An Acoustic Analysis of the Vowels of Mebêngôkre and Panará
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Introduction
About Mebêngôkre and Panará
• Languages of the Jê family
• Number of speakers in 2010 (Povos Indígenas do Brasil, 2011):
  - Mebêngôkre: 10,456
  - Panará: 437
• Both spoken in the Brazilian Amazon

Research questions
1. Where are each one of the vowels of Mebêngôkre and Panará situated within the acoustic space?
2. Can a theory of Dispersion account for the organization of the vowels of Mebêngôkre and Panará?

Data collection
Participants
• 12 male speakers of Mebêngôkre
  - Village of Djuîdjîkó
  - Aged between 18 and 47 years (mean=29)
• 12 male speakers of Panará
  - Village of Niseapotiti
  - Aged between 22 and 45 years (mean=31)

Materials
• 5 practice items
• Carrier phrase
  - Mebêngôkre: “Ba [X] bit jæ”
  - Panará: “Ik jæ ké ka sï [X]”
• One target word for each vowel phoneme
  - Monosyllabic
  - CV (C is a bilabial stop)

Procedure
• Target word presented with a picture on a computer screen inside a carrier sentence
• Words presented in semi-randomized order
• Each target word repeated 10X

MATERIALS
• Spectra for [g] and [ʒ], from Beddor et al. 1986

Dispersion theories
• Predict the dispersion of sounds within the acoustic space, such that contrastive sounds are maximally distinct.
• The theory of adaptive dispersion (Ladefoged, 1972, 1990)
• The dispersion-localization theory of vowel systems (Schwartz et al., 1997a)
• The dispersion theory of contrast (Flemming, 1996, 2004, 2006, among others)

Why does this happen?
• Nasal formants are introduced in the acoustic signal when the oral and nasal cavities are coupled.
• FN1 is generally found around 400-500 Hz.
• FN1 and F1 are perceptually merged by listeners.
• The center of gravity is reanalyzed.
• Low vowels are raised.
• High vowels are lowered.
• Overall reduction of the acoustic space in the F1 dimension for nasal vowels.

Discussion
• Although Mebêngôkre is said to have an additional nasal vowel ([ã]), this vowel is merged with the mid central nasal vowel ([ɨ]).
• Mebêngôkre and Panará share the same organization for nasal vowels.
• Panará has only 3 central oral vowels (as opposed to 4 in Mebêngôkre), suggesting that its mid high ([i]) and mid low ([ɛ]) vowels may have merged with [a].
• Panará’s mid central vowel ([ɨ]) is distributed over the same acoustic space as Mebêngôkre’s mid high ([i]) and mid low ([ɛ]) central vowels.
• Nasal and oral vowels are analyzed separately.
• The forces constraining the organization of the two types of systems are different.
• The separate analysis is generally accepted in the literature (Schwartz et al., 1997b).
• The perceptual process by which the acoustic space of nasal vowels is reduced is well attested in the literature (Beddor et al., 1986; Beddor, 1993; Maeda, 1993, among others).
• Our knowledge of the way in which nasal vowel inventories are organized remains unintegrated into phonological theories of vowel systems (see Beddor, 1991).

Proposal
• The acoustic space for nasal vowels is inherently smaller along the F1 dimension than for oral vowels.
• Dispersion applies normally for nasal vowels.
• The reduced size of nasal vowel inventories (Kingston 2007) is a natural consequence of the contracted acoustic space.

Future directions
• According to recent fieldwork data, all vowel qualities in Panará are contrastive in length.
• A way to predict the direction of the shift in the height of nasal vowels.
• A way to predict the degree to which the acoustic space for nasal vowels is reduced.

Acknowledgements
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Vowel inventories

<table>
<thead>
<tr>
<th>Mebêngôkre (17)</th>
<th>Panará (15)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oral (10)</td>
<td>Oral (9)</td>
</tr>
<tr>
<td>Nasal (7)</td>
<td>Nasal (6)</td>
</tr>
<tr>
<td>i</td>
<td>ë</td>
</tr>
<tr>
<td>ü</td>
<td>a</td>
</tr>
<tr>
<td>ɨ</td>
<td>ɔ</td>
</tr>
<tr>
<td>ɛ</td>
<td>u</td>
</tr>
</tbody>
</table>

Adapted from Salanova & Reis Silva, 2010.
Salanova, 2001; Stout & Thompson, 1974

Acoustic analysis

<table>
<thead>
<tr>
<th>Mebêngôkre</th>
<th>Panará</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1 (ms)</td>
<td>F1 (ms)</td>
</tr>
<tr>
<td>F2 (Hz)</td>
<td>F2 (Hz)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Spectra</th>
<th>F1 (Hz)</th>
<th>F2 (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2500</td>
<td>2200</td>
<td>2500</td>
</tr>
</tbody>
</table>

Adapted from Dourado, 2001

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