DIPF
Leibniz-Institut für Bildungsforschung und Bildungsinformation

IDeA
Individual Development and Adaptive Education

GOETHE UNIVERSITÄT FRANKFURT AM MAIN

Session 4: Inference II

Dr. Elena Galeano Weber

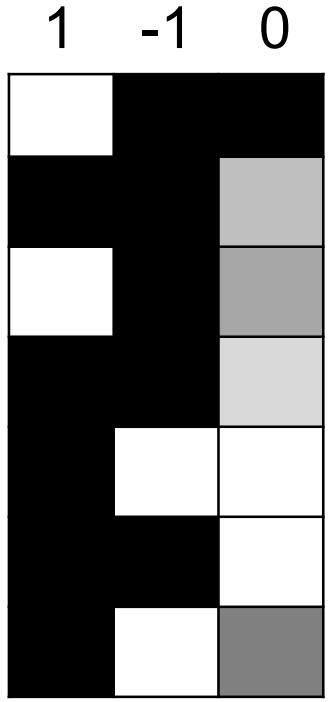
e.galeano-weber@dipf.de

Education and Human Development & Individualized Learning Laboratory, DIPF | Leibniz Institute for Research and Information in Education

Recap of last week

General recap.

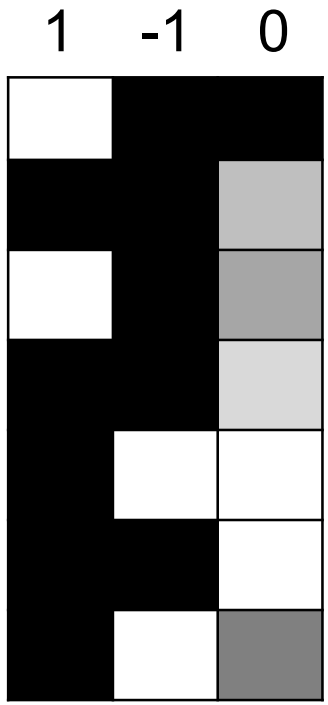
- Beta estimates cannot be interpreted directly.
- T and F contrasts can be used to compare conditions.
- Beware of contrasts against implicit baseline.
- Contrast vectors are widely used and powerful when we have complex comparisons.
- When designing an experiment, always chose an appropriate baseline.



Functional MRI. Group-level analysis.

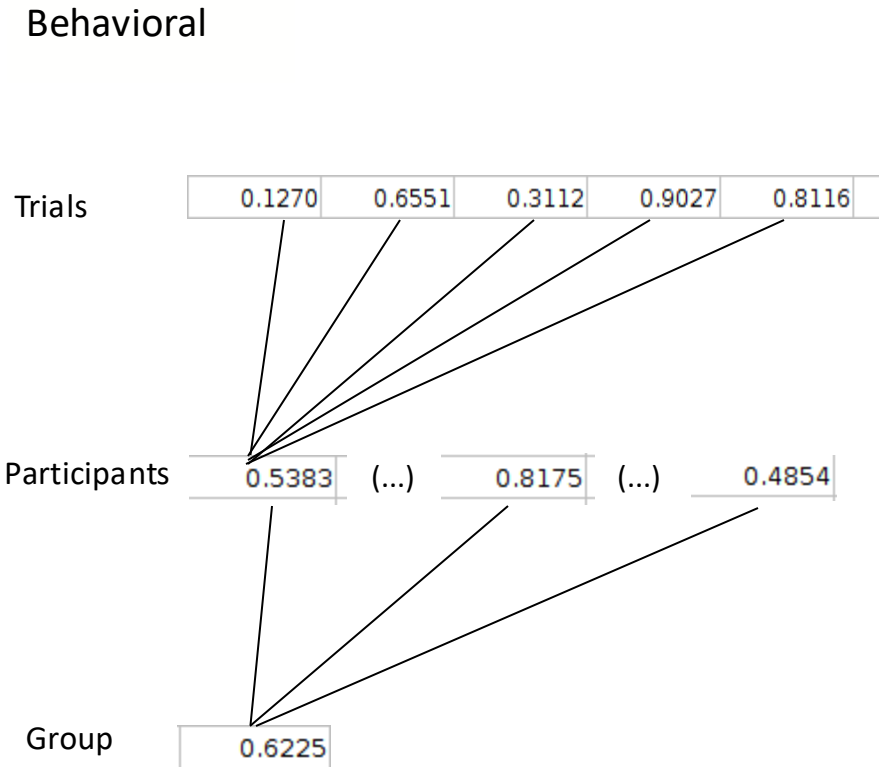
We have obtained contrast maps for each participant in our study. These contrast maps contain the values for each participant that correspond to our contrast vectors. Namely, the differences between conditions (in the directions specified by the vectors).

