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Auditory bubbles reveal sparse time-frequency cues suberving 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 suberving 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 \(\rightarrow\) 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:

<table>
<thead>
<tr>
<th>Humans</th>
<th>Computer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity and bias</td>
<td></td>
</tr>
<tr>
<td>(d' = 1.49 (\pm 0.40)) (bias toward voices)</td>
<td>(d' = 1.47)</td>
</tr>
<tr>
<td>(c = 1.04 (\pm 0.38)) (bias toward voices)</td>
<td>(c = 0.51)</td>
</tr>
</tbody>
</table>

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 (\(q < 0.05\)).

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: