Decoding semantic representations from fNIRS signals

Benjamin D. Zinszer[1*], Laurie Bayet[1,2,3], Lauren Emberson[4], Richard N. Aslin[1]

1. University of Rochester, NY, USA; 2. Boston Children's Hospital, MA, USA; 3. Harvard Medical School, MA, USA; 4. Princeton University, NJ, USA

*** contact: bzinszer@gmail.com**

Introduction

Semantic Decoding & fNIRS – Why?

- Neural decoding compares patterns of brain responses to theoretical models based on corpora or behavioral judgments.
- Semantic decoding studies using fMRI have proven enormously powerful for explaining neural activity associated with words or images based on external semantic models (e.g., text corpora).
- This tool would be useful for studying infants' and children's language representation, which would be difficult with fMRI.

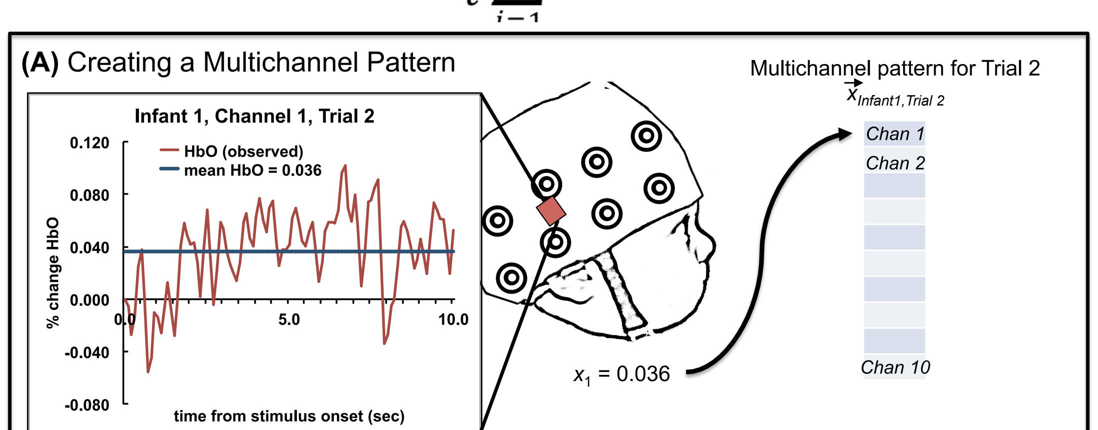
This study demonstrates for the first time that semantic decoding methods also work with fNIRS data, lowering cost and allowing for child participation.

Multivoxel & Multichannel pattern analysis

- Multivoxel pattern analysis (MVPA) asks whether the ***pattern*** of BOLD signals can discriminate between conditions.
- MVPA shifts the focus in neuroimaging from mean activation differences in a brain region to the information contained within patterns of brain activity within that region.
- Multi*channel* pattern analysis applies the same multivariate principles as MVPA to fNIRS data to broaden application to infants, paradigms requiring movement, and other studies outside the fMRI environment (Emberson et al., 2016).

Equation 1: Each channel is represented by the average % change in oxygenated hemoglobin (HbO) in a given time window.

