Multi-dimensional sampling of individual brains

– Multi-modal and multi-task human brain imaging dataset –

Reference Manual

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Introduction

This document introduces the dataset of “Multi-dimensional sampling of Individual Brains (MULDS)”, which aims to measure human brain activities of individual subjects comprehensively. MULDS includes brain activities of 5 subjects recorded with the following 4 modalities:

- magnetoencephalography (MEG)
- electroencephalography (EEG)
- functional magnetic resonance imaging (fMRI)
- near-infrared spectroscopy (NIRS)

when they performed the following 4 tasks:

- Face recognition task
- Language task
- Audio-Visual task
- Resting-state task.

Furthermore, MULDS includes their brain structures measured with

- T1-weighted MRI (T1)
- T2-weighted MRI (T2)
- diffusion-weighted MRI (dMRI).

Subjects

Five healthy subjects (Table 1) participated in all the experiments. All gave written informed consent for the experimental procedures, which were approved by the ATR Human Subject Review Committee. All had normal or corrected-to-normal visual acuity.

Subject ID	Age	Sex	Dominant hand
s045	26	Male	Right
s093	23	Male	Right
s095	24	Male	Right
s096	25	Male	Right
s097	24	Male	Right

Table 1. Subject information.

Tasks

Face recognition

Stimuli. The experimental protocol of Face recognition task was designed based on Wakeman and Henson, 2015. Unfamiliar face and scrambled face stimuli (Fig. 1A) obtained from "A multi-subject, multi-modal human neuroimaging dataset" (Wakeman & Henson, 2015) were used.

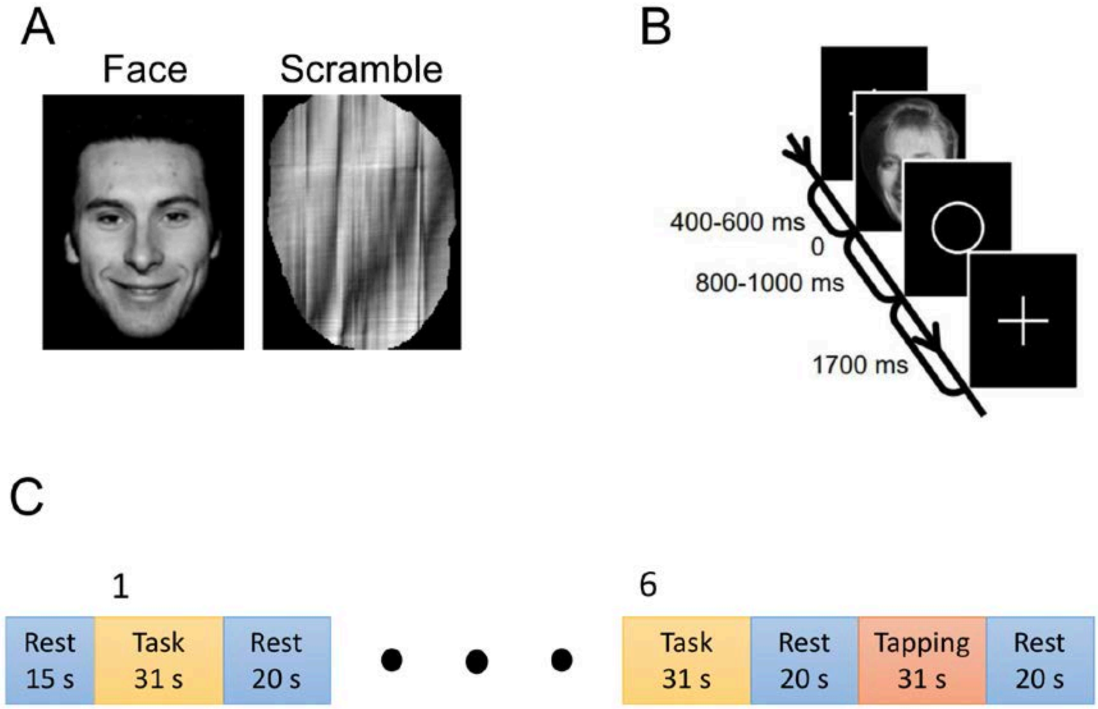

Figure 1. Face task. A: Stimuli. B: Each trial in M/EEG experiment. C: Block design in fMRI and NIRS experiments.

