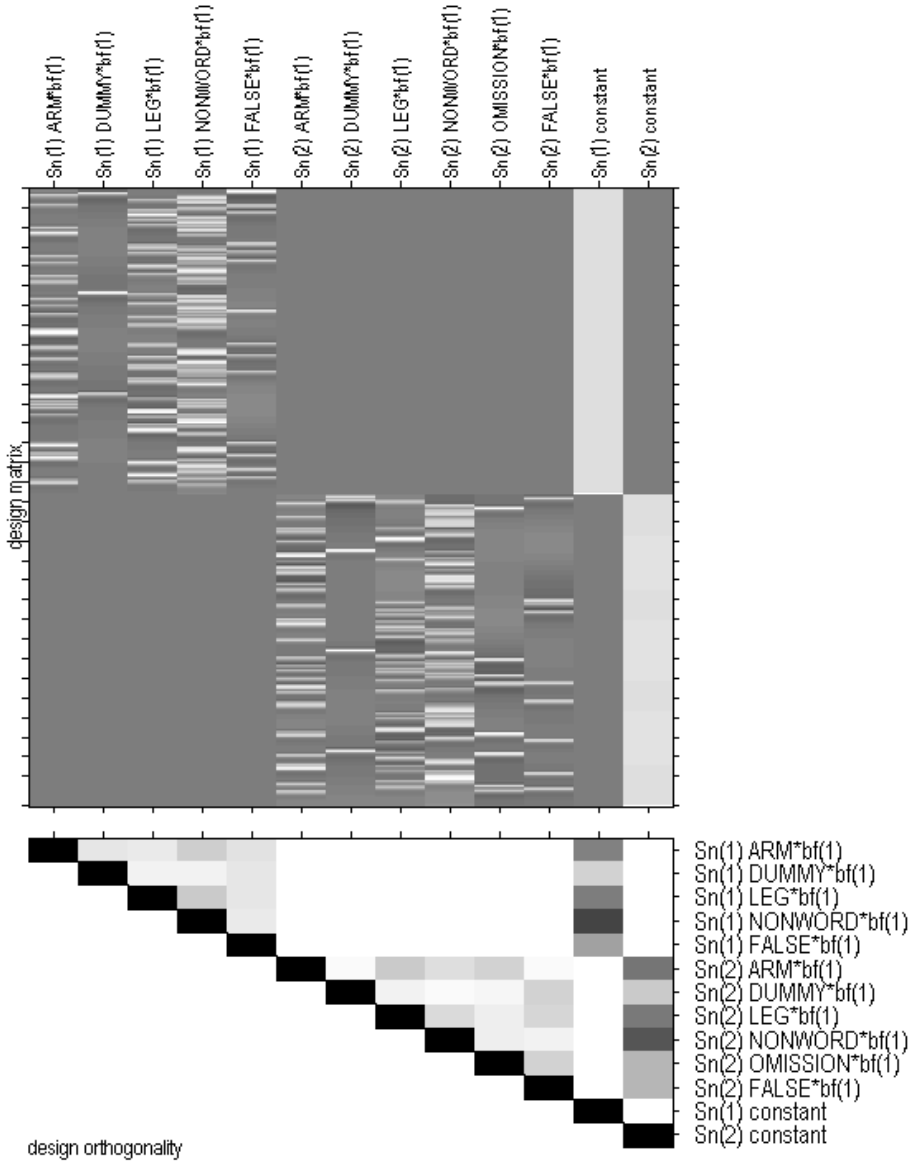
- **False Alarm:**
  - Easy (Median, Q1-Q3): 9%, 6%-10%
  - Hard (Median, Q1-Q3): 7%, 5%-12%



