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BRAIN BASES FOR AUDITORY STIMULUS-DRIVEN FIGURE-GROUND SEGREGATION

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Auditory figure-ground segregation

Listeners' ability to extract a particular sound from a background of other simultaneous sounds

Processes:

i. grouping of simultaneous figure components from the spectral array,
ii. grouping of figure components over time,
iii. separation of grouped components from rest of the acoustic scene.

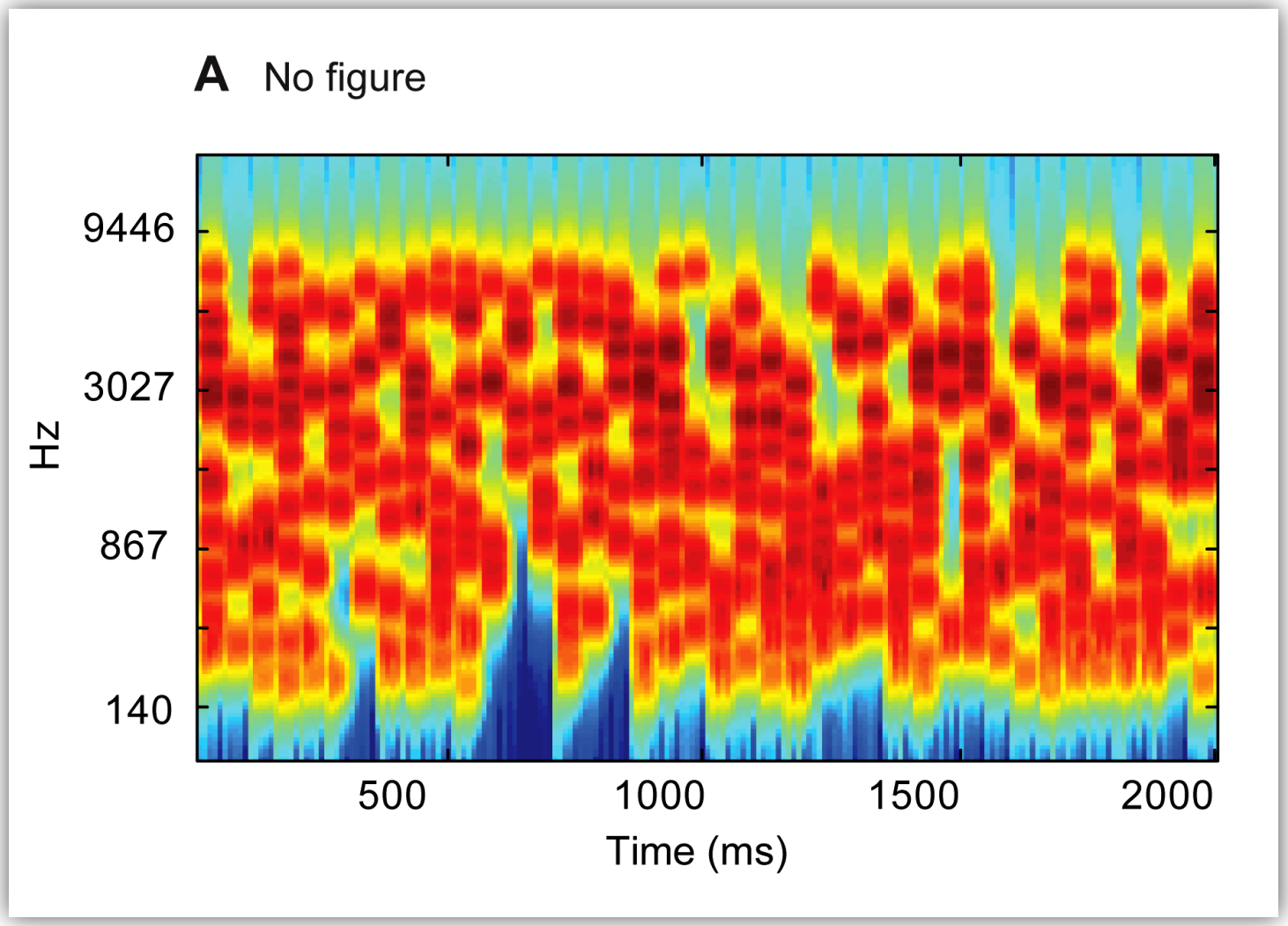
Neural Substrates:

Distributed network: auditory periphery, medial geniculate body, primary auditory cortex to non-primary auditory areas

Stimuli:

Streaming stimuli: alternating sequence of low and high frequency tones
- lack the rich spectrotemporal complexity of natural sounds.

