Neural circuitry for vision and reading

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QUANTITATIVE MEASUREMENTS

∞

COMPUTATIONAL MODELS

∞

CHECK AND SHARE
25 research labs (10 new hires)
Theory center (6 PIs)
Campus hub for 200 neuroscience labs
Building to be occupied fall 2019
Wu Tsai Neurosciences Institute building (March 19, 2019)

25 research labs (10 new hires)
Theory center (6 PIs)
Campus hub for 200 neuroscience labs
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**Neuro-Discovery**

Our scientists develop cutting-edge techniques to make fundamental discoveries in brain science — discoveries that could unlock new medical treatments, transform education, inform public policy.

**Neuro-Engineering**

Our engineers are developing ways to manipulate neural circuits with electricity, light, ultrasound and magnetic fields. They are inventing algorithms and theories to guide understanding.

**Neuro-Health**

Our clinicians collaborate with scientists and engineers to pioneer novel treatments for psychiatric and neurological disease, easing the devastating consequences of diseases such as stroke, epilepsy, and depression.
Stanford’s Center for Cognitive and Neurobiological Imaging (CNI)

• Support neuroscience discovery for enhancing society
• Develop and disseminate imaging methods
• Create a structured, safe, and innovative teaching environment for human neuroscience research
CNI: The most heavily used MRI research scanner on Stanford campus

**CNI Investigators**

- Users from Med School, Basic Sciences, Engineering, Ed School and Business School
- More than 40 research groups and 200 grants
- More than 1050 students and postdocs trained

**CNI Data**

- Scanner uptime estimated at 99%
- 6,000 subjects
- 100 T of MRI data just at this one center
Talk plan: Neural circuitry for vision and reading

1. Experimental design for diagnosis

2. Advances in brain measurements with MRI
   a. How much of the world can we see
   b. Connections between brain regions

3. Storing, sharing and analyzing large data sets
1. Experimental design for diagnosis

- **Goal:** Determine as early as possible the best way to help a particular child to become a successful reader.

- The distribution (blue) at the right shows a population distribution of a potentially helpful diagnostic measurement.

![Histogram showing a distribution with N = 1000](image)
1. Experimental design for diagnosis

- **Goal**: Determine as early as possible the best way to help a particular child to become a successful reader.

- The distribution (blue) at the right shows a population distribution of a potentially helpful diagnostic measurement.

- The filled circles are measurements from two children; we would like to use the measurement to decide how to support the child.
1. Experimental design for diagnosis - the problem with group comparisons

- This example shows a typical group comparison one might see reported in the literature

- We would never use this measure to diagnose a child – it does not distinguish the groups well
1. Experimental design for diagnosis - the problem with group comparisons

- These are the same data as the histograms, but plotted as a group comparison

- We often see publications that show the mean and the SEM, as in this bar chart

- The author might conclude that we have a potential biomarker, although when N is large that will not be true
Use experimental designs for single subjects and choose experiments and analyses that can diagnose individuals, not groups.
2. Advances in cortical mapping – why use neural measurements

- It may be possible to find satisfactory methods using only behavioral measures.

- The interest in brain imaging arises because of concerns about the reliability of behavior.

- The possibility that neural measures will help with diagnoses is a hope for now.
2. Advances in cortical mapping: eccentricity map

(Engel et al., 1994, 1997; Sereno; Tootell, DeYoe; Others)

- Inflated brain
- Gray/white are sulci/gyri
2. Advances in cortical mapping: eccentricity map
2. Advances in cortical mapping: angular map
Summary point: Visual field maps
2. Advances in cortical mapping: functional specializations

- Ventral occipito-temporal cortex (VOTC), near the visual field maps, contains several specialized processing regions.

- Each region responds better to some class of stimuli than others (functional specialization).

- The visual word form area (VWFA) is one of these specializations.

Grill-Spector and Weiner
Nature Reviews Neuroscience, 2014
A single voxel within, say V1, responds to a small part of the visual field and thus has a small field of view.
2. Advances in cortical mapping – the field of view of V1

Amano et al. 2009

- A single voxel within, say V1, responds to a small part of the visual field and thus has a small field of view

- Combining the pRFs from the voxels in a region, say all of V1, describes the region’s field of view
• Using these methods, we have learned that the portion of cortex engaged in reading only sees a small part of the visual field – it has a small field of view.