Sample dataset – First level design

Lexical Decision

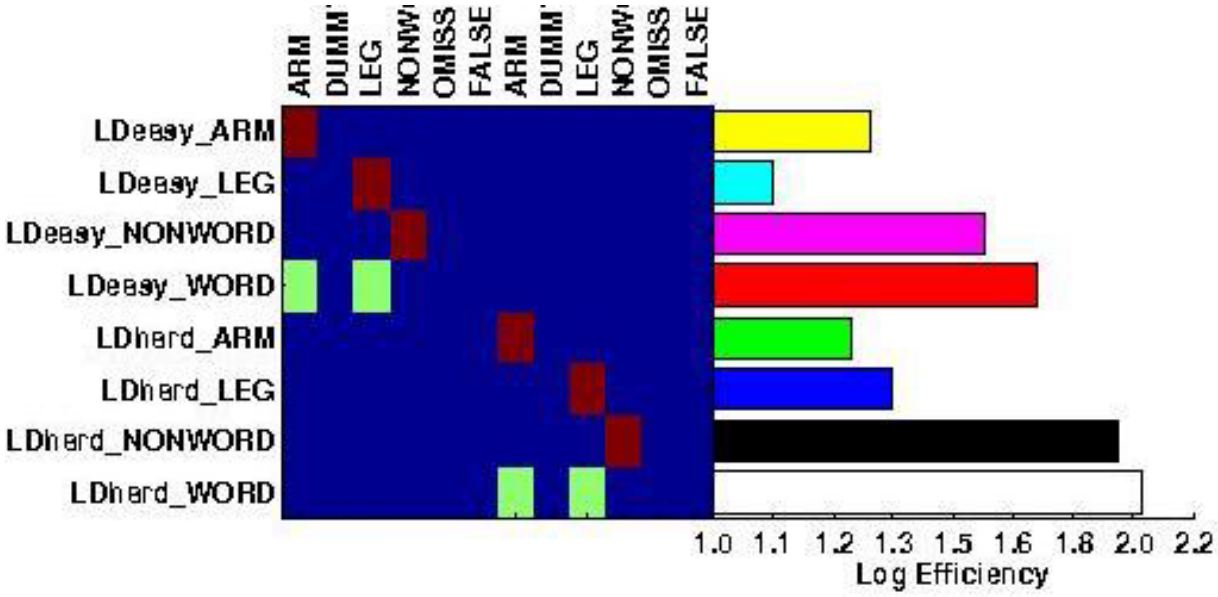
- **First-level model**
  - Concatenated
    - Easy
    - Hard
  - Regressors
    - ARM
    - DUMMY
    - LEG
    - NONWORD
    - OMISSION
    - FALSE (alarm)



Sample dataset – First level contrast

Lexical Decision

- **First-level contrasts**
  - Word
    - 0.5*ARM + 0.5*LEG
  - NonWord
    - 1*NONWORD



Sample dataset – Second level analysis

Scripts

Question	Test	Script
Group summary	One sample t-test	AA_LD_OsT.m
Group correlation	One sample t-test with covariate	AA_LD_OsT_Cov.m
Group (gender) difference	Two sample t-test	AA_LD_TsT.m
Group (gender) difference in correlation	Two sample t-test with covariate	AA_LD_TsT_Cov.m
Condition (Word vs. Non Word) difference	Paired sample t-test[1]	AA_LD_PsT.m
Condition (Easy vs. Hard) difference in correlation	Paired sample t-test with covariate[1]	AA_LD_PsT_Cov.m
Interaction between Groupings (Gender effect and Language)	ANOVA (2-way: 2×2)	AA_LD_ANOVA.m
Interaction between conditions (Easy vs. Hard and Word vs. Non Word)	Repeated-measure ANOVA (2-way: 2×2) [1]	AA_LD_ANOVArep.m
Interaction between Grouping (Gender effect) and Condition (Word vs. Non Word)	Mixed ANOVA (2-way: 2×2)	AA_LD_ANOVAmixed2.m
Interaction between Grouping (Gender effect), Task Difficulty (Easy vs. Hard) and Lexicality (Word vs. Non Word)	Mixed ANOVA (3-way: 2×2×2)	AA_LD_ANOVAmixed3.m