Stochastic Figure-Ground (SFG) stimulus



SFG: Stimulus design

Stimulus:

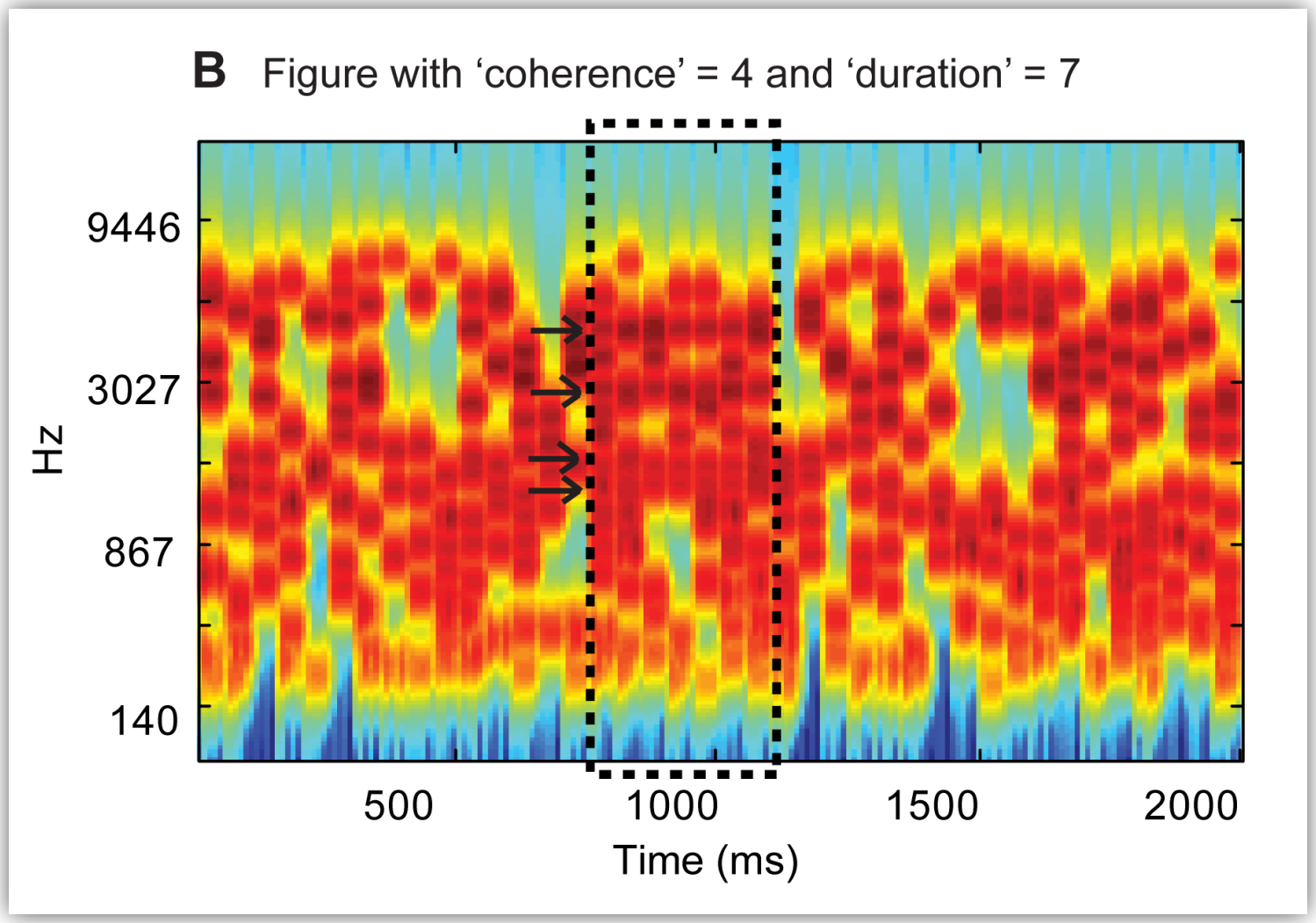
Sequence of random chords consisting of pure tone components

