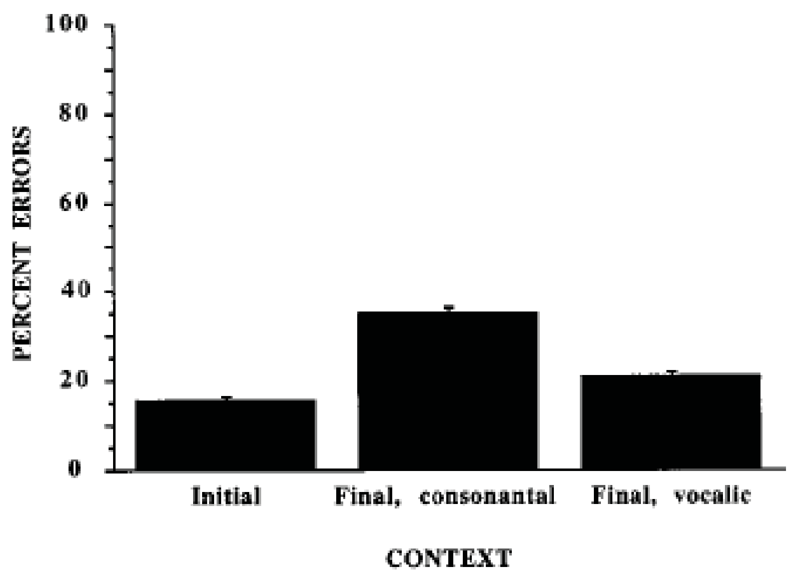
24.915/24.963 Linguistic Phonetics

Perception II: Distinctiveness and cue strength



Source: Redford, Melissa A., and Randy L. Diehl. "The relative perceptual distinctiveness of initial and final consonants in CVC syllables." The Journal of the Acoustical Society of America 106, no. 3 (1999): 1555-1565.

Readings for next week - Speech production:

- Keating (1990)
- Browman and Goldstein (1990)

Assignment:

- Recording and measurements for affricate voicing experiment.
- Talk to me about your final project

- Sorry, no office hours tomorrow (Wed 10/4)

Perceptual distinctiveness in phonology

- Perceptual distinctiveness plays a central role in recent phonological theory.
  - Related concept of cue strength: stronger cues to a contrast imply that the contrast is more distinct.
- There is hypothesized to be a general preference for more distinct (less confusable) contrasts:
  - Theory of Adaptive Dispersion – vowel inventories
  - Distribution of retroflex vs. apical alveolar contrasts (1st lecture)
  - Distribution of major place contrasts

Distribution of retroflexion contrasts in Gooniyandi

Summary:

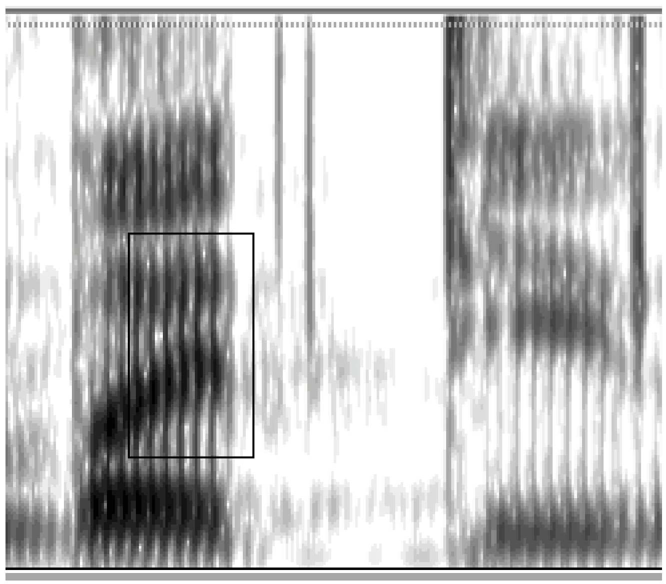
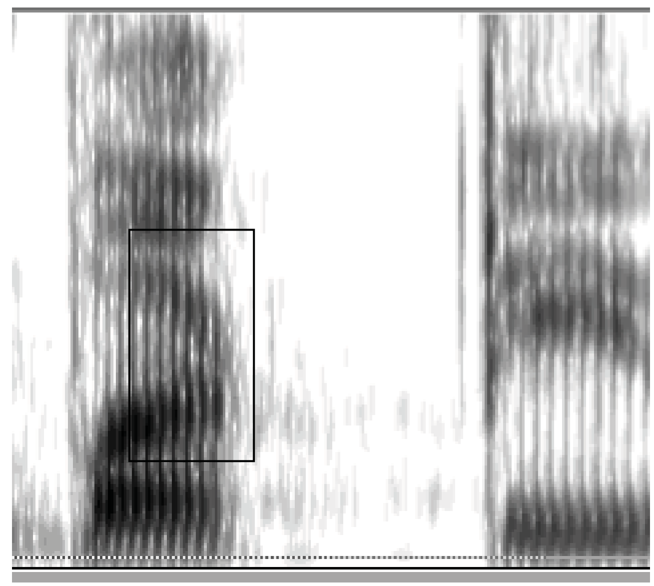
- Contrast between retroflex and apical alveolar **after vowels** V_#, V_V, V_C
- No contrast elsewhere #_, C_
- This pattern of distribution is common in Australian and Dravidian languages.
- Probable universal: If a language contrasts retroflexes and apical alveolars in contexts with no preceding vowel, then it also contrasts these sounds following vowels.
  - ➢ Why?

Distribution of retroflexion contrasts

Outline explanation (Steriade 1995, 2001 etc):

- Contrasts preferentially appear in environments where they are more distinct perceptually.
- Apical alveolars are more distinct from retroflexes when they are preceded by a vowel.
- Therefore some languages only allow the contrast in this context.
- The primary cues to the contrast between retroflexes and apical alveolars are located in the VC transitions
  - lowered F3 and/or F4 before retroflexes
- Most retroflex stops are retroflexed at closure, but the tongue tip moves forward during closure.

The phonetics and phonology of retroflex consonants

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apical alveolar [t]　　　　retroflex [ʈ]

Malayalam

Neutralization of major place contrasts

	_V (_L)	**_#**	**_(N) _T (_F)**
Spanish Japanese		neutralization	assimilation
Diola Fogny			assimilation
Russian			

V = vowel; L= glides & liquids; N = nasals, T = stops, F = fricatives

Jun (1995), DeLacy (2002), Steriade (2001)

Neutralization of major place contrasts

- E.g. Spanish nasals
  - Place contrast prevocalically

    mata, nata, ɲata

    kama, kana, kaɲa
  - Neutralization word-finally - pre-pausally, the only nasal is [n] in Castilian, [ŋ] in many other varieties.

    adan 'Adam' albun 'album'
  - Neutralization before obstruents (assimilation)

kampo	'country'	*kanpo, etc
manto	'cloak'	*mamto, etc
maŋko	'one-handed'	*manko, etc

Major place neutralization

Diola Fogny nasals (Sapir 1957)

- Place contrasts before vowels [m, n, ɲ, ŋ]
- Contrast word-finally (after a vowel):

ɹum	'bite'	famfan	'lots'	buɹuŋ	'road'

- Neutralization before consonants - nasal must be homorganic with a following obstruent of nasal (medial or final)
  - Nasals delete before approximants.

kəguːmp	'ashes'	bunt	'lie'
kaŋg	'be furthest away'	maɲɟ	'know'

/ni-gam-gam/	→	niga**ŋg**am	'I judge'
/ku-bɔɲ-bɔɲ/	→	kubɔ**mb**ɔɲ	'they sent'
/na-tiːŋ-tiːŋ/	→	natiː**nt**iːŋ	'they sent'

Major place neutralization

- Pattern 3: E.g. Russian

anglijə	'England'	mgla	'fog'
gbaronu	'the baron'	kto	'who
tkan^{j}ja	'weaving'		

