Introduction to the Natural Scenes Dataset

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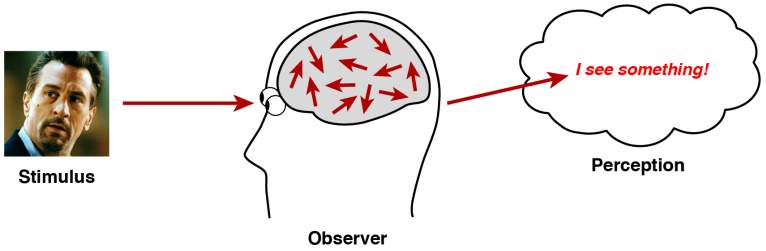
Why NSD?

- **How does visual cortex work?**
  - Characterize the computations by which information is transformed and re-represented in the brain.
  - Build models of neural information processing. (Kay, *NeuroImage*, 2018)
  - We need to sample a lot of stimuli!



- Goal: To establish a massive benchmark dataset that can be used to answer a variety of scientific questions about vision

- Fields that might be interested in NSD:
  - Visual neuroscience
  - Cognitive neuroscience
  - Computational neuroscience
  - Theoretical neuroscience
  - Neuroimaging

Many recent ‘big data sharing’ efforts

- Algonauts
- Allen Brain Observatory
- BOLD5000
- Brain-Score
- CNeuroMod
- DoctorWho
- HCP (Human Connectome Project)
- Individual Brain Charting
- Midnight Scan Club
- MyConnectome
- StudyForrest
- UK Biobank
- vim-1, vim-2
- (and others...)

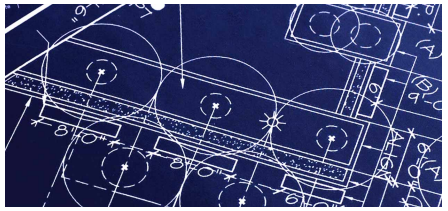
Design principles for NSD

- **Priority 1:** Big.
  - Large data per subject
  - Reasonably large number of subjects

- **Priority 2:** High SNR, high resolution.
  - 7T fMRI
  - Screen for the best subjects

- **Priority 3:** Push envelope on acquisition and analysis methods.

- **Priority 4:** Paranoid on details and documentation.