Duration of each chord:	50 ms
Inter-chord interval:	0 ms
Total stimulus duration:	2000 ms (40 consecutive chords)

Chords:

No. of pure tone components:	5-15
Component frequency range:	179 – 7246 Hz
Cosine ramp:	10 ms for onset and offset

SFG: Figure present



SFG: Figure

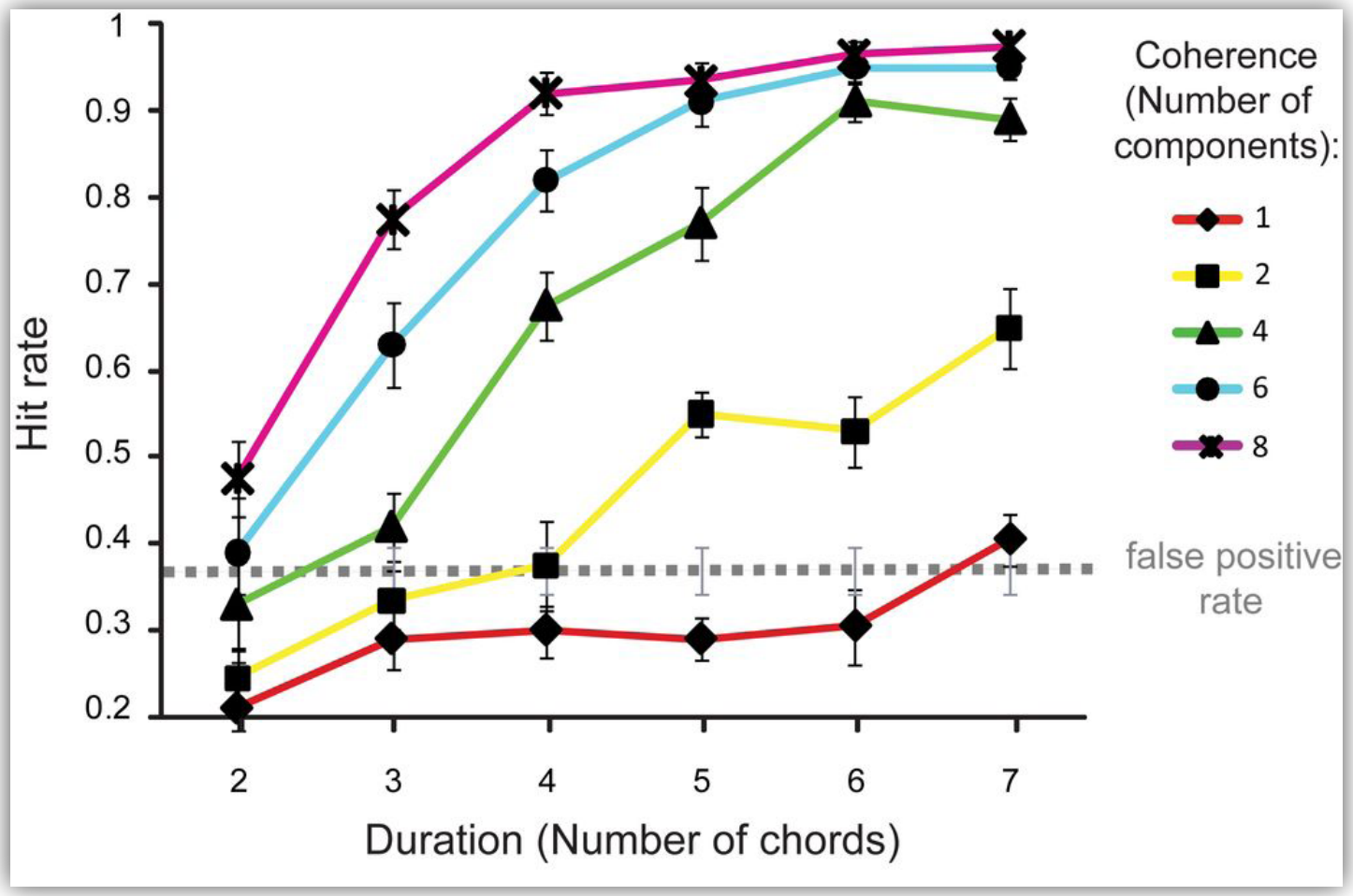
Coherence: Number of different repeating frequencies : **1,2,4,6,8**