$$x_{chan} = \frac{1}{t}\sum_{i=1}^{t} HbO_{chan,i}$$

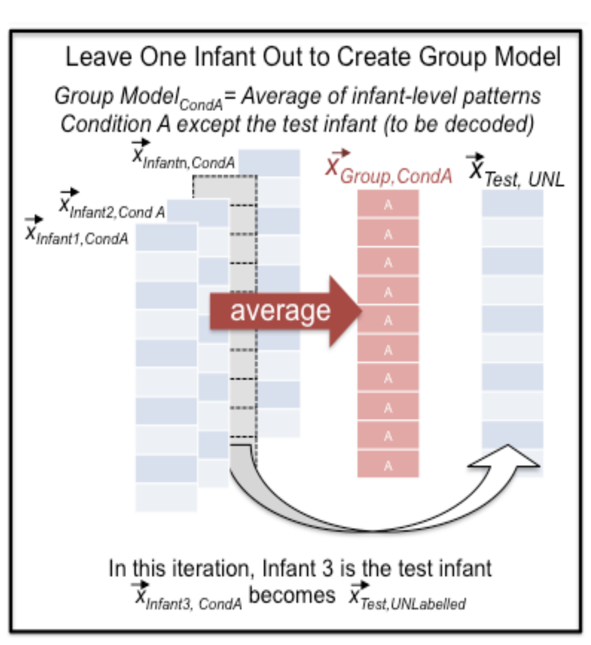


Equation 1

Equation 2: Multichannel patterns are averaged across trials (within condition) for each participant. For example, given *r* trials in Condition A:

$$x_{Infant,Cond} = \frac{1}{r}\sum_{j=1}^{r} x_{Infant\ n,Cond\ A,Trial\ j}$$

N-Fold Cross-Validation



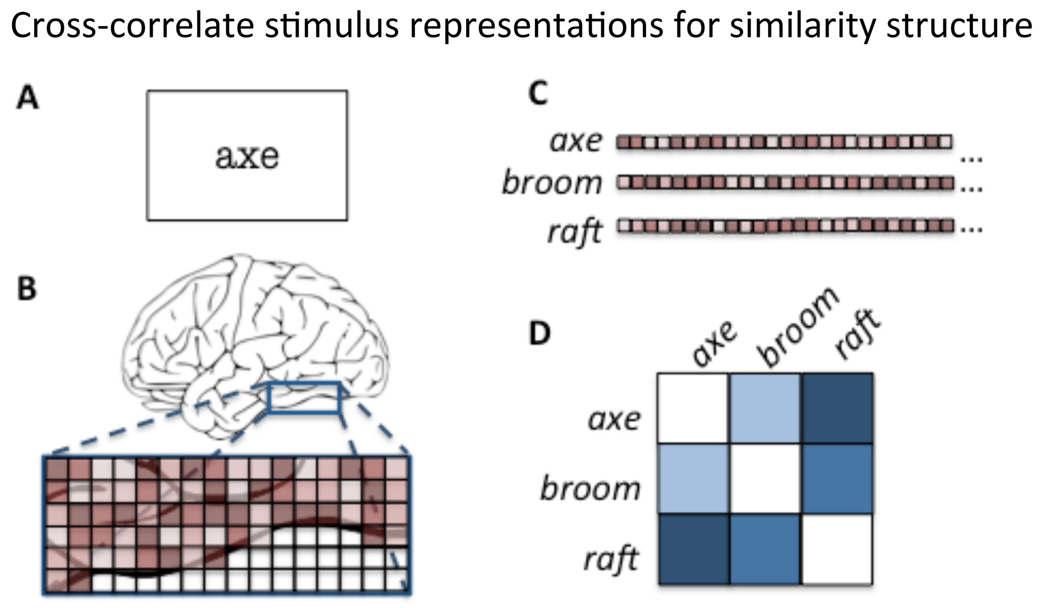
Participant-level condition patterns are then averaged across participants to produce a **Group Model** (also referred to as the training set in cross-validation).

One participant is excluded from the group to serve as a **Test Case**. Accuracy of re-labeling the Test Case based on the Group Model is then assessed.

This procedure is repeated once for each participant to serve as test case against the other participants (*n*-fold cross validation).

Representational Similarity Analysis (RSA)

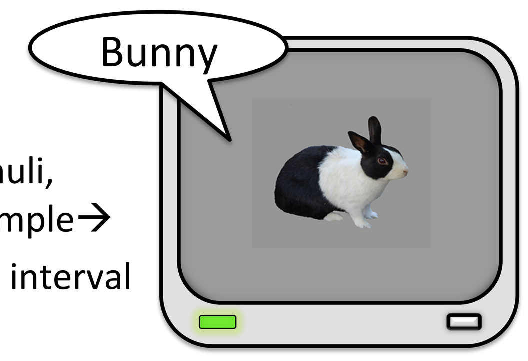
A. Present a word stimulus as text on screen to participant
B. Measure signal (fMRI / fNIRS) during exposure to stimulus
C. Each stimulus represented as n-dimensional vector of neuroimaging data (either voxels of channels)
D. Cross-correlate stimulus representations for similarity structure



fNIRS Data

Procedure

- N=8 adult participants
- Passively viewed audiovisual stimuli, repeated over 12 blocks, see example→
- 3 sec exposure, 6-9 sec inter-trial interval