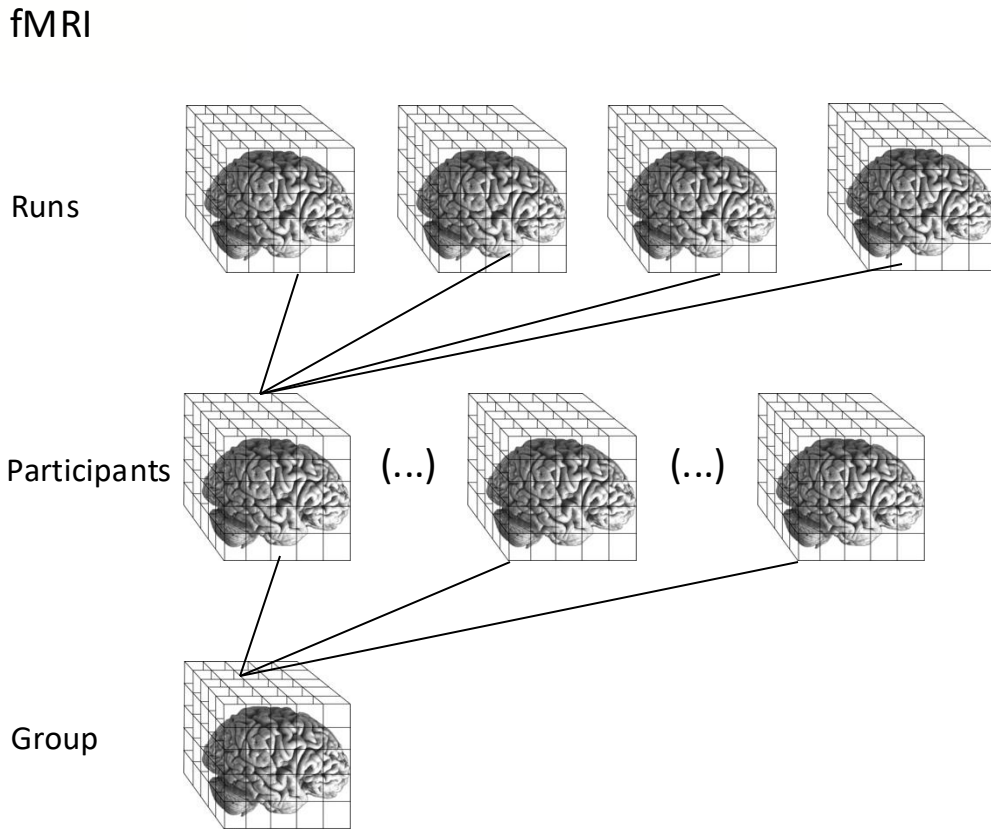
Similar as for a behavioral study, now we would want to see how consistent are those differences across the entire sample.



Functional MRI. Group-level analysis.

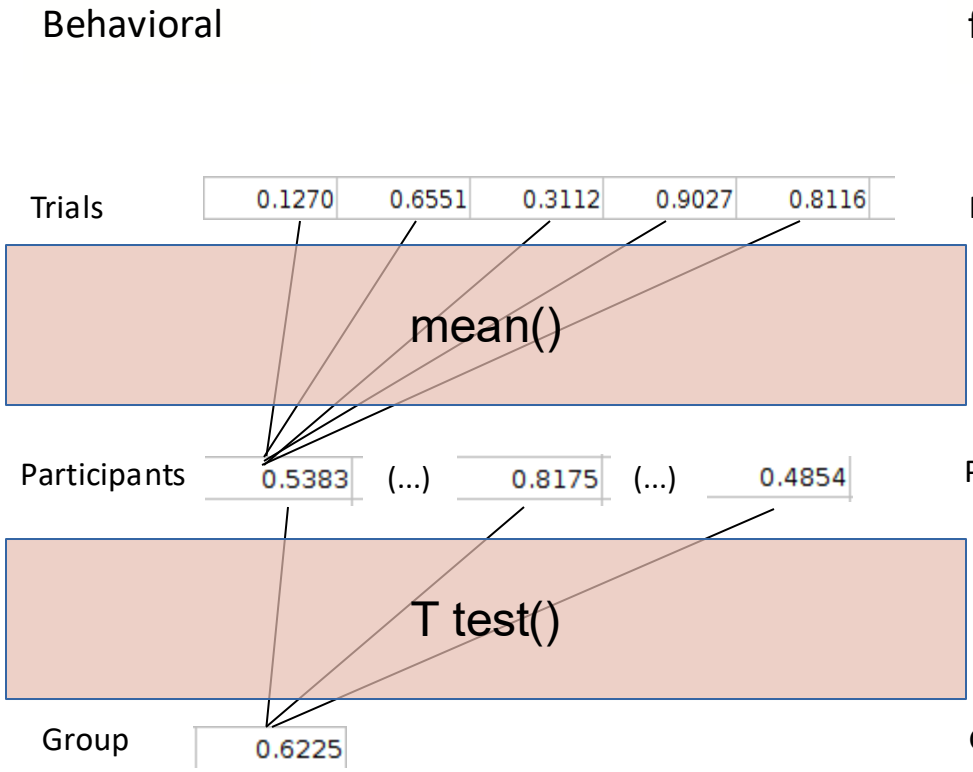
What are group-level analysis?
Comparison with a (rather) equivalent process to understand the rationale of the steps that we have done.

