The Transition from Physical to Abstract Taste: An fMRI Study on Sweet, Sour, and Salty

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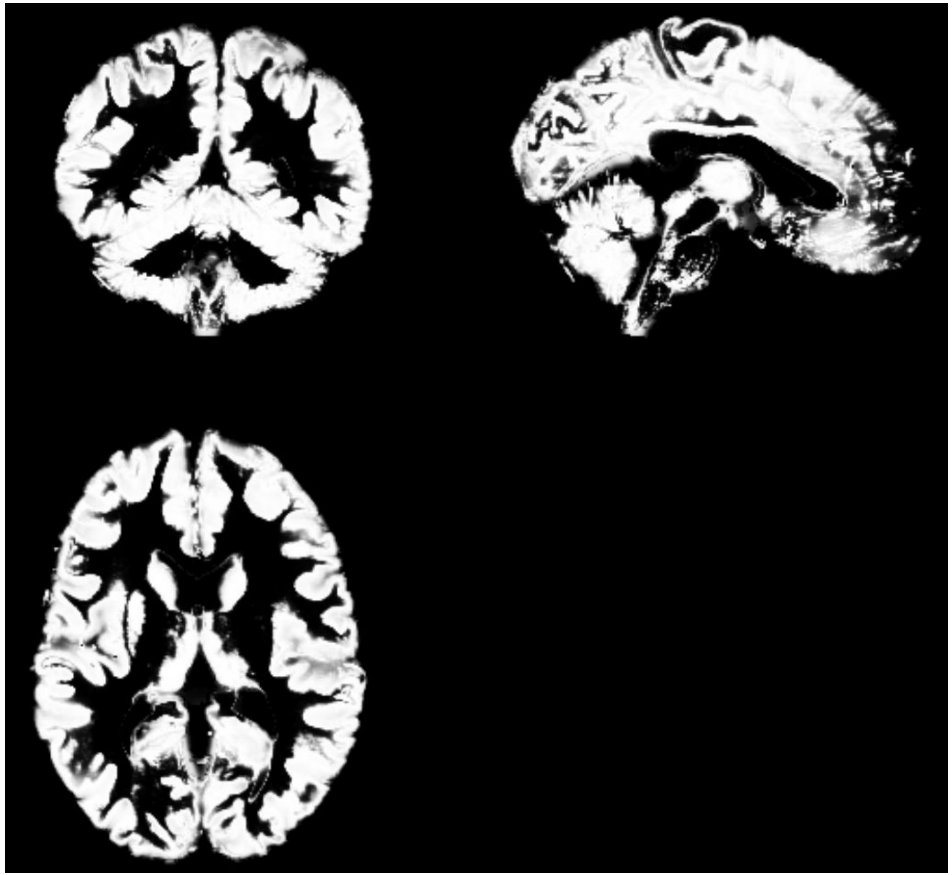
Motivation



Segmented brain
Gray matter
Sub-007
1st study

Introduction:

This ice cream tastes **sweet**! (Physical)

You're so **sweet**! (Abstract)

Introduction:

- **Embodiment theory** posits that abstract thought is grounded in concrete, sensorimotor experiences.
- **Taste**, while fundamentally a **physical** sensation, is frequently extended into the **abstract** domain (e.g., "sweet success," "bitter truth").
- This conceptual overlap suggests that abstract uses of taste may recruit **similar neural mechanisms** as literal, physical taste experiences.

Hypothesis:

- **Abstract** taste expressions will partially **overlap** with **physical** taste processing regions (e.g., insula, primary gustatory cortex).
- This overlap will be spatially reduced, and abstract taste will additionally recruit regions associated with semantic and conceptual processing.
- Connectivity between abstract-related areas and primary taste regions will reflect grounding in physical experience.

Participant

Best Pair (female)

- **Dataset 1:** `sub-007` (68 kg, 24, F)
- **Dataset 2:** `sub-072` (65.5 kg, 26, F)
    - *Same gender, age difference = 2 years, weight difference = 2.5 kg.*

Methodology

1. 1st level analysis: Visual inspection across both group by best pair.
   - Choosing a comparable pair from both group.
   - Preprocessing data > 1st level analysis (SPM12).
   - Visual inspection.
2. 2nd level analysis: Comparison across both group.
   - Adding comparable pairs (female, male, different ages).
   - Including all participants.

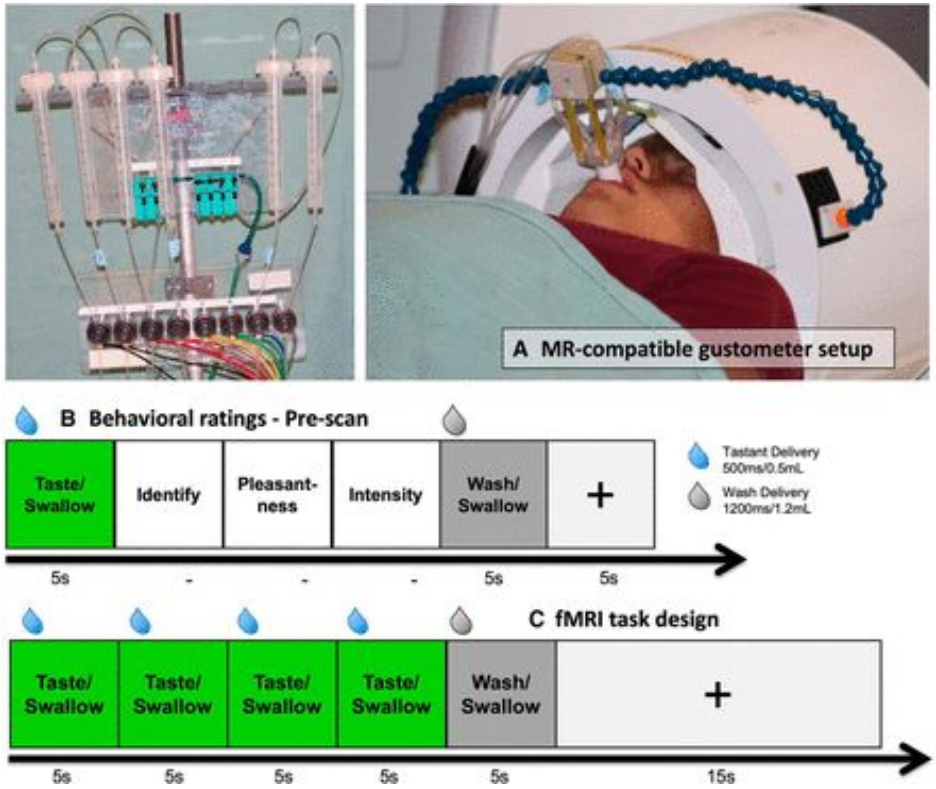
Source:

Taste Quality Representation in the Human Brain (2020)
A common neural code for representing imagined and inferred tastes (2023)

1st study:

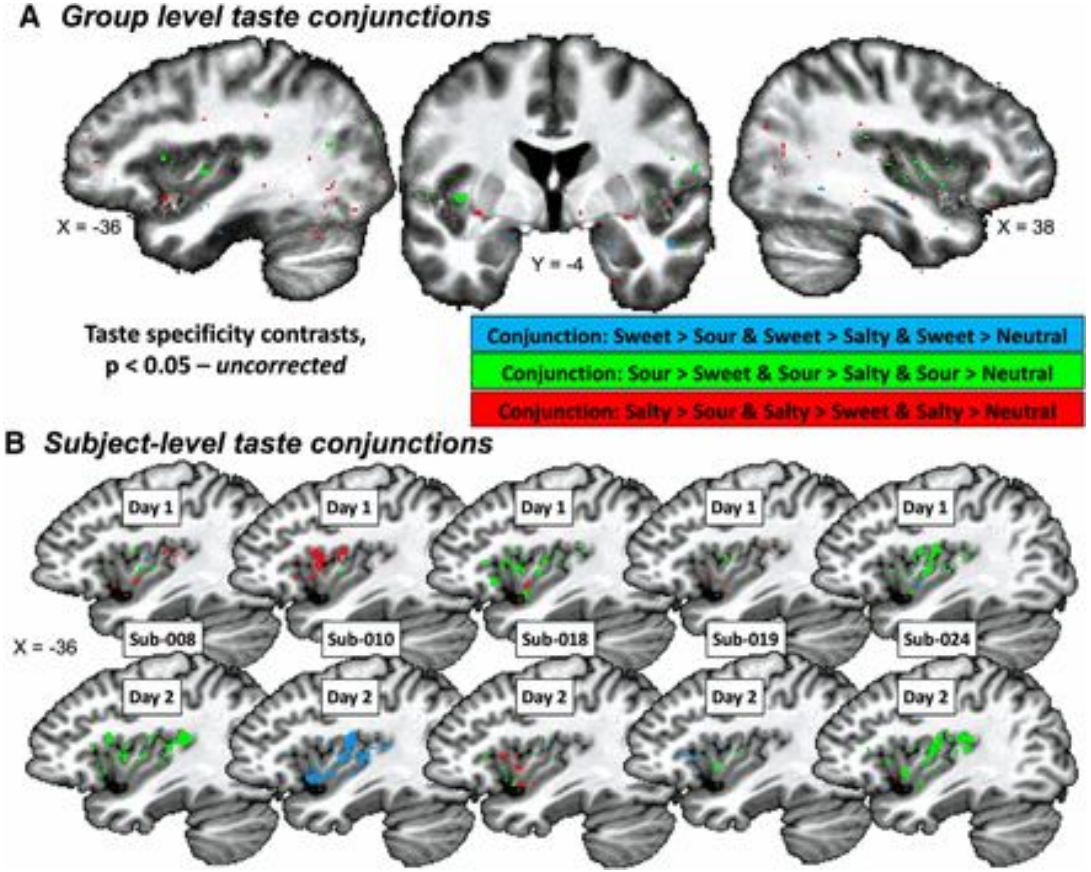
onset	duration	trial_type
5	20	sour
25	5	wash
45	20	neutral
65	5	wash
85	20	salty
105	5	wash
125	20	sweet
145	5	wash
165	20	sour
185	5	wash
205	20	salty
225	5	wash
245	20	neutral
265	5	wash
285	20	sweet
305	5	wash

*8 runs

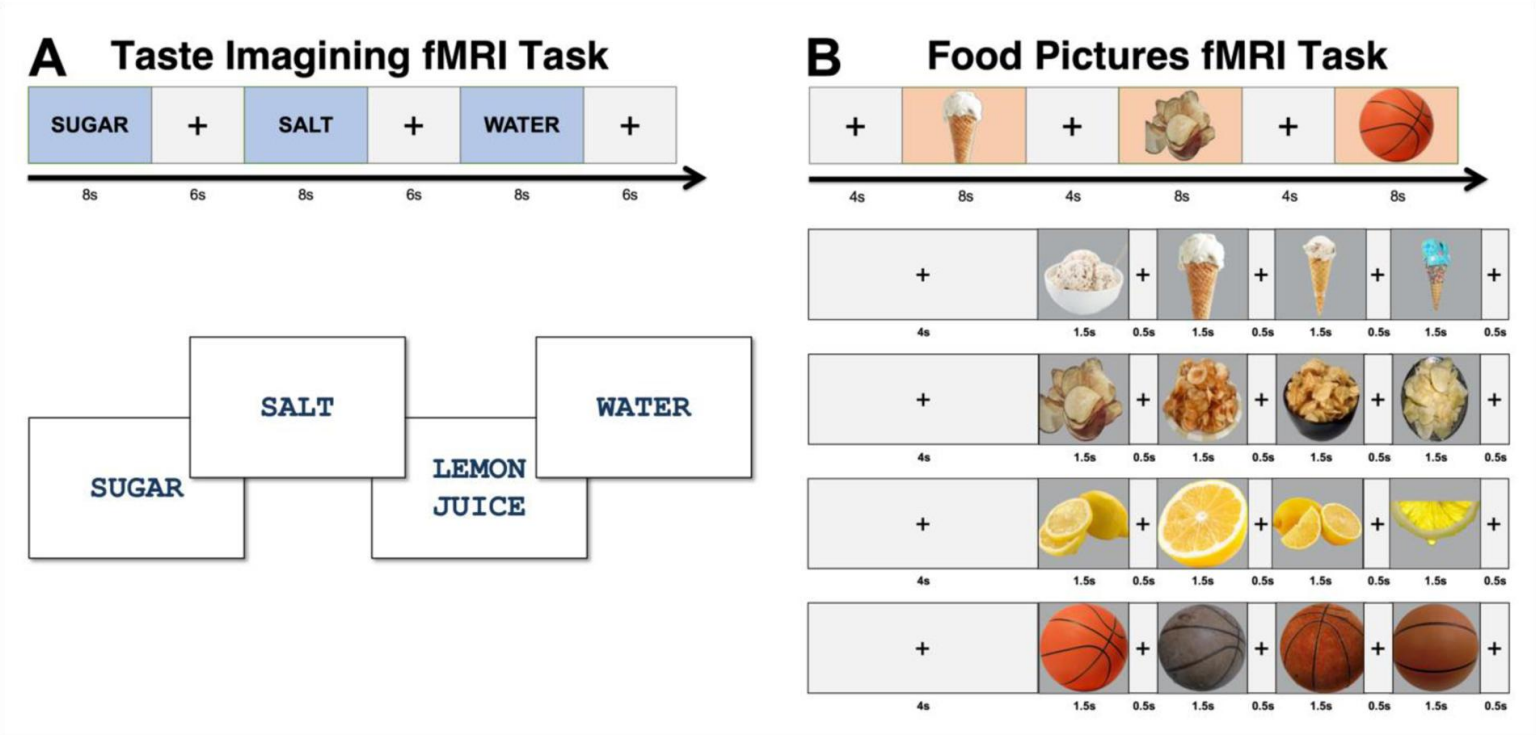


1st study:

The brain **does not** have strongly segregated, stable topographic **maps** for **basic tastes** (sweet, salty, sour) at the group level, and even **individual subjects** showed inconsistent patterns across sessions.



2nd study:


A Taste Imagining fMRI Task
SUGAR
+
SALT
+
WATER
+
8s
6s
8s
6s
8s
6s
SUGAR
SALT
LEMON JUICE
WATER
B Food Pictures fMRI Task
4s
8s
4s
8s
4s
8s
4s
1.5s
0.5s

2nd study:

Tatseimagine- Run1/4

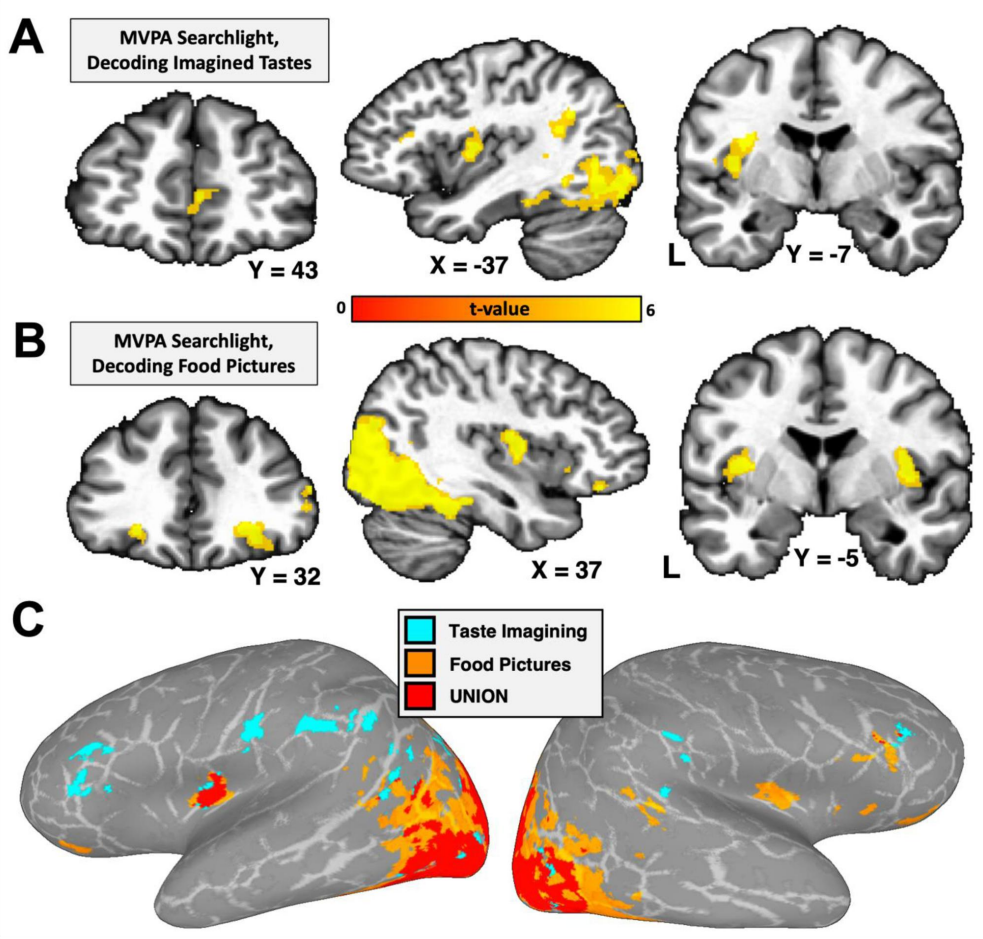
onset	duration	trial_type
6000	8000	water
20000	8000	lemon
34000	8000	sugar
48000	8000	lemon
62000	8000	water
76000	8000	salt
90000	8000	sugar

Foodpicture-Run 1/4

onset	duration	trial_type
4000	8000	salty
16000	8000	sour
28000	8000	sweet
40000	8000	sour
52000	8000	object
64000	8000	sour
76000	8000	object

2nd study:

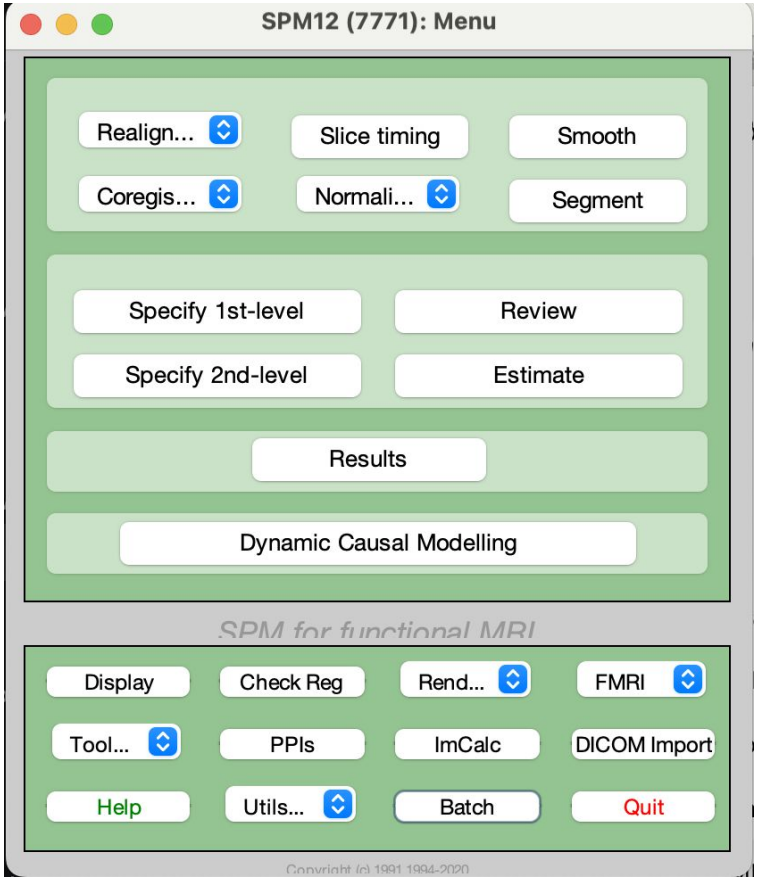
- No brain region analysis for specific taste
- Inclusion of objects may affect the results for Food picture tasks.



Pipeline

Preprocessing pipeline: SPM

- Check Reg (Motion Correction)
- Realign & Reslice
- Slice timing
- Coregister T1 EPI
- Segmentation



Data downloading

Download with DataLad

Public datasets can be downloaded with DataLad or Git Annex from GitHub.

```
datalad install https://github.com/OpenNeuroDatasets/ds002995.git
```

Check out getting started with DataLad for more on how to use this download method.

Download with a shell script

A script is available to download with only curl. This may be useful if your download environment makes it difficult to install DataLad or Node.js.

Download shell script

Datalab

```
                  [PATH ...]
(base) MacBook-Pro-de-Annamarie:~ annamarie$ cd /Users/annamarie/ds004312
(base) MacBook-Pro-de-Annamarie:ds004312 annamarie$ datalad get sub-072
get(ok): sub-072/ses-01/anat/sub-072_ses-01_T1w.nii.gz (file) [from s3-PUBLIC...]

get(ok): sub-072/ses-01/fmap/sub-072_ses-01_dir-PA_epi.nii.gz (file) [from s3-PUBLIC...]
get(ok): sub-072/ses-01/func/sub-072_ses-01_task-foodpicture_run-01_bold.nii.gz (file) [from s3-PUBLIC...]
get(ok): sub-072/ses-01/func/sub-072_ses-01_task-foodpicture_run-02_bold.nii.gz (file) [from s3-PUBLIC...]
get(ok): sub-072/ses-01/func/sub-072_ses-01_task-foodpicture_run-03_bold.nii.gz (file) [from s3-PUBLIC...]
get(ok): sub-072/ses-01/func/sub-072_ses-01_task-foodpicture_run-04_bold.nii.gz (file) [from s3-PUBLIC...]
get(ok): sub-072/ses-01/func/sub-072_ses-01_task-tasteimagine_run-01_bold.nii.gz (file) [from s3-PUBLIC...]
get(ok): sub-072/ses-01/func/sub-072_ses-01_task-tasteimagine_run-02_bold.nii.gz (file) [from s3-PUBLIC...]
get(ok): sub-072/ses-01/func/sub-072_ses-01_task-tasteimagine_run-03_bold.nii.gz (file) [from s3-PUBLIC...]
get(ok): sub-072/ses-01/func/sub-072_ses-01_task-tasteimagine_run-04_bold.nii.gz (file) [from s3-PUBLIC...]
get(ok): sub-072 (directory)
action summary:
  get (ok: 11)
(base) MacBook-Pro-de-Annamarie:ds004312 annamarie$
```

