Favored syllabic patterns in languages and sensori-motor constraints

Nathalie Vallée

Institut de la Communication Parlée - Grenoble

vallee@icp.inpg.fr

Typological studies

- Possible syllabic patterns in the world's languages
- Great tendencies in
  - the nature of syllable-internal structures
  - the syllabic organization of lexical units
- More precisely,
  - Relationship between feature and segment position in syllables/words
  - Co-occurrence restrictions between two or more segment positions

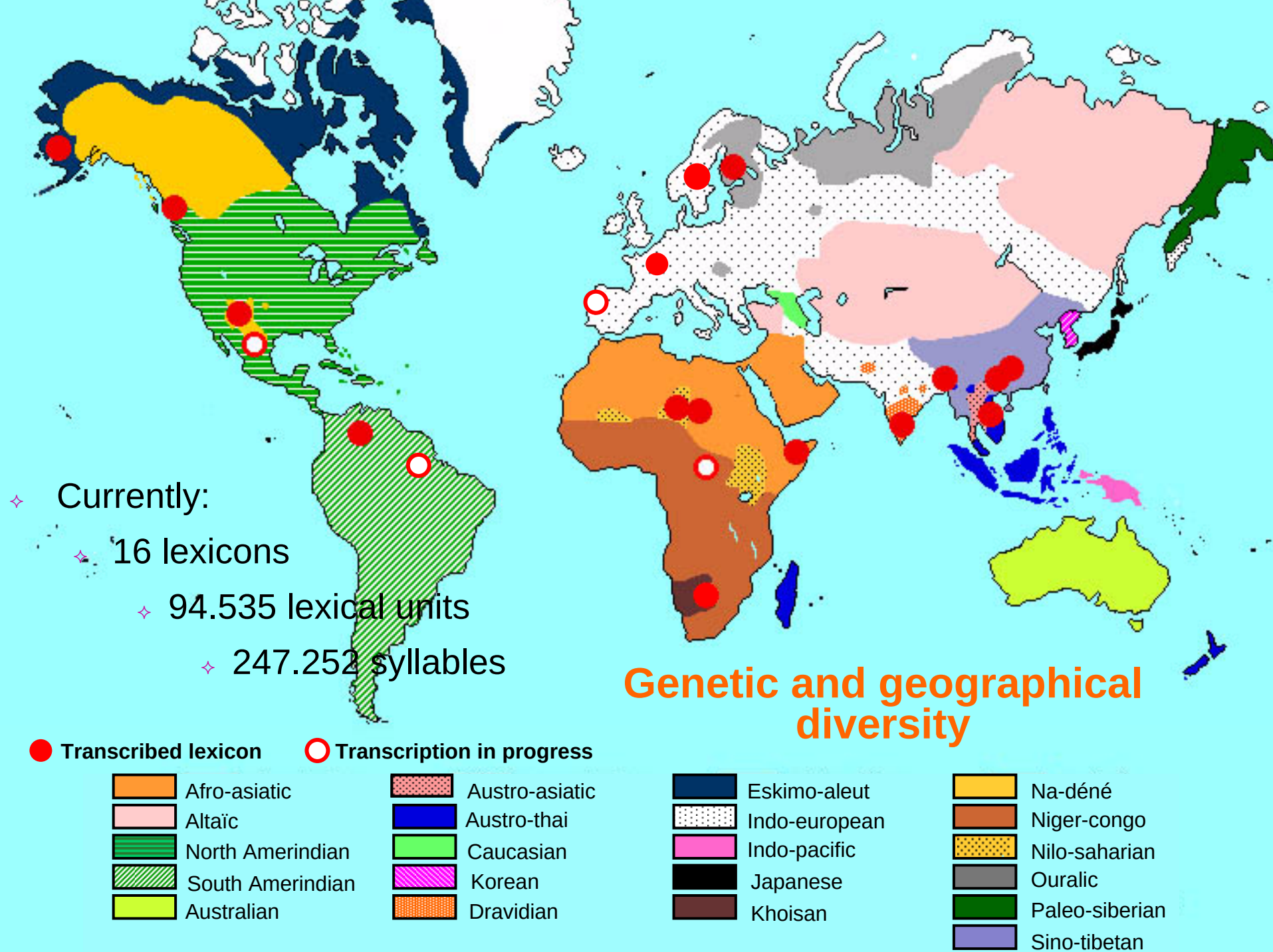
ULSID

UCLA Lexical and Syllabic Inventory Database

- Lexicon of 14 languages (in bold) (from Maddieson & Precoda's data, 1992), divided into syllables
  - *Asia*: Standard Chinese, Tibetan, Korean, **Thai**, Jeh, **Wa**, **Nyahkur**, **Sora**, **Kannada**, darai
  - *Americas*: Comanche, Totonac, **Quechua**, **Navaho**, **Kwakw'ala**, **Yup'ik**, Shipibo, Pirahã
  - *Africa*: !**Xóõ**, **Ngizim**, Maninka, Gbaya, **Kanuri**, Igbo, **Afar**
  - *Europe*: Turkish, Polish, **Finnish**
  - *Pacific*: Fasu, Hawaiien, Kadazan, Rotokas
- Swedish (Berlitz, 1981) and French BDLex-Syll (Pérennou & Calmès, 2002) added to ULSID in 2004

➢ Genetic and geographical diversity

➢ Sound system size and content diversity


Currently:
16 lexicons
94.535 lexical units
247.252 syllables
Genetic and geographical diversity
Transcribed lexicon
Transcription in progress
Afro-asiatic
Altaïc
North Amerindian
South Amerindian
Australian
Austro-asiatic
Austro-thai
Caucasian
Korean
Dravidian
Eskimo-aleut
Indo-european
Indo-pacific
Japanese
Khoisan
Na-déné
Niger-congo
Nilo-saharian
Ouralic
Paleo-siberian
Sino-tibetan

ULSID

Divisions into and within syllables

Divisions are marked in these manners:

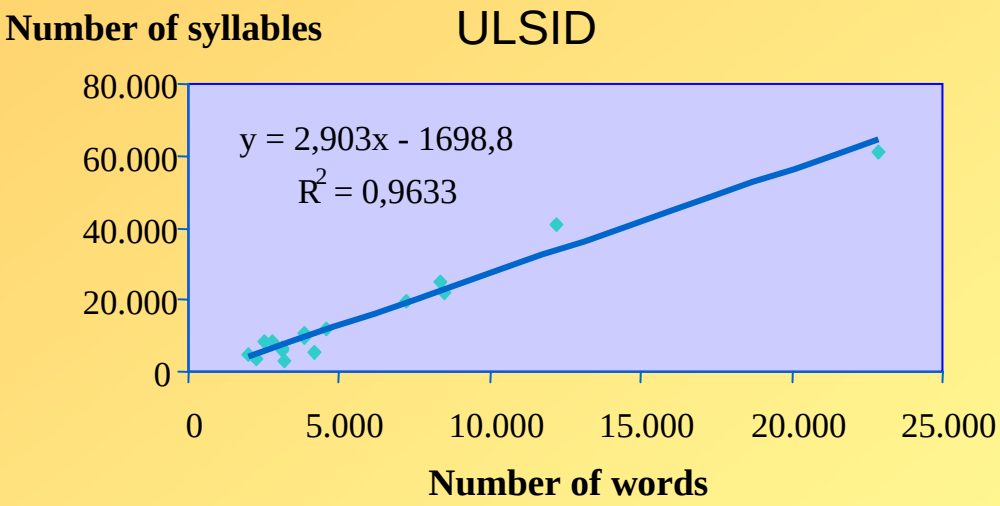
- the point separates syllables
- the space divides
  - syllable constituents (onset, nucleus, coda)
  - segments (in the case of complex onset and coda)

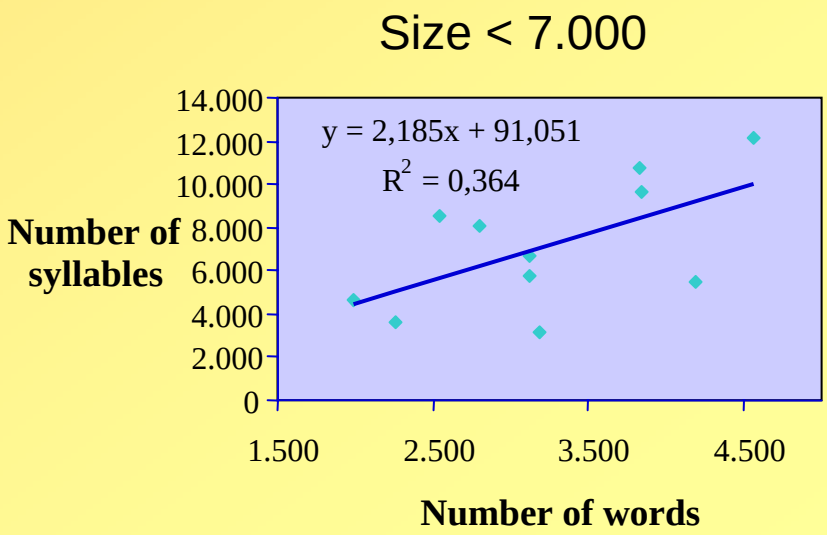
➔ We have observed specifically syllable types and co-occurrences at word-level syllabification

Not at later (re)syllabification *i.e.* at the level of the phonological phrase

Size of the lexicon

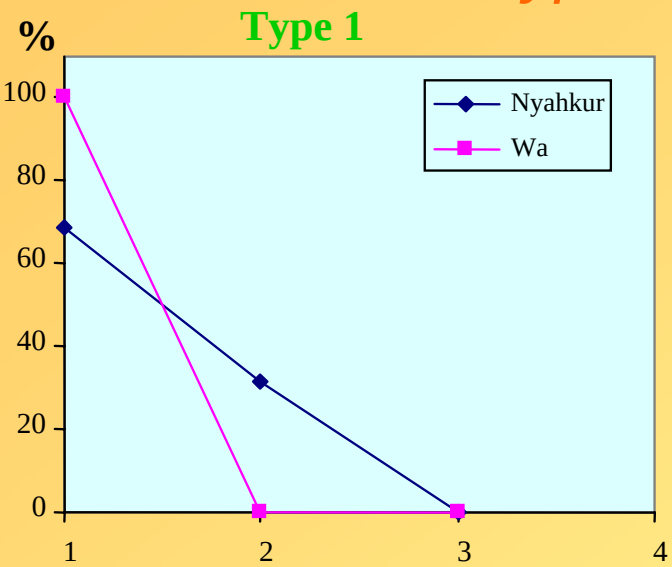
- 1.989 words for Ngizim to 12.181 for French
- Mean 5.908 lexical items
- 5 languages have more than 7.000 items
- Size of lexicon *vs.* number of syllables