M/EEG experiment. Its design is shown in Fig. 1B. Each trial began with the appearance of a fixation cross for 0.4–0.6 s, after which the face or scrambled face was superimposed for 0.8–1 s. The subjects were instructed to judge whether the presented stimulus was 'more' or 'less symmetric' than average. They were also instructed to indicate their judges during the circle by pushing one of two buttons. The subjects were only allowed to blink during this period. Each run consisted of 145 trials. The subjects participated in 4 runs, resulting in 580 trials in total (290 trials for face and scrambled face stimuli, respectively).

fMRI and NIRS experiments. We used a block design (Fig. 1C). There were three kinds of blocks: task, rest, and tapping. In the task block, the subjects performed Face recognition task (Fig. 1B) for 10 trials while fixating each trial's duration at 3.1 s. In the tapping block, the same stimuli (Fig. 1B) were presented except the face stimuli were removed. The subjects were instructed to push one of the two buttons alternately during the circle. We include the tapping block to remove motor-related brain activities. Each run consists of 6 sets of the task and rest blocks followed by 1 set of the tapping and rest blocks (Fig. 1C). The subjects participated in 6 runs, resulting in the 36 task blocks for fMRI experiment and in 7 runs, 42 task blocks for NIRS experiment.

Language

Stimuli. The experimental protocol of Language task was designed based on Ihara et al., 2007. Word pairs (prime and target) were used as the stimuli. All the prime words were written in Japanese morphograms (kanji). The target words were ambiguous or unambiguous written in Japanese syllabograms (kana). The ambiguous words were homonyms that had one pronunciation but multiple unrelated meanings. The unambiguous works, in contrast, were not homonyms that had only one meaning. There were the following 4 conditions.

(1) The two words were related, and the target word was ambiguous.

(2) The two words were unrelated, and the target word was ambiguous.

(3) The two words were related, and the target word was unambiguous.

(4) The two words were unrelated, and the target word was unambiguous.

M/EEG experiment. Its design is shown in Fig. 2A. The prime and target words were visually presented for 0.3 s with a stimulus onset asynchrony (SOA) of 1 s. The subjects were instructed to read the words silently while gazing at the fixation point. They were also asked to judge whether the target words were semantically related or unrelated to the prime one. The fixation point became larger 1.8 s after the onset of the target words, which was the cue for subjects to press a button for related pairs and to press another one for unrelated pairs. Each run consisted of either 66 or 67 trials. The subjects participated in 6 runs, resulting in 400 trials in total (100 trials/condition).