Duration: Number of chords over which frequencies repeat : **2-7**

Features of SFG:

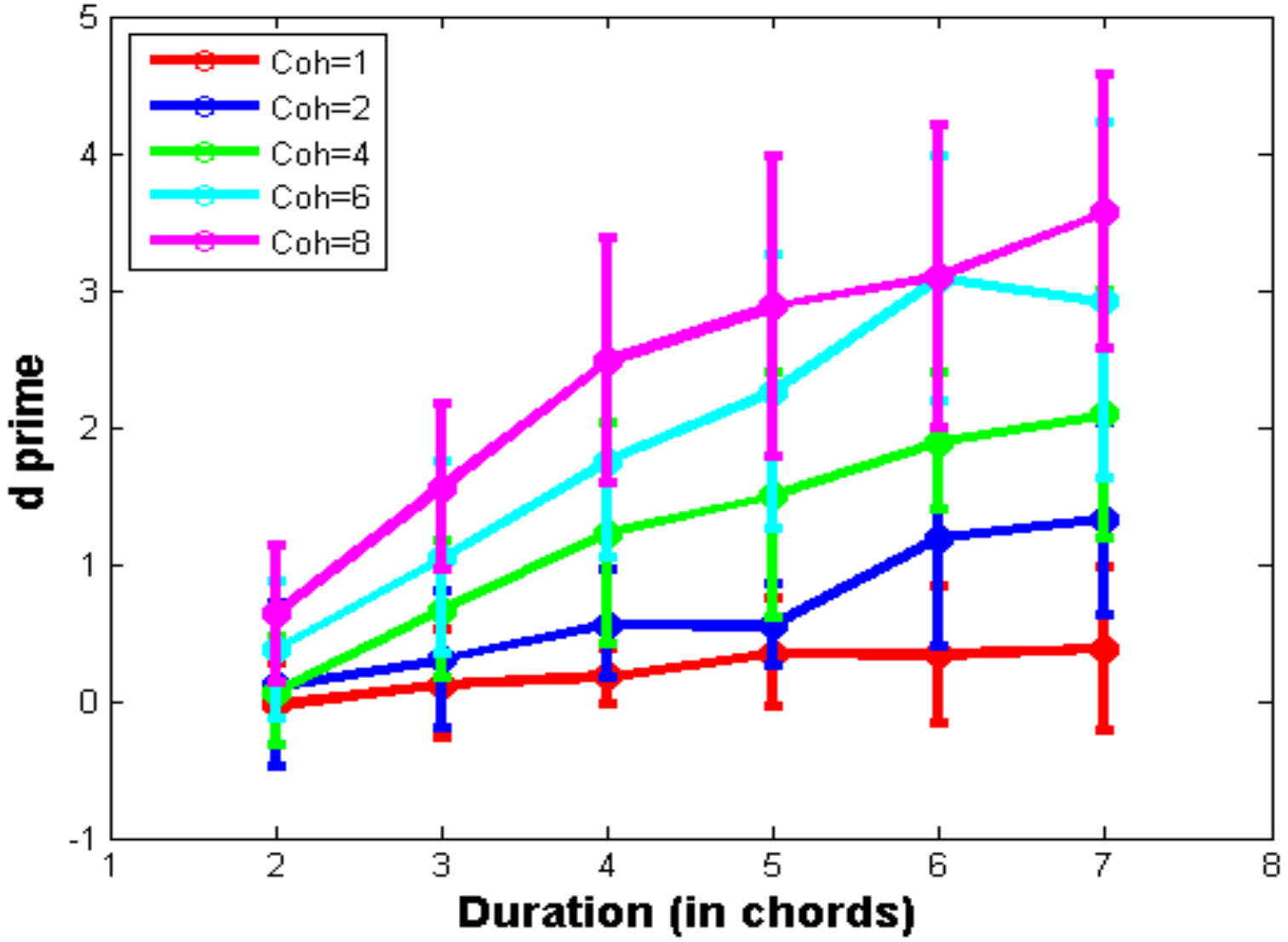
- Figure and background signals do not differ in low-level acoustic attributes
- No spectral ‘protective’ region between figure and background
- Figure and background signals are indistinguishable at each point in time
- Figure can only be extracted by integrating over time and frequency
- Enables parametric variation of figure salience