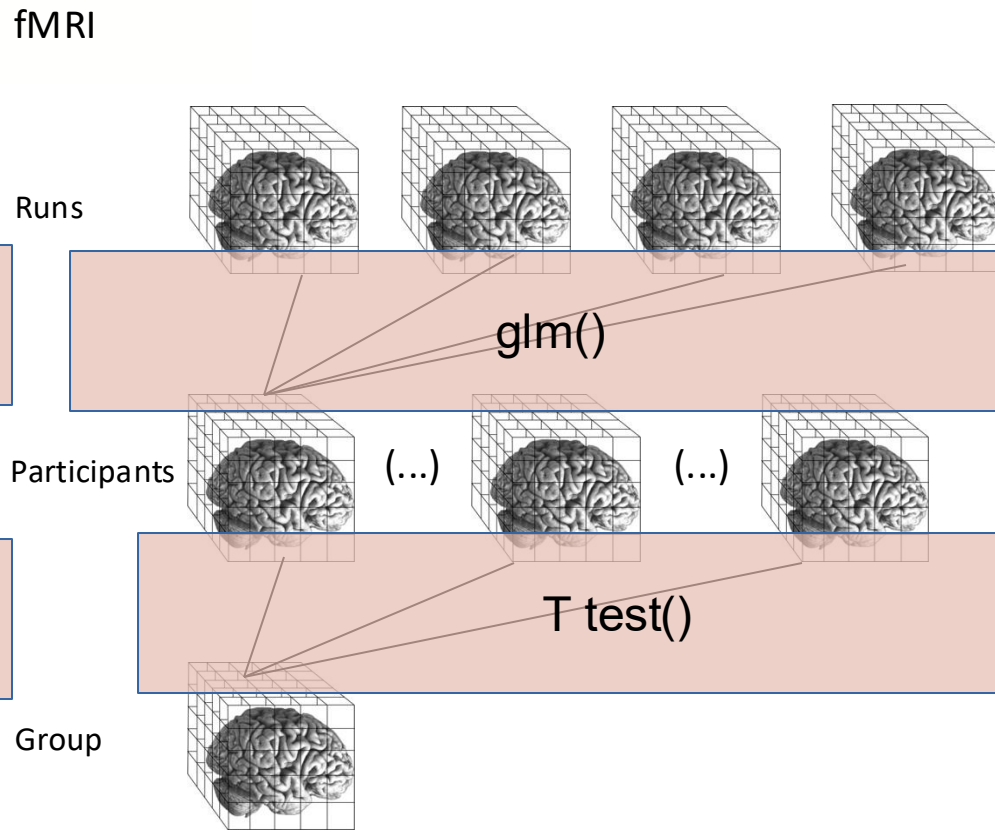




Functional MRI. Group-level analysis.

What are group-level analysis?
Comparison with a (rather) equivalent process to understand the rationale of the steps that we have done.





Functional MRI. Group-level analysis.

Quick note: Different names for the same (conceptual) steps on different packages.

	FSL	SPM
Subjects	1st level	1st level
Runs	2nd level	
Group	3rd level	2nd level

Functional MRI. Group-level analysis.

So how do we do this? Back to RTs...

Participants / Conditions	Congruent (ms)	Incongruent (ms)	Congruity effect (ms)
1	750	889	139
2	322	569	247
3	477	789	312
4	566	865	299
(...)	(...)	(...)	(...)

Functional MRI. Group-level analysis.

So how do we do this? Back to RTs...

Participants / Conditions	Congruent (ms)	Incongruent (ms)		Congruity effect (ms)
1	750	889		139
2	322	569		247
3	477	789		312
4	566	865		299
(...)	(...)	(...)		(...)

We can take these values and run T test against zero.

We will get a T value.

QUESTION:
What will this test tell us?

Functional MRI. Group-level analysis.

What if we do this in one voxel?

Participants / Conditions	Congruent	Incongruent	Congruity effect
1	1750	889	-861
2	2322	2569	247
3	-477	-789	-312
4	638	1556	918
(...)	(...)	(...)	(...)

Functional MRI. Group-level analysis.

What if we do this in one voxel?

Participants / Conditions	Congruent	Incongruent	Congruity effect
1	1750	889	-861
2	2322	2569	247
3	-477	-789	-312
4	638	1556	918
(...)	(...)	(...)	(...)

We can take these values and run T test against zero.

We will get a T value.

QUESTION:
What will this test tell us?

Functional MRI. Group-level analysis.

And if we run it in all the voxels in the brain….?

Participants / Conditions	Congruent	Incongruent	Congruity effect
1	1750	889	-861
2	2322	2569	247
3	-477	-789	-312
4	638	1556	918
(...)	(...)	(...)	(...)

We can take these values and run T test against zero.

We will get a T map.

