Nasal place assimilation and the perceptibility of place contrasts

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1

Outline of the Talk

- Introduction
- Experiment I, II: Similarity judgment experiments
- Experiment III, IV: Identification experiments in noise
- General Discussion

2

Introduction

3

General issue

- To what extent is phonology affected by phonetics?
  - Phonetics and phonology are more or less independent systems (Anderson 1981).
  - Phonetics and phonology constitute one integrated system (Flemming 2001; Steriade 2000).
  - Phonetic factors influence phonological patterns, but they are nevertheless different systems (Kochetov and So 2007).

4

Nasals in Place Assimilation

- Cross-linguistically, nasal consonants are more likely to assimilate in place than oral consonants (Cho1990; Jun, 1995, 2004).
- This asymmetry arises because the place contrast is less perceptible in nasals than in oral stops (Jun, 1995, 2004).

5

Example from Malayalam (Mohanan 1993)

(1) Malayalam nasal place assimilation
  a. [kamalam] 'Kamalam (proper name)'
  b. [kamalaŋ-karaññu] 'Kamalam cried'
  c. [kamalaɳ-ʈaʈiccu] 'Kamalam became fat'
  d. [kamalañ-caaṭi] 'Kamalam jumped'

(2) Oral stops do not assimilate in Malayalam
  a. [akṣaram] 'letter'
  b. [utkarṣam] 'progress'
  c. [saptam] 'eight'

6

Example of Hindi (Ohala 1975)

(3) Hindi nasal-stop clusters
   a. [pʰəŋki] 'handful'
   b. [gend] 'ball'
   c. [tamba] 'copper'
   d. [gəŋga] 'Ganges'

(4) Non-homorganic stop-stop sequences
   a. [gətka] 'a type of club'
   b. [gupta] 'last name'

7

Puzzling Asymmetry

- Standard phonological feature theories assume that [place] in nasal and [place] in oral consonants are the same feature.
- Jun (1995, 2004) argues that the asymmetry arises from the perceptibility difference of [place] in nasal and oral consonants.
- The general underlying principle (a.k.a. P-map): speakers are more willing to neutralize contrasts that are less perceptible (Steriade 2001).

8

In terms of perceptual distances

Perceptual Distance Map (Steriade 2001)

[m]------[n]
[b]---------------[d]
[p]---------------[t]

- Nasal consonants are more similar to each other than oral consonants.
- Speakers are more willing to make articulatory changes which involve less of perceptual change (Steriade 2001).

9

Previous Studies

- Is Jun's assumption supported?
- Mohr and Wang (1968)-Nasals were judged to be more similar.
  - Nasal minimal pairs were placed in codas, while oral consonant pairs were placed in onsets.
  - However, we independently know that phonological contrasts are generally better perceived in onsets (Fujimura et al. 1978).

10

Previous studies

- Pols (1983)-controlled for placement in words and presented stimuli under noise. Dutch speakers more reliably identified oral consonants than nasal consonants.
- Hura et. al. (1992) – identification experiment of coda consonants in pre-consonantal positions. Nasals showed a higher confusion rate compared to oral stops.
  - However, the difference did not reach significance.
  - The overall misidentification rate is just 5.2%.

11

Previous Studies

- Winters' (2002) identification experiments had four listening conditions:
  - comfortable listening level
  - 6dB SN ratio
  - -6dB SN ratio
  - speech reception threshold (at about 40dB).
- Only the last condition showed a significant result in the expected direction.

12

Previous Studies: Verbal art

- Speakers are more willing to pair nasal consonants than oral consonants in imperfect rhyming and puns.
  - Japanese rap rhyming (Kawahara 2007)
  - Japanese imperfect puns (Kawahara and Shinohara 2009)
  - English rock lyrics (Zwicky 1976)
  - English imperfect puns (Zwicky and Zwicky 1986)
- Japanese data are based on onset positions. No statistical comparisons for English data.

13

Aims of this study

- It is not clear from the previous experiments that nasal place contrasts are indeed less perceptible than oral consonant place contrasts.
- The only study that unambiguously supports Jun's idea is Pols (1983).
- This study attempts to settle the disagreement among the previous studies by answering the following questions:
  1. Do we find a significant perceptibility difference in place between nasal and oral consonants at all?
  2. If so, in what environments, and under what conditions?
- This study consists of two similarity judgment experiments and two identification under noise experiments

14

Experiment I

15

Experiment I

- A similarity judgment task: A pair of sounds were presented to the participants and they judged how similar the sounds were based on a 5-point scale.
- Mohr & Wang (1968) used this paradigm to investigate knowledge of perceived similarity.
  - (see also Babel & Johnson 2010, Fleischhacker 2001, Huang 2004, Kato et al. 1997 among others for studies using this paradigm)