Psychophysics (n = 10)



- Listeners are remarkably sensitive to the appearance of figures
- Sensitive to parametric variations of coherence and duration

Psychophysics II (n = 10)



fMRI Experiment

Aim: Identify brain areas whose activity varies with parametric variations in coherence and duration of the figure

Stimulus:
i. Fixed coherence: 4, varying duration: 2-7 chords
ii. Fixed duration: 4, varying coherence: 1,2,4,6,8

= 9 stimulus conditions (40 repetitions each)

Paradigm:
i. Passive listening
ii. Active figure-detection

fMRI Paradigm

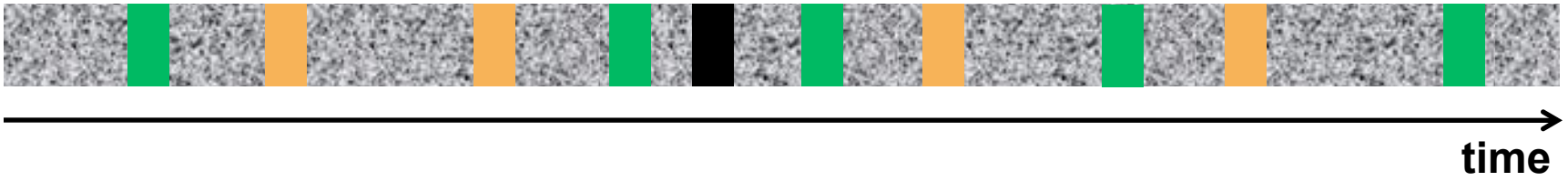


Figure (fixed coherence)

Figure (fixed duration)