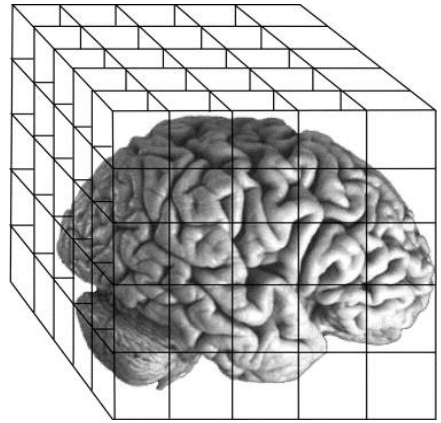
Functional MRI. Group-level analysis.

And if we run it in all the voxels in the brain….?

Participants / Conditions	Congruent	Incongruent	Congruity effect
1	1750	889	-861
2	2322	2569	247
3	-477	-789	-312
4	638	1556	918
(...)	(...)	(...)	(...)

We can take these values and run T test against zero.

We will get a T map.



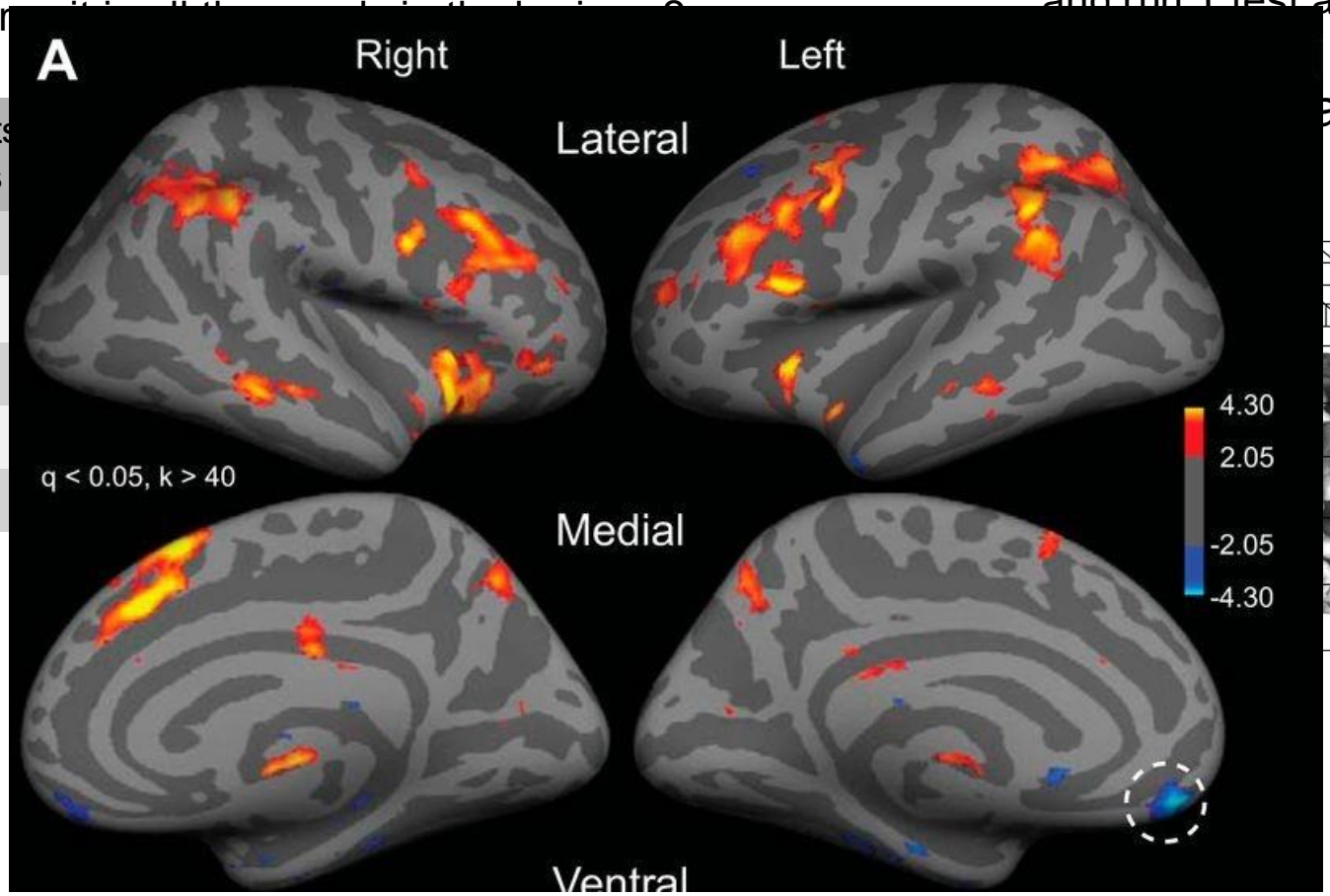
Functional MRI. Group-level analysis.