Neutralization of major place contrasts

	_V (_L)	_#	_(N) _T (_F)
Spanish Japanese		neutralization	assimilation
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V = vowel; L= glides & liquids; N = nasals, T = stops, F = fricatives

Jun (1995), DeLacy (2002), Steriade (2001)

Major place neutralization

Unattested language type:

- Place contrasts / _ V: ma - na
- Neutralization /V_#: an, *am
- Contrast / _ C: anta – amta

Another unattested language type:

- Neutralization / _ V: na, *ma
- Contrast /_C: anta – amta
    - NB specific place contrasts may be permitted finally but not initially, e.g. English velar nasal [æm – æn - æŋ], but [mæ-næ- *ŋæ]

Major place neutralization

- Preferred environments for major place contrasts are contexts where the contrasting sounds are more distinct (Steriade 1999 etc).

_V	pa - ka	ma - na
	>	>
V_#	ap - ak	am - an
	>	>
V_T	ap˺ta - ak˺ta	amta - anta

- Evidence?

Measuring perceptual distinctiveness

- Perceptual distinctiveness is related to confusability: less distinct sounds are more confusable.
- One way to measure confusability is via an identification task:

- Play a number of pre-vocalic consonants [pa, ta, …] and post-vocalic consonants [ap, at,…] that differ in place of articulation.
- Ask subjects to label the stimuli (words, orthographic nonce words).
- Observe rates of confusion (e.g. stimulus [ap] is identified as [at]).
- Is place confused more often in the post-vocalic context?

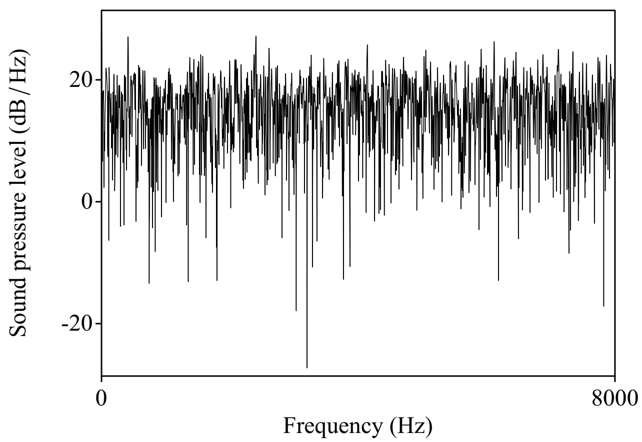
Redford & Diehl (1999)

- Compares the confusability of a variety of consonants (including [p,t,k]) in prevocalic and post-vocalic contexts.
- An identification experiment with natural stimuli.
- Stimuli: CVC syllables
  - All combinations of C = [p, t, k, f, θ, s, ʃ], V = [i, a, u] (7×3×7).
  - Frame sentences ‘Say CVC some more’, ‘Say CVC again’
    - 3 conditions: #<u>C</u>V, V<u>C</u>#C, V<u>C</u>#V
  - Read by two male and two female speakers of American English.
  - Presented in a low level of pink noise (15 dB SNR).
  - Noise is often added to stimuli in studies of confusability in order to encourage errors.

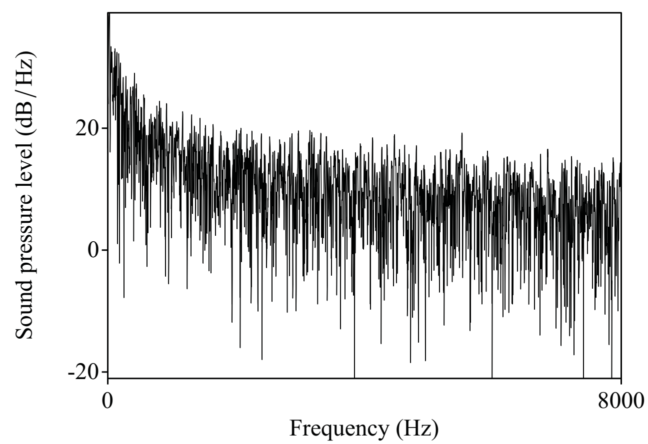
Addition of noise

- Varieties of noise:
  - White noise - flat spectrum
  - Pink noise - spectrum slopes down at 3dB/octave.
  - ‘Cocktail party’ noise, a.k.a. multi-talker babble

white



pink



- Level specified as Signal-to-Noise Ratio - difference between average intensity of speech and noise in dB.
  - Examples have 0dB SNR, Redford & Diehl used 15 dB SNR.