Background

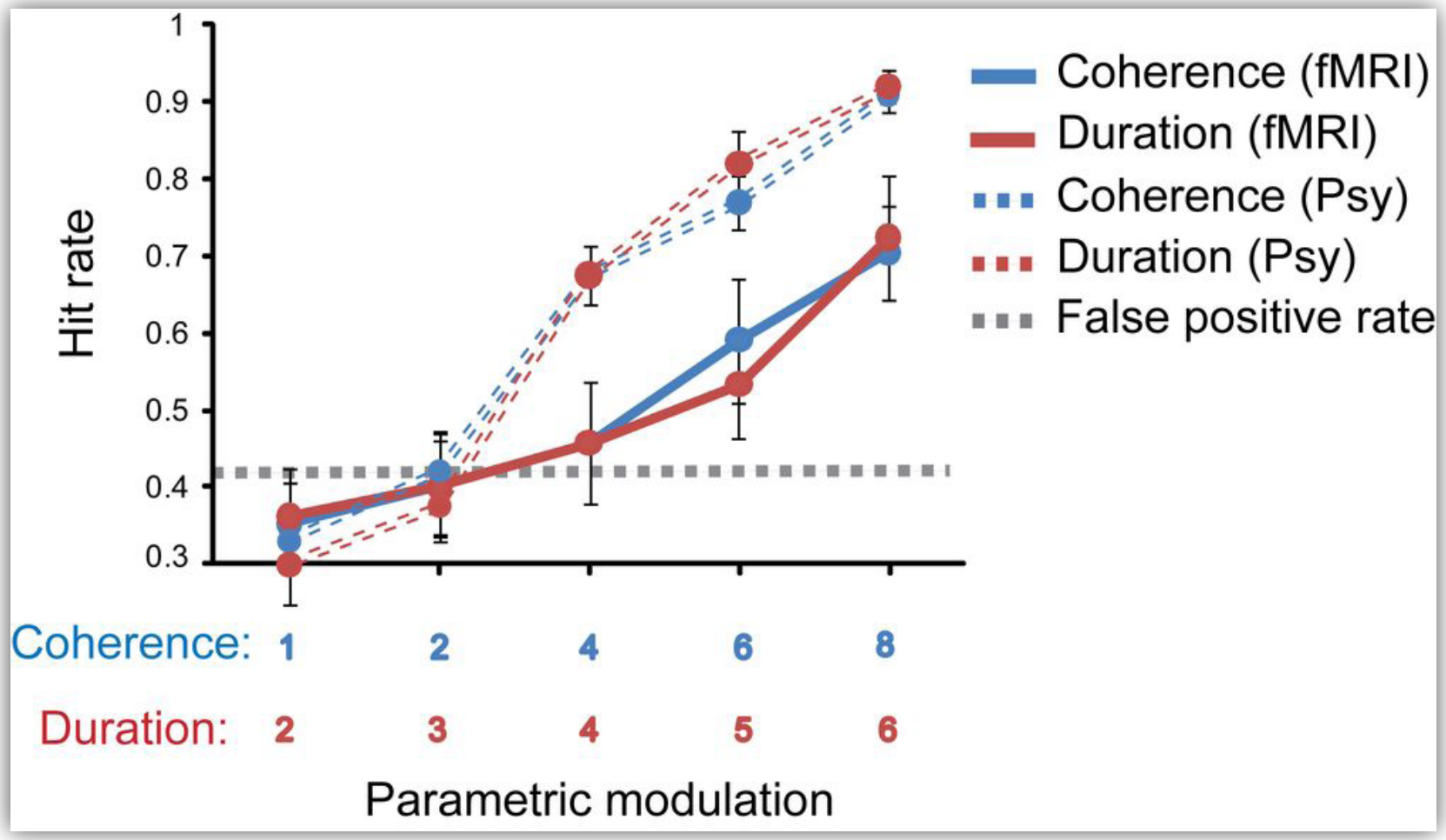
Decoy

Task: **Detect decoy stimuli (noise bursts; 10% of stimuli)**

- **Subjects not actively detecting figures**

- 3 Tesla Siemens Allegra MRI Scanner
- Continuous scanning
- 42 contiguous slices per volume
- TR: 2.52 s; TA: 2.88 s; TE: 30 ms
- Slice thickness: 2 mm with 1mm gap between slices
- In-plane resolution: 3.0 x 3.0 mm^2
- 3 scanning sessions: 510 volumes per subject

Behaviour in scanner



fMRI Analysis

- 14 subjects (normal hearing, no audiological disorders)
- Standard pre-processing with SPM8
- Whole brain analysis
- Statistical model based on General Linear Model
- Random effects design

