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Auditory bubbles reveal sparse time-frequency cues subserving identification of musical voices and instruments

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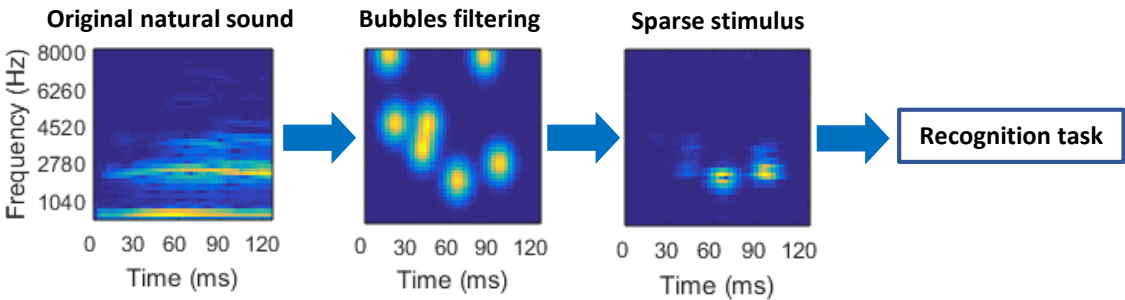
Introduction:

- Human listeners identify effortlessly natural sounds.
- What are the auditory cues underlying the recognition of natural sounds?

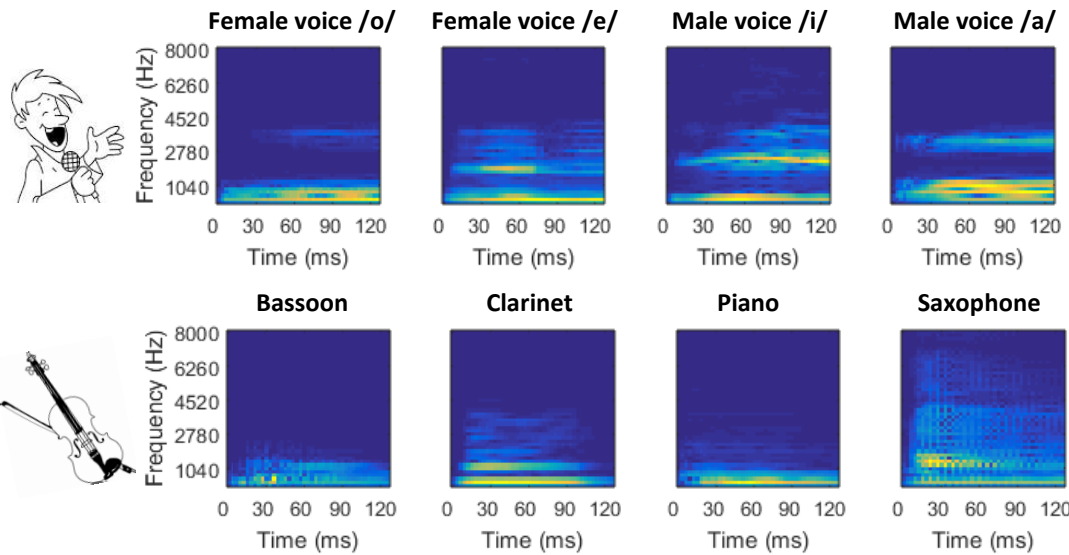
Identification of sparse time-frequency patterns subserving timbre recognition of natural sounds.

- Perceptual task vs. computational model.

Rationale: adapt a random search method called “Bubbles” proposed in vision (Gosselin & Schyns, 2001).

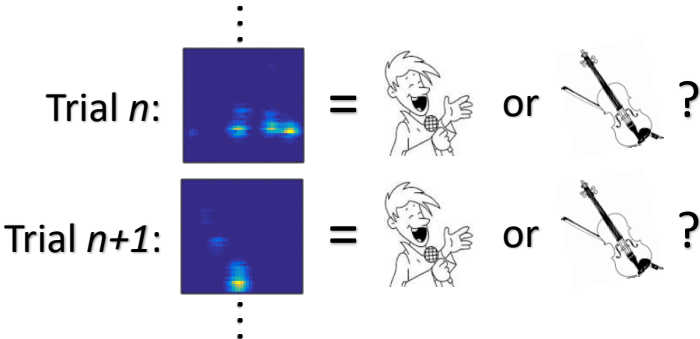


Original natural sounds: musical voices and instruments with same pitch (F#4) and same duration (128 ms with the attack).