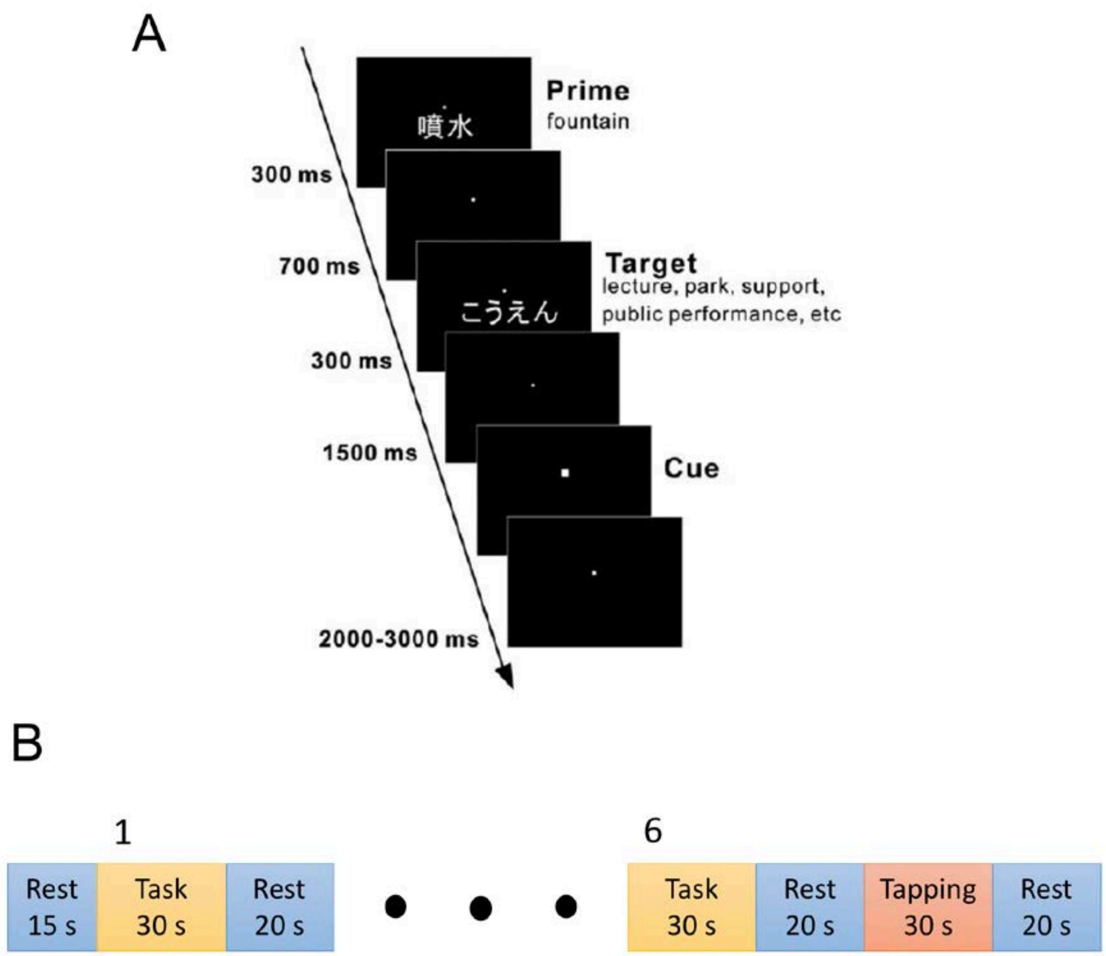

Figure 2. Language task. A: Each trial in M/EEG experiment. B: Block design in fMRI and NIRS experiments. Fig. 2A is derived from Ihara et al., 2007.

fMRI and NIRS experiments. We used a block design (Fig. 2B). There were three kinds of blocks: task, rest, and tapping. In the task block, the subjects performed Language task (Fig. 2A) for 5 trials while fixating each trial's duration at 6 s. In the tapping block, the same stimuli (Fig. 2A) were presented except that the prime and target words were removed. The subjects were instructed to push one of the two buttons alternately during the cue. We include the tapping block to remove motor-related brain activities. Each run consists of 6 sets of the task and rest blocks followed by 1 set of the tapping and rest blocks (Fig. 2B). The subjects participated in 6 runs, resulting in the 36 task blocks.

Audio-Visual

Stimuli. The experimental protocol of Audio-Visual task was designed based on Shinozaki et al., 2016. Three types of movie stimuli were presented (Fig. 3A): Audio-Visual (AV), Audio-Only (AO), and Visual-Only (VO). In the AV stimuli, a native Japanese male speaks “ba” or “ga”. The AO stimuli were produced by replacing the visual component of the AV stimuli by the still face of that speaker. The VO stimuli were produced by deleting the auditory component of the AV stimuli.