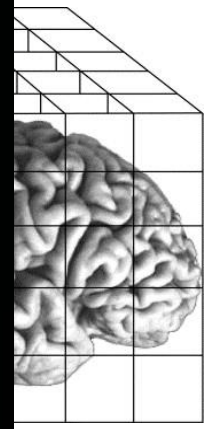
We can take these values and run T test against zero.

And if we r

Participants Conditions
1
2
3
4
(...)

a T map.



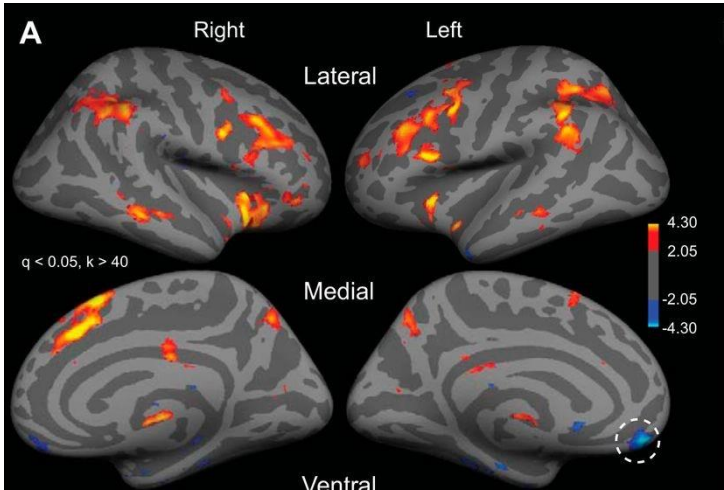


So… activation maps are not activity maps per se: they are Statistical Parametric Maps (SPM) -T values in this case-.

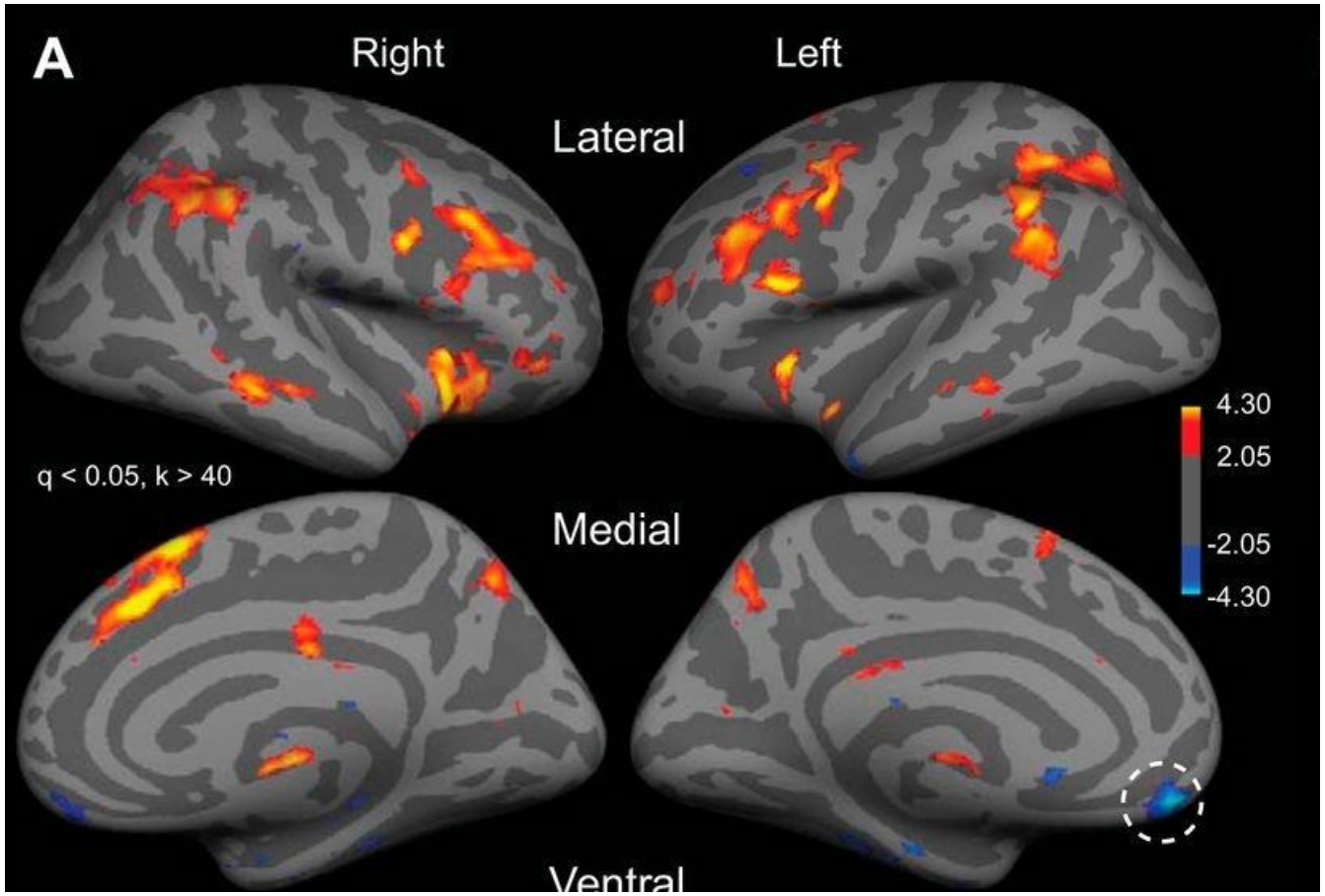
Inference II.