Procedure: at each trial:

- Random selection of one sound → bubbles filtering.
- 2-AFC task: Voice or Instrument?

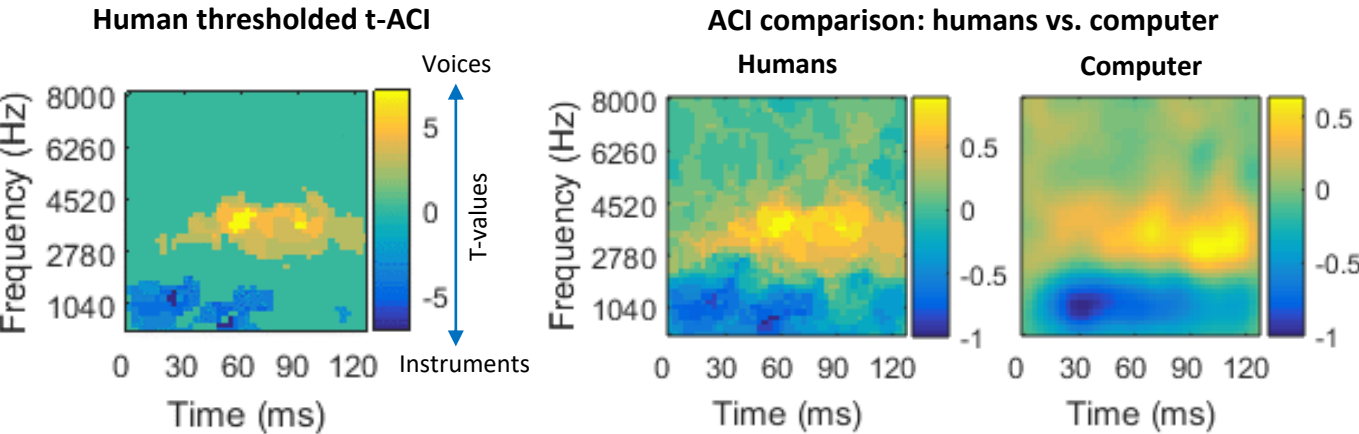


Decision:

- Humans:** 8 participants; 1500 trials.
- Computational model:** auditory distances between the sparse stimulus and the original sounds (cf. Isnard et al., 2016); 6400 trials.

Results:

Humans	Computer
Sensitivity and bias	
<ul style="list-style-type: none">d' = 1.49 (± 0.40)c = 1.04 (± 0.38) (bias toward voices)	<ul style="list-style-type: none">d' = 1.47c = 0.51
Auditory Classification Images (ACIs) computations	
<ul style="list-style-type: none">ACI: normalized mean correct image by participant and for each sound category, then subtraction.Permutation test: 1000 permutations by participant.Thresholding of each ACI's time-frequency bin compared to the 95th percentile of its permutation distribution.T-tests on each TF bin, then FDR for multiple hypothesis testing (q < 0.05).	<ul style="list-style-type: none">ACI: 400 correct responses by category with the highest auditory distances, then subtraction.



Background:

- Bubbles adapted very recently in the auditory domain by few authors studying speech intelligibility (Mandel et al., 2016; Venezia et al., 2016).
- Using this technique, we follow the recent view of sparse auditory perception allowing the recognition of natural sounds (see Isnard et al., 2016).

Discussion:

- Main result:** sparse features allow timbre recognition in particular:
 - Voice recognition = formant recognition.
 - Instrument recognition = attack recognition in lower frequencies.
- Auditory distance model between natural sound categories:**
 - Striking similarity with the ACI obtained with human participants.
 - Auditory recognition of sparse stimuli seems to rely on the comparison with referent sounds from the different auditory categories implicated in the task.

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