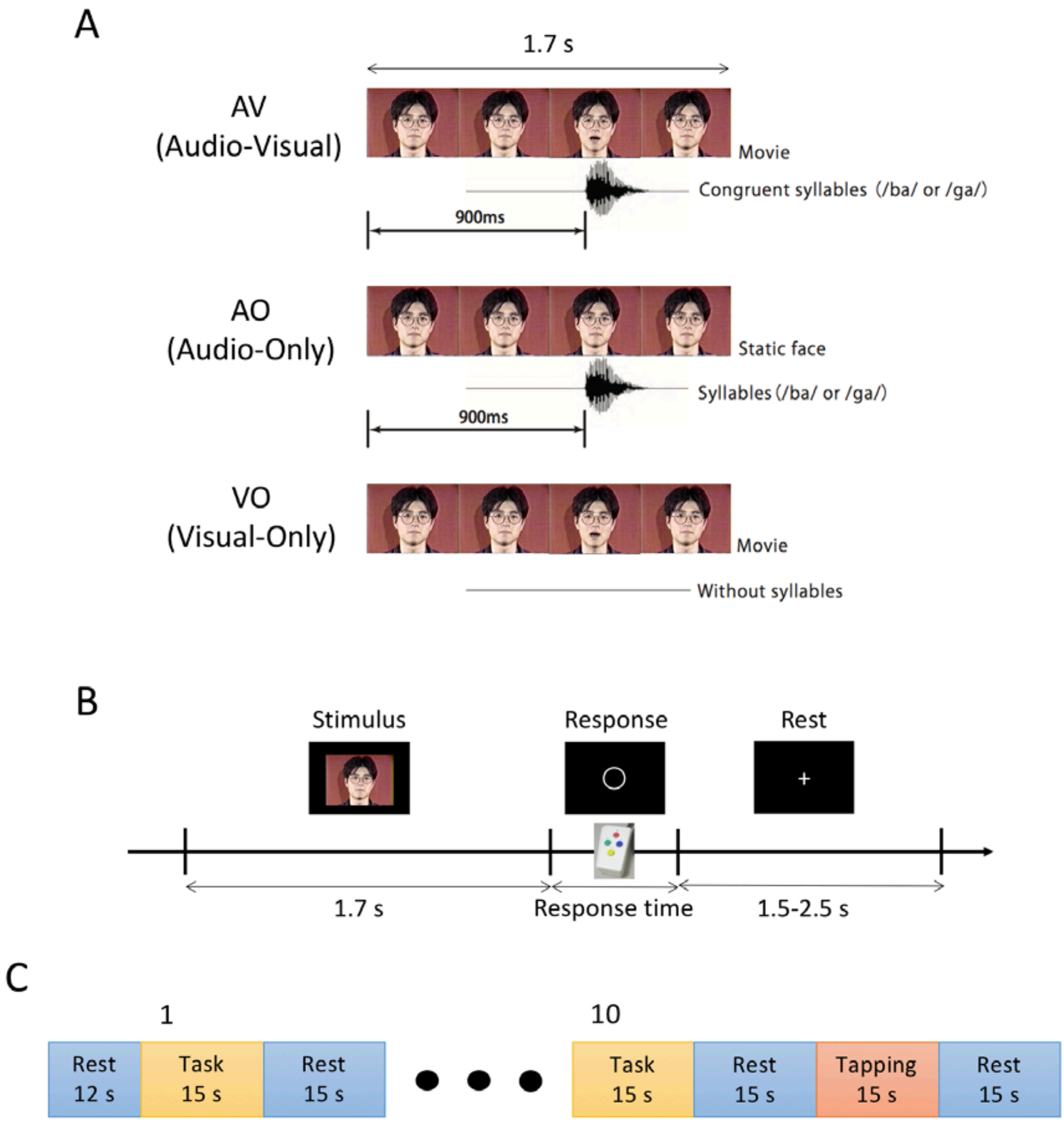

Figure 3. Audio-Visual task. A: Stimuli. B: Each trial in M/EEG experiment. C: Block design in fMRI and NIRS experiments.

M/EEG experiment. Its design is shown in Fig. 3B. Each trial consisted of stimulus, response, and rest periods. During the stimulus period, the movie stimulus was presented. The subjects were instructed to judge whether the speaker said “ba” or “ga”. They were also instructed to indicate their judges by pushing one of two buttons during the response period. The rest period began after the subjects' responses. The subjects were only allowed to blink during the response and rest periods. In each run, the same types of the stimuli (e.g. the AV stimuli) were presented for 90 trials (45 "ba" and "ga" trials, respectively). The subjects participated in 6 runs, resulting in 540 trials in total (180 trials for the AV, AO, and VO stimuli, respectively).

fMRI and NIRS experiments. We used a block design (Fig. 3C). There were three kinds of blocks: task, rest, and tapping. In the task block, the subjects performed Audio-Visual task (Fig. 3B) for 5 trials while fixating each trial's duration at 3 s. In the tapping block, the same stimuli (Fig. 3B) were presented except that the movie stimuli were replaced with a fixation cross. The subjects were instructed to push one of the two buttons alternately during the response period. We include the tapping block to remove motor-related brain activities. Each run consists of 10 sets of the task and rest blocks followed by 1 set of the tapping and rest blocks (Fig. 3C). In each run, the same types of the stimuli (e.g. the AV stimuli) were presented. The subjects participated in 6 runs, resulting in the 60 task blocks (20 blocks for the AV, AO, and VO stimuli, respectively).

Resting-state

Stimulus. We presented a fixation cross on the screen (Fig. 4).