Subjects & Procedure

- 7 female, 7 male, native speakers of American English
- Stimuli presented over headphones.
- Subjects heard each stimulus once in random order at 3.5 s intervals.
- Subjects asked to record the target words in orthography.

Results

- Confusion matrices

- #<u>C</u>V

	p	t	k	f	θ	s	ʃ	Other	None	
p	**2295**	15	23	9		1			9	
t	6	**2254**	5	24	3	1	1	5	53	T
k	39	14	**2251**	4	6	2		2	34	a
f	384	24	20	**1678**	113	65		14	54	r
θ	129	44	12	670	**1274**	197	3	7	16	g
s	10	25	1	84	87	**2106**	27	3	9	e
ʃ	1		2	2	3	38	**2302**	2	2	t

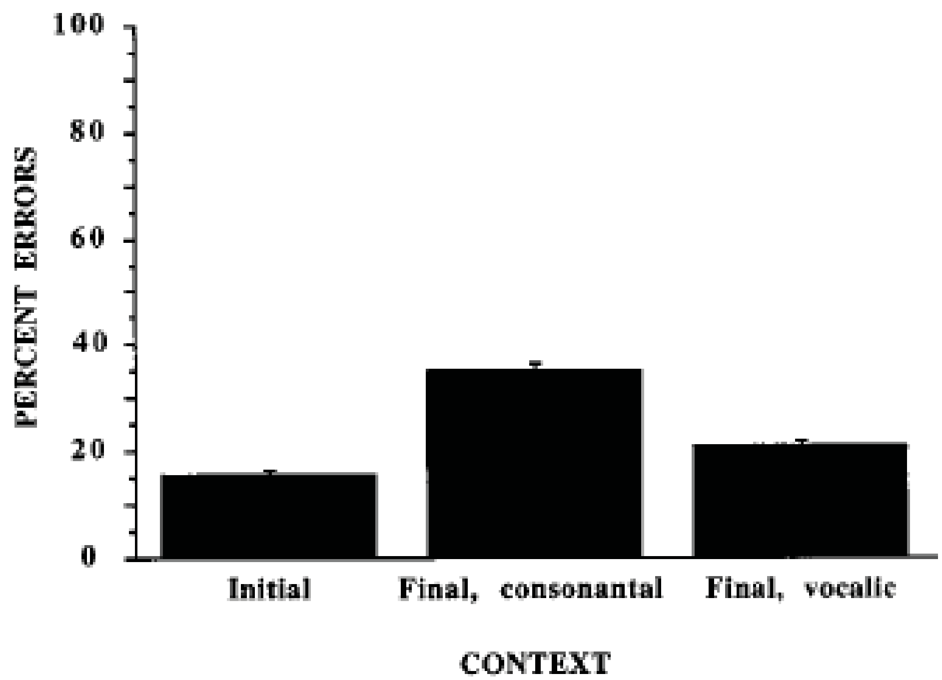
- V<u>C</u>#C

	p	t	k	f	θ	s	ʃ	Other	None	
p	**1007**	37	38	32	42	2		15	3	
t	76	**950**	38	11	72	2		20	7	T
k	32	13	**1063**	15	14	1		30	8	a
f	431	35	90	**366**	184	19	6	37	8	r
θ	249	52	104	122	**589**	23		23	14	g
s	17	29	9	41	180	**748**	81	30	41	e
ʃ	1			3	7	31	**1119**	11	4	t

Source: Redford, Melissa A., and Randy L. Diehl. "The relative perceptual distinctiveness of initial and final consonants in CVC syllables." The Journal of the Acoustical Society of America 106, no. 3 (1999): 1555-1565.