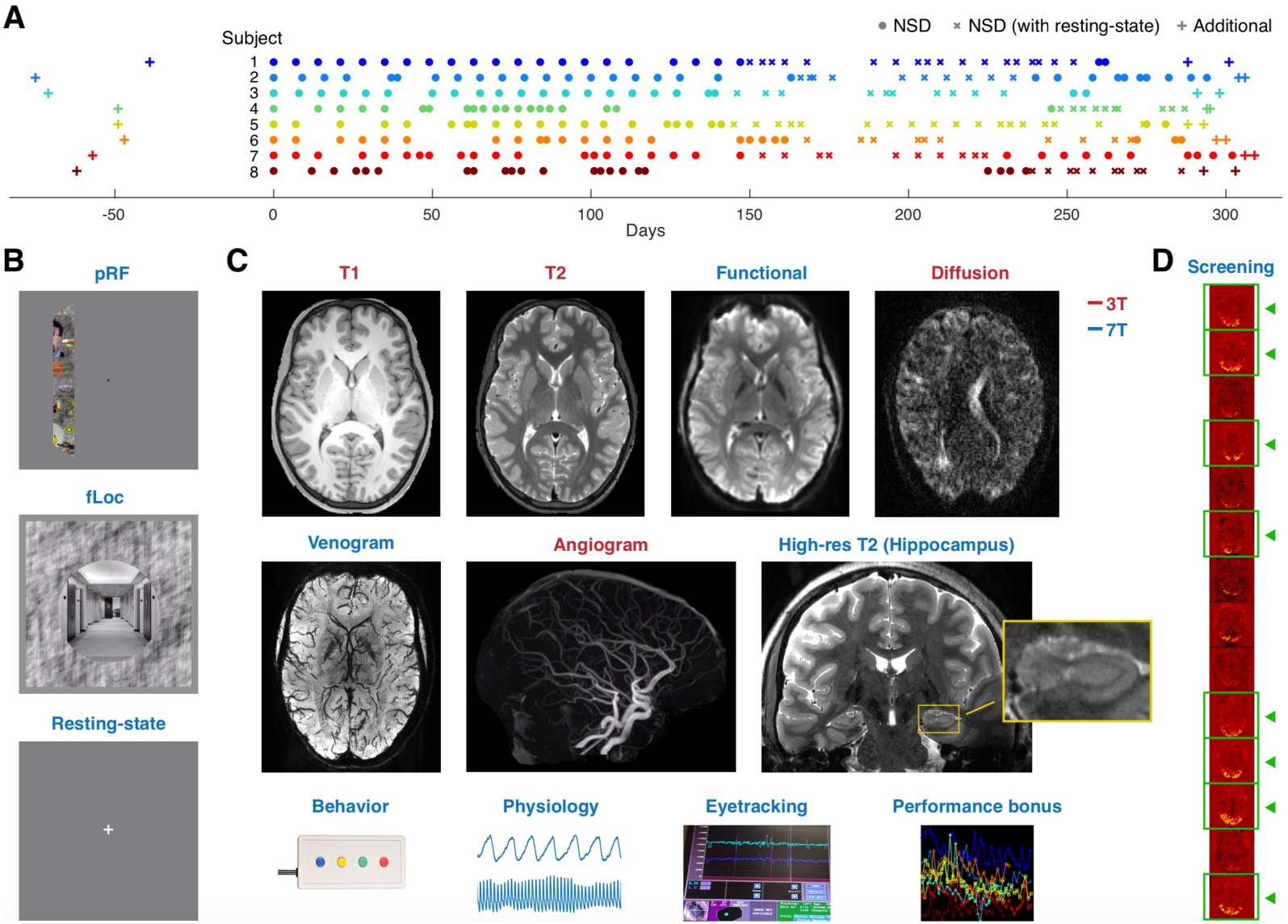


What could the data be useful for?

- Study representation of visual dimensions (orientation, spatial frequency, contrast, color, objects, scenes, etc.)
- Benchmark encoding models
- Train neural networks
- Characterize individual differences
- Topography and mapping
- Integration with other neuroimaging modalities
- Study short-term and long-term memory
- Investigate subcortical regions (LGN, cerebellum)
- Develop fMRI analysis methods

(Recent pre-prints and papers using NSD are listed on the NSD Data Manual)

Overview of acquisition



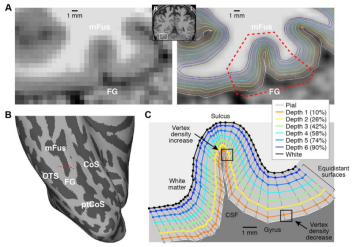
What's in the dataset?

- **Type of data**
  - Functional data (7T)
    - NSD data (color natural scenes)
    - Resting-state data
    - Functional localizers (pRF mapping, category localizer)
    - Synthetic stimuli
  - Anatomical data (3T)
    - 6 T1s, 3 T2s
    - Diffusion
    - Angiogram, venogram
  - Behavioral data
  - Physiological data (pulse oximeter, respiratory belt)
  - Eyetracking data
- **Quantity of data**
  - 8 subjects
  - 30–40 hours of NSD data per subject (up to 10,000 images x 3 reps)
  - Whole-brain including cerebellum
- **Quality of data**
  - MRI image quality, imaging stability
  - Behavioral compliance (head motion, task performance)
  - Quality of single-trial BOLD response estimates
- **Value added by pre-processing**
  - Best possible spatial and temporal processing and denoising
  - Manually edited cortical surfaces and manually defined ROIs
  - Extensive inspections of data quality

fMRI acquisition details:
- 7T
- 32-channel RF coil
- Caseforge headcases
- Whole-brain EPI (1.8 mm, 1.6 s, MB3, IPAT2)
- Multiple fieldmaps in each session