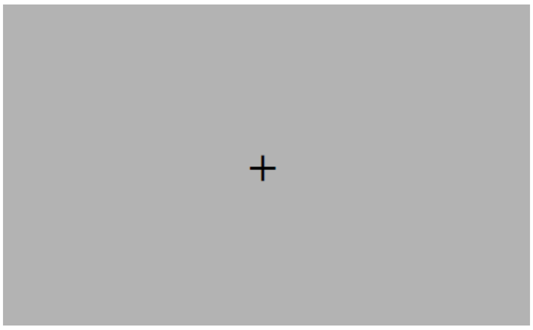

Figure 4. Stimulus of Resting-state task.

M/EEG experiment. Resting-state brain activities were recorded for 5 min. The subjects were instructed to fixate on the cross, to let their mind wander, and to not focus on any one thing.

fMRI and NIRS experiments. Resting-state brain activities were recorded for 10 min. The subjects were instructed to fixate on the cross, to let their mind wander, and to not focus on any one thing.

Recordings

One subject participated nine days of experimental session; three days of fMRI/MRI recordings, three days of MEG+EEG simultaneous recordings and three days of whole-head NIRS recordings (table 2). All the experiments were done within two months.

	MRI	MEG+EEG	NIRS
Day1	- **Rest run1** - **Face run1-6** - **Fieldmap** - **T1** - **T2**	- **Rest run1** - **Face run1-4** - (Rest run2) - **Empty-room**	- **Rest run1** - **Face run1-7**
Day2	- (Rest run1) - **Lang run1-6** - **Fieldmap**	- (Rest run1) - **Lang run1-6** - (Rest run1) - (Empty-room)	- (Rest run1) - **Lang run1-6**
Day3	- **AV run1-6** - **Fieldmap** - **dMRI98AP** - **dMRI98PA** - **dMRI99AP** - **dMRI99PA**	- (Rest run1) - **AV run1-6** - (Rest run2) - (Empty-room)	- (Rest run1) - **AV run1-6**

Table 2. All experimental sessions.

Recordings in bold text are included in this dataset.

M/EEG

MEG and EEG were simultaneously recorded with a whole-head 400-channel system (210-channel Axial and 190-channel Planar Gradiometers; PQ1400RM; Yokogawa Electric Co., Japan) and a whole-head 63-channel system (BrainAmp; Brain Products GmbH, Germany), respectively (Fig. 5). The sampling frequency was 1 kHz. Electrooculogram (EOG) signals were also simultaneously recorded and stored in the EEG.

Figure 5. Simultaneous recording of MEG and EEG.

The stimulus onsets were detected using a photosensor. At the same time as the stimulus presentation, we presented a white square at the edge of the screen and recorded the luminance of that place with the photosensor. The square was hidden from the subjects. The outputs of the photosensor were stored in both MEG (channel “432”) and EEG (*.vmrk file).

MRI

Three Tesla MR scanner (MAGNETOM Prisma, Siemens, Erlangen, Germany) with a Siemens 12-channel head coil was used to obtain fMRI, fieldmap, T1, T2, and dMRI. The following are the acquisition parameters.

T1 (MP-RAGE)

TR 2400 ms, TE 2.22 ms, TI 1000ms, Flip angle 8 deg., FOV 256 mm, Matrix 320x320, Thickness 0.8 mm, 256 slices.

T2 (SPACE, Sampling Perfection with Application optimized Contrast using different flip angle Evolution)

TR 3200 ms, TE 562 ms, FOV 256 mm, Matrix 320x320, Thickness 0.8 mm, 256 slices.

EPI (with Multiband technique)

Multiband factor 4, TR 1500 ms, TE 30 ms, Flip angle 60 deg., FOV 200 mm, Matrix 100x100, Thickness 2 mm, 72 slices/volume.

Field map

TR 751 ms, TE1 5.24 ms, TE2 7.70 ms, Flip angle 50 deg., FOV 200 mm, Matrix 100x100, Thickness 2 mm, 72 slices, effective echo spacing = 0.66ms, acceleration factor =1, Phase encode direction AP

dMRI 1 (with Multiband technique)

Multiband factor 4, TR 3230 ms, TE 89.2 ms, FOV 210 mm, Matrix 140x140, Thickness 1.5 mm, 92 slices, b-value 3000s/mm^2, 98 directions, Phase encode direction AP.

dMRI 2 (with Multiband technique)

Multiband factor 4, TR 3230 ms, TE 89.2 ms, FOV 210 mm, Matrix 140x140, Thickness=1.5mm, 92 slices, b-value 3000s/mm^2, 98 directions, Phase encode direction PA.

dMRI 3 (with Multiband technique)

Multiband factor 4, TR 3230 ms, TE 89.2 ms, FOV 210 mm, Matrix 140x140, Thickness 1.5 mm, 92 slices, b-value 3000s/mm^2, 99 directions, Phase encode direction AP.

dMRI 4 (with Multiband technique)

Multiband factor 4, TR 3230 ms, TE 89.2 ms, FOV 210 mm, Matrix 140x140, Thickness 1.5 mm, 92 slices, b-value 3000s/mm^2, 99 directions, Phase encode direction PA.

