# Adaptation to Reverberation in Speech and Distance Perception

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# Outline

**Reverberation** affects many auditory functions:

- speech perception,
- sound localization and externalization,
- separation of sounds in cocktail party situations,
- musical perception / enjoyment (“envelopment”)

Effect of **reverberation**:

- usually **detrimental**: e.g., **speech perception**, horizontal localization.
- sometimes **beneficial**: e.g., **distance perception**, musical enjoyment.

Two ALT studies:

- **Adaptation to room reverberation in phonetic perception (Eleni)**
- **fMRI study of cortical distance representation in reverb (Noro)**

# Adaptation to Room Reverberation in Phonetic Perception

ELENI

# Behavioral and fMRI study of distance representation with reverberant cues

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# Intro

Distance perception is important in many everyday situations.

However, the psychoacoustic cues and neural mechanisms underlying it are not well understood.

Kopco et al. (2012) identified intensity-independent cortical area representing distance for lateral sources.

Goals:

- Examine cortical distance representation for frontal sources.
- Is the identified cortical distance area representing distance percept or cues?

# Distance perception: Main cues

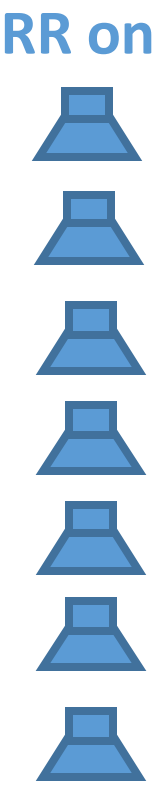
- Multiple cues (for a review, see Zahorik et al., 2005)
- **Intensity cue – often dominant** but requires **familiarity** (Warren, 1999)
- **Main intensity-independent cues** (Kopčo et al., 2012):

**ILD**

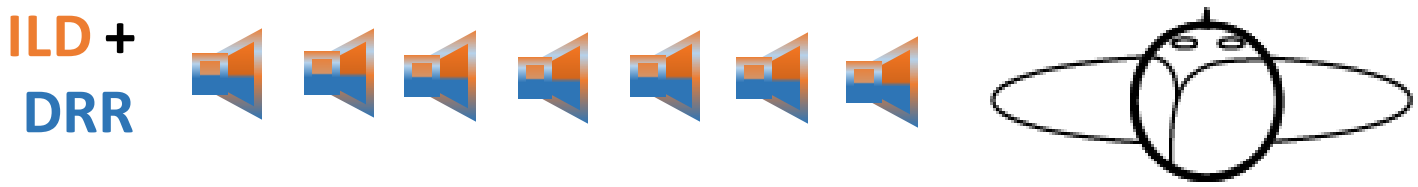
- Binaural
- Direction-dependent
- Anechoic (?and reverberant?) space (Brungart, 1999)

**DRR**

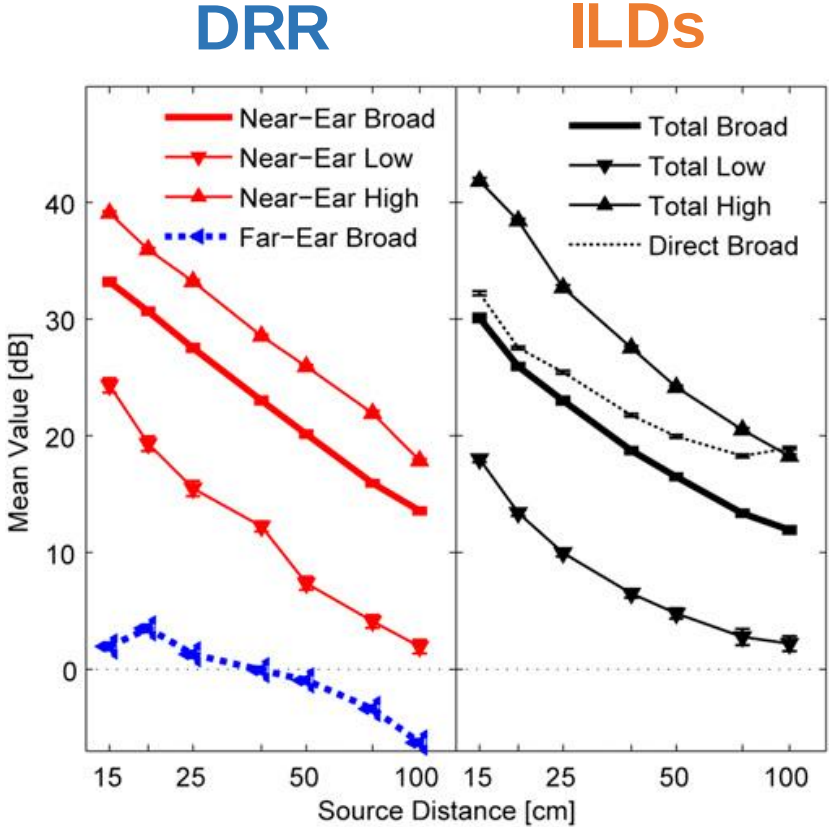
- Binaural or monaural? (Larsen et al., 2008)
- Direction-independent
- Reverberant space (Kopčo et al., 2012)




- Direction-dependence of ILD and DRR cues:
- Adaptation needed.



# Distance perception: Cue analysis


Distance dependence of cues varies with frequency. Main cue is likely the monaural near-ear **DRR** (Kopčo, Shinn-Cunningham, 2011).

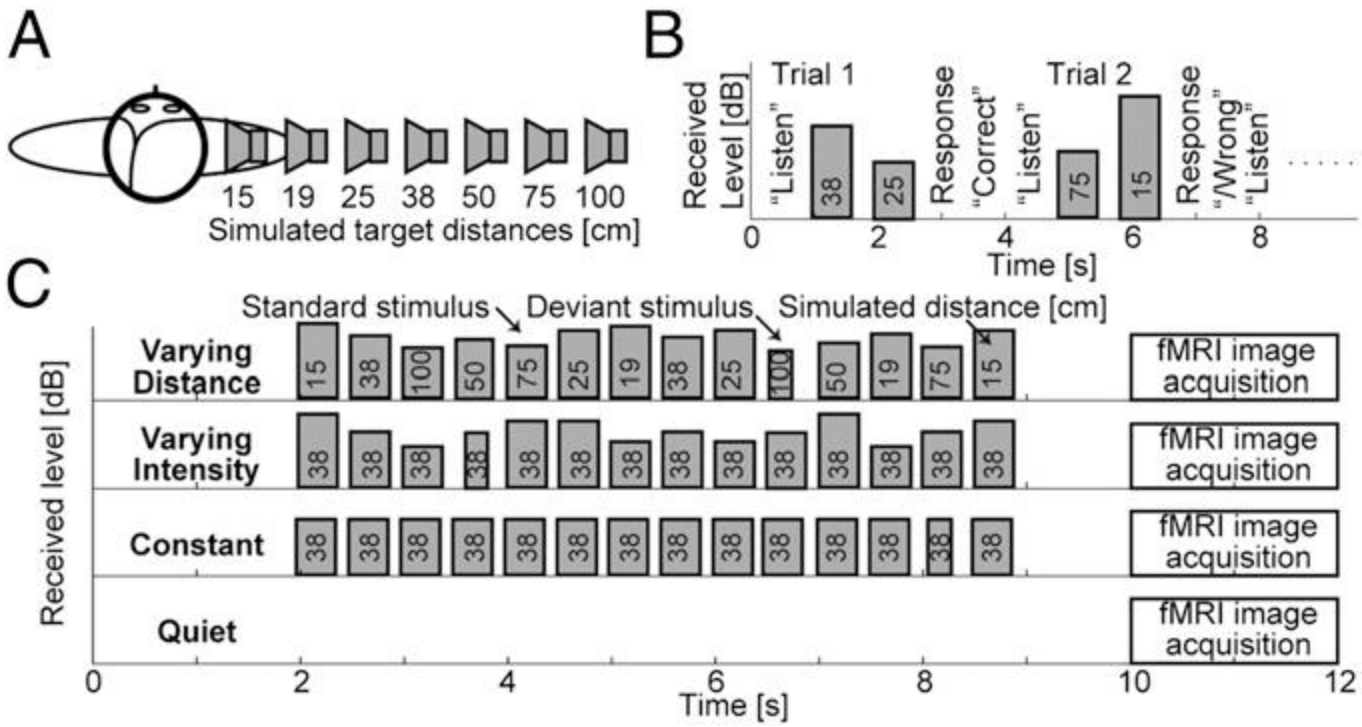
Cues also vary from room to room. Adaptation to rooms is necessary (Shinn-Cunningham, 2000).

Kopco et al. (2012) examined cortical distance representation of lateral source (w/ **ILD** and **DRR**).

# Cortical auditory distance representation

Kopco et al. (2012) methods:

- lateral sources,
- constant, or varying in distance or intensity,
- sparse-sampling adaptation fMRI,
- behavioral discrimination experiment to confirm intensity-independent sensitivity to distance.