=> amex-encoded file

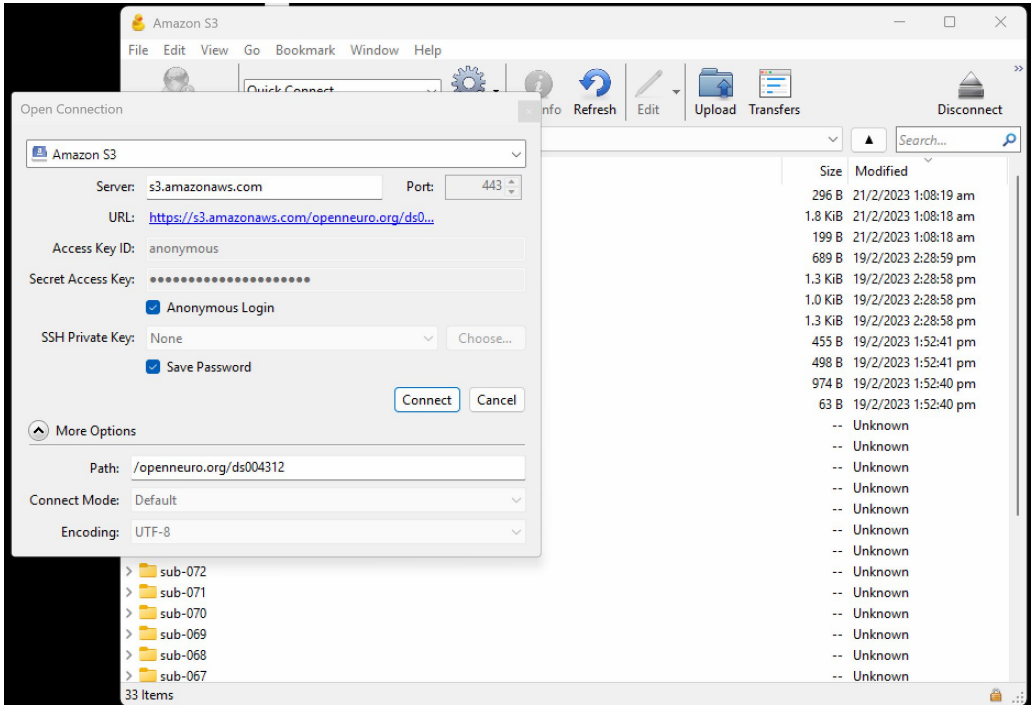
Shell script

```
#!/bin/sh
curl --create-dirs https://s3.amazonaws.com/openneuro.org/ds002995/CHANGES?versionId=kcth4K.Ji68clv8NJBhw4_LOWJIUBweh -o ds002995-1.0.1/CHANGES
curl --create-dirs https://s3.amazonaws.com/openneuro.org/ds002995/README?versionId=pd6tB8NAJWjmbrvA2mVcby5n_zL_Zk2n -o ds002995-1.0.1/README
curl --create-dirs https://s3.amazonaws.com/openneuro.org/ds002995/dataset_description.json?versionId=g6YfEuE4BTqO4nhZIzxMjZBj2U9.t2af -o ds002995-1.0.1/dataset_description.json
curl --create-dirs https://s3.amazonaws.com/openneuro.org/ds002995/._README?versionId=_I9pPUBNEubaYHCbv98wWPjjqQPn2RfL -o ds002995-1.0.1/._README
curl --create-dirs https://s3.amazonaws.com/openneuro.org/ds002995/T1w.json?versionId=yb4FTs.yKyiKOr1dUZY0uJd.UJhvzg3r -o ds002995-1.0.1/T1w.json
curl --create-dirs https://s3.amazonaws.com/openneuro.org/ds002995/dir-PA_epi.json?versionId=yf0eZoTs3fpU_izMDOcLmlZHtnTdLPtG -o ds002995-1.0.1/dir-PA_epi.json
curl --create-dirs https://s3.amazonaws.com/openneuro.org/ds002995/participants.json?versionId=dPWt__WzP9uTOxZv01q3mO22Zhp9FQiW -o ds002995-1.0.1/participants.json
curl --create-dirs https://s3.amazonaws.com/openneuro.org/ds002995/participants.tsv?versionId=WoLgUvkZh2ZZ8wxMadMFhnyxr0VE6r_A -o ds002995-1.0.1/participants.tsv
curl --create-dirs https://s3.amazonaws.com/openneuro.org/ds002995/task-tastemap_bold.json?versionId=VEbvZFCLNdPhsnbAsTvXB0qJaJisU5mG -o ds002995-1.0.1/task-tastemap_bold.json
curl --create-dirs https://s3.amazonaws.com/openneuro.org/ds002995/task-tastemap_events.json?versionId=Qe1IbfxyFhWxVXQq9ZJsuQBFUprJBx7l -o ds002995-1.0.1/task-tastemap_events.json
curl --create-dirs https://s3.amazonaws.com/openneuro.org/ds002995/sub-007/ses-01/anat/sub-007_ses-01_T1w.nii.gz?versionId=HT7UVYG2yxqAyQjPuWM9XbIHBdFyybV3 -o
    ds002995-1.0.1/sub-007/ses-01/anat/sub-007_ses-01_T1w.nii.gz
curl --create-dirs https://s3.amazonaws.com/openneuro.org/ds002995/sub-007/ses-01/fmap/sub-007_ses-01_dir-PA_epi.nii.gz?versionId=d7l7IrCwNZSs5W.ZuiA2LJEX07dTJQ6R -o
    ds002995-1.0.1/sub-007/ses-01/fmap/sub-007_ses-01_dir-PA_epi.nii.gz
curl --create-dirs https://s3.amazonaws.com/openneuro.org/ds002995/sub-007/ses-01/func/._sub-007_ses-01_task-tastemap_run-01_events.tsv?versionId=zyv_x2cosDkby4eos4zok.Synu8ShmcF
    -o ds002995-1.0.1/sub-007/ses-01/func/._sub-007_ses-01_task-tastemap_run-01_events.tsv
curl --create-dirs https://s3.amazonaws.com/openneuro.org/ds002995/sub-007/ses-01/func/._sub-007_ses-01_task-tastemap_run-02_events.tsv?versionId=N8eVZhskDmKcujYJt0J8flkRMB95jROz
    -o ds002995-1.0.1/sub-007/ses-01/func/._sub-007_ses-01_task-tastemap_run-02_events.tsv
curl --create-dirs https://s3.amazonaws.com/openneuro.org/ds002995/sub-007/ses-01/func/._sub-007_ses-01_task-tastemap_run-03_events.tsv?versionId=KKncroUkJ4CbBZ4eOisBIcChFSBvd7aM
    -o ds002995-1.0.1/sub-007/ses-01/func/._sub-007_ses-01_task-tastemap_run-03_events.tsv
```

=> complicated

Cyberduck >Amazon S3

=> Path spec



Slice-timing

=> Check README, json file.


```
    "Columns": 1440,
    "PixelSpacing": "1.2000000476837 1.2000000476837",
    "SliceTiming": [
            0.000,
            1.845,
            1.183,
            0.517,
            2.362,
            1.697,
```

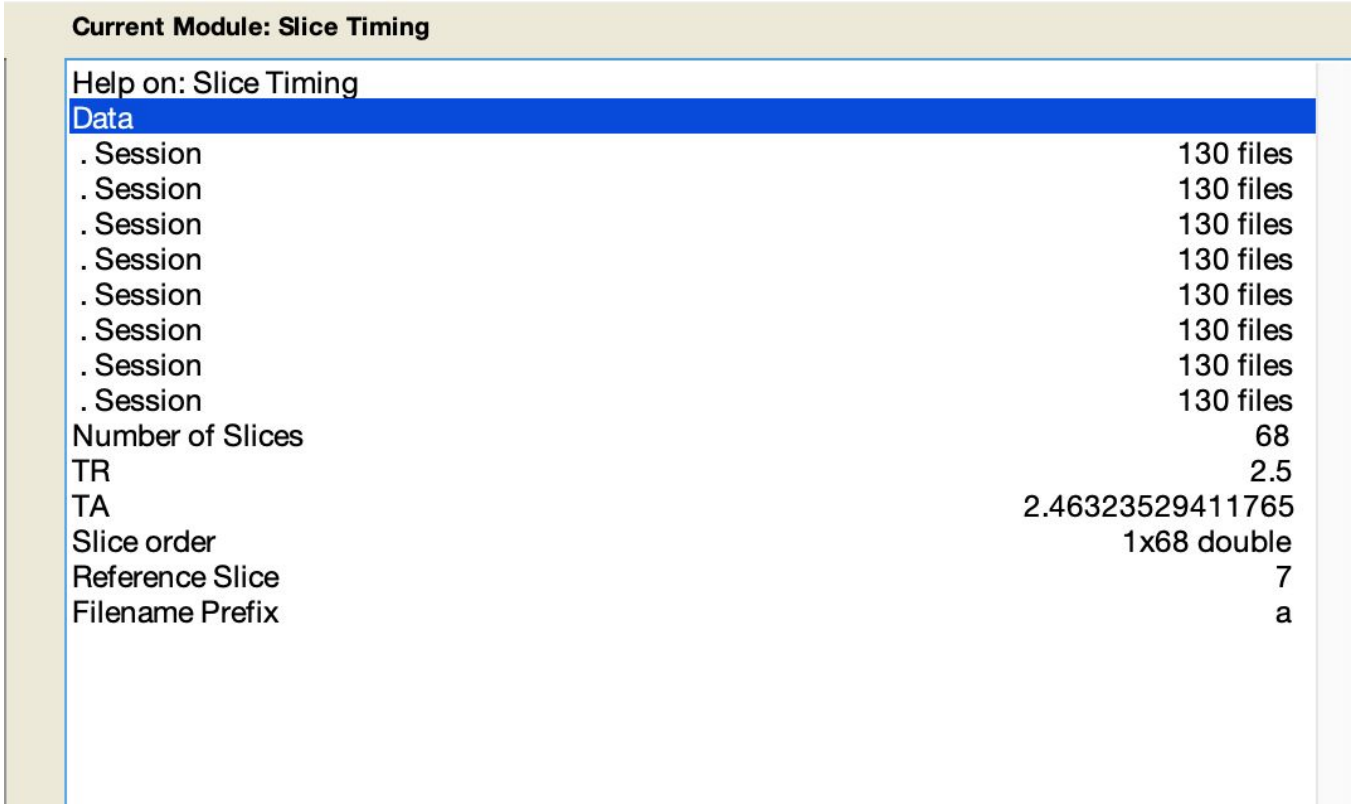
Matlab > Slice-timing info

```
>> % Step 1: Define your SliceTiming (from your JSON)
SliceTiming = [ ...
    0.000, 1.845, 1.183, 0.517, 2.362, 1.697, 1.035, 0.370, ...
    2.215, 1.550, 0.887, 0.222, 2.068, 1.403, 0.738, 0.075, ...
    1.920, 1.255, 0.590, 2.435, 1.773, 1.107, 0.442, 2.287, ...
    1.625, 0.960, 0.295, 2.140, 1.477, 0.813, 0.147, 1.992, ...
    1.330, 0.665, 0.000, 1.845, 1.183, 0.517, 2.362, 1.697, ...
    1.035, 0.370, 2.215, 1.550, 0.887, 0.222, 2.068, 1.403, ...
    0.738, 0.075, 1.920, 1.255, 0.590, 2.435, 1.773, 1.107, ...
    0.442, 2.287, 1.625, 0.960, 0.295, 2.140, 1.477, 0.813, ...
    0.147, 1.992, 1.330, 0.665 ];

% Step 2: Compute slice acquisition order
[~, slice_order] = sort(SliceTiming);

% Step 3: Find reference slice (closest to 1.0s)
[~, ref_slice] = min(abs(SliceTiming - 1.0));

% Step 4: Display results
fprintf('Slice acquisition order:\n');
disp(slice_order);

fprintf('Reference slice (closest to 1s): %d\n', ref_slice);
```

Matlab > Slice-timing info

```
Slice acquisition order:
  Columns 1 through 12

     1    35    16    50    31    65    12    46    27    61     8    42

  Columns 13 through 24

    23    57     4    38    19    53    34    68    15    49    30    64

  Columns 25 through 36

    11    45    26    60     7    41    22    56     3    37    18    52

  Columns 37 through 48

    33    67    14    48    29    63    10    44    25    59     6    40

  Columns 49 through 60

    21    55     2    36    17    51    32    66    13    47    28    62

  Columns 61 through 68

     9    43    24    58     5    39    20    54

Reference slice (closest to 1s): 7
```

Matlab > Slice-timing info



No slice-timing info? Assume or skip ?

Slice Order for Siemens Scanner with 58 Slices

Because:

- **Vendor**: Siemens
- **Acquisition**: 2D EPI
- **Slices**: 58 (even number)
- **No `SliceTiming` provided**

Then according to **Siemens' standard interleaved rule** for **even number of slices**, the slice order is:

slice_order = [2:2:58 1:2:57];

Reference Slice

SPM needs you to pick a **reference slice** — usually the one acquired **closest to the middle of the TR**, to reduce temporal bias.

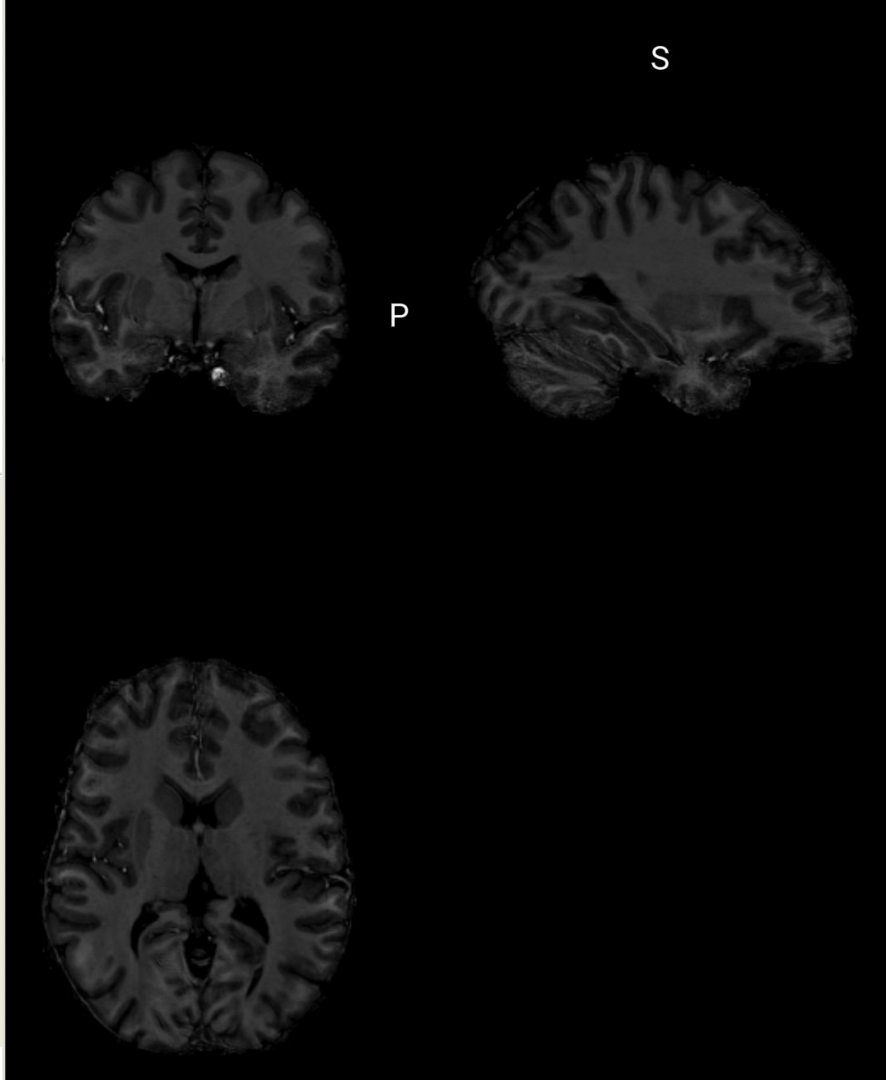
Cogister T1 EPI

No T2 image

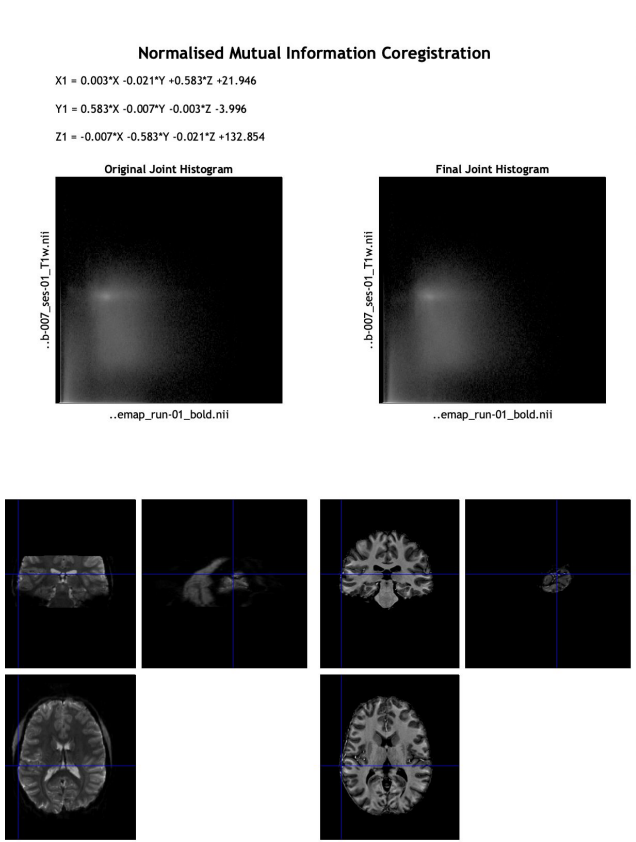
T1 > EPI

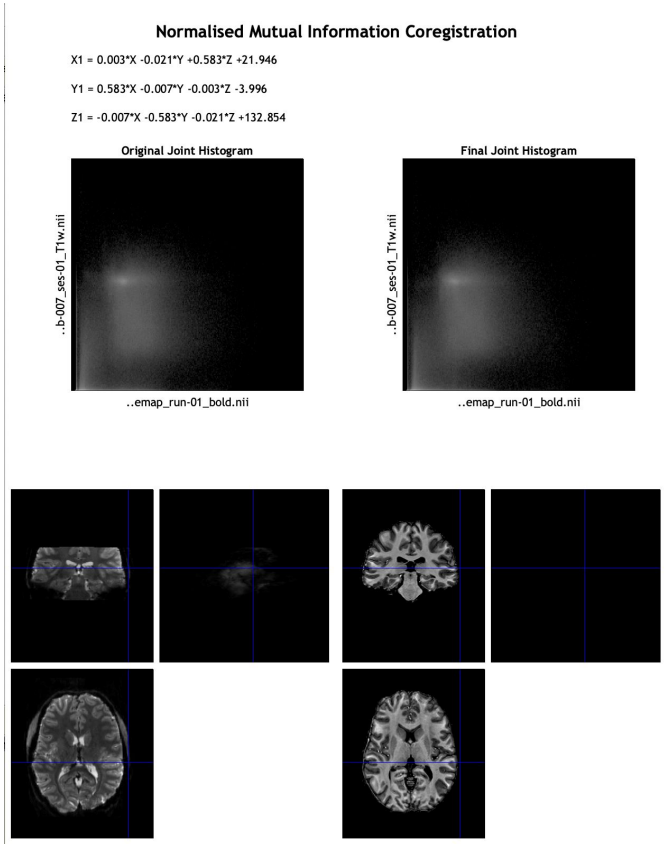
Current Module: Coregister: Estimate

Help on: Coregister: Estimate	
Reference Image	...01/func/arsub-007_ses-01_task-tastemap_run-01_bold.nii,1
Source Image	.../ds002995/sub-007/ses-01/anat/sub-007_ses-01_T1w.nii,1
Other Images	
Estimation Options	
. Objective Function	Normalised Mutual Information
. Separation	[4 2]
. Tolerances	1x12 double
. Histogram Smoothing	[7 7]

