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

Vincent Isnard, Clara Suied, Guillaume Lemaitre

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Vincent Isnard [1,2] (vincent.isnard@ircam.fr), Clara Suied [2], Guillaume Lemaitre [1]

[1] Institut de Recherche et Coordination Acoustique/Musique (IRCAM), CNRS UMR 9912, Equipe Perception et Design Sonore, Paris

[2] Institut de Recherche Biomédicale des Armées (IRBA), Département Action et Cognition en Situation Opérationnelle, Unité Perception, Brétigny-sur-Orge

Introduction:

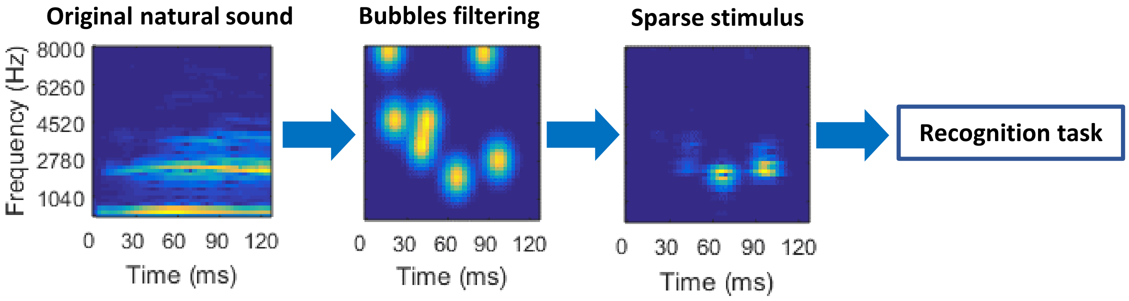
- Human listeners identify effortlessly natural sounds.
- What are the auditory cues underlying the recognition of natural sounds?

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

- Perceptual task vs. computational model.

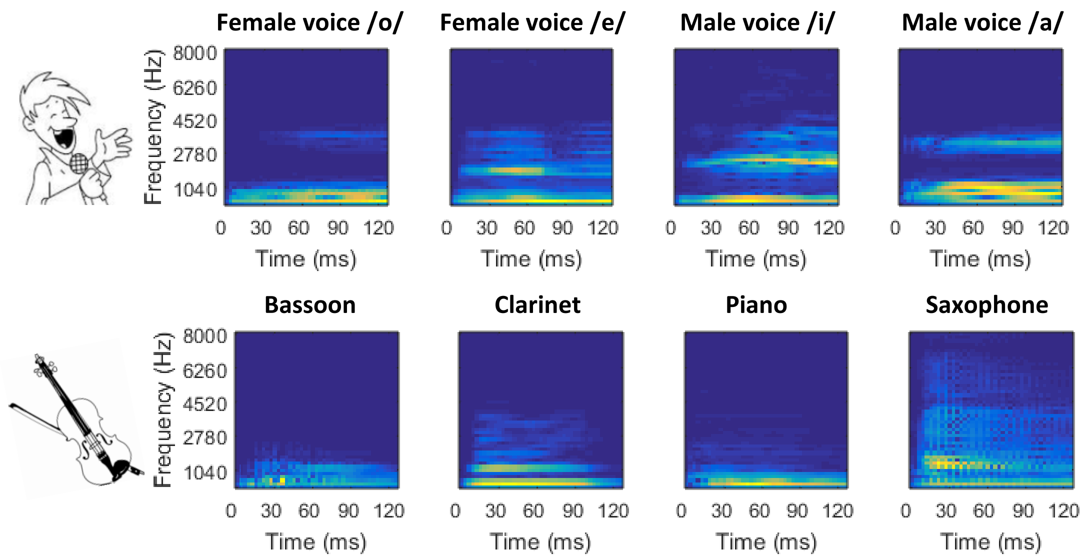
Rationale:

adapt a random search method called "Bubbles" proposed in vision (Gosselin & Schyns, 2001).



Original natural sounds:

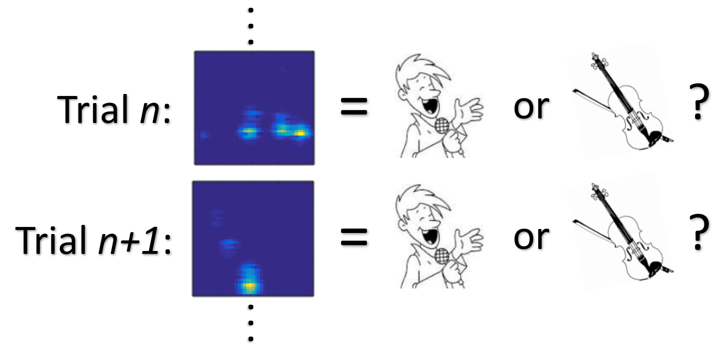
musical voices and instruments with same pitch (F#4) and same duration (128 ms with the attack).



Procedure:

at each trial:

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



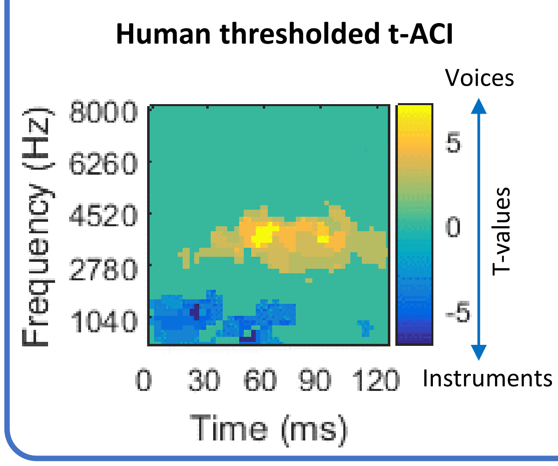
Decision:

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

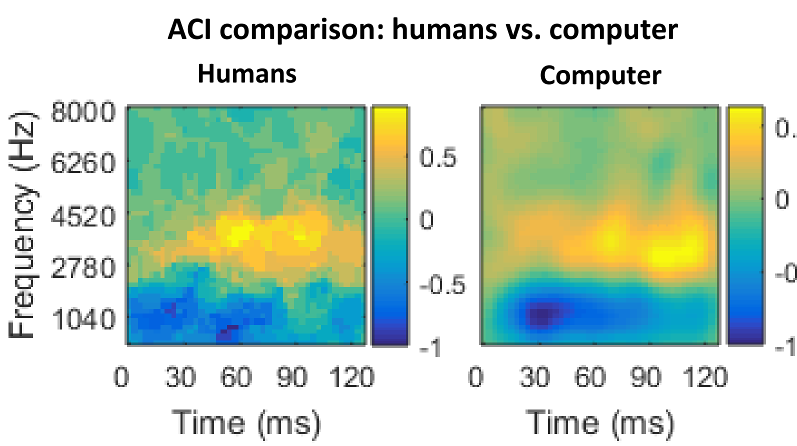
Results:

Humans	Computer
Sensitivity and bias	
• d' = 1.49 (± 0.40) • c = 1.04 (± 0.38) (bias toward voices)	• d' = 1.47 • c = 0.51
Auditory Classification Images (ACIs) computations	
• **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).	• **ACI:** 400 correct responses by category with the highest auditory distances, then subtraction.

Human thresholded t-ACI



ACI comparison: humans vs. computer



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.

References.

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