Neural correlates of auditory distance perception

Keerthi Doreswamy [1,2] Jyrki Ahveninen[2]
Samantha Huang[2], Stephanie Rossi[2] Norbert Kopčo[1]

[1] Institute of Computer Science, P.J. Šafárik University, Košice
[2] Athinoula A. Martinos Center for Biomedical Imaging,
Harvard Medical School/Massachusetts General Hospital

Athinoula A. Martinos Center For Biomedical Imaging

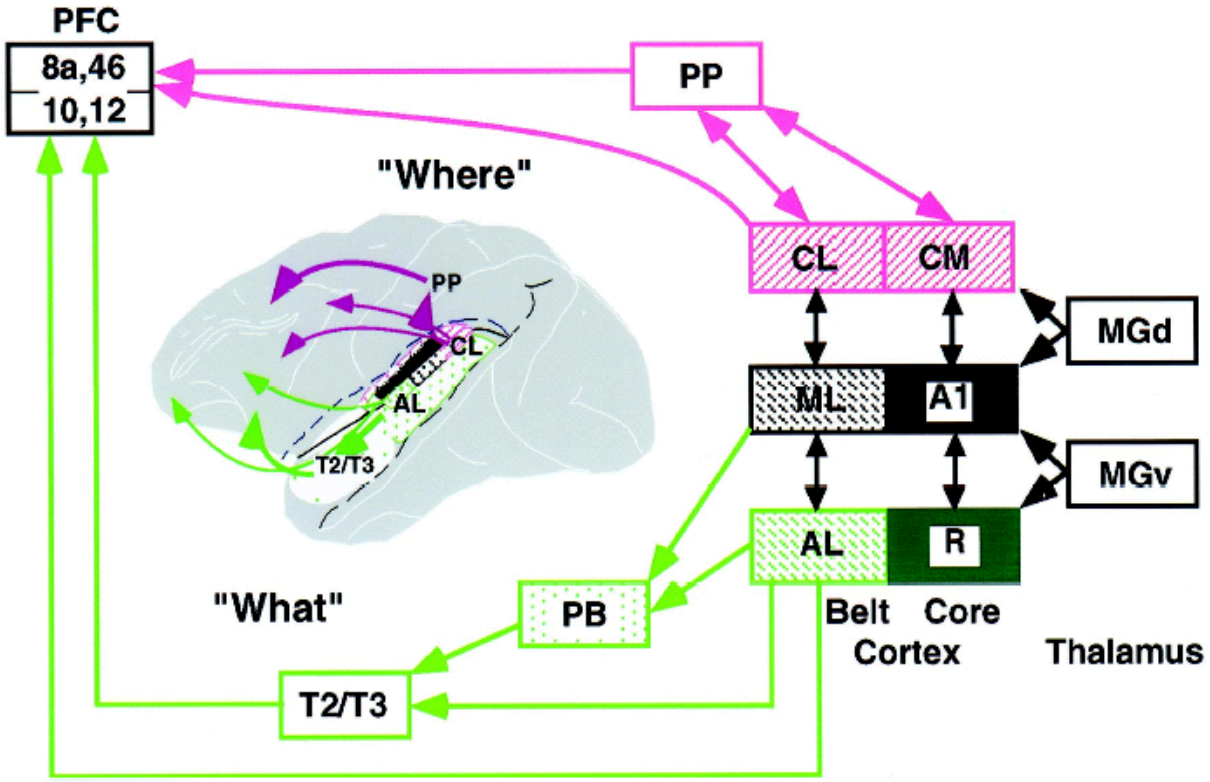
MASSACHUSETTS GENERAL HOSPITAL
HARVARD MEDICAL SCHOOL

Date: 08-10-21 (EST)
Place: Sweet home

Supported by the EU H2020-MSCA-RISE-2015 project #691229 and NIH grants R01DC017991, R01DC016915, R01DC016765, and R21DC014134

Background

An abundance of neuroimaging evidence exists of human auditory cortices (ACs) anatomical subdivisions and functional pathways.



Rauschecker, 1998a; Rauschecker and Tian 2000, 2001;

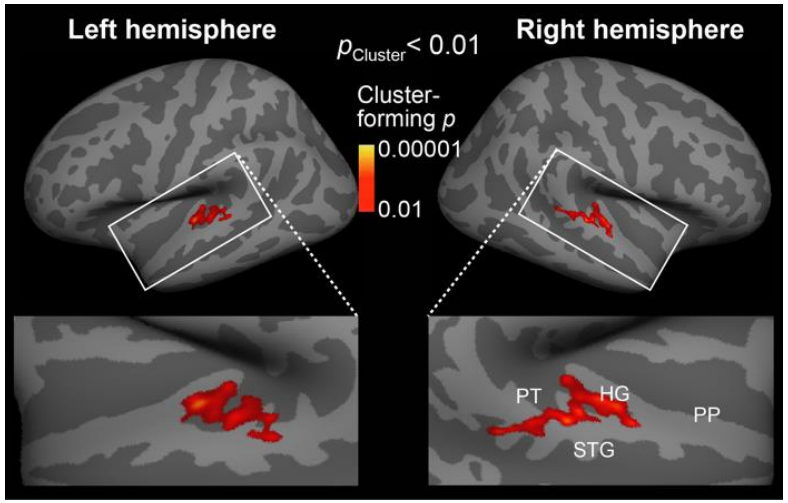
Rauschecker and Tian 2000, Griffiths and Warren, 2002; Ahveninen et al., 2014; Rauschecker, 2015

- Posterior non-primary ACs : Planum temporale (PT) and posterior superior temporal gyrus (pSTG)
- Sound direction changes, auditory motion stimuli

Background

Kopco et al., 2012

- Planum temporale (PT) and posterior superior temporal gyrus (pSTG)
- Auditory distance
- Intensity-independent
- Lateral source (ILD & DRR)



Planum temporale (PT) and posterior superior temporal gyrus (pSTG)