Sample dataset – Second level analysis

Group summary: One sample t-test

- AA_LD_OsT.m

Group correlation: One sample t-test with confounding variable (covariate)

- AA_LD_OsT_Cov.m

Group (gender) difference: Two sample t-test

- AA_LD_TsT.m

Condition (Word vs. Non Word) difference: Paired sample t-test

Modelling within-subject effect

- AA_LD_PsT.m

Sample dataset – Second level analysis

Interaction between Groupings (Gender effect and Language): ANOVA (2-way: 2×2)

- Between-subject effect: Grouping, Language (Native, Learned)

- Contrasts for Interaction:
  1. Learned Gender > Native Gender
  2. L(F>M) > N(F>M)
  3. (LF>LM) > (NF>NM)
  4. (LF-LM) - (NF-NM)
  5. LF-LM - NF+NM
  6. +NM -NF -LM +LF
  7. [1 -1 -1 1]

Language (Learned>Native)	-1	-1	1	1
Gender (Female>Male)	-1	1	-1	1
Interaction	**1**	**-1**	**-1**	**1**

Sample dataset – Second level analysis

Interaction between conditions (Easy vs. Hard and Word vs. Non Word): Repeated-measure ANOVA (2-way: 2×2)

- Modelling within-subject effect

Sample dataset – Second level analysis

Interaction between Grouping (Gender effect) and Condition (Word vs. Non Word): mixed ANOVA (2-way: 2×2)

- Between-subject effect: Grouping
- Within-subject effect (condition): Condition
  - Modelling within-subject effect

Sample dataset – Second level analysis

Interaction between Grouping (Gender effect), Task Difficulty (Easy vs. Hard) and Lexicality (Word vs. Non Word): mixed ANOVA (3-way: 2×2×2)

- Between-subject effect: Grouping
- Within-subject effects (conditions): Task Difficulty, Condition
  - Modelling within-subject effect

- Contrast for 3-way interaction:
  1. Female Interaction (Task×Lexicality) > Male Interaction (Task×Lexicality)
  2. Female(Hard Lexicality > Easy Lexicality) > Male(Hard Lexicality > Easy Lexicality)
  3. G2(H(N>W) > E(N>W)) > G1(H(N>W) > E(N>W))
  4. G2((HN>HW) > (EN>EW)) > G1((HN>HW) > (EN>EW))
  5. ((G2HN>G2HW) > (G2EN>G2EW)) > ((G1HN>G1HW) > (G1EN>G1EW))
  6. ((G2HN-G2HW) - (G2EN-G2EW)) - ((G1HN-G1HW) - (G1EN-G1EW))
  7. (G2HN-G2HW - G2EN+G2EW) - (G1HN-G1HW - G1EN+G1EW)
  8. G2HN-G2HW - G2EN+G2EW - G1HN+G1HW + G1EN-G1EW
  9. -G1EW +G1EN +G1HW -G1HN +G2EW -G2EN -G2HW +G2HN
  10. [-1 1 1 -1 1 -1 -1 1]

Sample dataset – Second level analysis

Interaction between Grouping (Gender effect), Task Difficulty (Easy vs. Hard) and Lexicality (Word vs. Non Word): mixed ANOVA (3-way: 2×2×2)

- Between-subject effect: Grouping
- Within-subject effects (conditions): Task Difficulty, Condition
  - Modelling within-subject effect

- Contrast for 3-way interaction:

Group (F>M)	-1	-1	-1	-1	1	1	1	1
Condition (H>E)	-1	-1	1	1	-1	-1	1	1
Condition (N>W)	-1	1	-1	1	-1	1	-1	1
Interaction	**-1**	**1**	**1**	**-1**	**1**	**-1**	**-1**	**1**