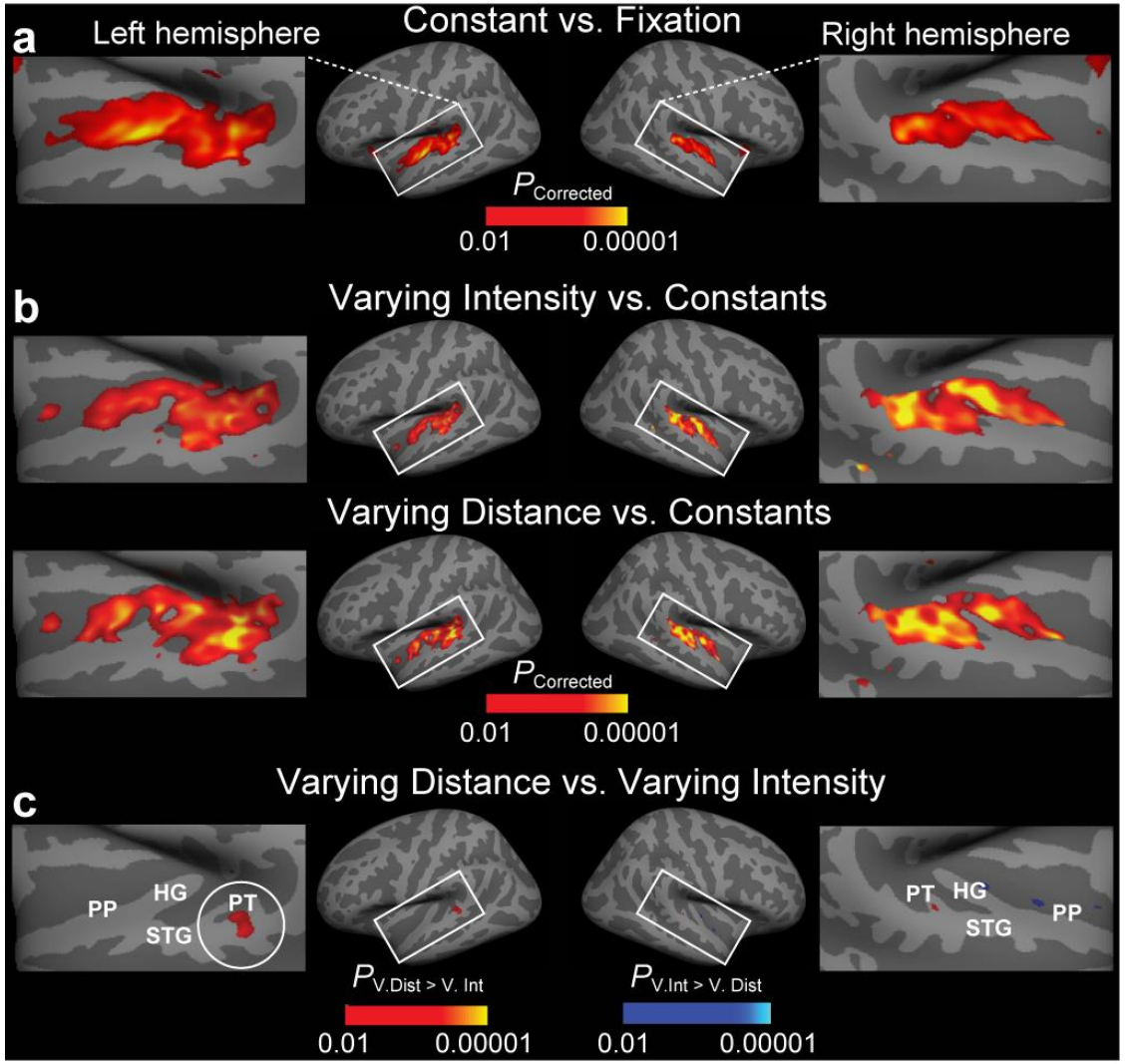

Kopco N, Huang S, Belliveau JW, Raij T, Tengshe C, Ahveninen J (2012). Neuronal Representations of Distance in Human Auditory Cortex. Proceedings of the National Academy of Sciences of USA, 109 (27), 11019-11024.

# Cortical auditory distance representation

Kopco et al. (2012) results:

The distance-encoding area identified as a difference between varying-distance vs. varying intensity.

Surface-based:
**Area** in **planum temporale** (PT) and **superior temporal gyrus** (STG) contralateral to stimuli.

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# Cortical auditory distance representation

Kopco et al. (2012) results:

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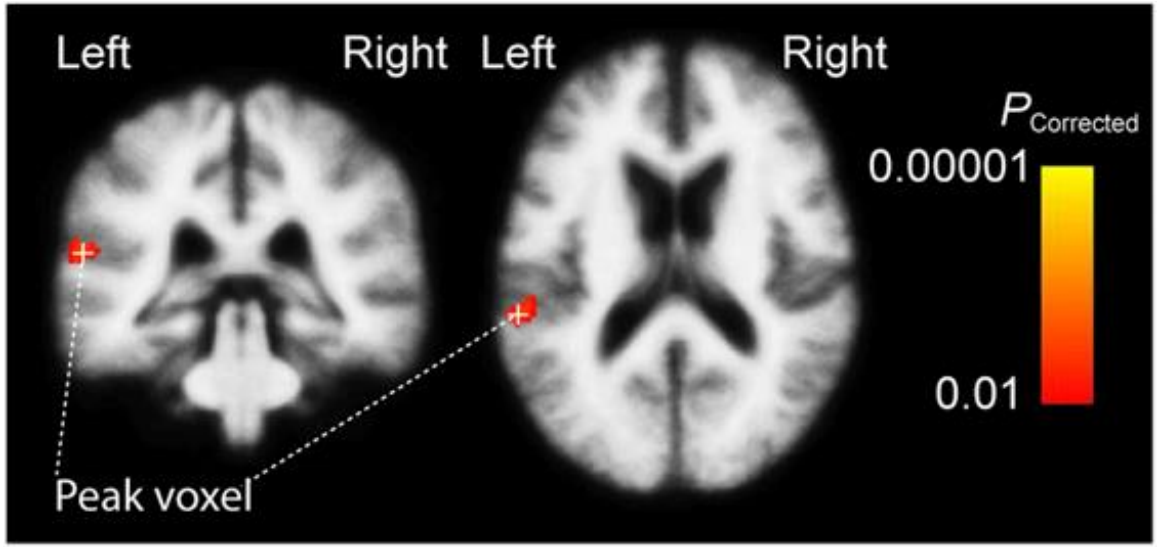


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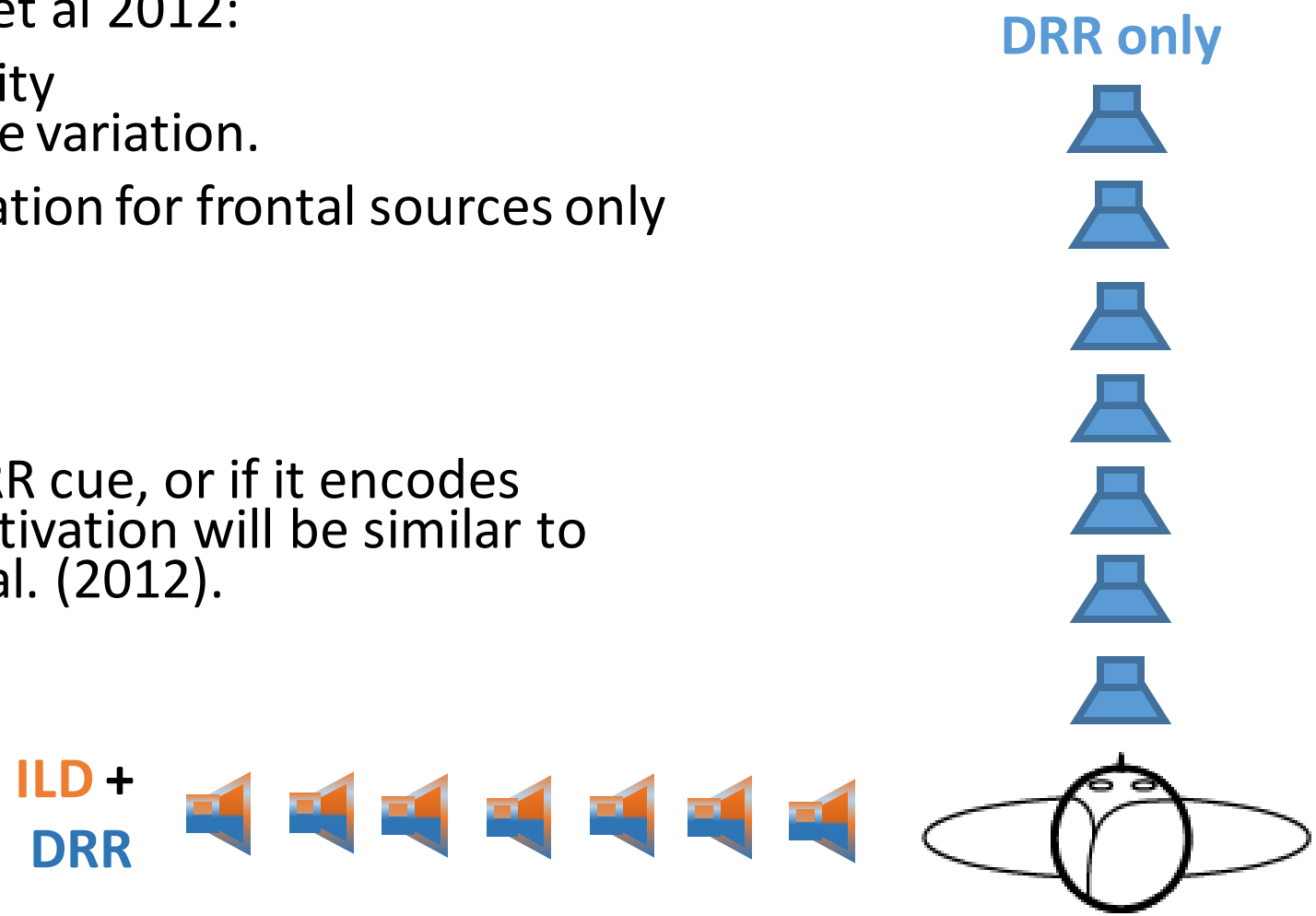
# Current study: Experiment 1 - Frontal

Using methods similar to Kopco et al 2012:

1. Compare behavioral sensitivity to lateral and frontal distance variation.
2. Examine distance representation for frontal sources only containing **DRR**.

**Hypothesis**:

If the identified area encodes DRR cue, or if it encodes distance percept, then frontal activation will be similar to lateral activation from Kopco et al. (2012).