Interim recap.

- First level analysis take in raw BOLD signals and produce beta maps.
- In a univariate contrast analysis, we subtract beta maps for each of our conditions from one another to obtain contrast maps.
- Contrast maps are brought to a Second level (Third level in FSL) to aggregate across subjects.
- Activation maps are actually statistical parametric maps.



Functional MRI. Group-level analysis.

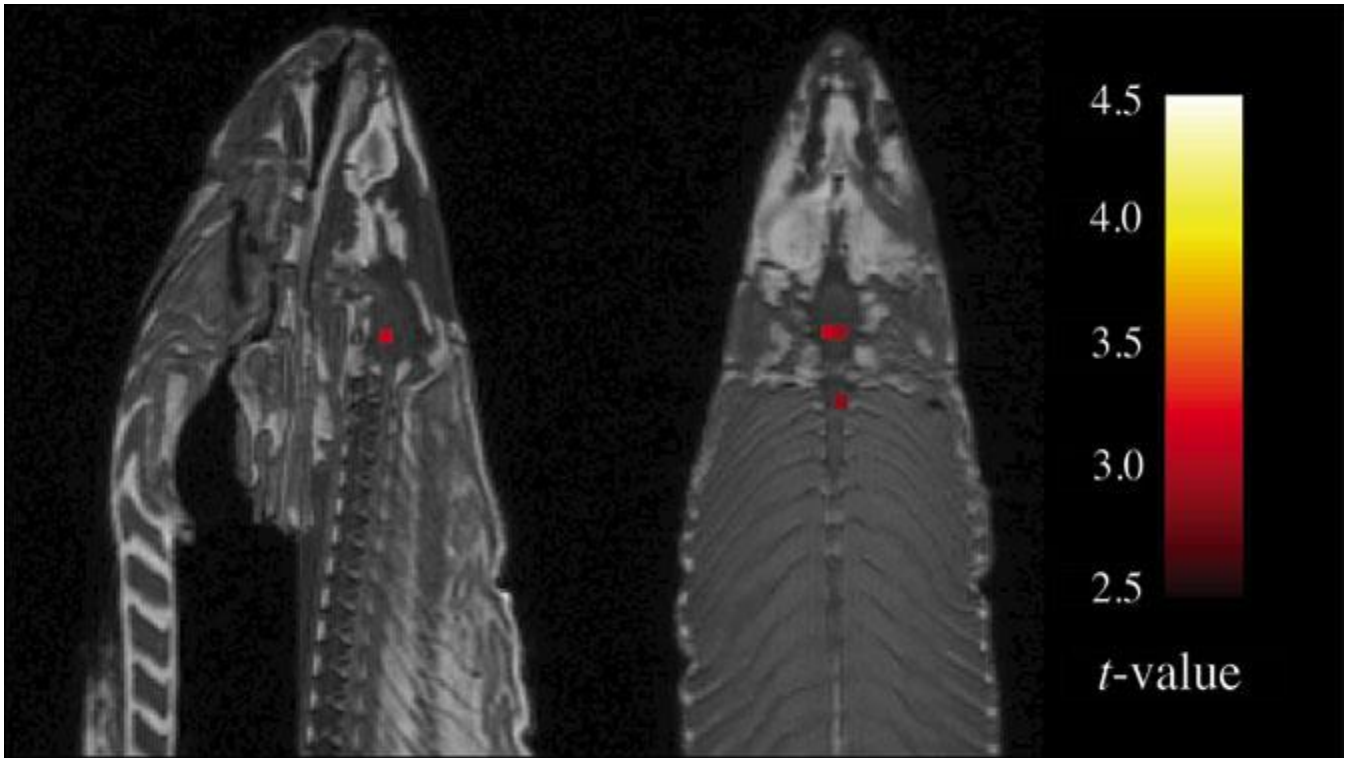


QUESTION:
Why is not the entire brain colored?

} Hint

Functional MRI. Group-level analysis.

Enter: The dead salmon and MCC.



Neural correlates of interspecies perspective taking in the post-mortem Atlantic Salmon: An argument for multiple comparisons correction

Craig M. Bennett[1], Abigail A. Baird[2], Michael B. Miller[1], and George L. Wolford[3]

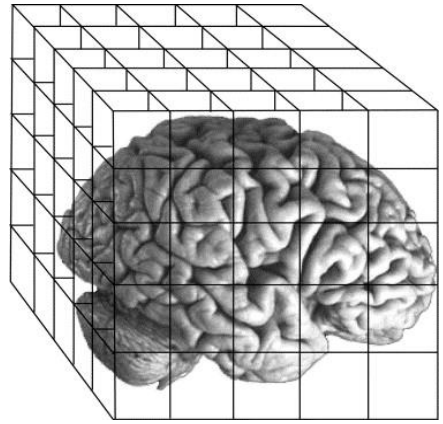
Functional MRI. Group-level analysis.