Results

- error rate - percentage of erroneous identifications.
  - only manner and place errors were counted, not voicing errors.



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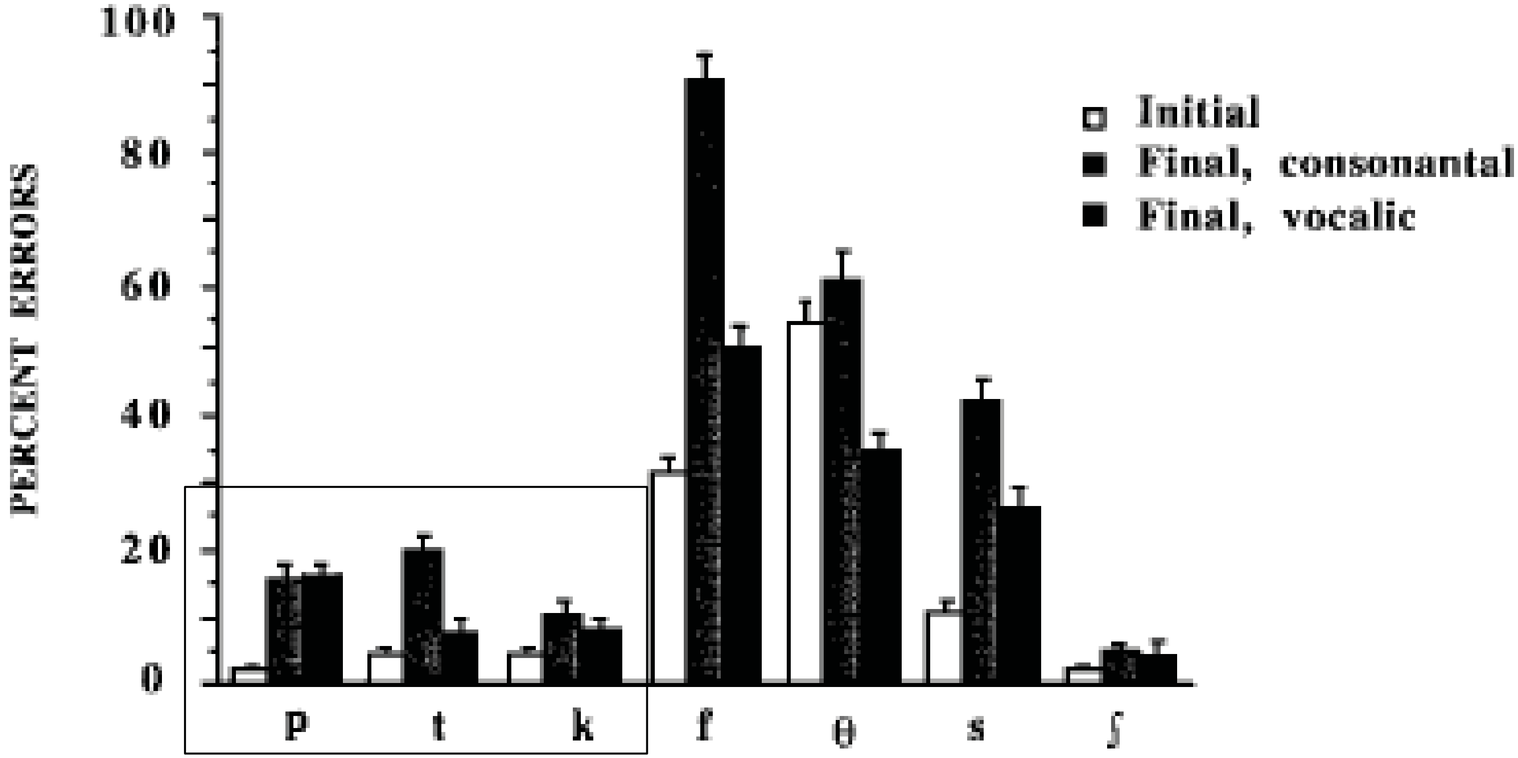
Redford & Diehl (1999)

- Obstruent contrasts in place and manner are more distinct before vowels than before consonants.