Kopco et al., 2020

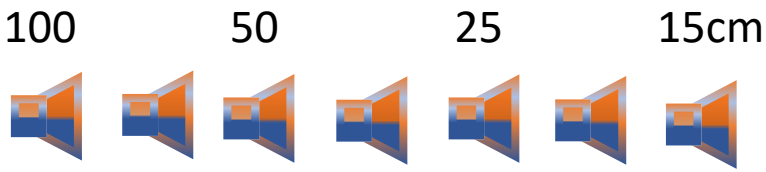
Kopco et al., 2020

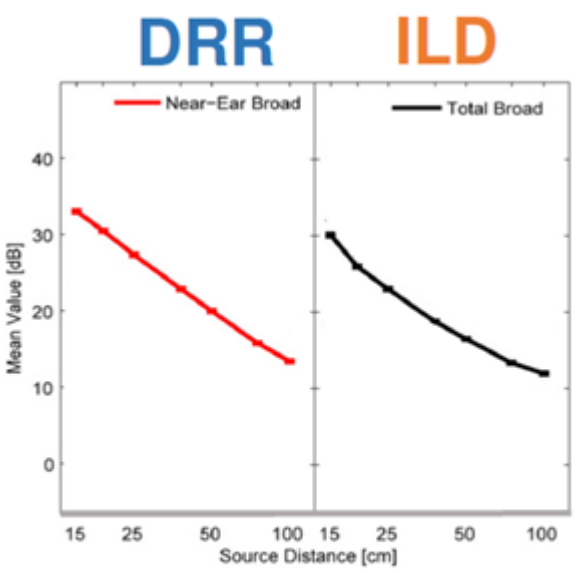
- Planum temporale (PT) and posterior superior temporal gyrus (pSTG)
- Auditory distance
- Intensity and direction cues independent
- Frontal source (DRR)

Does the auditory distance areas PT & pSTG encode DRR cue or distance percept ??