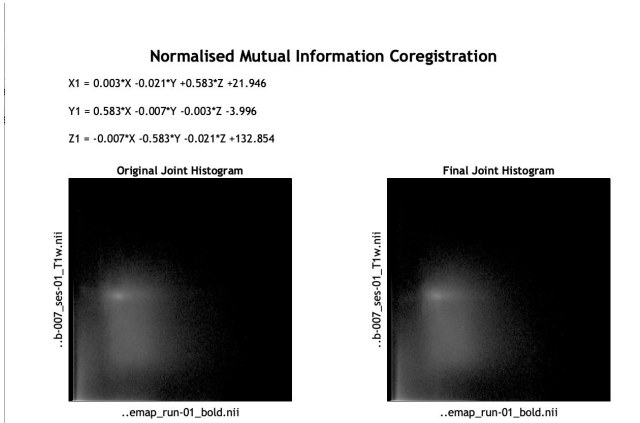


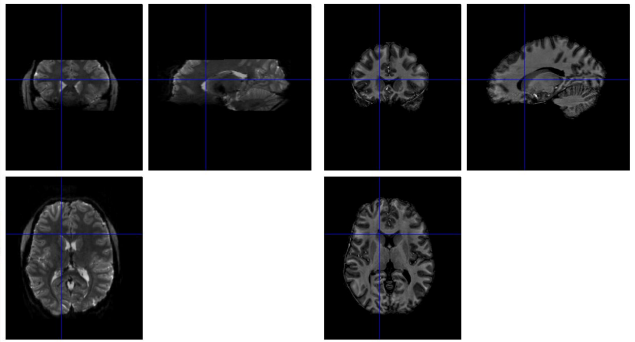
Missing brain image

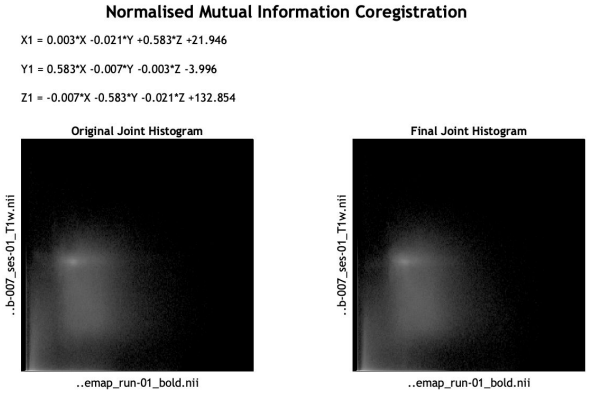


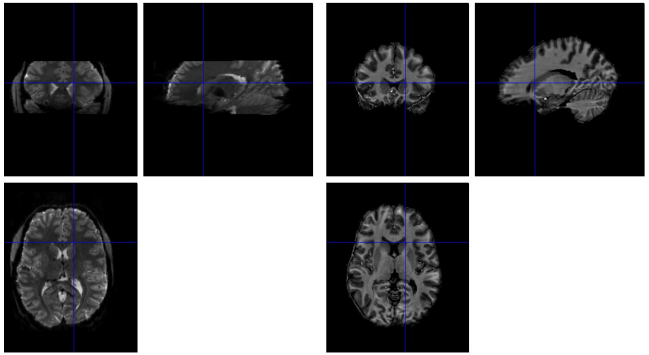


Missing brain image

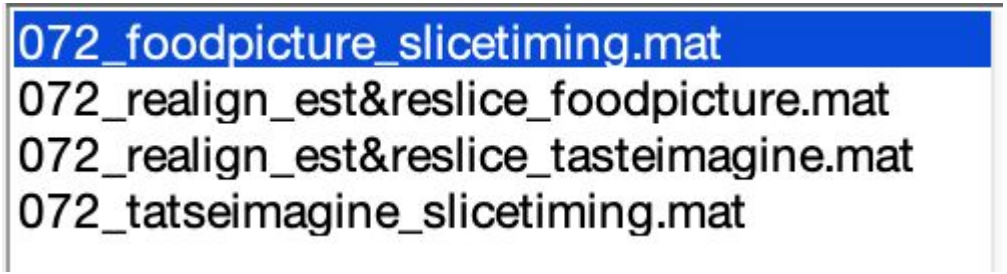




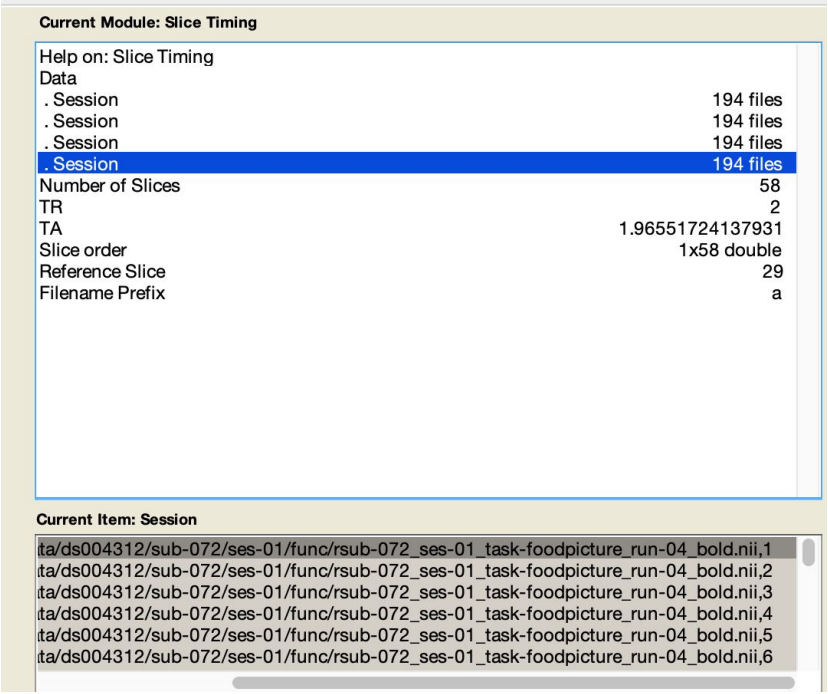




Two runs: Move T1 twice, or duplicate?



I moved on…



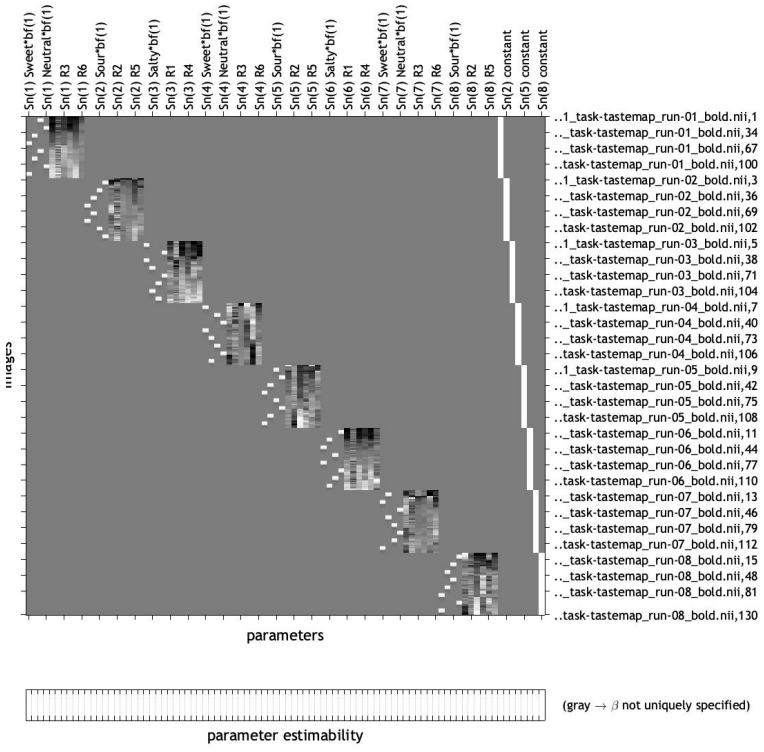
1st level analysis

Something's off….

Current Module: fMRI model specification

Help on: fMRI model specification	
Directory	/Users/annamarie/1stlevel/ds002995/sub-007/results
Timing parameters	
. Units for design	Seconds
. Interscan interval	2.5
. Microtime resolution	68
. Microtime onset	7
Data & Design	
. Subject/Session	
. . Scans	130 files
. . Conditions	
. . Multiple conditions	...arie/1stlevel/ds002995/sub-007/ses-01/func/Run1.mat
. . Regressors	
. . Multiple regressors	...unc/rp_sub-007_ses-01_task-tastemap_run-01_bold.txt
. . High-pass filter	128
. Subject/Session	
. . Scans	130 files
. . Conditions	
. . Multiple conditions	...arie/1stlevel/ds002995/sub-007/ses-01/func/Run2.mat
. . Regressors	
. . Multiple regressors	...unc/rp_sub-007_ses-01_task-tastemap_run-02_bold.txt

Statistical analysis: Design



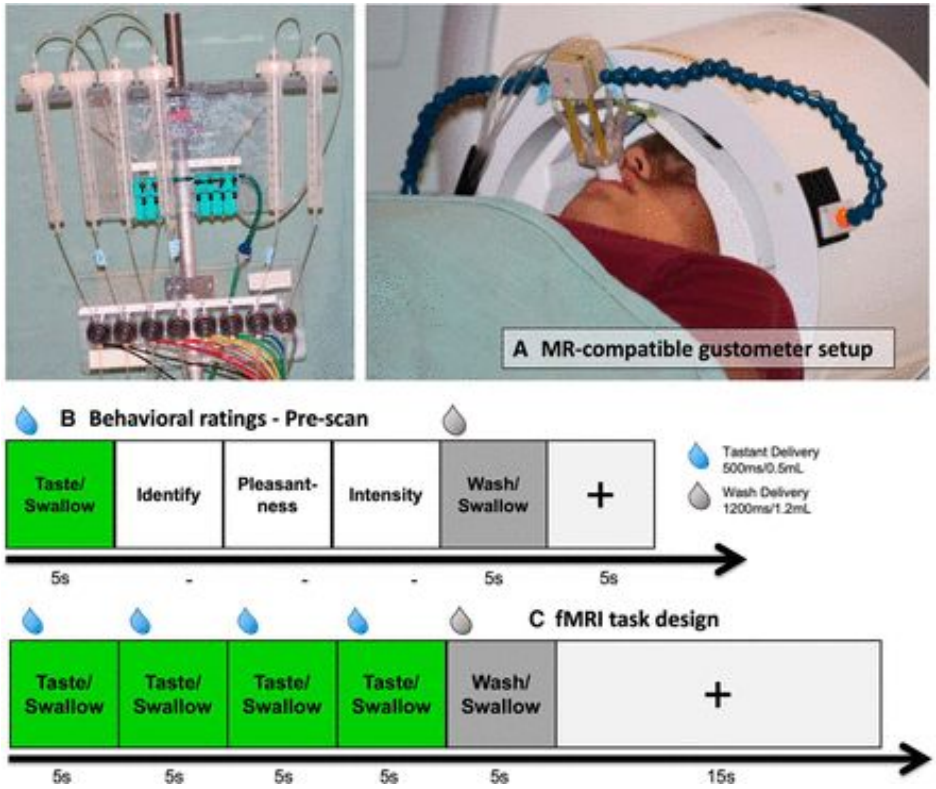
Design description...

Basis functions : hrf
Number of sessions : 8
Trials per session : 4 4 4 4 4 4 4 4
Interscan interval : 2.50 {s}
High pass Filter : [min] Cutoff: 128 {s}
Global calculation : mean voxel value
Grand mean scaling : session specific
Global normalisation : None

1st study:

onset	duration	trial_type
5	20	sour
25	5	wash
45	20	neutral
65	5	wash
85	20	salty
105	5	wash
125	20	sweet
145	5	wash
165	20	sour
185	5	wash
205	20	salty
225	5	wash
245	20	neutral
265	5	wash
285	20	sweet
305	5	wash

*8 runs



1st level analysis

Checking .mat

```
>> load('Run1.mat')
>> whos
  Name            Size                Bytes  Class    Attributes

  ans             1x54                  108  char
  durations       4x1                   480  cell
  names           1x4                   458  cell
  onsets          4x1                   480  cell
```

1st level analysis

Doing .mat again manually

```
>> names = {'sour', 'neutral', 'salty', 'sweet'};

onsets = {
    [5, 165],       % sour
    [45, 245],      % neutral
    [85, 205],      % salty
    [125, 285]      % sweet
};

durations = {
    [20, 20],       % sour
    [20, 20],       % neutral
    [20, 20],       % salty
    [20, 20]        % sweet
};
```

```
>> save('Run1.mat', 'names', 'onsets', 'durations')
```

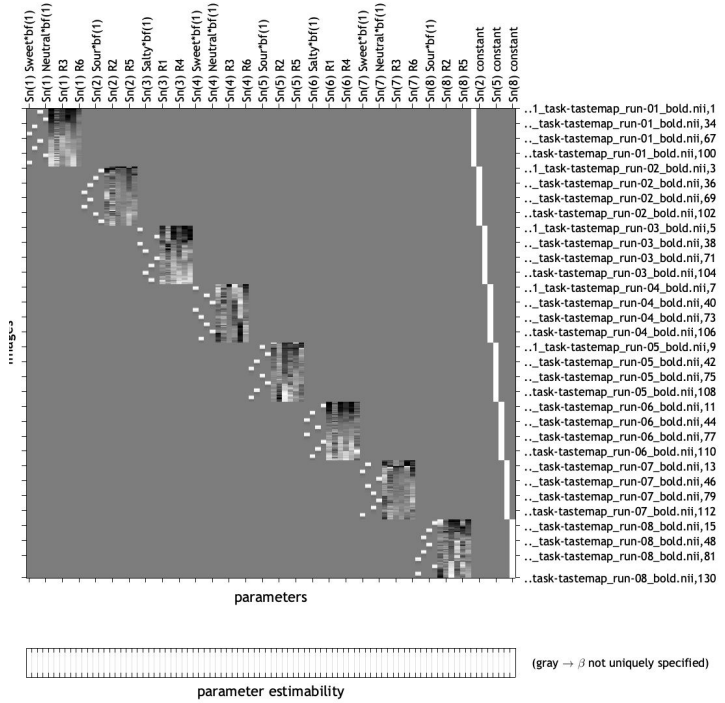
1st level analysis

Nothing changed

Current Module: fMRI model specification

Help on: fMRI model specification	
Directory	/Users/annamarie/1stlevel/ds002995/sub-007/results
Timing parameters	
. Units for design	Seconds
. Interscan interval	2.5
. Microtime resolution	68
. Microtime onset	7
Data & Design	
. Subject/Session	
. . Scans	130 files
. . Conditions	
. . Multiple conditions	...arie/1stlevel/ds002995/sub-007/ses-01/func/Run1.mat
. . Regressors	
. . Multiple regressors	...unc/rp_sub-007_ses-01_task-tastemap_run-01_bold.txt
. . High-pass filter	128
. Subject/Session	
. . Scans	130 files
. . Conditions	
. . Multiple conditions	...arie/1stlevel/ds002995/sub-007/ses-01/func/Run2.mat
. . Regressors	
. . Multiple regressors	...unc/rp_sub-007_ses-01_task-tastemap_run-02_bold.txt

Statistical analysis: Design



Design description...

Basis functions : hrf
Number of sessions : 8
Trials per session : 4 4 4 4 4 4 4 4
Interscan interval : 2.50 {s}
High pass Filter : [min] Cutoff: 128 {s}
Global calculation : mean voxel value
Grand mean scaling : session specific
Global normalisation : None

Future Direction

- Manually input conditions
- Checks if smoothing/additional steps needed before model specification
- 1st level > 2nd level analysis
- Move beyond visual inspection.
- Make a T shirt with sweet contrast