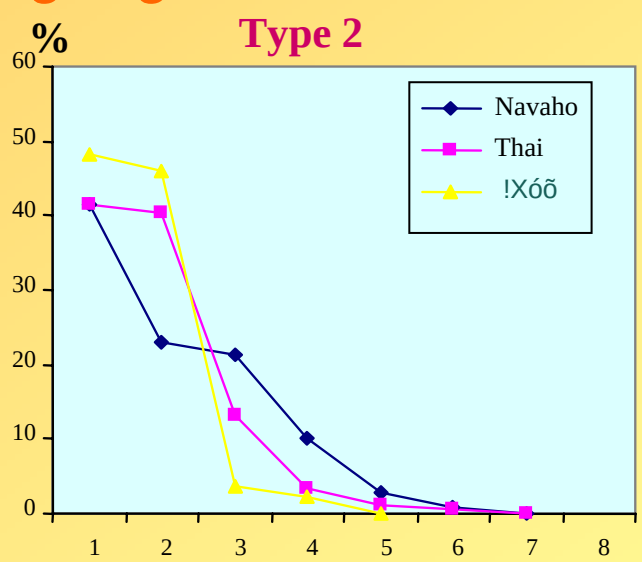


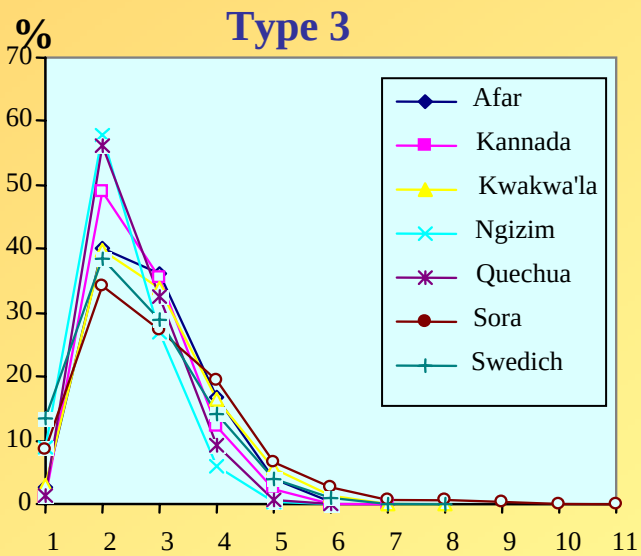


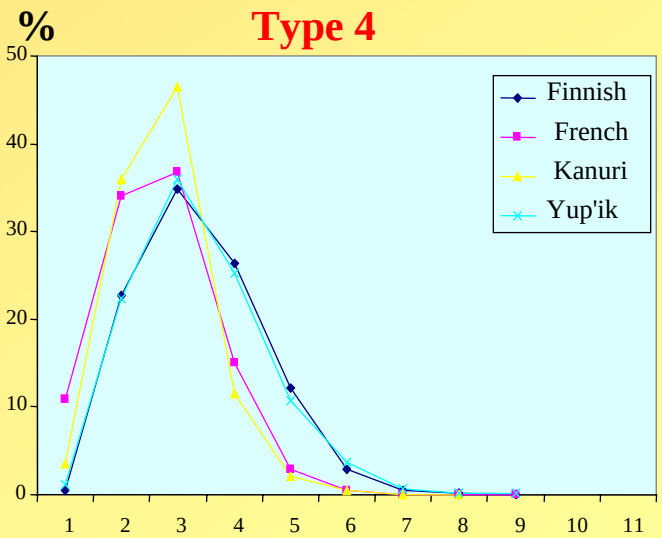
Typology and lexical structures

4 types of languages







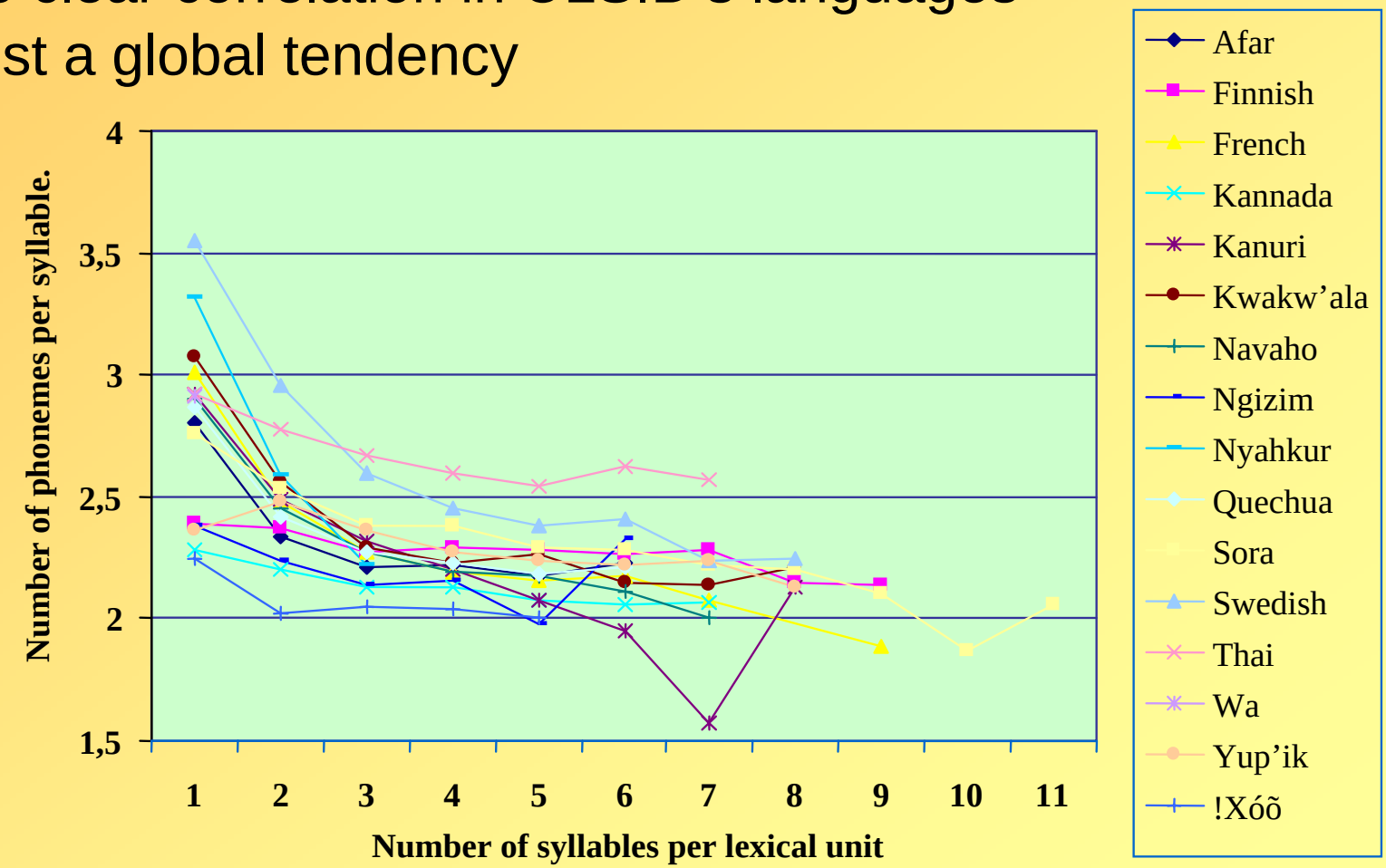


Number of syllables per lexical unit

Menzerath's principle (1954)