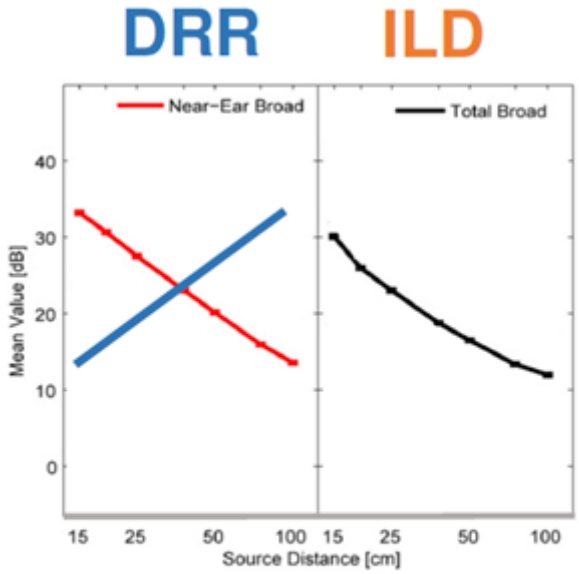
Distance perception: main auditory cues

ILD +
DRR

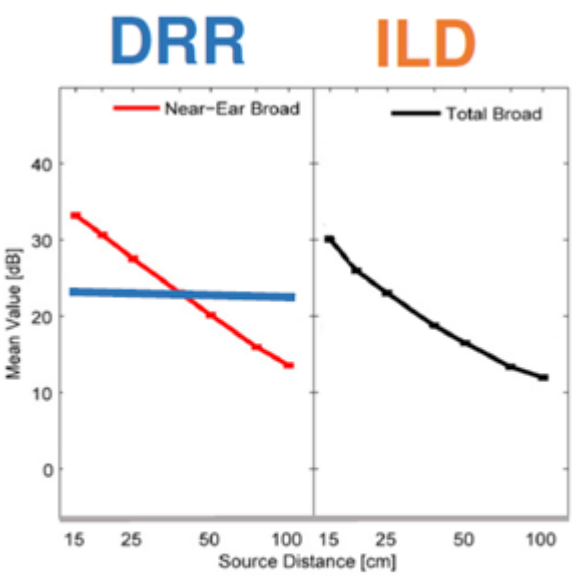




Congruent condition



Incongruent condition



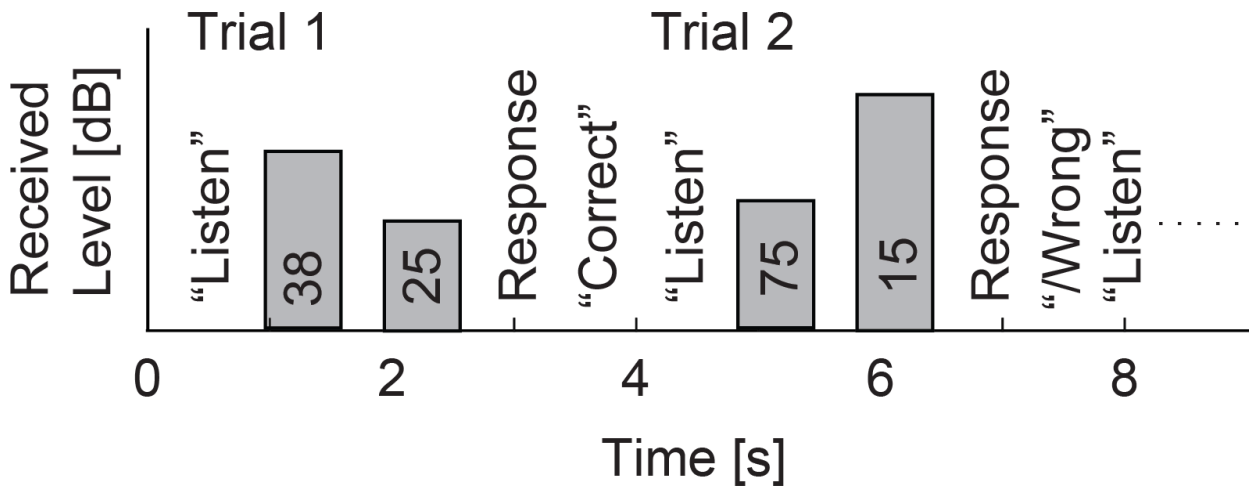
ILD-only condition

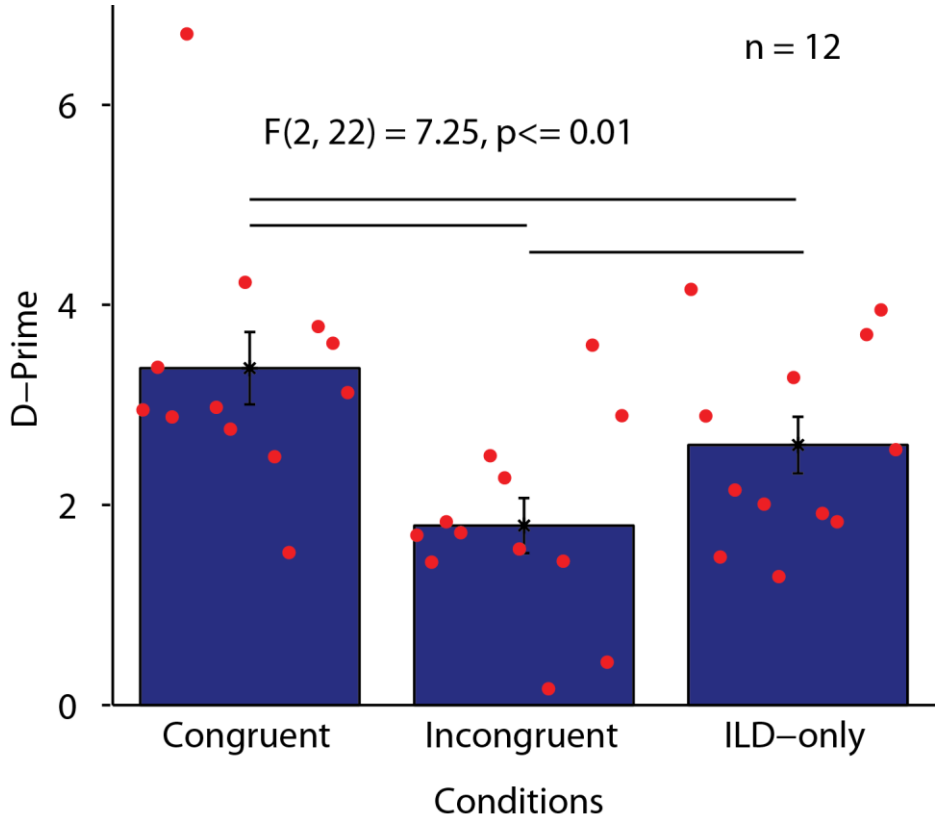
Behavioral experiments

Task:

Which of the sounds is closer to the listener?

*Subjects were instructed to ignore the intensity cue.

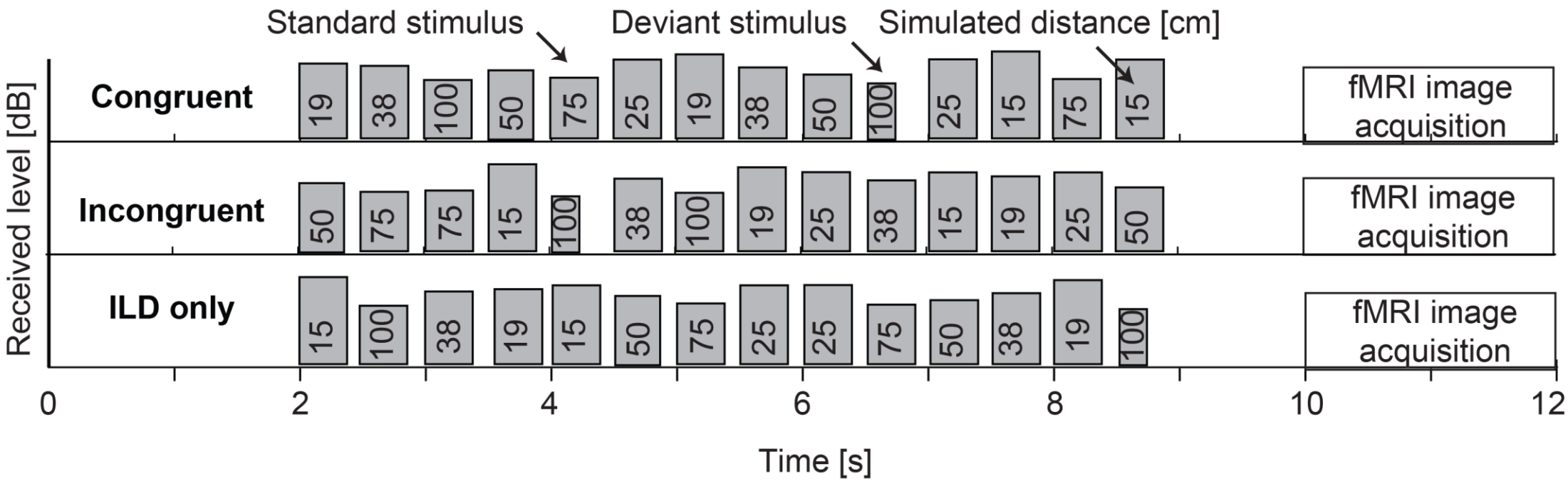




fMRI experiments

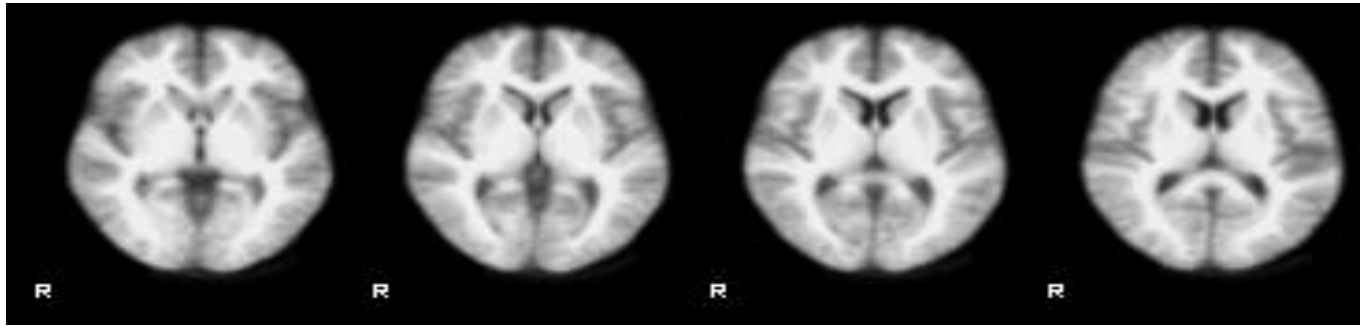
Task:

To detect the short-duration deviants.