# Exp 1: Behavioral discrimination task

- Stimuli: 300-ms noise bursts
- virtual reverberant environment
- nonidividualized BRIRs recorded in a small classroom (Shinn-Cunningham et al., 2005)

- 2 sounds presented sequentially (ISI = 1s) at varying distance in front or on the side of listener (fixed within block)

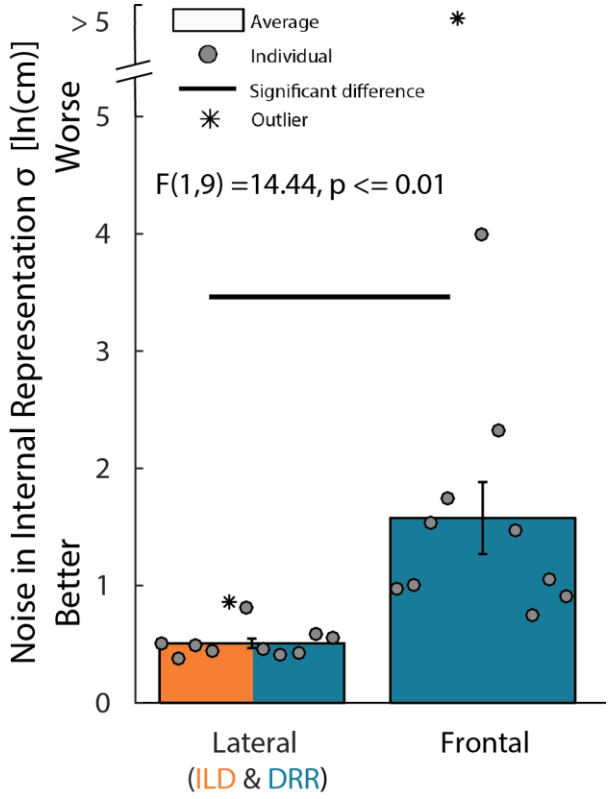
- **Task**: Which of the sounds is closer to the listener?
- Subjects instructed to ignore the intensity cue.
- Relative judgment

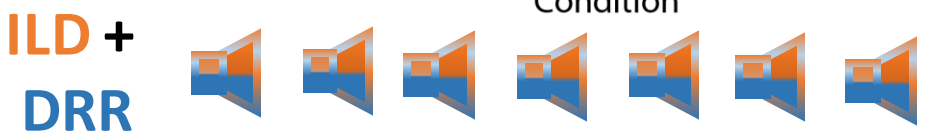
# Exp 1: behavioral results

Performance **worse** for **frontal** than **lateral** sources.

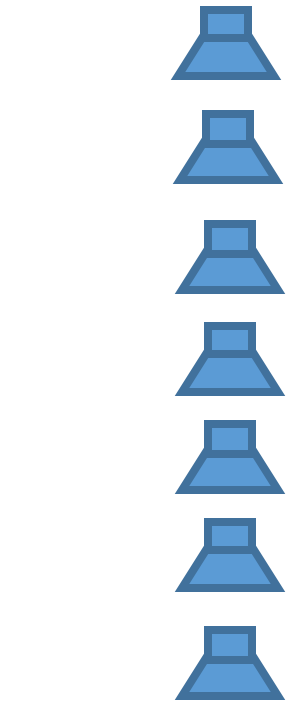
Either because multiple cues available, or because **DRR** provides better information (varies over larger range) on the side.

**Frontal performance still good for these stimuli, so fMRI can be performed.**



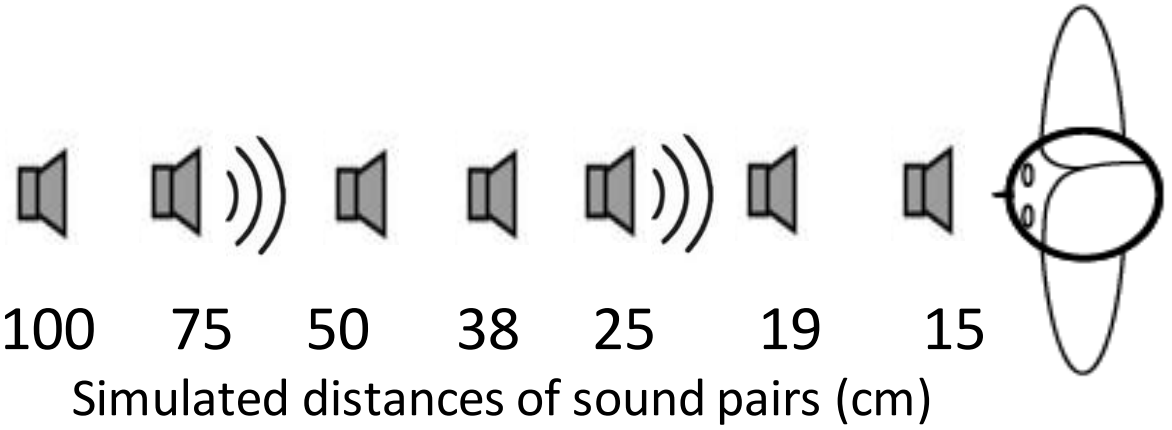

DRR only

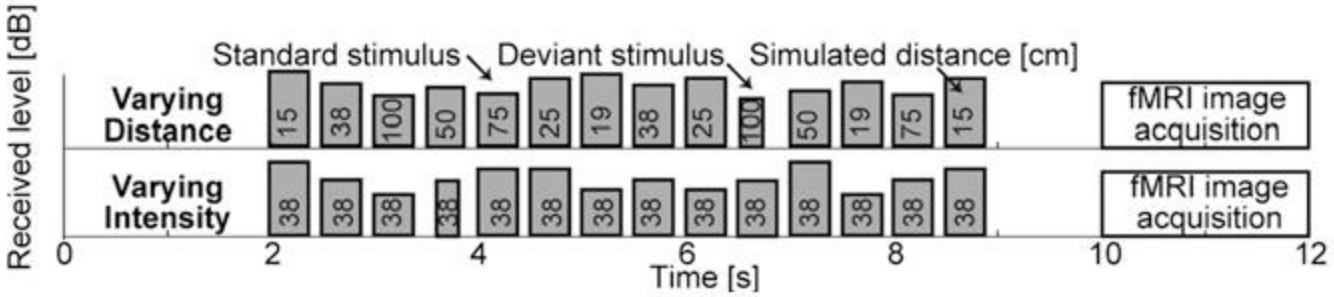


# Exp 1: fMRI experiment

Methods similar to Kopco et al. (2012) :