Multiple comparison problem:

A standard MNI brain has over 260,000 voxels.

Running a T test on every voxels implies running over 260,000 tests.

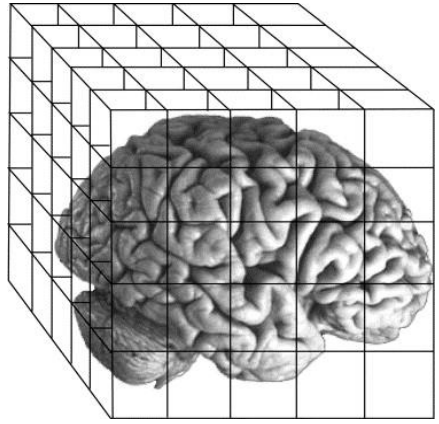
QUESTION:
What is the implication of this huge number of tests for our statistical inferences?



Functional MRI. Group-level analysis.

Multiple comparison correction:

- Bonferroni.
- False Discovery Rate (peak level. For a nice visualization of the procedure see https://andysbrainbook.readthedocs.io/en/latest/fMRI_Short_Course/fMRI_Appendices/Appendix_A_ClusterCorrection.html#appendix-a-clustercorrection)
- False Discovery Rate (cluster level).

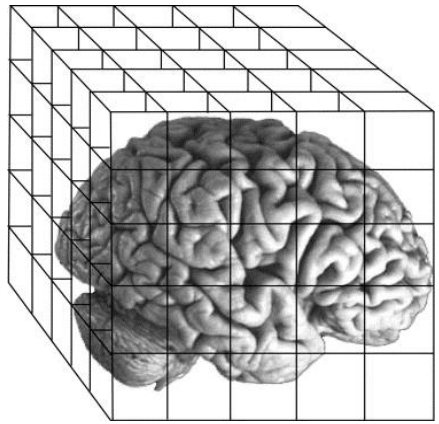


Functional MRI. Group-level analysis.

Bonferroni correction.

Corrected alpha = alpha / number of tests.

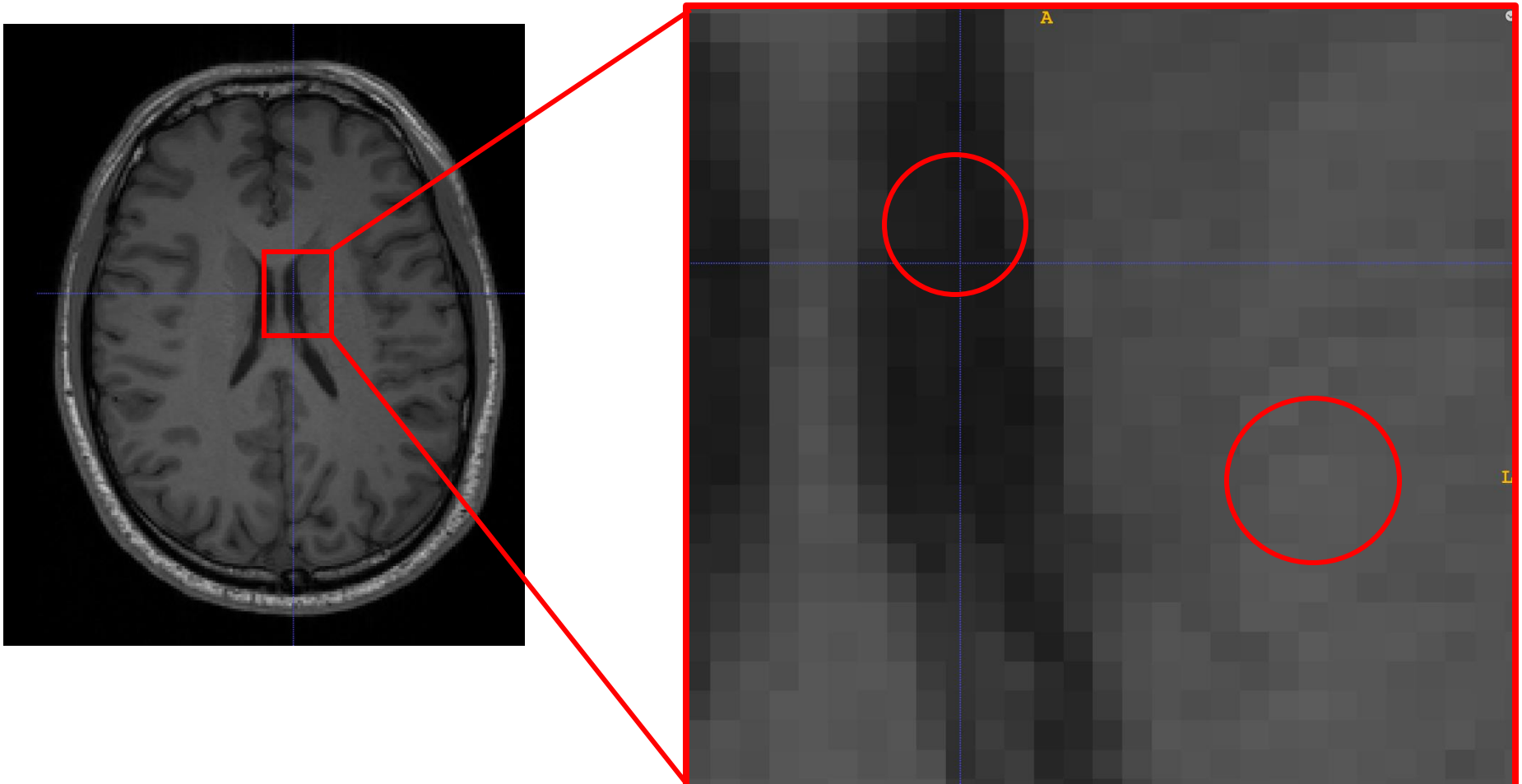
QUESTION:
Do you spot any problems with this type of correction?