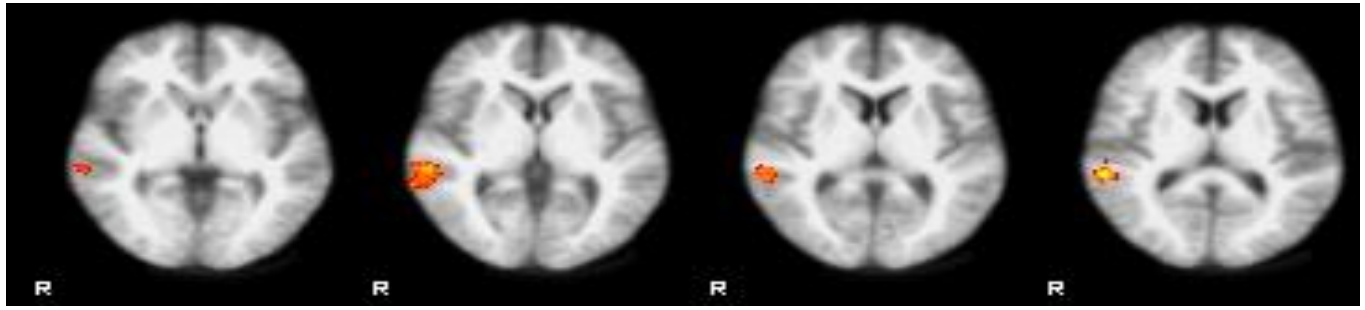


fMRI experiments

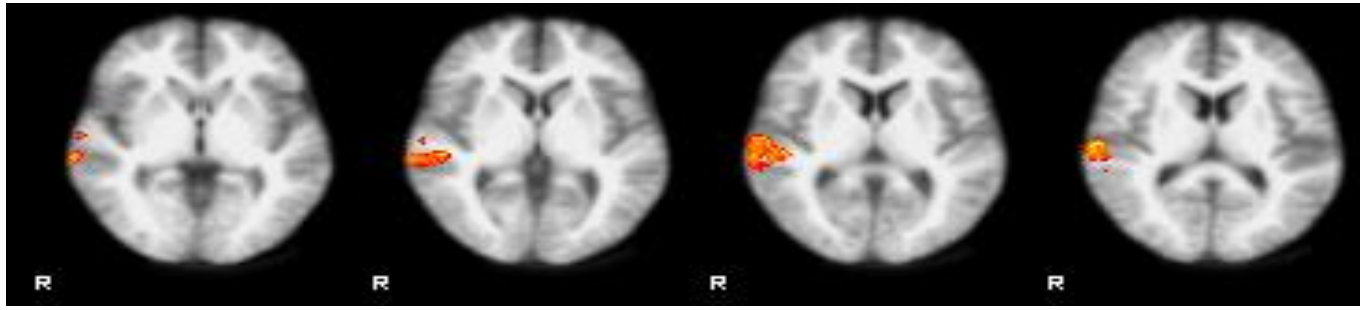
Congruent vs Incongruent



Congruent vs ILD only



Incongruent vs ILD only



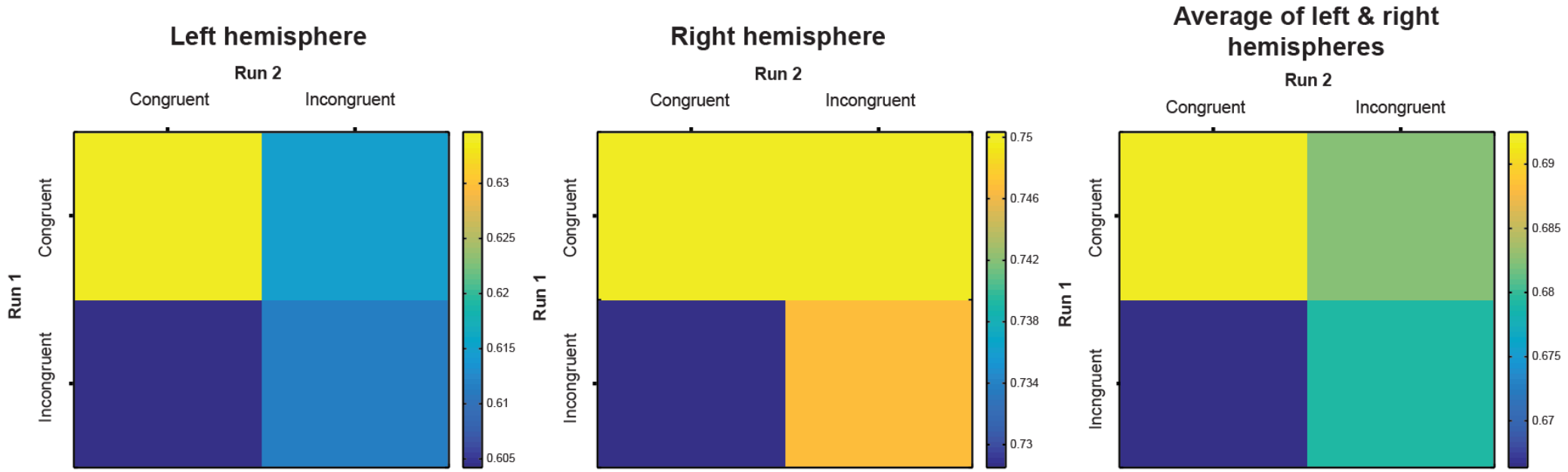
Volume-based fMRI analysis

Slices: 19-22

fMRI Multivariate pattern analysis (MVPA)

An average difference in z-transformed correlations between same and different-condition correlations:

- Left hemisphere: (mean ± SD) 0.022 ± 0.059, right hemisphere: 0.020 ± 0.031, (difference between hemispheres not significant)
- Value of the average difference: 0.021 ± 0.038, t(13) = 2.085, p = 0.028* (one-tailed).