- **frontal** sources,
- **ONLY 2 CONDs:** varying in distance or intensity, in random order,
- sparse-sampling adaptation fMRI.

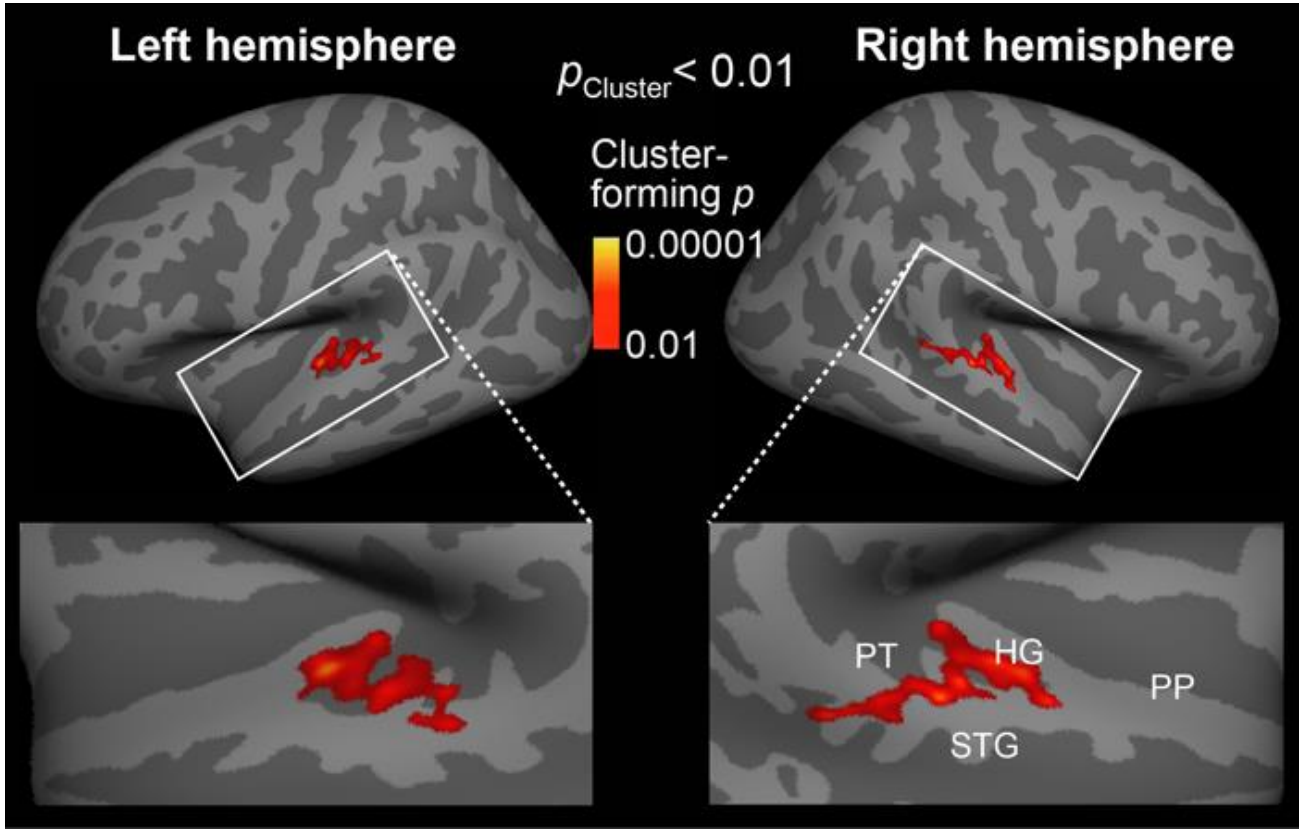


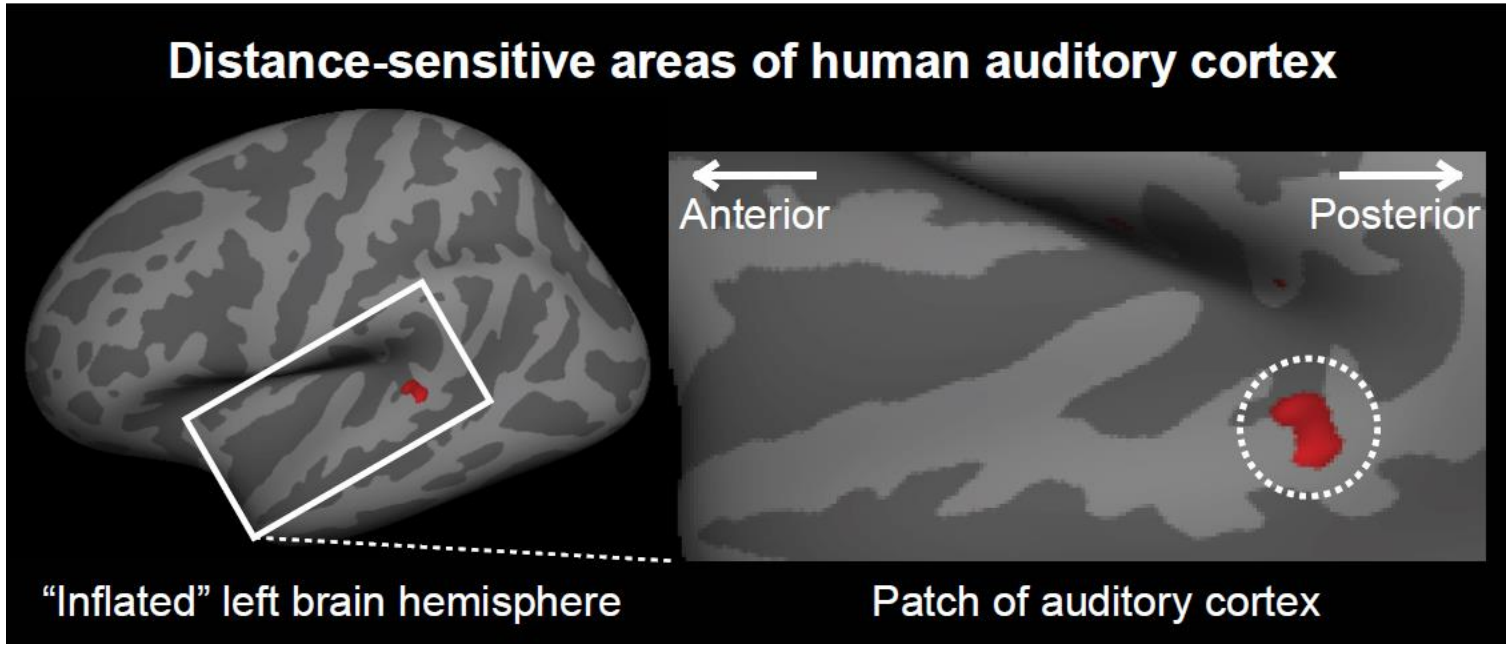
# Exp 1: fMRI results

The distance-encoding area identified as a difference between varying-distance vs. varying intensity.