• We can measure these in individual participants.
2a. Advances in cortical mapping – VWFA field of view in different subjects

- There are significant differences between participants

- We will correlate these differences with measures of word recognition and eye movement patterns
2. Advances in cortical mapping – summary

The visual circuitry for seeing words can be identified and certain properties, such as the field of view, can be reliably estimated in single subjects. These measurements are quantitative and might help diagnose part of the reading circuitry.
2b. Connections between brain regions

- There are many long-range connections

- These connections are not passive – they change their properties in response to use

- A system with active wires

Courtesy Professor Ugur Ture
2b. Connections between brain regions - tracts

**Introduction to LiFE**

**Extension to ensemble method**

**Review of diffusion imaging**

Left IFOF

150 Directions, 2 mm³, B=2000 projected on a 1 mm³ T1 anatomical image
2b. Connections between regions – good and poor readers develop differently

- Measured brain and behavior at 4 time points (data management!)
- The first measurements predict reading over the next few years
- The rate and direction of FA development differs between good and poor readers in the Arcuate and the ILF

- Fractional anisotropy (FA)
- Displaced vertically for each participant
- Ordered by slope
- Colored by reading score
2b. Connections between regions – good and poor readers develop differently

(Yeatman et al., 2012, *PNAS*)

- Development measured by dMRI in the ILF and Arcuate, but not others tracts, correlates with the ability to rapidly see words

- This is one reason we think that the wires are active, changing in response to learning and memory
2b. Connections between regions – people differ

VOT
Specialized processing for faces, words, other things

General visual inputs
2b. Connections between regions – can this difference be a factor in poor reading?

General visual inputs
**Goal:** We want a measure with its population distribution that we can use to assess a child.

- For the neuroimaging measures, FOV size or tract FA, we must collect, store and be able to analyze large datasets.
- This requires sharing data and using a database that can be used for computing and comparing.
4. Data and computational management: both are important for diagnosis

- Most MRI Centers provide one of these data retrieval options from the MRI scanner
  - Copy data to CD, DVDs, USB hard drive
  - Copy to a server and remote login
- Data and metadata are transferred to a system controlled by a student or post-doc
- **Limitations** – reuse and sharing become burdensome; metadata and pre-processing information are frequently lost

Data transferred to laboratories from the scanner
4. Data and computational management: both are important for diagnosis

- Archiving MRI Center data eliminates the need for users to gather the data again for publication

- The data should be available through a platform-independent web browser to simplify access

- Basic tools, such as search, visualization, and pre-processing can be available through the browser

- The data are ready for sharing and reuse; metadata can be stored; pre-processing methods shared can be shared

Data transferred to laboratories from the data system
Modern Informatics Platform
for Biomedical Research and Collaboration

Cloud-Scale Research Solution

Clinical & Research Data
- Imaging Modalities
- PACS / VNA
- Any Research Data

Research Applications
- Machine Learning
- Imaging Research
- Multi Center Studies

Capture
Curate
Compute
Collaborate

Imaging Research Centers
Clinical Research
Clinical Trials

Data Privacy & Regulatory Compliance

I am a co-founder of the company
4. Data and computational management – computation

- The algorithms you used and their parameters are stored in the Provenance tab
- Here is a FreeSurfer run
Search

• Index all metadata
• Visual search
  • In project
  • Across projects
• Act on results
  • Save to collections
  • Download
  • Batch process (Gears)
  • Create ML Training Set
Machine Learning Workflow

- Classification & Labeling
- Visual ROIs / Labeling
- Train, Validate, Test
- Track Everything

Prepare Training Data
Train (re-train) Models
Deploy Models for Testing

- PACS
- VNA
- Healthcare API

Clinical Images
Supplemental Reports

Training Data
Trained Models

Machine Learning Tools
- TensorFlow
- PyTorch
- Cloud ML
- Auto ML Vision API
Talk review: Neural circuitry for vision and reading

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