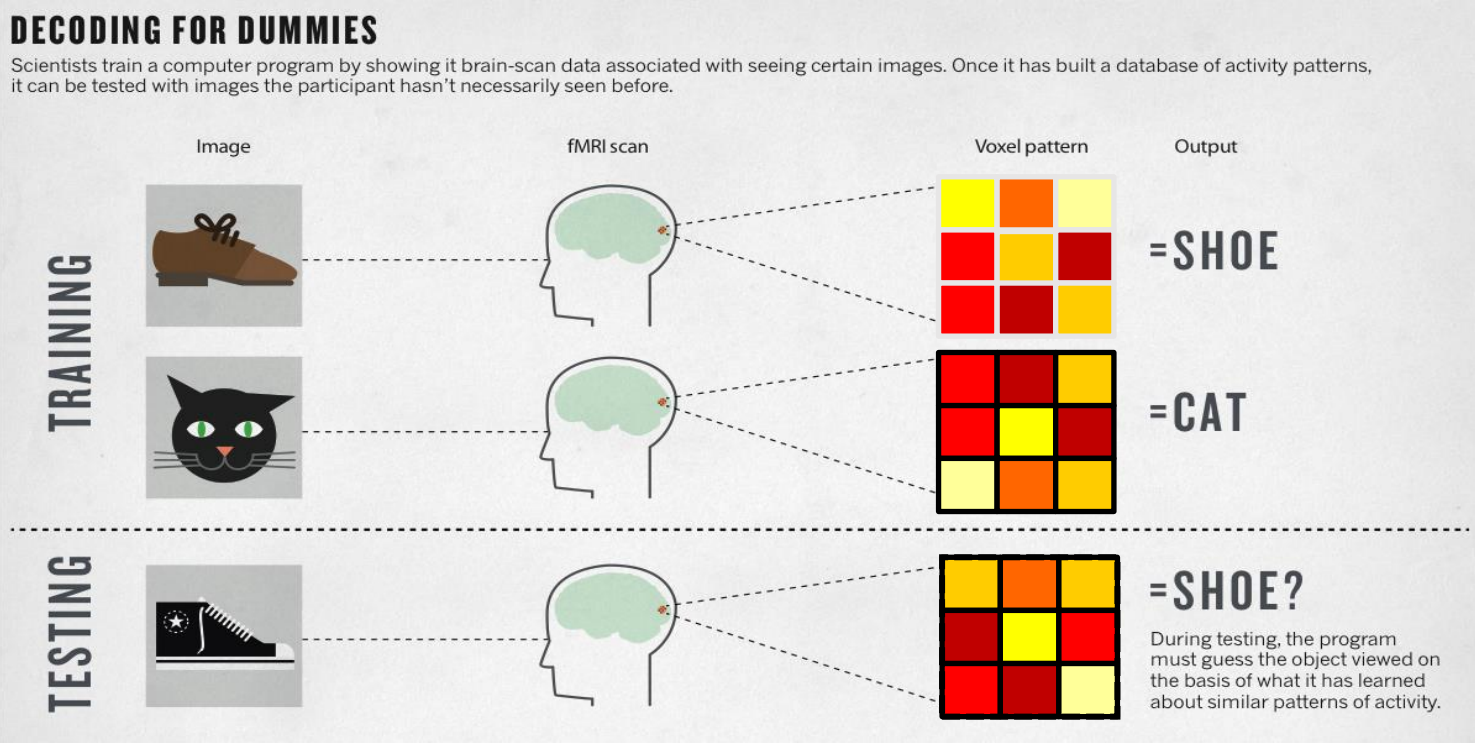
Average split-half correlation across subjects for the Congruent-vs-Incongruent contrast (n= 14).

Coda

- Behavioral results showed that subjects performed better when cues varied with distance congruently, confirming that the distance percepts are based on both ILD and DRR.
- Univariate fMRI results suggest that the contralateral activations represents the DRR cue and overlap with ROI's (PT and pSTG).
- Split-half correlation MVPA analysis of activation pattern in the auditory cortex ROI encompassing the PT and pSTG differed depending on cue congruency.
- Overall, these results are consistent with the hypothesis that the PT and pSTG is a spatial computational hub representing the spatial percepts as well as the acoustic cues.

What next ??

More sensitive searchlight-based MVPA and possibly different classification algorithms (SVM, LDA etc...)



Kerri Smith, 2013, Nature, "Reading Minds"

Acknowledgements

Norbert Kopčo,
Perception and cognition lab (PCL),
Institute of Computer Science, P.J. Šafárik University, Košice

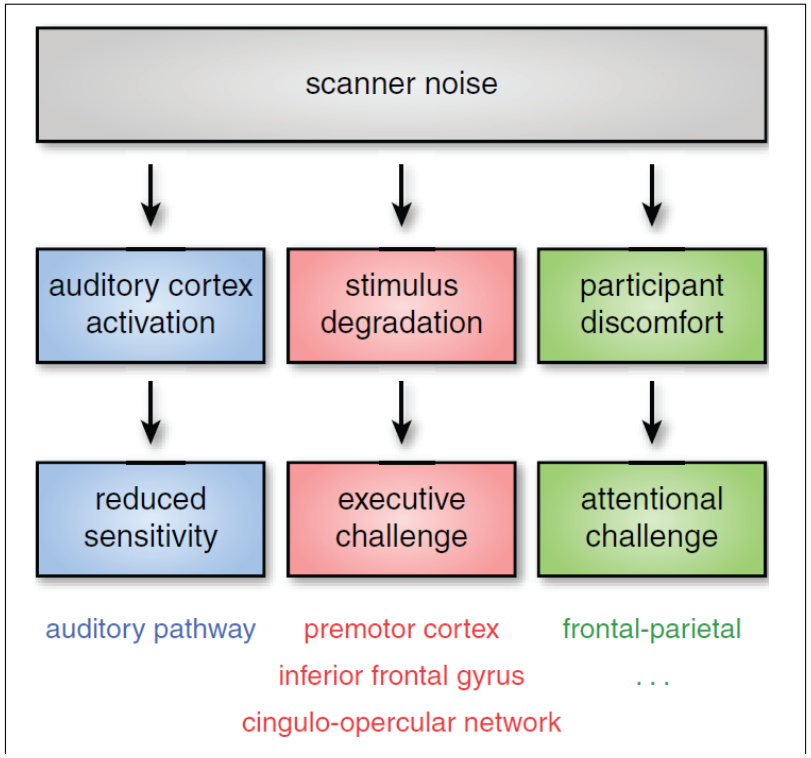
Jyrki Ahveninen,
Martinos Center for Biomedical Imaging, Harvard Medical School/Massachusetts General Hospital