- **Parametric Modulation**

  I. Effect of Duration: Fixed coherence (4); varying duration (2-7)

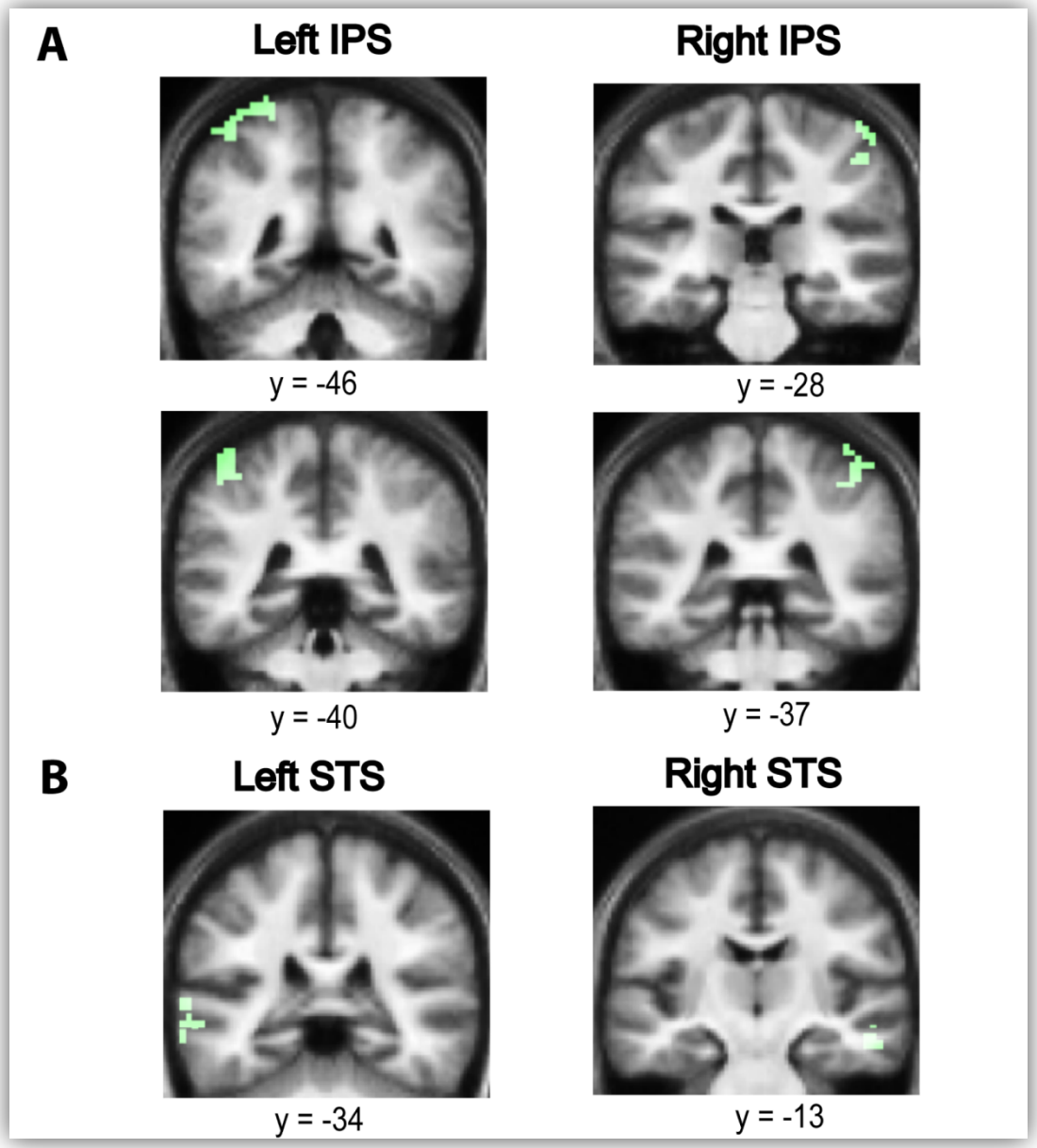
  II. Effect of Coherence: Fixed duration (4); varying coherence (1,2,4,6,8)

fMRI Results

I. Effects of Duration:

Intraparietal Sulcus (IPS)	(bilateral; anterior)
Superior Temporal Sulcus (STS)	(bilateral)
Planum Temporale	(R)
Medial Geniculate Body (MGB)	(bilateral)

Effects of Duration

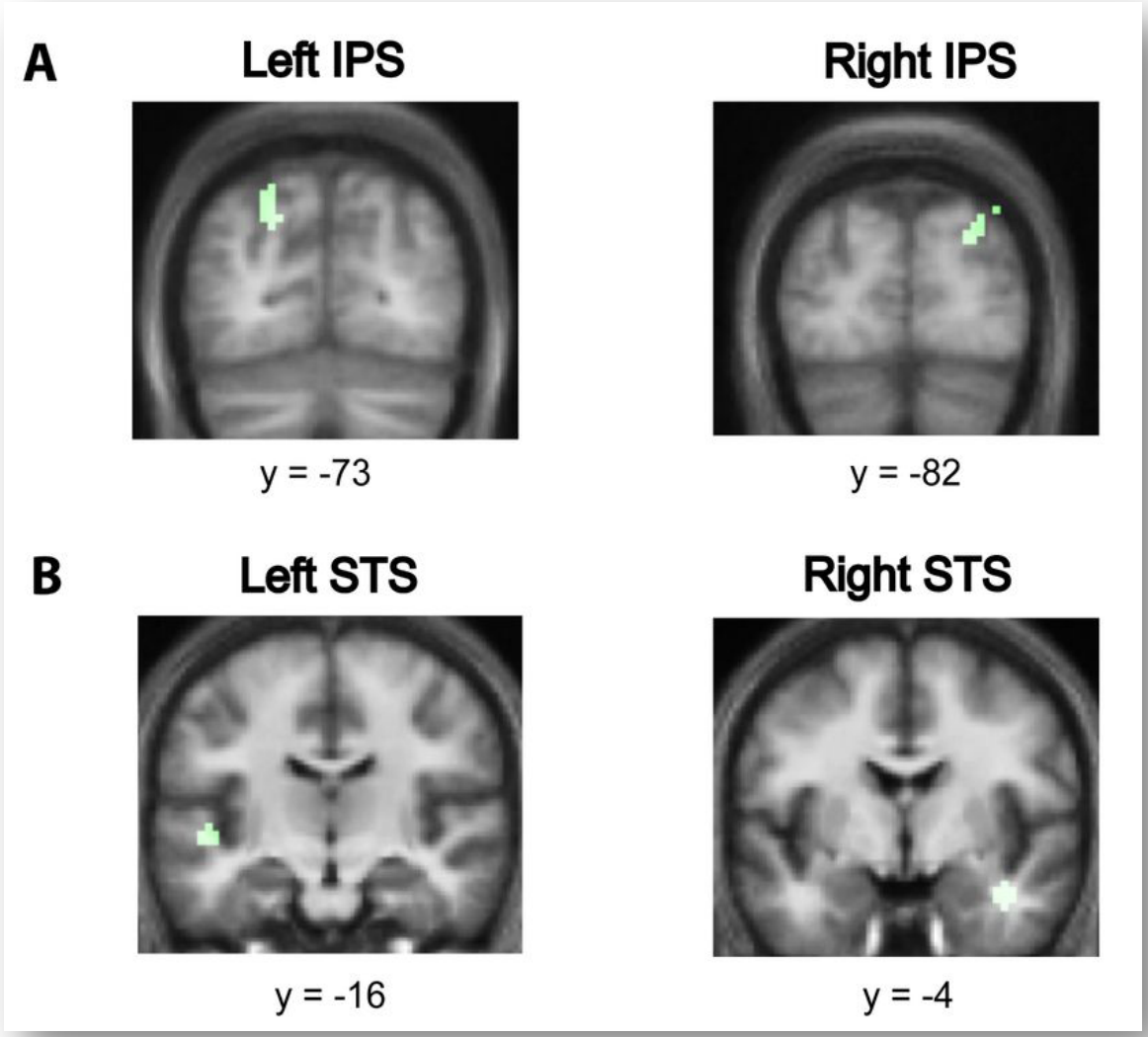


fMRI Results

II. Effects of Coherence:

Intraparietal Sulcus	(bilateral; posterior)
Superior Temporal Sulcus	(bilateral)

Effects of Coherence



What about the auditory cortex ?

- No activation in Primary Auditory Cortex (PAC) for either contrast
- Confirmed using volume of interest analysis based on PAC maps (Morosan et al., 01)
- Consistent with one previous fMRI study (Cusack, 2005)

Reasons…

- More complex and naturalistic stimulus
- Naïve subjects and short figures
- PAC recruited during active figure-ground segregation (i.e., in behavioural context) with possibly top-down modulation by IPS?

Role of STS

- STS activity modulated by changing duration and coherence of the figure

- Implicated in:
  - analysis of spectral shape (Warren et al., 2005)
  - dynamic changes in spectrum (Overath et al., 2008)
  - detection of increasing changes in spectrotemporal coherence within textures (Overath et al., 2010)

IPS and Perceptual Organization

Role of IPS consistent with Cusack (2005):

- Implicated IPS in perception of two streams vs. one stream, based on the same physical streaming signal that evoked a bistable percept.
- IPS activity likely reflects top-down application of attention (shift between streams)
- Found no activation in primary auditory cortex

IPS is involved in structuring sensory input and perceptual organization:

- Encoding visual object representations
- Binding of sensory features within and across different modalities
- control and shift of auditory attention

What does the IPS activity reflect?

➢ ***automatic, bottom-up segregation of auditory object from stochastic background***

Summary

SFG stimulus

- More representative of the natural complexity of acoustic scenes
- Figure can only be extracted by integrating over frequency-time space
- Shorter build up time (~300ms; compared to ~2s for streaming stimuli)
- Enables parametric approach to study auditory figure-ground segregation

Substrates

- IPS and STS: pre-attentive, stimulus-driven, bottom-up segregation
- No role of primary auditory cortex in such bottom-up segregation

Questions...

- Is IPS involved in active figure-ground segregation ? And PAC?
- Functional connectivity between IPS and the auditory system ?

For complete details, see: Teki, Chait et al., J Neurosci (2011)

Acknowledgments

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