NIRS

We used two continuous-wave near-infrared imaging system (FOIRE-3000, Shimadzu Corporation) to cover whole the head (Fig. 6). The two systems were synchronized. One of the system (Master) controlled the other system (Slave). The head cap for simultaneous NIRS and EEG recording (Shimadzu Corporation) was used to hold the optodes, though EEG was not recorded in this experiment. Measured data from the two systems were merged in same files. The wavelengths of the near-infrared light were 780 nm, 805 nm, and 830 nm. The sampling frequency was 4 Hz.

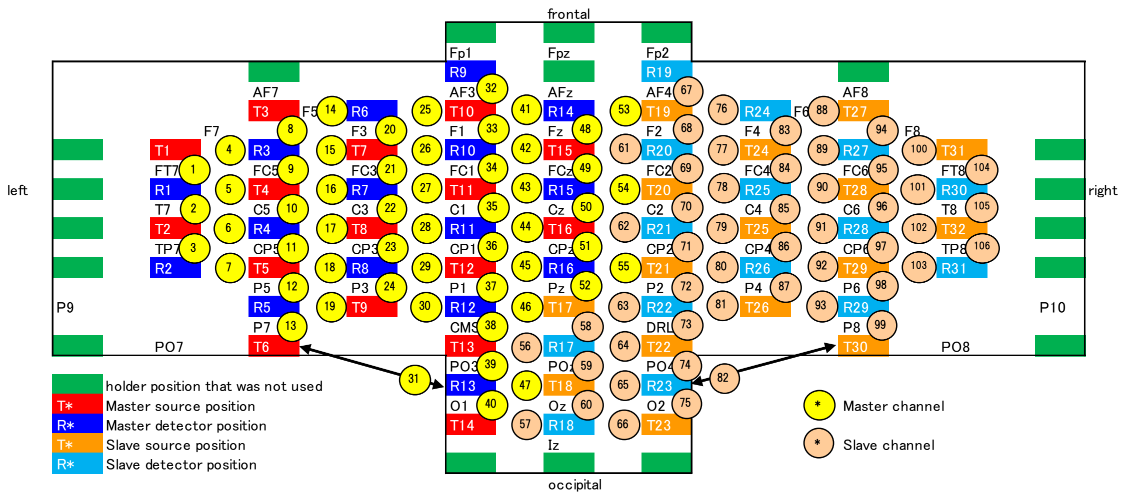

Figure 6. Positions of optodes and channels (probe pairs). The EEG labels of the international 10-20 system are presented to indicate location information.

Data

Directory structure

Each subject data is stored in the directory structure as follows:

```
$SUBJECT
 |-- EEG
 |    |-- AV
 |    |    `-- log
 |    |-- Face
 |    |    `-- log
 |    |-- Lang
 |    |    `-- log
 |    `-- Rest
 |-- MEG
 |    |-- AV
 |    |    `-- log
 |    |-- Face
 |    |    `-- log
 |    |-- Lang
 |    |    `-- log
 |    `-- Rest
```

```
|-- NIRS
|     |-- AV
|     |-- Face
|     |-- Lang
|     `-- Rest
|-- T1
|-- T2
|-- dMRI
`-- fMRI
      |-- AV
      |     |-- fieldmap
      |     |-- log
      |     |-- run1
      |     |-- run2
      |     |-- run3
      |     |-- run4
      |     |-- run5
      |     `-- run6
      |-- Face
      |     |-- fieldmap
      |     |-- run1
      |     |-- run2
      |     |-- run3
      |     |-- run4
      |     |-- run5
      |     `-- run6
      |-- Lang
      |     |-- fieldmap
      |     |-- run1
      |     |-- run2
      |     |-- run3
      |     |-- run4
      |     |-- run5
```

```
|     `-- run6
`-- Rest
      |-- fieldmap
      `-- run1
```

where $SUBJECT = s045, s093, s095, s096, or s097.

Detailed information of data files in each directory is explained below.

Log

The orders of the presented stimuli and conditions are described in the following files.

- $SUBJECT/MEG/Face/log/stim_order.txt
- $SUBJECT/MEG/Lang/log/condition_order.txt
- $SUBJECT/MEG/AV/log/stim_order.txt
- $SUBJECT/EEG/Face/log/stim_order.txt
- $SUBJECT/EEG/Lang/log/condition_order.txt
- $SUBJECT/EEG/AV/log/stim_order.txt

MEG

The MEG files are stored in $SUBJECT/MEG/$TASK (e.g. s045/MEG/Face), where $TASK = AV, Face, Lang, Rest.

This directory contains the following files.

- .con: MEG signals recorded by the Yokogawa system. The trigger signals, the outputs of the photosensor, were recorded in the channel '432'.
- .pos.mat: Position information of MEG sensors, the transformation matrix of the MEG sensors to a RAS coordinate. In this coordinate, +x = right, +y = anterior, +z = superior and the origin [0 0 0] corresponds to the center of the T1 image ($SUBJECT/T1/defaced.nii).
- .pos.txt: Ascii file generated from .pos.mat file.

We recommend to use VBMEG (Variational Bayesian Multimodal EncephaloGraphy; http://vbmeg.atr.jp/) to import and analyze the MEG files. In VBMEG, .con files are imported together with .pos.mat files.

EEG

The EEG file are stored in $SUBJECT/EEG/$TASK (e.g. s045/EEG/Face).

This directory contains the following files.

- .eeg: raw EEG files from the BrainAmp system
- .vhdr: Parameters of EEG recording from the BrainAmp system
- vmrk: Time information of stimulus onsets from the BrainAmp system
- allruns.pos.mat: Position information of EEG sensors. EEG sensors positions are described with the RAS coordinate, where +x = right, +y = anterior, +z = superior and the origin [0 0 0] corresponds to the center of the T1 image ($SUBJECT/T1/defaced.nii).
- allruns.pos.txt: Ascii file generated from allruns.pos.mat

We also recommend to use VBMEG to import and analyze the EEG files. In VBMEG, .eeg files are imported together with .pos.mat files.

fMRI

fMRI and fieldmap files with NIFTI format are stored in

- $SUBJECT/fMRI/$TASK/$RUN (e.g. s045/fMRI/Face/run1),
- $SUBJECT/fMRI/$TASK/fieldmap (e.g. s045/fMRI/Face/fieldmap),

respectively, where $RUN = run1, run2, …, or run6.

In the fMRI analysis, the volumes during the first rest periods (Figs. 1C, 2B, and 3C) need to be excluded to remove non-steady state volumes.

NIRS

NIRS data was saved with the 'Shared Near Infrared File Format' of the Society for functional near infrared spectroscopy (http://fnirs.org/resources/software/snirf/) (version 1.0, updated Aug 1, 2013) as $SUBJECT/NIRS/$TASK/allruns.snirf (e.g. s045/NIRS/Face/allruns.snirf).

The time information of the stimulus presentation was recorded in the 'mark_count' in different ways depending on the tasks as follows.

- Face recognition: start of both the rest and task intervals
- Language: start of the task interval (but not the start of the rest interval)
- Audio-Visual: start of both the rest and task intervals
- Resting-state: start and end of the resting task, the moments when the experimenter pressed the Mark key detecting subject's large motion

T1

T1 images were bias-corrected, defaced, and saved as $SUBJECT/T1/defaced.nii (e.g. s045/T1/defaced.nii).

T2

T2 images were defaced and saved as $SUBJECT/T2/defaced.nii (e.g. s045/T2/defaced.nii).

dMRI

Based on the tools available in FSL (https://fsl.fmrib.ox.ac.uk/fsl/fslwiki/), dMRI files are stored in $SUBJECT/dMRI/ as follow.

- AP_b1500_b3000.nii.gz : NIFTI image file containing dMRI data measured with AP phase encoding direction
- AP_b1500_b3000.bval : Text file specifying the b-values
- AP_b1500_b3000.bvec : Text file specifying diffusion encoding directions
- PA_b1500_b3000.nii.gz : NIFTI image file containing dMRI data measured with PA phase encoding direction
- PA_b1500_b3000.bval : Text file specifying the b-values
- PA_b1500_b3000.bvec : Text file specifying diffusion encoding directions.

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History

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