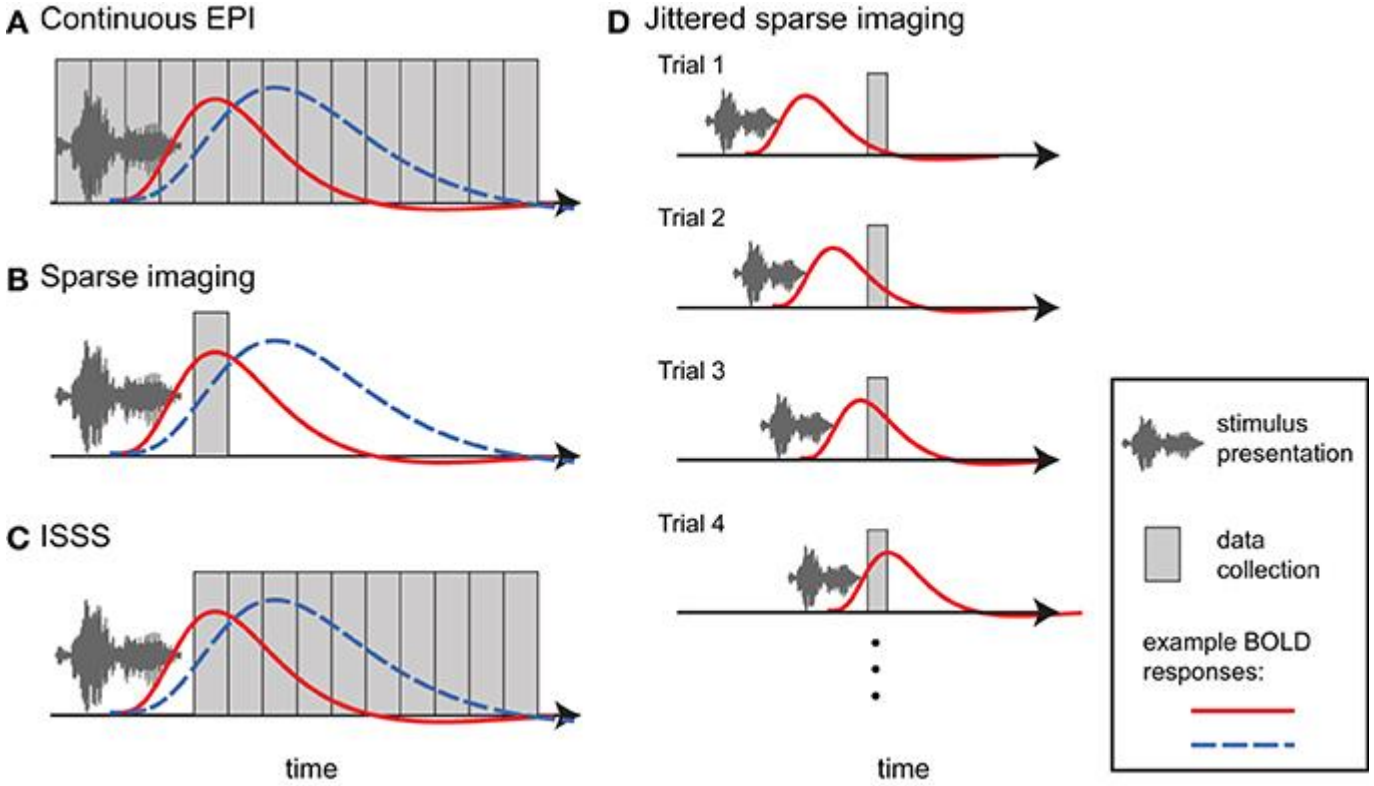
- **PCL members**
- **Samantha Huang, MGH**
- **Stephanie Rossi, MGH**

Supported by the EU H2020-MSCA-RISE-2015 project #691229 and NIH grants R01DC017991, R01DC016915, R01DC016765, and R21DC014134

Athinoula A. Martinos Center For Biomedical Imaging
MASSACHUSETTS GENERAL HOSPITAL
HARVARD MEDICAL SCHOOL
MARIE CURIE ACTIONS
HORIZON 2020
PRÍRODOVEDECKÁ FAKULTA UNIVERZITY P. J. ŠAFÁRIKA V KOŠICIACH • 1963 •
UNIVERZITA PAVLA JOZEFA ŠAFÁRIKA V KOŠICIACH • 1959 •