16

Experiment I, Stimuli

- Stimuli consisted of three conditions: nasals, voiced and voiceless stops.
- For each condition three place combinations were tested: labial-coronal, labial-dorsal, coronal-dorsal
- All of the stimuli were post-vocalic [aX]

Manner		**Place**	
	Labial-coronal	Labial-dorsal	Coronal-dorsal
Nasals	am-an	am-aŋ	an-aŋ
Voiced	ab-ad	ab-ag	ad-ag
Voiceless	ap-at	ap-ak	at-ak

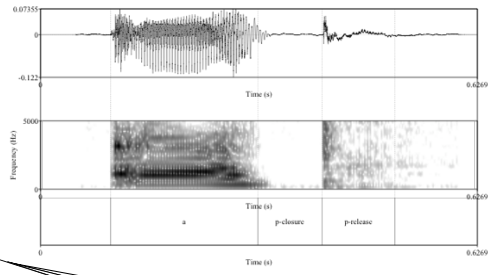
17

Experiment I, Stimuli

- Stimuli were created from speech of two female native speakers of English.
- Target stimuli were extracted at zero crossings using Praat.
- To prevent non-relevant factors from affecting similarity ratings, the stimuli were re-synthesized with a flat pitch contour at 250Hz with the peak amplitude at 0.7.

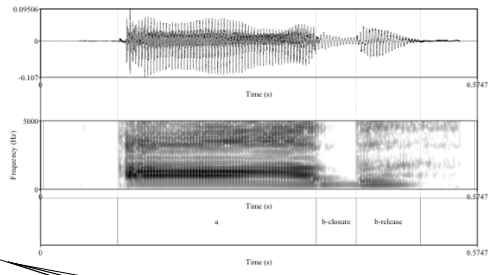
18

Sample [ap]



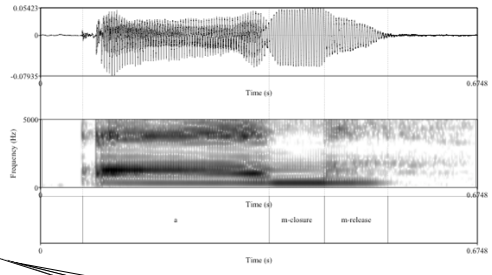
19

Sample [ab]



20

Sample [am]



21

Sound pairs

- Pairs were created by concatenating two stimuli with a 500 ms silence interval.

Labial-coronal combination chains:

[ab-ad]
[ap-at]
[am-an]

22

Experiment I, Procedure

- The experiment was run on Superlab and consisted of a practice block and two main sessions differing by speaker.
- For each phonological pair, the listeners judged their similarity 56 times (7 repetitions * 4 tokens * 2 speakers).
- The participants judged the similarity on a 5-point scale:
  1-almost identical
  2-very similar
  3-similar
  4-not so similar
  5-completely different

23

Experiment I, Analysis

- 19 native speakers of English participated.
- A statistical analysis: a general linear mixed model (details not reported in the slides).
- NB: All differences between different manners are significant in all four experiments.

24

Experiment I, Results

		Ratio	Manner	
		Nasals	Voiced Stops	Voiceless Stops
	Labial vs. Coronal	2.69	3.64	3.98
Place	Labial vs. Dorsal	2.49	3.67	4.00
	Coronal vs. Dorsal	2.57	3.60	4.02
	Average	**2.59**	**3.63**	**4.00**

25

Experiment I, Discussion

- Nasal pairs were judged to be most similar to each other.

  [m]-----[n]
  [b]----------[d]

- The results support the hypothesis that the place contrast is less salient in nasal pairs than in oral stop pairs.

26

Experiment I, Discussion

- We also found a difference in similarity ratings between voiced and voiceless stops

  [b]----------[d]
  [p]----------[t]

- Any phonological reflex? (More on this later)

27

Experiment II

28

Experiment II

- Experiment I used tokens with clear release.
- Another similarity judgment task with voiced and voiceless consonants that had weakened releases.

29

Experiment II, Background

- Released consonants tend to resist assimilation, because release bursts provide a strong cue to the place distinction (Jun 2003; Padgett 1995).
- Questions:
  - Can the previous results be an artifact of clear releases?
  - Does the similarity rating pattern still hold without clear release bursts?

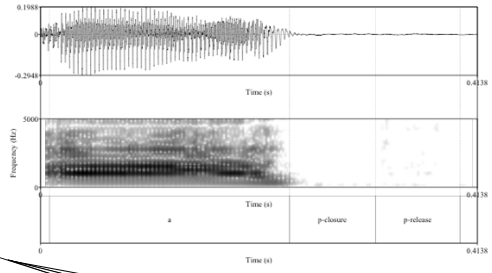
30

Experiment II, Stimuli

- We spliced off original releases and added a weak release from one speaker.
- The average RMS amplitudes were adjusted:
  - To 70dB for the original tokens
  - To 40dB for the releases
- Nasal tokens retained their release and the average amplitude was set at 70dB.

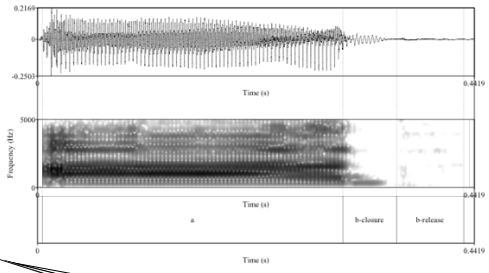
31

Sample [*a*p] without clear burst



32

Sample [*a*b] without clear burst



33

Experiment II, Procedure

- The same 5-point scale was used for the similarity rating with 1 "almost identical" to 5 "completely different"
- All other aspects of the method were identical to Experiment 1, except that for each chain we included both orders.
- Each chain was repeated 56 times= (7 repetition * 4 tokens * 2 orders).

34

Experiment II, Analysis

- 18 native English speakers participated.
- There was no overlap of those who participated in Experiment I.

35

Experiment II, Results

		Ratio	Manner	
		Nasals	Voiced Stops	Voiceless Stops
	Labial vs. Coronal	3.12	3.52	3.72
Place	Labial vs. Dorsal	2.68	3.45	3.79
	Coronal vs. Dorsal	2.79	3.14	3.78
	Average	**2.86**	**3.37**	**3.76**

36

- With much weakened releases, the oral stops pairs were judged to be more similar, as compared to Experiment I.
- Nevertheless, nasal pairs were judged to be more similar than oral consonant pairs.
- Perceptual Distance Map in Experiment II

[m]------[n]
[b]----------[d]
[p]--------------[t]

37

Experiment II, Discussion

- Even when the releases are weakened on the voiced and voiceless consonants, the place distinction for nasals is still the least salient one.
- Voiced consonant pairs were judged to be more similar than voiceless consonant minimal pairs
- The perceptual distance hierarchy: nasals < voiced < voiceless is maintained.

38

Experiment III

39

Experiment III

- Experiments III and IV were identification tasks in noise.
- Stimuli were presented in isolation, covered by noise at different signal to noise ratios.

40

Experiment III, Background

- Hura et al. (1992) used clear listening environment and obtained only a 5.2% of misidentification.
  - This low percentage of misidentification may be why they did not obtain a significant difference between nasals and oral consonants
- Pols (1983) and Winters (2002) had conflicting results, so we ran follow-up identification tests.
- We used cocktail party noise to simulate the most naturalistic conversational setting.

41

Experiment III, Stimuli

- A female native English speaker pronounced all of the stimuli in the most naturalistic way possible.
- The noise files consisted of six recordings of cocktail party noise that were superimposed one top of one another (Kawahara 2006).
- There were three S/N ratios: -6dB, -12dB, and -15dB where the signal dB was kept at the average of 60dB RMS amplitude.
- [ɑb] under noise at -6dB, -12db, and -15db

42

Experiment III, Method and Procedure

- Superlab was once again used to present the stimuli.
- The responses possible were binary
  - E.g.: auditory stimulus [ɑm], one possible visual response was "am" or "an" and the other was "am" or "aŋ".
- Both possible orders of visual cues were presented.
  - E.g. for auditory stimulus [ɑm]: "am–an" and "an–am"

43

Stimulus structure summary

- 9 auditory stimuli (e.g. [ɑm], [ɑn]….)
- 5 tokens each
- 2 binary comparison types (e.g. "am"–"an" and "am"–"aŋ")
- 2 visual orders (e.g. "am"–"an" and "an"–"am")
- Hence 180 tokens per each S/N ratio condition.
- The entire experiment blocked by S/N ratio.

44

Experiment III, Analysis

- 23 native English speakers participated (no overlap with previous experiments).
- We used a signal detection analysis which allows us to tease apart the perceptual distance from response biases.
- As a measure of perceptual distance, we calculated its d' score, using:
  z(Hit) − z(FalseAlarm)

45

Experiment III, Results: -6dB

		Ratio	Manner	
		Nasals	Voiced Stops	Voiceless Stops
	Labial vs. Coronal	0.51	0.43	1.93
Place	Labial vs. Dorsal	0.26	1.21	0.91
	Coronal vs. Dorsal	0.34	1.25	2.37
	Average	**0.37**	**0.96**	**1.73**

46

Experiment III, Results: -12dB

		Ratio	Manner	
		Nasals	Voiced Stops	Voiceless Stops
	Labial vs. Coronal	0.11	0.24	2.02
Place	Labial vs. Dorsal	0.21	0.76	0.93
	Coronal vs. Dorsal	0.27	0.77	2.32
	Average	**0.20**	**0.59**	**1.76**

47

Experiment III, Results: -15dB

		Ratio	Manner	
		Nasals	Voiced Stops	Voiceless Stops
	Labial vs. Coronal	0.24	0.14	1.68
Place	Labial vs. Dorsal	0.65	0.65	0.63
	Coronal vs. Dorsal	-0.03	0.81	1.98
	Average	**0.09**	**0.53**	**1.43**

48

Perceptual Distance Map in Experiment III

[m]------[n]
[b]----------[d]
[p]--------------[t]

- Very similar to what we obtained in the two similarity judgment experiments.

49

Experiment III, Results

- The results again show the perceptibility hierarchy: nasal < voiced stop < voiceless stop.
- Nasal place contrasts seem almost non-perceptible at -12 and -15 dB S/R ratio (the lower bounds of 95% CIs of the d'-values overlap with zero).

50

Experiment IV

51

Experiment IV

- Finally, we ran a second identification task in order to test whether the same perceptibility hierarchy holds when the stimuli are in pre-consonantal position.
- Place assimilation occurs pre-consonantally.

52

Experiment IV, Stimuli

- To create the pre-consonantal environment, we recorded [bə, də, gə, pə, tə, and kə] in post-stress position and adjusted the amplitudes to 60dB.
- We then concatenated the CV-syllable with a consonant that is non-homorganic to either options.
  - For example, [ɑb] would be in stimuli [ɑbdə] and [ɑbgə].

53

Experiment IV, Procedure and Method

- Only the -6dB and -12dB S/N ratios were run because a pilot test showed that in the -15dB condition, participants only performed at chance.
- Participants were asked to identify the quality of the first syllable
- [ɑbdə] -6dB -12dB

54

Experiment IV, Analysis

- 22 native speakers of English participated
- We again calculated d' for each contrastive pair.

55

Experiment IV, Results: -6dB

			Manner	
		Nasals	Voiced Stops	Voiceless Stops
	Labial vs. Coronal	0.29	0.12	0.98
Place	Labial vs. Dorsal	0.08	0.49	0.78
	Coronal vs. Dorsal	0.14	0.55	1.68
	Average	**0.17**	**0.39**	**1.15**

56

Experiment IV, Results: -12dB

			Manner	
		Nasals	Voiced Stops	Voiceless Stops
	Labial vs. Coronal	0.00	0.00	0.73
Place	Labial vs. Dorsal	0.15	0.33	0.45
	Coronal vs. Dorsal	-0.11	0.07	1.63
	Average	**0.01**	**0.13**	**0.93**

57

Experiment IV, Discussion

- The d' values are generally lower in this experiment than in the previous experiment showing that the presence of a following consonant can mask the perception of coda consonants.
- Once again we observe the perceptibility hierarchy: nasal < voiced stop < voiceless stop

58

General discussion

59

Discussion

- Two similarity judgment experiments and two identification experiments under noise all show the perceptibility hierarchy: nasal < voiced stop < voiceless stop.
- The hierarchy holds under various conditions:
  - Clear release (Expt I) vs. very weak release (Expt II)
  - Quite (Expts I, II) vs. noisy environment (Expts III, IV)
  - Word-final (Expts I,II,III) vs. pre-consonantal (Expt IV)
  - Conscious judgments (Expts I, II) vs. identification task (Expts III, IV)
- The difference between nasals and oral stops support Jun's idea (1995) that this perceptibility difference underlies the cross-linguistic asymmetry in place assimilation.

60

Discussion

- However, the perceptibility difference between voiced stops and voiceless stops does not seem to be reflected in phonological patterns.
- Not instantiated in Jun's typological survey.
- i.e. We do not know of any language in which only voiced stops assimilate in place, but not voiceless stops.
- E.g. /d+g/ => [gg]
  /t+k/ => [tk]

61

Two possibilities

- 1. A further investigation of place assimilation will reveal an existence of such a language.
- 2. Or not all perceptibility differences are reflected in phonology (Kochetov and So 2007).

62

General implication

- Phonetic factors (perceptibility of [place]) can influence phonological patterns (place assimilation).
- It seems however that not all perceptibility differences are reflected in phonology.

63

Thank you

64