All data hosted on Amazon S3 – freely downloadable

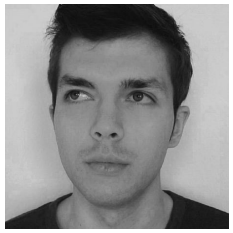
Both raw data (BIDS) and pre-processed data are available



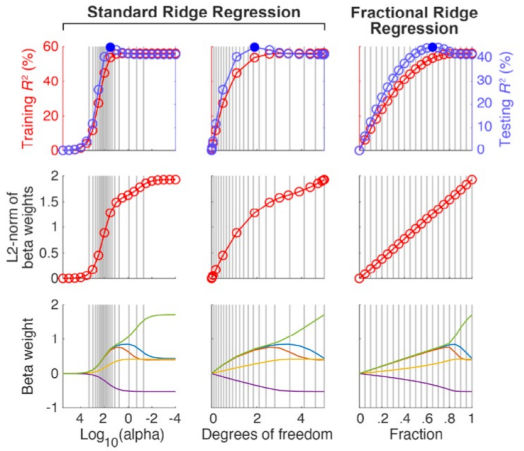
→ Adopt insights from sub-millimeter 0.8-mm fMRI
Kay, Jamison, Vizioli, Zhang, Margalit, Ugurbil
NeuroImage, 2019

NSD drove methods development

1. “Jitterupsample” project – Logan Dowdle, Faruk Gulban



2. Fractional ridge regression – Ariel Rokem
   - Rokem & Kay, *GigaScience*, 2020



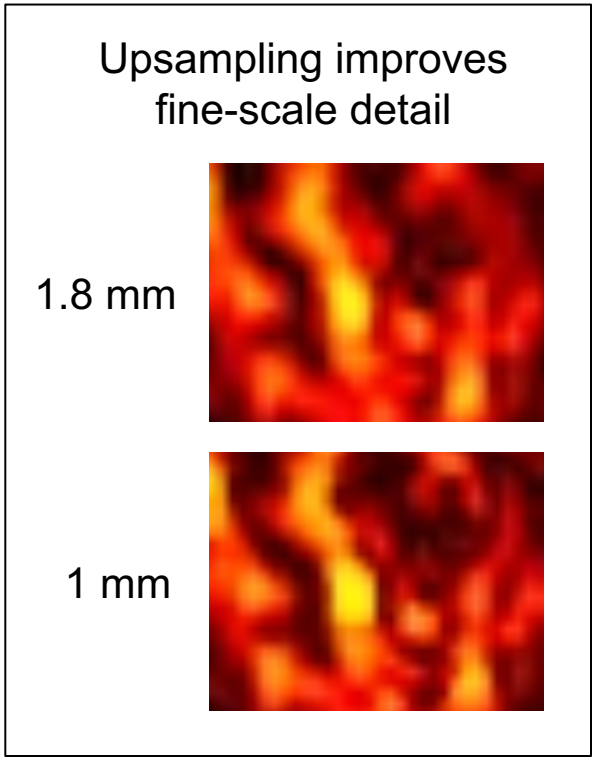
3. GLM methods for fMRI data – Jacob Prince
   - 3.1. Library of HRFs
   - 3.2. GLMdenoise for single trials
   - 3.3. Ridge regression for regularizing single trials

glmsingle.org
Prince et al., *bioRxiv*, 2022

fMRI pre-processing

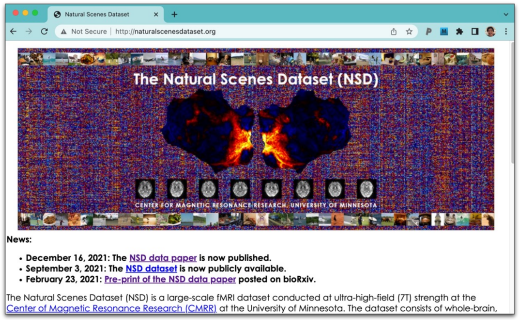
- One temporal interpolation
  (slice time correction, upsampling)

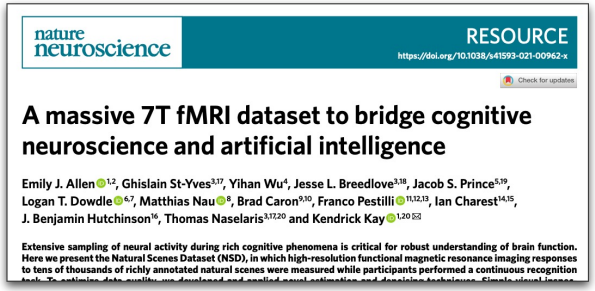
- One spatial interpolation
  (time-varying fieldmaps, gradient nonlinearities, head motion, upsampling)

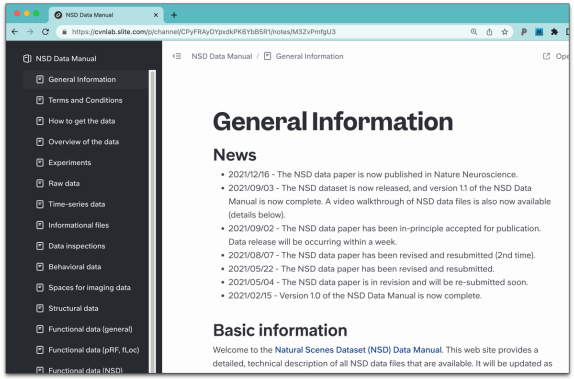


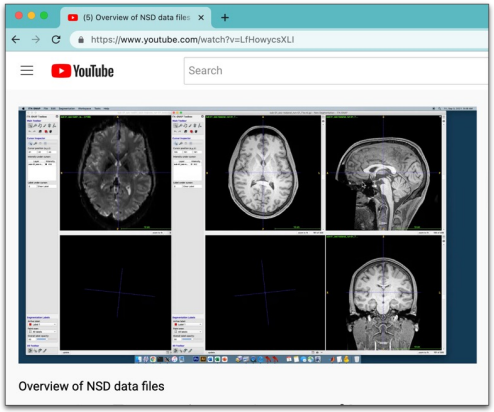
Where to find information

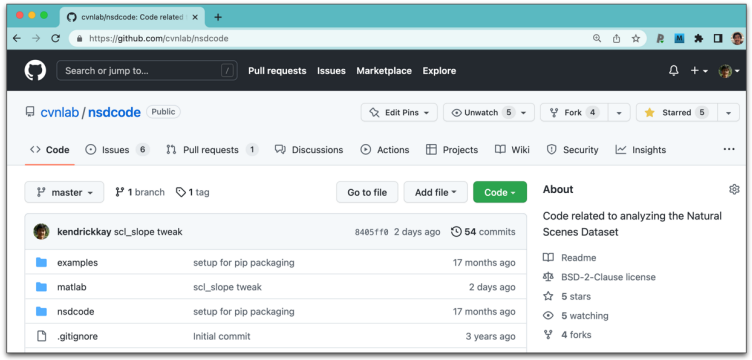
- naturalscenesdataset.org
- The NSD data paper (Allen et al., *Nature Neuroscience*, 2022)
- The NSD data manual
- A detailed video walkthrough of NSD files
- The nsdcode utilities











Closing thoughts / discussion

What is the relevance of NSD for cognition and neuroscience?

Some general themes:

- 'Deep' sampling approach
- Advances in data quality/processing
- Feeding frenzy for modelers (data, data, ...)
- Integration of subfields/approaches

But... let's consider the limitations:

- Does it even make sense to sample "random" naturalistic scenes?
- Do we need 'big data'? What are the pitfalls?
- What are the limits to model building?
- What are the limits of fMRI?
- For what situations are large-scale datasets useful?

Where are things going in the field?

- Computation and modeling
- Machine learning
- Big data / data science
- Connectivity
- Individual differences
- Biomarkers
- Team science (multiple labs)
- Improved measurement methods

Where **should** things go?