Sparse sampling adaptation fMRI

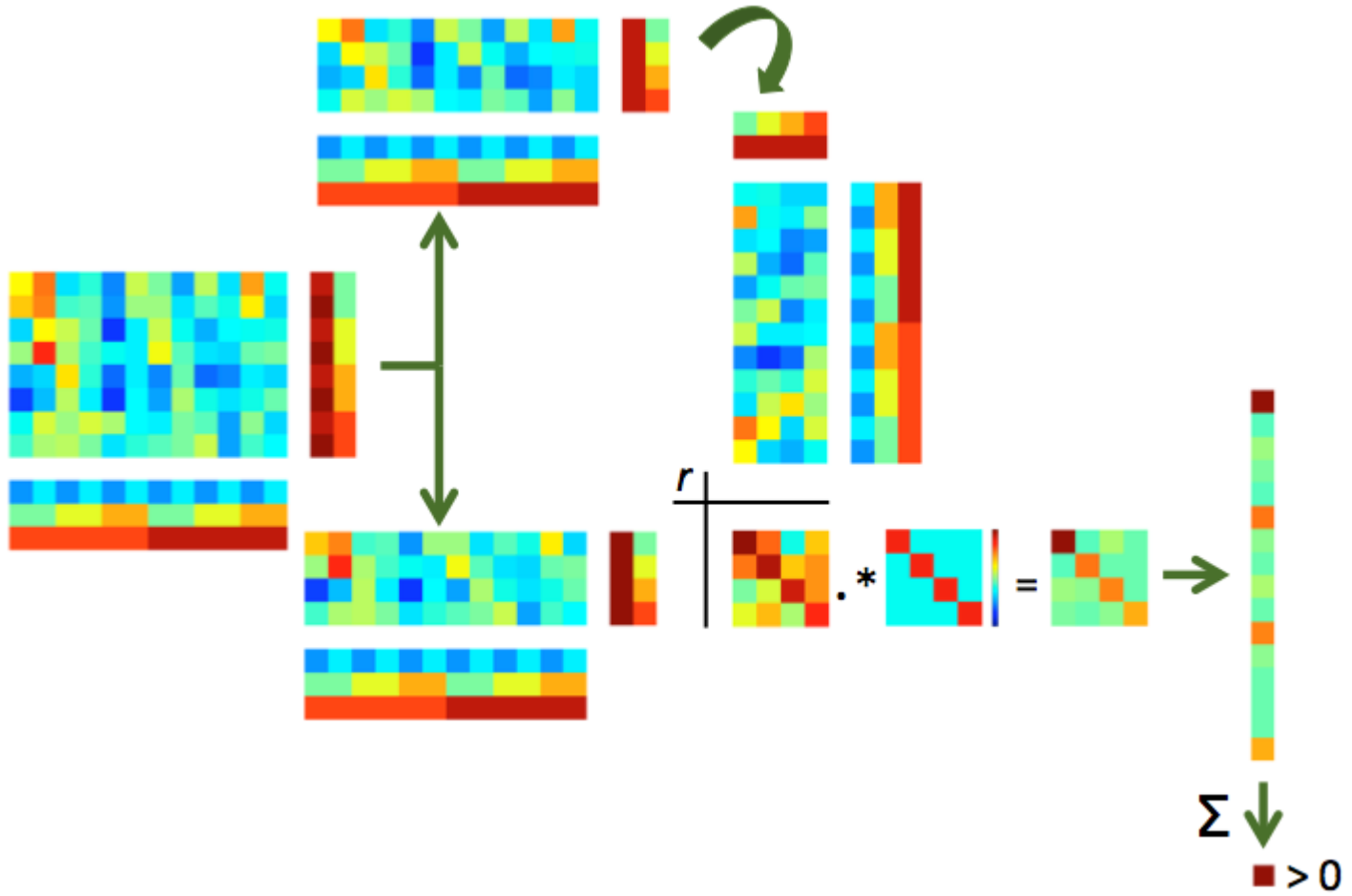




Jonathan Peelle, 2014

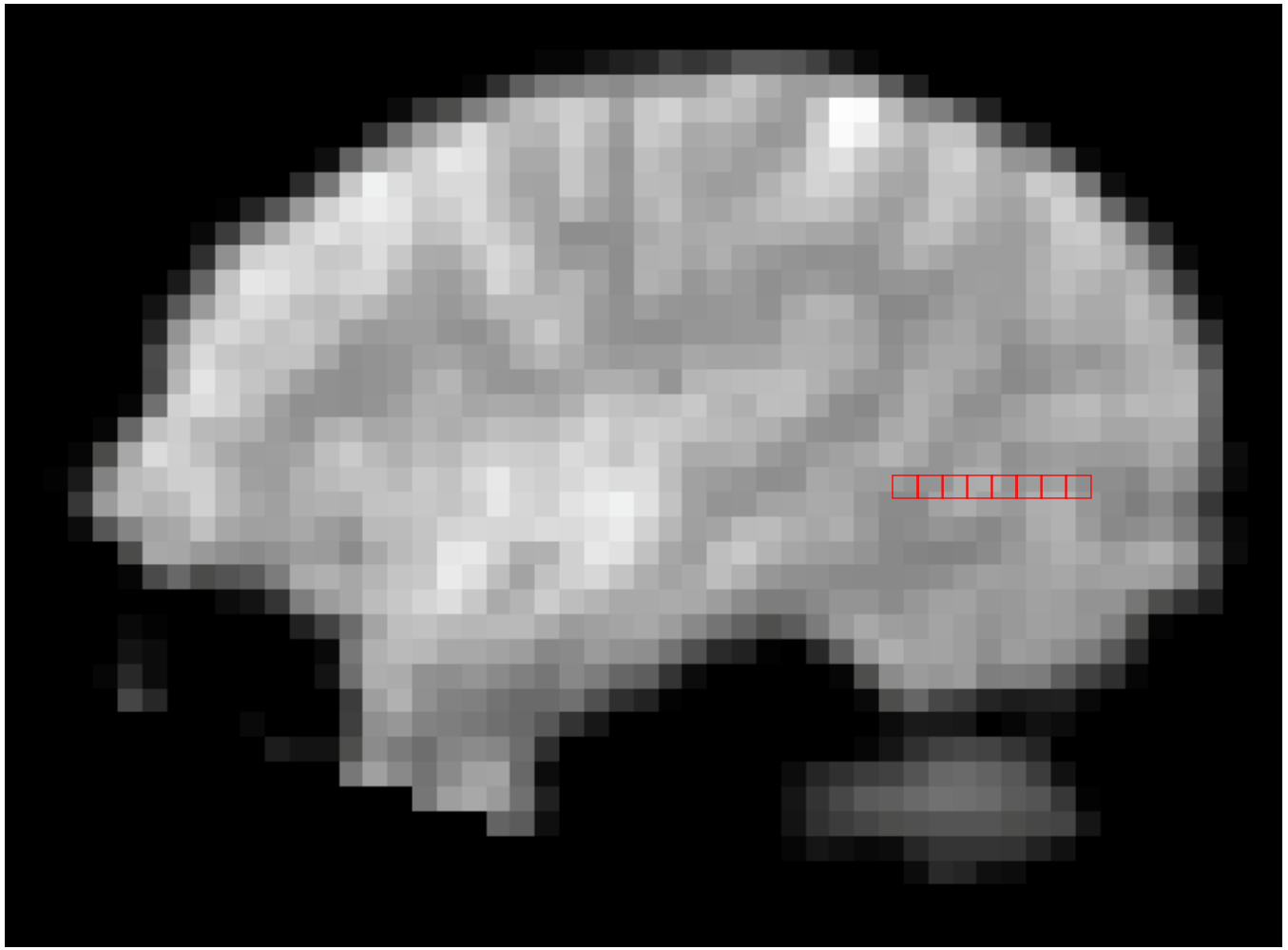
Split half correlation

For split-half correlations, the data is split in two chunks (top and bottom, or odd and even trials). Each pattern in one half is correlated with each pattern in the other half



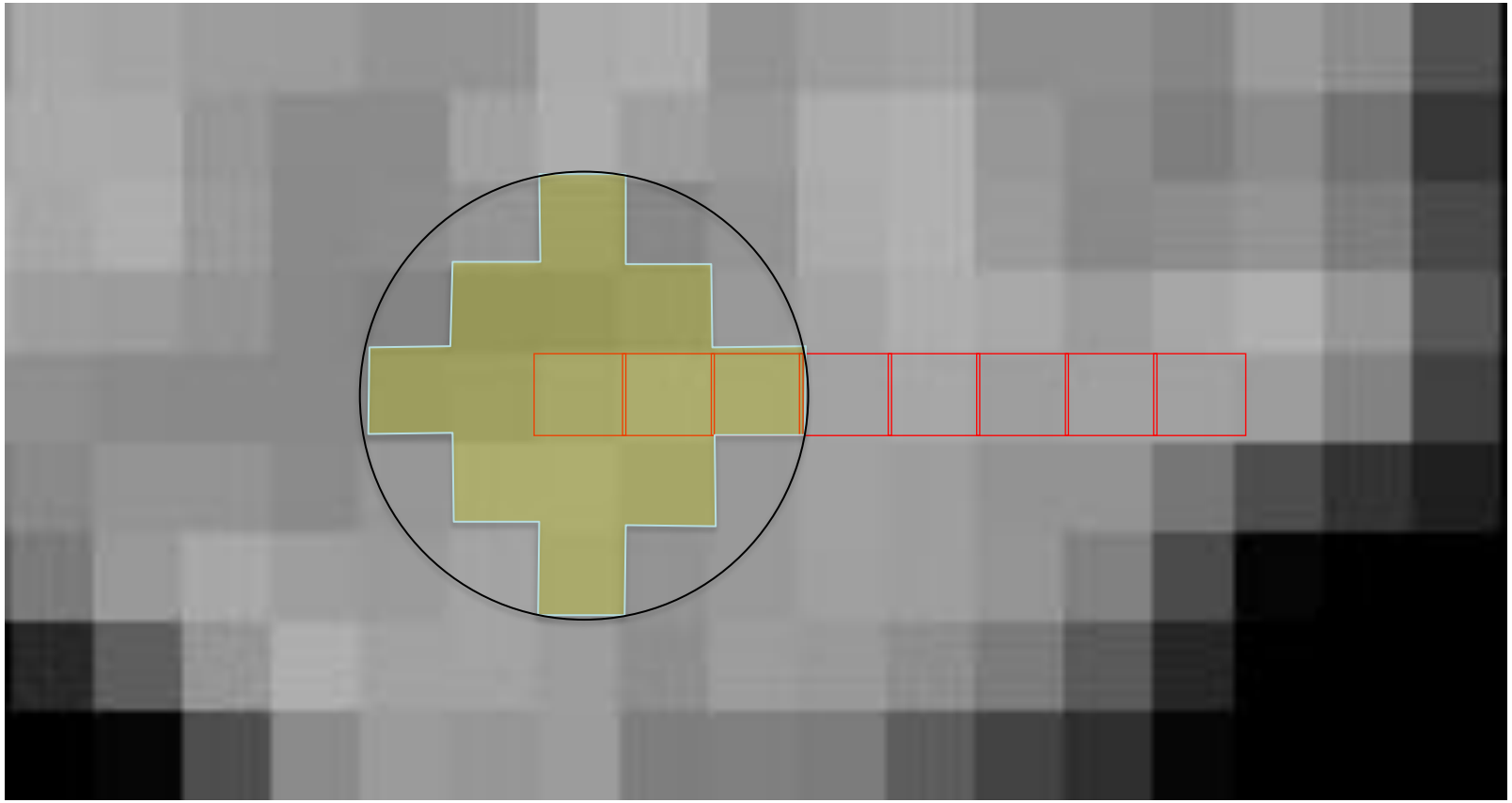
Source: https://cosmomvpa.org/ex_splithalf_correlations.html

Searchlight



Kriegeskorte, Goebel & Bandettini, 2006, PNAS

Searchlight

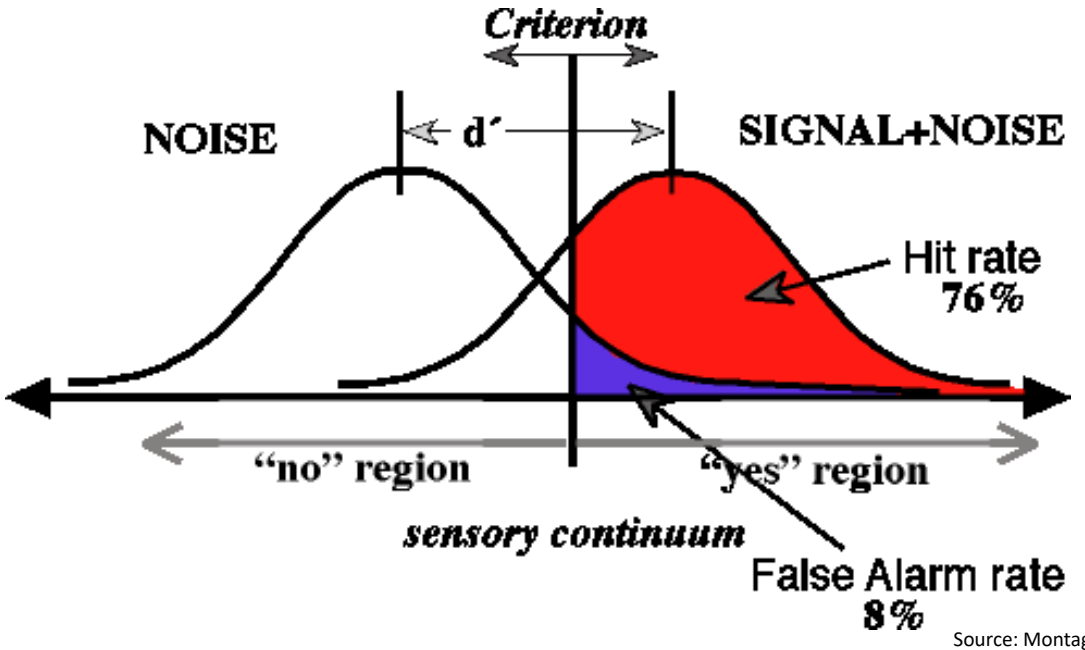


Kriegeskorte, Goebel & Bandettini, 2006, PNAS

Methods: Modelling

- Zahorik, 2002a suggests that consistent cues get more perceptual weight and irrelevant ones get fewer weights while combining the cues. Final distance percept is the weighted sum of the estimates from the individual cues.
- A model based on signal detection theory will be used to evaluate the performance of the discrimination tasks and also to predict the performance. (Durlach & Braida, 1969; N. Kopco et al., 2012)

Methods: Modelling



Source: Montag, http://www.cis.rit.edu/

Where: Pc – Percentage of correct performance
$d' = | \ln s1 - \ln s2 | / \sigma$,
s1 and s2 are distances
σ subject's estimate

$$P_c = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\frac{d'}{2}} e^{\frac{-t^2}{2}} dt,$$

Methods: fMRI data acquisition

- Whole-head fMRI was acquired at 3T using a 32-channel coil (Siemens TimTrio, Erlagen, Germany).
- To circumvent response contamination by scanner noise, we used a sparse-sampling gradient-echo blood oxygen level dependent (BOLD) sequence (TR/TE = 12,000/30 ms, 9.82 s silent period between acquisitions, flip angle 90°, FOV 192 mm) with 36 axial slices aligned along the anterior-posterior commissure line (3-mm slices, 0.75-mm gap, 3 × 3 mm2 in-plane resolution).
- The coolant pump was switched off during the acquisitions. T1-weighted anatomical images were obtained using a multi-echo MPRAGE pulse sequence (TR = 2510 ms; 4 echoes with TEs = 1.64 ms, 3.5 ms, 5.36 ms, 7.22 ms; 176 sagittal slices with 1 × 1 × 1 mm3 voxels, 256 × 256 mm2 matrix; flip angle = 7°) for combining anatomical and functional data.

Hit rates (HR) and reaction times (RT)

- The task difficulty was similar across the different stimulus types (across-subject average HR of 93.3% and 90.8% and RT of 1164 and 1181 ms, respectively).

- Confirming these observations, repeated measures ANOVAs performed on the HRs and RTs found no significant differences (HR: $F_{1,9} = 6.75$, $p > 0.31$; RT: $F_{1,9} = 4.5$, $p > 0.19$).