Functional MRI. Group-level analysis.

Bonferroni correction.

Corrected alpha = alpha / number of tests.



Functional MRI. Group-level analysis.

Multiple comparison correction:

- Bonferroni.

- FDR (peak level. For a nice visualization of the procedure see https://andysbrainbook.readthedocs.io/en/latest/fMRI_Short_Course/fMRI_Appendices/Appendix_A_ClusterCorrection.html#appendix-a-clustercorrection)

Functional MRI. Group-level analysis.

Multiple comparison correction:

- Bonferroni.
- FDR (peak level. For a nice visualization of the procedure see https://andysbrainbook.readthedocs.io/en/latest/fMRI_Short_Course/fMRI_Appendices/Appendix_A_ClusterCorrection.html#appendix-a-clustercorrection)
- FDR (cluster level). What is the minimum cluster size that we are going to consider relevant?

Functional MRI. Group-level analysis.

Multiple comparison correction:

- Bonferroni.
- FDR (peak level. For a nice visualization of the procedure see https://andysbrainbook.readthedocs.io/en/latest/fMRI_Short_Course/fMRI_Appendices/Appendix_A_ClusterCorrection.html#appendix-a-clustercorrection)
- FDR (cluster level). What is the minimum cluster size that we are going to consider relevant?
- Random Field Theory (RFT). Not covered here.

Functional MRI. Group-level analysis.

Forward Inference (Task → Brain)

- Tests whether a cognitive task or condition consistently leads to activation in a specific brain region
- Hypothesis-driven, statistically valid approach

→ Does performing Task X activate Region Y more than a control condition?

Functional MRI. Group-level analysis.

Forward Inference (Task → Brain)

Example

- Task A: Stroop *incongruent* trials (conflict condition, CC)
- Task B: Stroop *congruent* trials (baseline, B)

H0: CC = B; H1: CC > B

If the anterior cingulate cortex (ACC) shows significantly greater activity during incongruent trials → evidence that the ACC is involved in conflict processing.

Functional MRI. Group-level analysis.

Reverse Inference (Brain → Task)

- draws conclusions about the mental state or cognitive process a person is experiencing, based on observed brain activity.

→ If Region Y is active, does that mean the person is performing Task X?

- statistically weak unless you have data on how selective the region is for that task

Functional MRI. Group-level analysis.

Reverse Inference (Brain → Task)
Example:
You observe activation in the ACC. You conclude:
The participant must be experiencing response conflict

This inference is flawed unless:
ACC is highly selective for conflict (it's not)
You know the prior probability of tasks that could activate it

Why it's risky:
Many brain regions are multi-functional (e.g., ACC, DLPFC)
Same region can activate for emotion, conflict, error, etc.

Functional MRI. Group-level analysis.

Summary Table: Forward/Reversed Inference

Feature	Forward Inference	Reverse Inference
Direction	Task → Brain	Brain → Task
Valid by default	Yes	Not without priors
Requires contrast	Yes	No (observational)
Common usage	Experimental analysis	Interpretation / decoding
Statistical support	Strong (GLM, t-tests)	Weak unless prior-based
Example	Stroop → ACC activation	ACC activation → "conflict"?

Inference II.

General recap.

- First level analysis take in raw BOLD signals and produce beta maps.
- In a univariate contrast analysis, we subtract beta maps for each of our conditions from one another to obtain contrast maps.
- Contrast maps are brought to a Second level (Third level in FSL) to aggregate across subjects.
- Activation maps are actually thresholded statistical parametric maps.
- Thresholding is done to account for the multiple comparison problem.
- Bonferroni is usually too-strict and fails to take into account spatial correlation of BOLD signal.
- FDR can help us obtain a good balance between specificity and sensitivity.
- Forward and Reversed Inteference