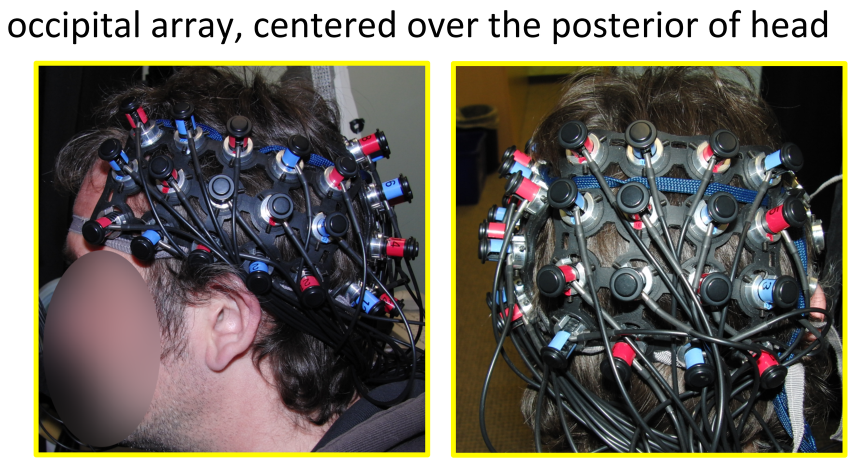
Stimuli

Eight familiar visual objects and their audio-recorded names

Imaging

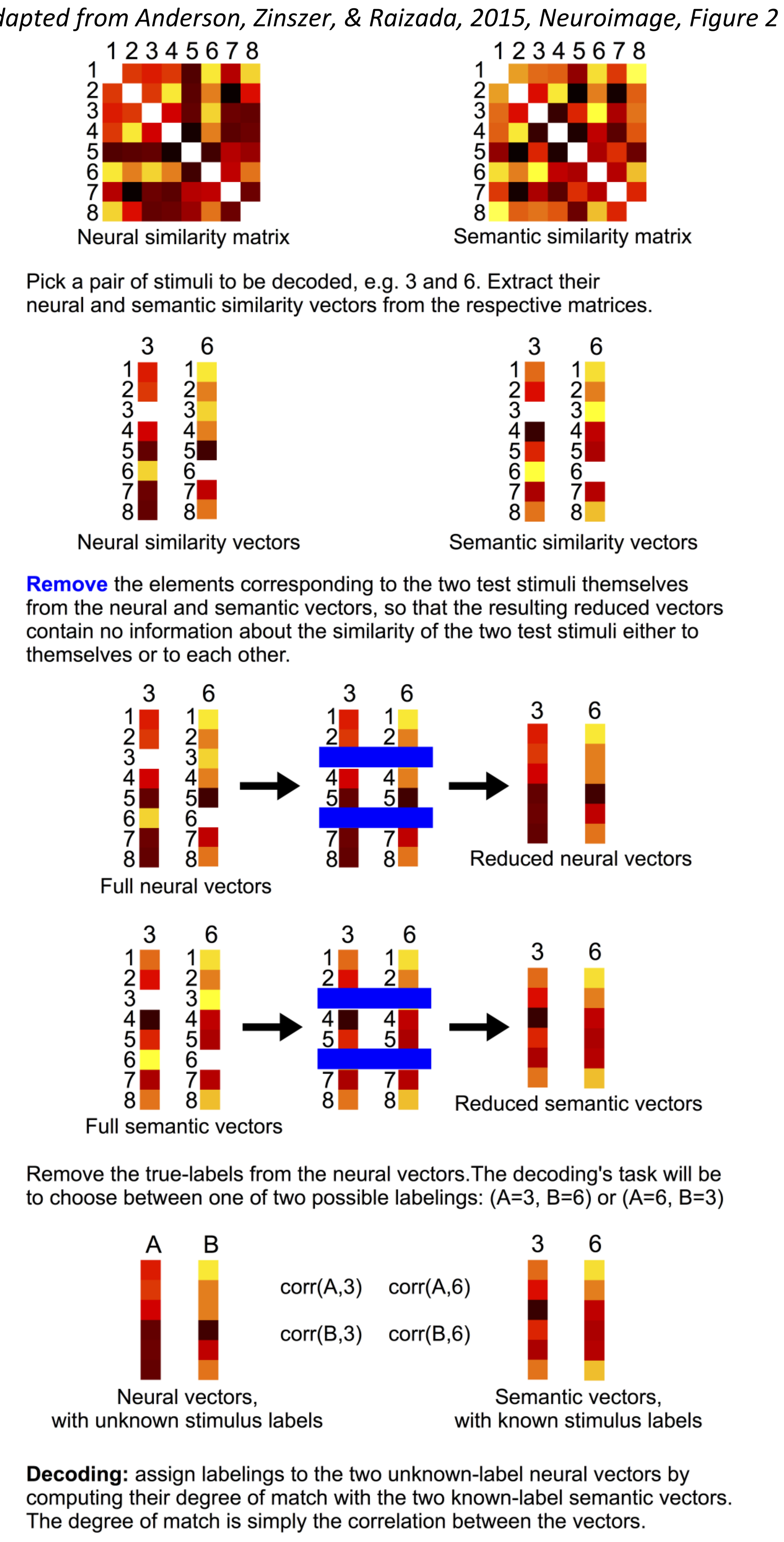
Hitachi ETG-4000 fNIRS system with two arrays, 10 Hz sampling