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Major place neutralization

- What explains the differences in distinctiveness of place contrasts across these contexts?

_V	pa - ka	burst, release transitions
	>	
V_#	ap - ak	burst, closure transitions
	>	
V_T	ap˺ta - ak˺ta	closure transitions

- More cues in V_# compared to V_T (for stops)
- stronger cues _V compared to V_#
  - Release transitions provide stronger cues than closure transitions (Fujimura et al 1978)

Cue strength

- Measuring cue strength
  - vary multiple cues, model contribution of each cue to perceptual judgments (cf. VOT and F0)
  - conflicting cue experiments: construct stimuli where different properties cue different percepts (e.g. voiced, voiceless).
    - The stronger cue is the one that dominates in perception.
- Fujimura et al (1978) employed the 'conflicting cue' methodology to investigate the relative strength of cues to stop place in VCV.
- Closure transitions vs. Release burst+release transitions
  - E.g. cross-spliced [ab-] from [aba] and [-da] from [ada]
    - Do listeners perceive [aba] or [ada]? (Example)
  - Stimuli created from Japanese utterances.

Conflicting cue experiments - Fujimura et al

- Results: Release cues dominate for English and Japanese listeners

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Source: Tables 2 & 3, Fujimura, Osamu, Marian J. Macchi, and Lynn A. Streeter. "Perception of stop consonants with conflicting transitional cues: A cross-linguistic study." Language and speech 21, no. 4 (1978): 337-346.

- Is this simply because burst+transitions > transitions?
- No: the same result was obtained when the stimuli were played backwards

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Source: Tables 2 & 3, Fujimura, Osamu, Marian J. Macchi, and Lynn A. Streeter. "Perception of stop consonants with conflicting transitional cues: A cross-linguistic study." Language and speech 21, no. 4 (1978): 337-346.

Major place neutralization

- What explains the differences in distinctiveness of place contrasts across these contexts?

_V	pa - ka	burst, release transitions
	>	
V_#	ap - ak	burst, closure transitions
	>	
V_T	ap̚ta - ak̚ta	closure transitions

- burst + release transitions > burst + closure transitions because release transitions provide stronger cues than closure transitions.
- Why is pre-obstruent context worse than word-final position for nasal place contrasts?
  - Overlap with the following consonant?

Perceptual space

- Identification experiments based on synthetic/edited speech can establish the perceptual significance of an acoustic property
- But they do not reveal the nature of perceptual representations
  - The dimensions of the perceptual space
- E.g. VOT is a cue to stop voicing, but is there a perceptual dimension that corresponds directly to VOT, or just something that correlates with VOT?
  - E.g. integrated intensity of aspiration noise (cf. Repp 1979)
- Multi-Dimensional Scaling is a method for investigating perceptual space directly.
  - But it does not reveal the mapping from acoustic signal to perceptual space.

Perceptual space - vowel quality

- The main dimensions of the perceptual space of vowel quality are related to the frequencies of the first two or three formants.
- Acoustic analysis shows that contrasting vowel qualities differ in formant frequencies.

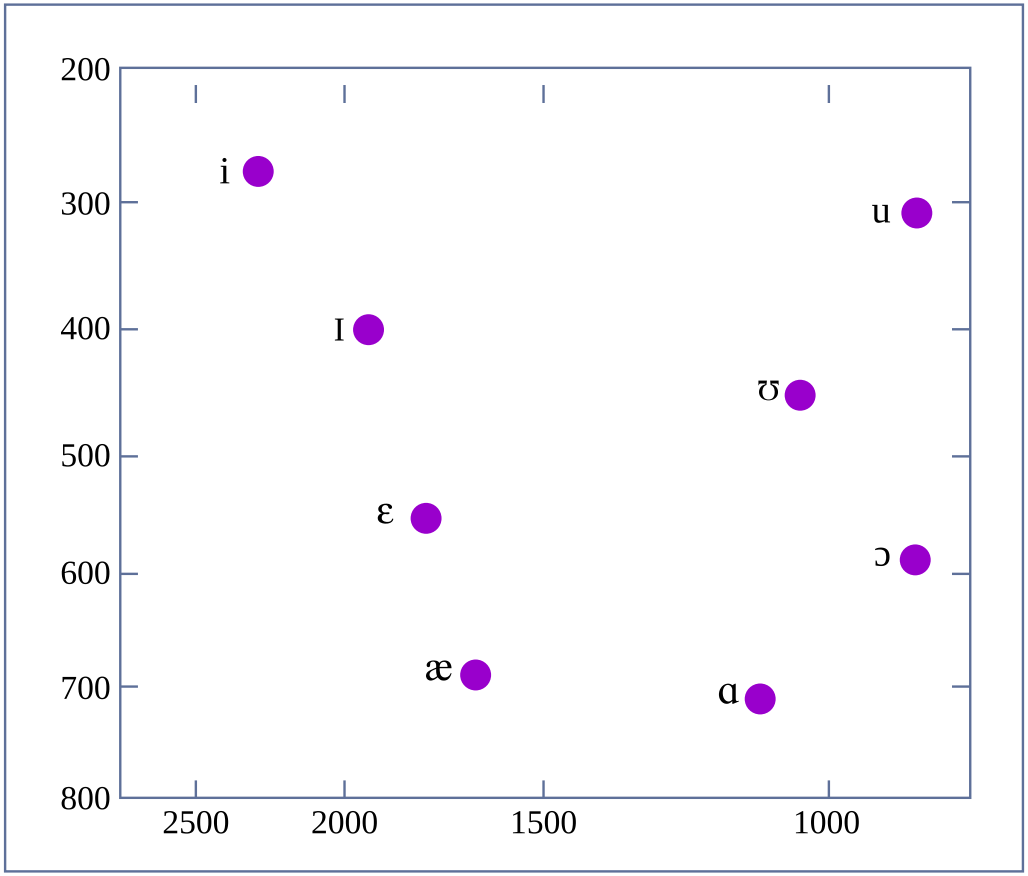

Image by MIT OCW.
Adapted from Peter Ladefoged. *A Course in Phonetics*. 5th ed. Berlin, Germany: Heinle, 2005. ISBN: 9781413006889. Available at: http://www.phonetics.ucla.edu/course/contents.html.

Perceptual space - vowel quality

- Perceived vowel quality is affected by formant frequencies.
- A wide range of vowel qualities can be synthesized with two formants (Delattre, Liberman, Cooper, and Gerstman 1952).
- Multi-Dimensional Scaling (MDS) analyses of vowel confusions and similarity judgements yield spaces in which the most significant dimensions correspond to F1 and F2.

Multi-Dimensional Scaling

- Techniques for constructing perceptual spaces from confusion or similarity data (Shepard 1957, 1972).

Multi-Dimensional Scaling

- Input: a confusion matrix
- e.g. Peterson & Barney 1952

perceived

intended		i	j
	i	p_{ii}	p_{ij}
	j	p_{ji}	p_{jj}

perceived

intended

	i	ɪ	ɛ	æ	ɑ	ɔ	ʊ	u	ʌ	ɹ
i	10267	4	6			3				
ɪ	6	9549	694	2	1	1				26
ɛ		257	9014	949	1	3			2	51
æ		1	300	9919	2	2			15	39
ɑ		1		19	8936	1013	69		228	7
ɔ			1	2	590	9534	71	5	62	14
ʊ			1	1	16	51	9924	96	171	19
u			1		2		78	10196		2
ʌ		1	1	8	540	127	103		9476	21
ɹ			23	6	2	3			2	10243

Multi-Dimensional Scaling

- Input: a confusion matrix
- e.g. Peterson & Barney 1952
- convert to probabilities

perceived

intended		i	j
	i	p_{ii}	p_{ij}
	j	p_{ji}	p_{jj}

perceived

intended

	i	ɪ	ɛ	æ	ɑ	ɔ	ʊ	u	ʌ	ɹ
i	0.9987	0.0004	0.0006	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000
ɪ	0.0006	0.9290	0.0675	0.0002	0.0001	0.0001	0.0000	0.0000	0.0000	0.0025
ɛ	0.0000	0.0250	0.8771	0.0923	0.0001	0.0003	0.0000	0.0000	0.0002	0.0050
æ	0.0000	0.0001	0.0292	0.9651	0.0002	0.0002	0.0000	0.0000	0.0015	0.0038
ɑ	0.0000	0.0001	0.0000	0.0018	0.8699	0.0986	0.0067	0.0000	0.0222	0.0007
ɔ	0.0000	0.0000	0.0001	0.0002	0.0574	0.9275	0.0069	0.0005	0.0060	0.0014
ʊ	0.0000	0.0000	0.0001	0.0001	0.0016	0.0050	0.9655	0.0093	0.0166	0.0018
u	0.0000	0.0000	0.0001	0.0000	0.0002	0.0000	0.0076	0.9919	0.0000	0.0002
ʌ	0.0000	0.0001	0.0001	0.0008	0.0525	0.0124	0.0100	0.0000	0.9221	0.0020
ɹ	0.0000	0.0000	0.0022	0.0006	0.0002	0.0003	0.0000	0.0000	0.0002	0.9965

Multi-Dimensional Scaling

- Input: a confusion matrix
- e.g. Peterson & Barney 1952
- convert to probabilities
- distances are symmetrical ($d_{ij} = d_{ji}$) by definition.
- Confusion matrices are usually not symmetrical.
  - Explanation is disputed. One possible source is bias.
- Convert confusion probabilities to a symmetrical measure of similarity, s_{ij}.
  - $s_{ii} = 1$

perceived

		i	j
intended	i	p_{ii}	p_{ij}
	j	p_{ji}	p_{jj}

$$S_{ij} = \frac{p_{ij} + p_{ji}}{p_{ii} + p_{jj}}$$

Multi-Dimensional Scaling

- Symmetrical similarity matrix
- Similarity is related to distance in psychological space by an exponential decay function, where D_{ij} is the perceptual distance between *i* and *j*:

$$S_{ij} = ae^{-bD_{ij}} + c$$

  - based on observation, derivation attempted in Shepard 19??.

	i	ɪ	ɛ	æ	ɑ	ɔ	ʊ	u	ʌ	ɹ
i	1.0000	0.0005	0.0003	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000
ɪ		1.0000	0.0512	0.0002	0.0001	0.0001	0.0000	0.0000	0.0001	0.0013
ɛ			1.0000	0.0660	0.0001	0.0002	0.0001	0.0001	0.0002	0.0038
æ				1.0000	0.0011	0.0002	0.0001	0.0000	0.0012	0.0022
ɑ					1.0000	0.0868	0.0045	0.0001	0.0417	0.0005
ɔ						1.0000	0.0063	0.0003	0.0099	0.0009
ʊ							1.0000	0.0086	0.0141	0.0009
u								1.0000	0.0000	0.0001
ʌ									1.0000	0.0012
ɹ										1.0000

Multi-Dimensional Scaling

- Symmetrical similarity matrix
- Similarity is related to distance in psychological space by an exponential decay function, where D_{ij} is the perceptual distance between *i* and *j*:

$$S_{ij} = ae^{-bD_{ij}} + c$$

  - based on observation, derivation attempted in Shepard 19??.
- MDS finds the best configuration of points for stimuli and the values of parameters *a, b, c* that provide the best fit to the similarity data (S_{ij}).
- Solutions are for a space with a specified number of dimensions.
  - Usually select dimensions based on how goodness of fit increases as number of dimensions is increased.

MDS analysis of vowel confusions

- Shepard (1972) presents a 3-dimensional MDS analysis of Peterson & Barney's vowel confusion data.

- MDS is based on confusions alone - can be difficult to relate derived space to physical stimulus dimensions.
- With vowel space, there are two nearly orthogonal dimensions that correlate well with F1, F2.
  - dimension that best correlates with F3 is not orthogonal - close to F2.
  - relation between dimensions of perceptual space and Hz formant frequencies are non-linear.

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