**Area** in **planum temporale** (PT) and **superior temporal gyrus** (STG).
**Activation bilateral**.



# Exp 2: distance percept vs. cues



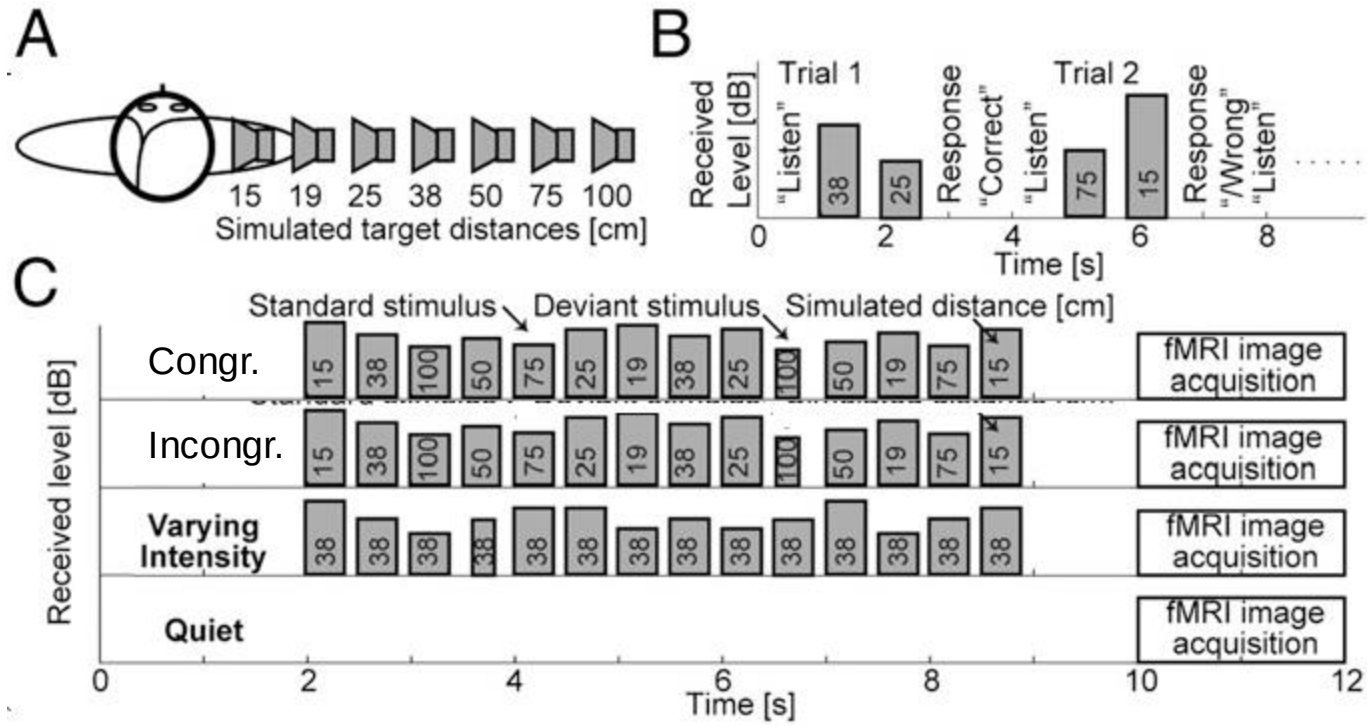

Is this the representation of distance, or of individual cues (ILD/DRR)?

In general, how are the cues combined?

Exp 2:
- contrast condition with ILD/DRR congruent vs. incongruent.
- Significant difference -> area represents "distance", otherwise "cues".

# Exp 2: Methods

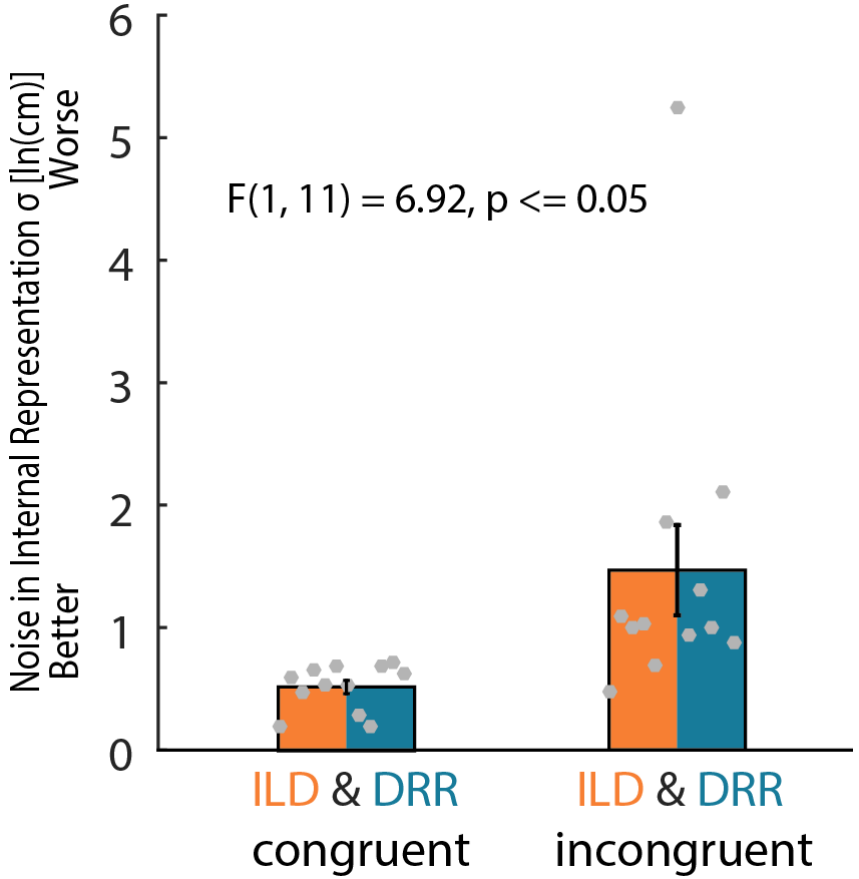
- lateral sources,
- varying **ILD** & **DRR** **congruently** or **incongruently**, or varying intensity,
- sparse-sampling adaptation fMRI,
- behavioral experiment to confirm higher sensitivity for congruent than incongruent stims.



# Exp 2: behavioral results

Performance **worse** with **incongruent** than **congruent** cues -> distance percept is weaker with incongruent cues.

**Difference in fMRI activation between congruent and incongruent conditions is expected to indicate representation of distance percept.**



# Exp 2: fMRI results (tentative)

No significant differences between congruent and incongruent conditions in univariate analysis (N = 13).

Split-half correlation analysis (MVPA) performed in left-hemisphere cortical subregions:

- significant ($p < 0.05$) activations in:
  - subregion of lateral Superior Temporal Gyrus (div. 2)
  - Middle Temporal Gyrus
  - Lateral Occipital Temporal Sulcus

**Representation either corresponding to cues, not percept, or representation more complex than what univariate analysis can identify.**

# Summary

Distance perception is highly adaptive.
It‘s difficult to identify cues used in a specific context and underlying neural mechanisms.

Current results show that a PT + STG area in “parietal” stream:

- encodes intensity-independent distance,
- for judgments based both on **DRR** (frontal) and **ILD** & **DRR** (lateral),
- hemisphere of activation varies with source laterality,

**Areas posterior to A1 likely are a complex computational center that:**

- **encodes auditory spatial information in all dimensions** (Higgins et al., 2017)
- is consistent with „What & Where“ model (Rauschecker & Tian, 1995)

(**Doreswamy** et al. poster on adaptation in cue weighting for distance perception.)