- 5x3 Left temporal array covering temporo-occipital, temporo-parietal, and a small amount of frontal cortices
- 4x4 occipital array, centered over the posterior of head



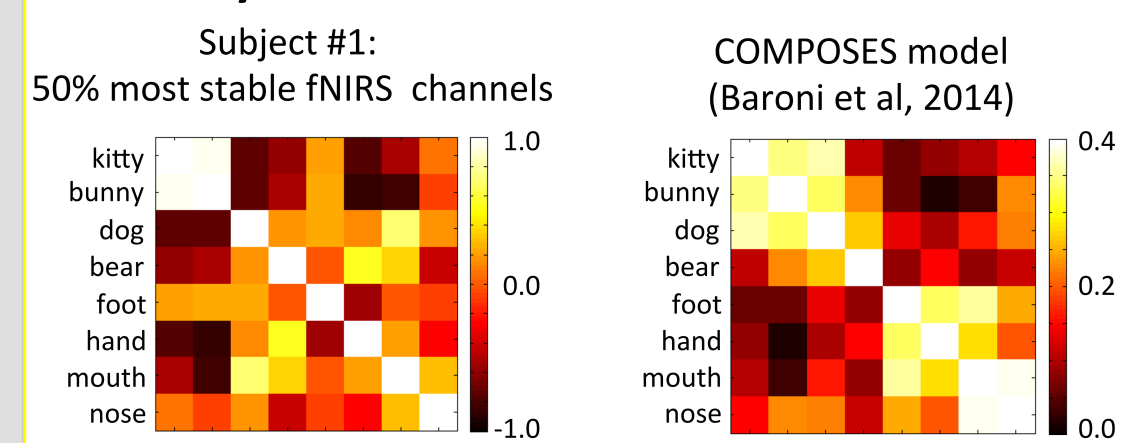
Decoding with RSA

Adapted from Anderson, Zinszer, & Raizada, 2015, Neuroimage, Figure 2



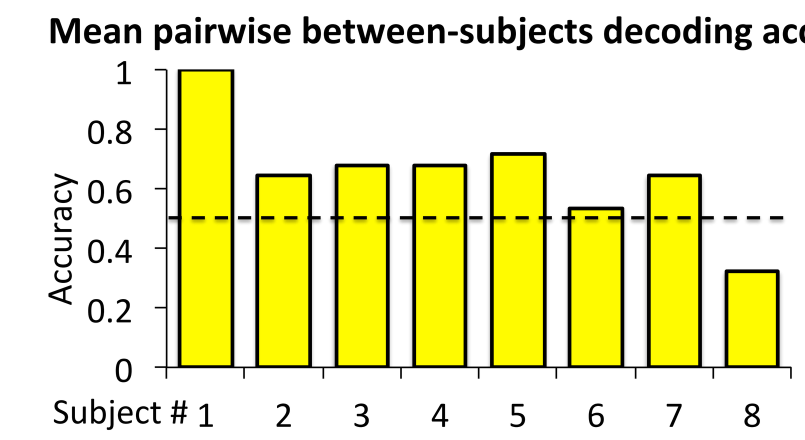
Decoding Results

Similarity Structures



N-Fold Cross-Validation (Between subjects)

How well does each participant's structure match the group?



Average decoding accuracy was significantly greater than chance: Mean Acc = 0.652, *p*=0.047 (permutation-based test)

Semantic Decoding (fNIRS vs. COMPOSES)

How well is each participant's structure explained by a corpus-based model of semantic representation?

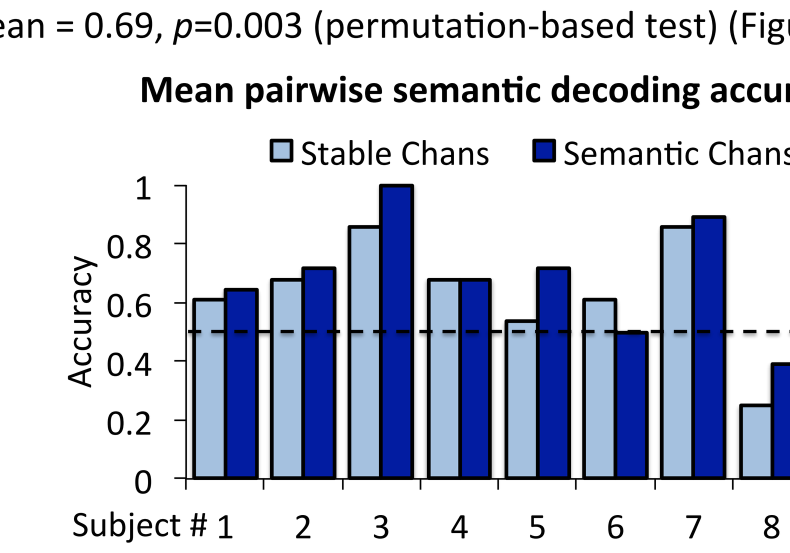
Average decoding accuracy was significantly greater than chance: Mean = 0.634, *p*=0.028 (permutation-based test) (Figure below)

Semantic Channel Selection

The channel sub-setting procedure of Emberson et al. (2016) is implemented to identify channels with best match to semantics.

In a leave-one-subject-out procedure, the best semantic channels are identified in the group (n=7) and these channels are used for decoding in the test subject (n=1). Repeated iteratively for all 8 Ss.

Mean = 0.69, *p*=0.003 (permutation-based test) (Figure below)



***Try it yourself!* Download the software:**

Dataset, scripts, and reprint for this poster:
http://bzinszer.github.io/SfNIRS-2016-demo

MCPA suite for two-class decoding:
http://teammcpa.github.io/EmbersonZinszerMCPA

Discussion

MCPA detects regularities in fNIRS signal

- Multichannel pattern analysis technique for fNIRS abstracts individual subjects' neural responses into similarity structures.
- Similarity structures can be compared across subjects and used for better-than-chance decoding of brain responses to semantic stimuli, such as audiovisual presentation of a word.

Semantic structure is encoded in the fNIRS signal

- A significant portion of individual subjects' fNIRS signal can be explained by semantics of the stimulus. Other features (e.g., phonetic or visual) may explain other parts of the fNIRS signal.
- Channel subsetting can pick out reliable semantic channels across subjects, thereby improving decoding performance.

Acknowledgements

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