"When number of phonemes per syllables decreases, number of syllables per word increases"

- No clear correlation in ULSID's languages
- Just a global tendency



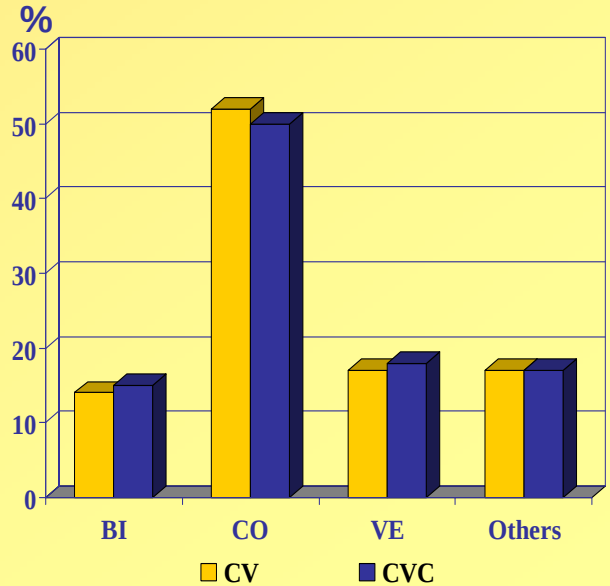
The most-favored phonetic features in syllable onsets

- In all the ULSID languages the most frequent places and manners of articulation in onsets are:
  coronal (up to 60%), velar (up to 25%), labial (up to 20%), plosive, fricative, nasal

⇨ They are also the most frequent consonantal features in phonological systems of the world's languages

- The most frequent places of onset are similar in both CV-type and CVC-type

➔ No influence of syllable structures (open or close) on onset places



Phonetic features of onset with consonant clusters

- Syllables with consonant cluster(s): 7.9%
- 72% of them present a cluster in the onset position
- For structures with consonant clusters C_1C_2 in onset, we observed principally:
  - A stop in C_1
  - A trill or a lateral approximant (coronal) in C_2 :
    - /r/ predominantly
    - then, /l/
- Onsets with consonant clusters are disfavored if the consonants have an identical place of articulation (homorganic consonants); Idem for coda.

The most-favored phonetic features in codas

- Also:

  coronal, velar, labial

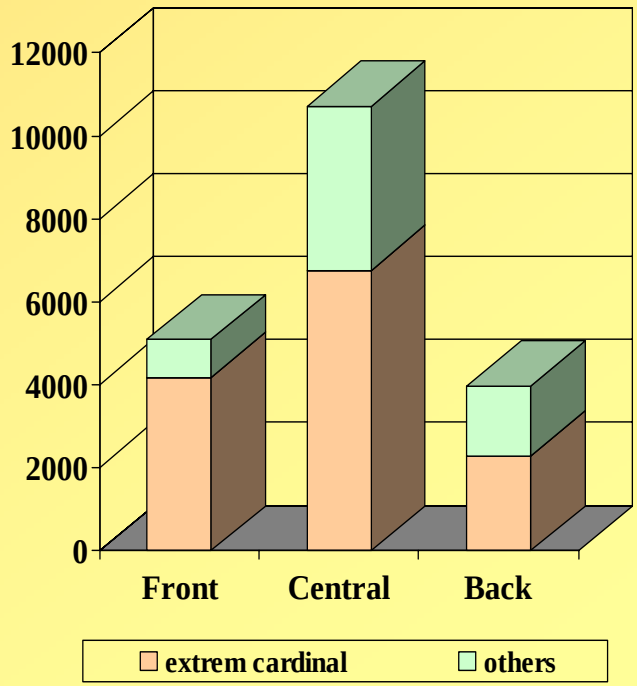
  voiceless plosive & fricative, nasal

- Coronals are the most favored
  - They represent always more than 30% of codas
  - Even in languages with poor restriction in coda positions (*e.g.* Afar, French)

- Segments with a second articulatory gesture (like aspiration, glottalization, labialization…) are clearly disfavored

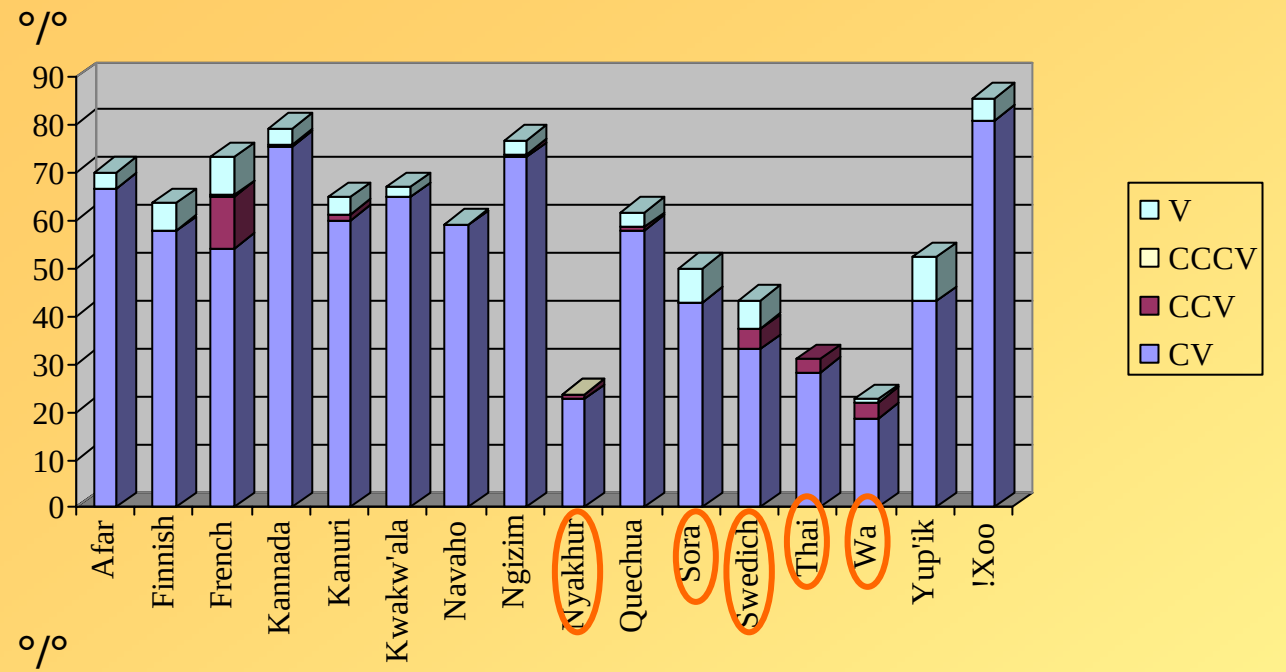
The most-favored phonetic features in syllable nuclei

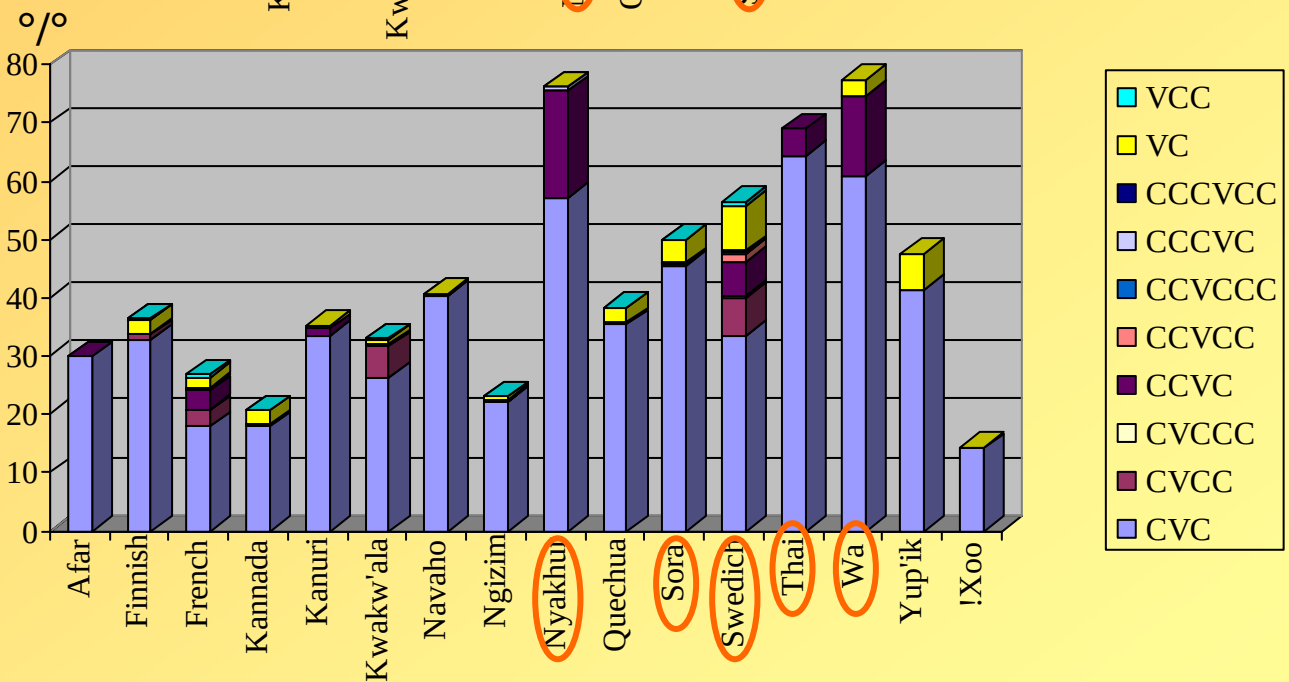
- Extreme cardinal vowels are the most frequent vowels in ULSID
- Central vowels /a ə/ are more important whatever the consonants, syllables and languages
- They represent 12,5 % (Wa) to 49,65 % (Thai) of all the nuclei
- For 12 languages they represent more than 1 nucleus out of 5



e.g. For Kanuri

CV or CVC: 2 types of language





CV and **CVC** represent more than 80% of ULSID syllables

5 languages predominantly CVC

CV predominance ⇒ Open syllables favored

CVC predominance ⇒ Closed syllables favored

Implicational laws and syllabic structures

- If clusters of n consonants are possible in a syllable in initial position, then clusters of (n-i) consonants appear in the onsets of the syllable system (with i = 1 to n-1)

  CCCCV => CCCV => CCV => CV

  CCCVC => CCVC => CVC

- Idem if clusters are in a syllable in final position

  CVCCCC => CVCCC => CVCC => CVC

- If syllable structures with initial vowel followed by a cluster are possible (no onset), then V structure appears in the syllabic system

  VCCC => VCC => VC => V

- Relationship between the frequency and the complexity of a syllabic structure: if n increases, the syllable structure frequency decreases

- We have the same implicational laws if we focus on the features of segments *e.g.* in kwakw'ala (structures with complexe coda)

  /lxs/ => /lx/ and /ʔxst/ => /ʔxs/ => /xs/

Favored C and V co-occurrences within syllables

Rousset (2004) PhD

Onsets and nuclei: (CCC)CV(CCCC)

	Coronal	Labial	Velar
Front	**1.09**	0.94	1.05
Central	0.87	**1.10**	0.70
Back	1.01	0.93	**1.32**

For each columns significant χ^2, $p<0.001$

Ratio : OBS/EXP

$$\frac{Nb\ (CV)}{Nb(C_{onset})Nb(V)}$$

Nuclei and codas: (CCC)VC(CCC)

	Front	Central	Back
Coronal	**1.11**	1.00	0.89
Labial	0.53	**1.32**	1.18
Velar	0.92	0.86	**1.22**

More favored co-occurrences between nuclei and codas than between onsets and nuclei

Favored onsets and codas co-occurrences in ULSID

- CVC syllable structures are disfavored if they have the same place of articulation in onset and coda (< 5 %), even for coronal *e.g.* /pap/ or /tat/ *vs.* /pat/ or /tap/
- CVC syllable structures with the same manner of articulation in onset and coda are possible, except if it is a trill (< 1 %) or an affricate (0 %) (they are not frequent in coda position)
- A relationship between coronal and velar seems to exist because coronal_velar and velar_coronal structures are clearly favored (11 languages), in the others only one pattern is predominant (3 Co_Ve, 1 Ve_Co), except in !Xóõ
- Only labial_coronal structures are favored, not coronal_labial (significant in 11 languages)

“The LC effect”
MacNeilage & Davis (2000)

- The LC effect: For dissyllabic CV.CV structures, languages prefer the Labial–V–Coronal–V pattern than the inverse Coronal–V–Labial–V pattern
- From lexicon of ten languages (MacNeilage, Davis, Matyear and Kinney, 2000) – only Finnish is common with ULSID– and the 27 universal roots found by Ruhlen (1997)
- Absent in babbling, it appears at the stage of first words
- It could be a consequence of articulatory properties and selection of simplest gestures
  - Labials ⇔ basic movement of jaw
  - Coronals ⇔ jaw + tongue movement (raising of the apex)

MacNeilage & Davis (2000):

(Labial_Coronal) / (Coronal_Labial) = 2,45 for CV.CV

“The LC effect” in ULSID

Rousset (2004) Vallee & Maupeu (2005)

Labial_coronal structures are favored in CV.CV and in CVC:

LC/CL in CVC syllables

LC/CL > 1 : 9 languages

LC/CL < 1 : 5 languages (Kanuri =0,48, Ngizim =0,85, Thai =0,66, Wa =0,47, !Xóõ =0.03) except Navaho (no labials in codas)

LC/CL in C V .C V sequences

LC/CL > 1 (13 languages)

LC/CL > 1 (2 languages: !Xóõ =0.33 and Wa (monosyllabic)

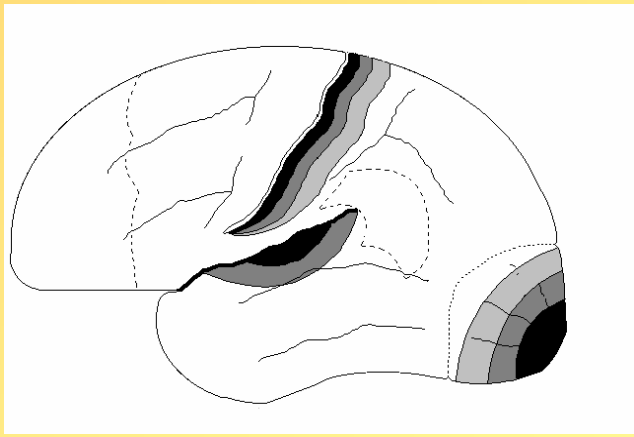
(Labial_Coronal) / (Coronal_Labial) = 1,80 for CVC

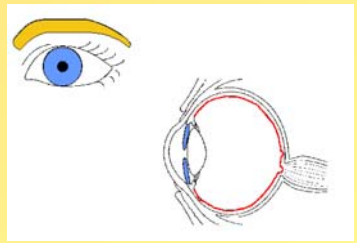
(Labial_Coronal) / (Coronal_Labial) = 2,39 for CV.CV

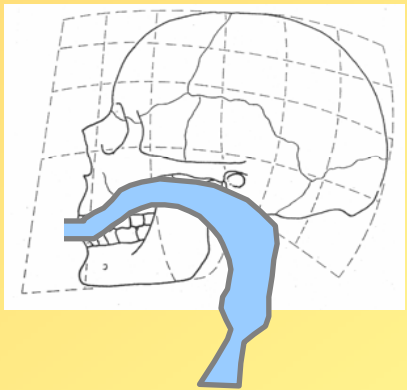
Main tendencies for syllables and lexical units

- Lexicon are predominantly di-, then tri- and monosyllabic
  - CVC is the predominant syllabic structure
- Favored syllables contains C and V of the most frequent phonological systems in the world's languages
- CV is more frequent than CVC and VC is never favored
- Simplest syllables are more frequent and syllables with clusters are disfavored
- More clusters and complex segments in onsets than in codas
- Favored C and V co-occurrences within syllables:
  - Place assimilation between C and V
  - No place parsimony between onset and coda in CVC
- More favored co-occurrences between onsets in CV.CV words and consonants in CVC syllables:
  - Labial_Coronal
  - Coronal_Velar and Velar_Coronal

How explain these tendencies in the frame of a substance-based approach?







"Lexicon are predominantly di-, then tri- and monosyllabic"
CVC is the predominant syllabic structure

Word length

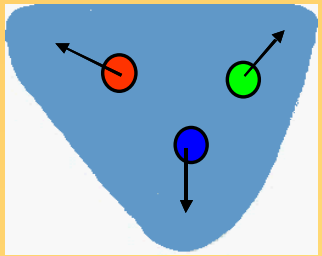
- Ducey & Abry (2004): "A developmental rendez-vous"
  - Babies produce monosyllabic or dissyllabic first-words in the order of a foot (600-700 msec ≅ 1.5 Hz)
  - First-words emerge with pointing gesture (forefinger and arm tended) specifying the referent (deixis)
- Recently, Ducey & Abry studied audiovisual data of 6 French infants from 7 to 18 month-old and observed their abilities to put "a foot in a arm"
- They (in progress) suggest a stroke duration of 600 msec for the pointing gesture constraining the word length to 2 syllables = 2 jaw cycles (2*[300-350 msec] ≅ 3 Hz)= 1 foot.

"Favored syllables contains C and V of the most frequent phonological systems in the world's languages"

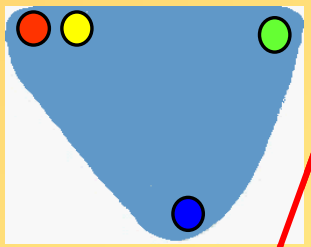
Favored C and V

Speech = Perception*action controls

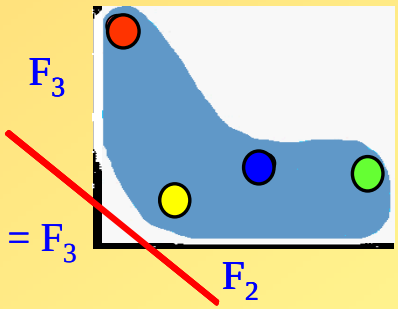
Dispersion



Focalization



$F_1 = F_2$



Vowels

Dispersion

Lindblom, 1986

and Focalization principles

Schwartz *et al.*, 1997

Consonants

Degrees of freedom of articulators

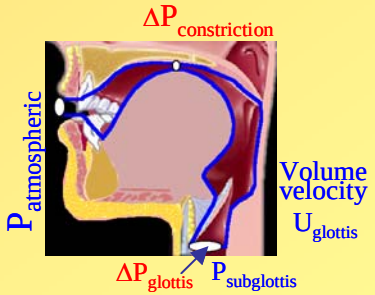
+

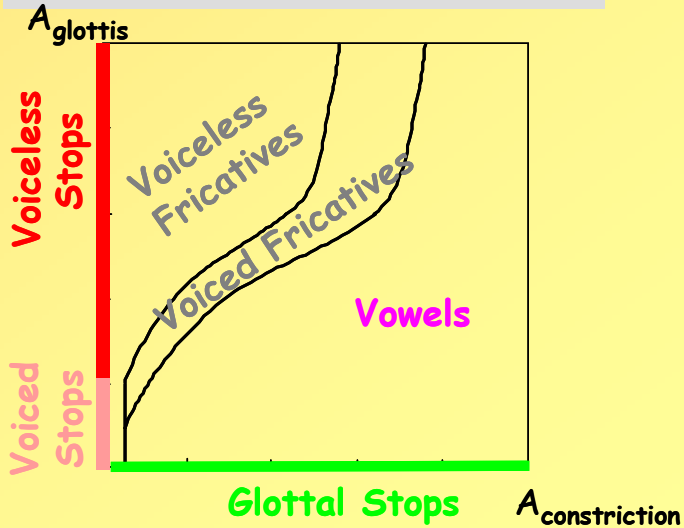
glottal and supra-glottal aerodynamic principles

Abry *et al.*, 1998; Jaeger, 1978

Mawass, 1997; Ohala, 1983; 1997

Vallée *et al.*, 2002



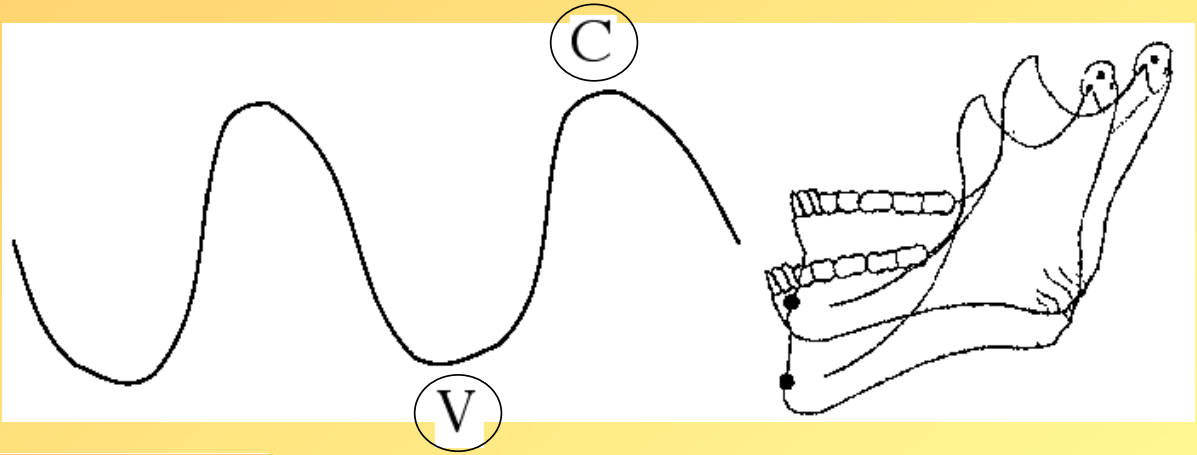


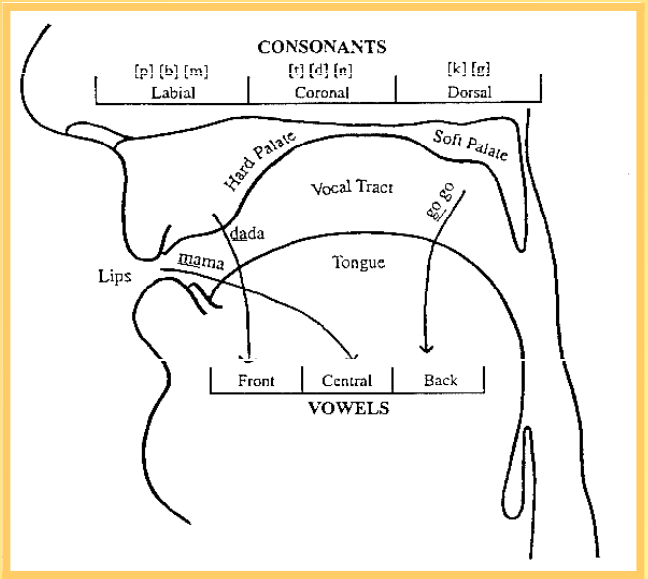
Favored syllabic organization of languages

The Frame, then Content Theory

MacNeilage & Davis (1990), MacNeilage (1998)

Oscillations of the mandible => CV alternation





The most frequent CV-like of babbling

The most frequent syllables in first words, languages, and proto-languages

MacNeilage & Davis (2000)

Pure-frame syllables

Syllabic organization of ULSID languages

- Pure-frame syllables represent over 30% of ULSID syllables (Swedish is not integrated into this result).
  - Favored onsets and nuclei co-occurrences:
    - Labial-Central in 9 languages
    - Coronal-Front and Velar-Back in 11 languages
  - Favored nuclei and codas co-occurrences:
    - Central-Labial and Front-Coronal in 9 languages
    - Back-Velar in 8 languages
- Pure-frame syllables are favored because they are economical sequences (as simplest syllables): articulators do not make extensive movements from the consonant gesture to the vowel gesture
- But they are other favored C and V co-occurrences:

	Other favored CV co-occurrences			
Languages	Labial-Front	Labial-Back	Coronal-Back	Velar-Central
Kwakw'ala			✓	✓
Navaho	✓			
Ngizim				
Nyakhur		✓		✓
Thai		✓		
Yup'ik			✓	✓
!Xóõ		✓	✓	✓

	Other favored VC co-occurrences					
Languages	Front-Labial	Back-Labial	Central-Coronal	Back-Coronal	Front-Velar	Central-Velar
Finnish		✓				
French		✓			✓	
Kannada		✓			✓	
Ngizim				✓		
Nyakhur			✓			
Quechua				✓	✓	
Sora		✓	✓		✓	
Thai		✓		✓	✓	
Wa		✓	✓			
Yup'ik	✓				✓	
!Xóõ		✓			✓	✓

Tendencies under discussion

- No-pure-frame sequences are favored:
  - Have they optimal properties for efficient perception?
- Five ULSID languages are predominantly CVC-type:
  - How can the Frame/Content theory take into account the CVC structures (the second frequency rank of syllable types in CV languages)?
- An identical consonant gesture in onset and coda is disfavored (even for coronals), as well as between onset of successive syllables (except for coronals in this case):
  - To compensate within the syllable the perceptual advantage for initial consonants over final consonants (Redford & Dhiel, 1999) *i.e.* to accentuate the distinctiveness of the coda affected by the syllable position
  - To avoid two successive identical production tasks (MacNeilage, Davis, Kinney et Matyear, 2000)

Properties of the jaw cycle

Redford, PHD (1999)

- Inherent asymmetries in the jaw cycle:
  - Closing phase is articulated with greater pick of velocity than opening phase
  - Opening phase have a greater duration than closing phase
  - Closing phase is articulated with greater displacement (distance between min and max opening for a phase) than opening phase in complex syllable
  - The degree of articulatory stiffness (slope of correlation between distance and velocity) is smaller for opening phase than for closing phase
- Are probably means to explain cross-language preferences
  - For syllable-initial consonants over syllable-final consonants
  - For single consonants over consonant clusters or complex consonants
  - For syllable-initial clusters over syllable-final clusters
  - For VC assimilations, more important than CV assimilations

Towards a perceptual Labial-Coronal Effect

Rousset, Sato, Schwartz & Vallée (2004)

- Experiment had consisted in testing perceptual stability of a LC pattern during a verbal transformation task
- Listeners were presented with reverse disyllabic CVCV sequences such as "pata" and “tapa" repeated 300 times with an ISI of 100 msec. They were asked to report what they had heard as soon as the sequence appeared to change into another form, even if it changed into one they had heard previously
- We assumed that whatever the stimuli, Labial-Coronal percepts were more stable (lasted longer before the next transformation) than Coronal-Labial percepts

Labial-Coronal experiment
Method

- Participants:
  - 24 undergraduates, native speakers of French
- Stimuli
  - /pa.ta/-/ta.pa/, /pi.ti/-/ti.pi/, /po.to/-/to.po/
  - selected from VoCoLex (Dufour et al., 2002)
  - had similar low word frequency and isolation point, neighborhood density and lexical frequency
  - created by inserting in a sound file each of the two appropriate CV sequences from six CV speech sequences /pa/, /ta/, /po/, /to/, /pi/, /ti/ individually recorded by a trained phonetician onto a digital audiotape
  - Mean duration of CV.CV sequences: 520 msec
- Transformations were collected via a microphone and directly recorded as individual sound files

Labial-Coronal experiment
Procedure

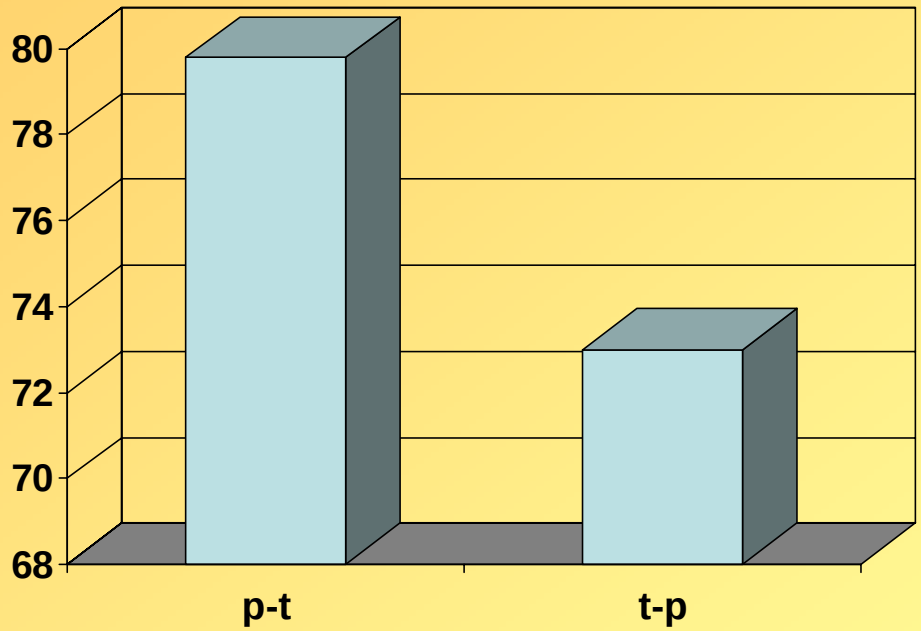
- For each subject and each stimulus unique reported forms were extracted with their respective number of transformations
- The perceptual stability duration of each form was calculated by summing the time spent perceiving the given form before switching to another one
- Two discrepancies were tested
  - between each pair of stimuli: stimulus condition - i.e., depending on the vowel type, /i/, /a/ or /o/
  - between each possible disyllabic form: pair-coupling condition - i.e., depending on the consonant order, /pV.tV/ vs. /tV.pV/

Labial-Coronal experiment

Results

Global analysis

- A significant effect of pair-coupling condition: /pV.tV/ stimuli yielding on average 2.26 more transformations than /tV.pV/ stimuli



Number of transformations as a function of pair-coupling condition (ANOVA [$F(1,23) = 4,61$, $p < 0,05$])

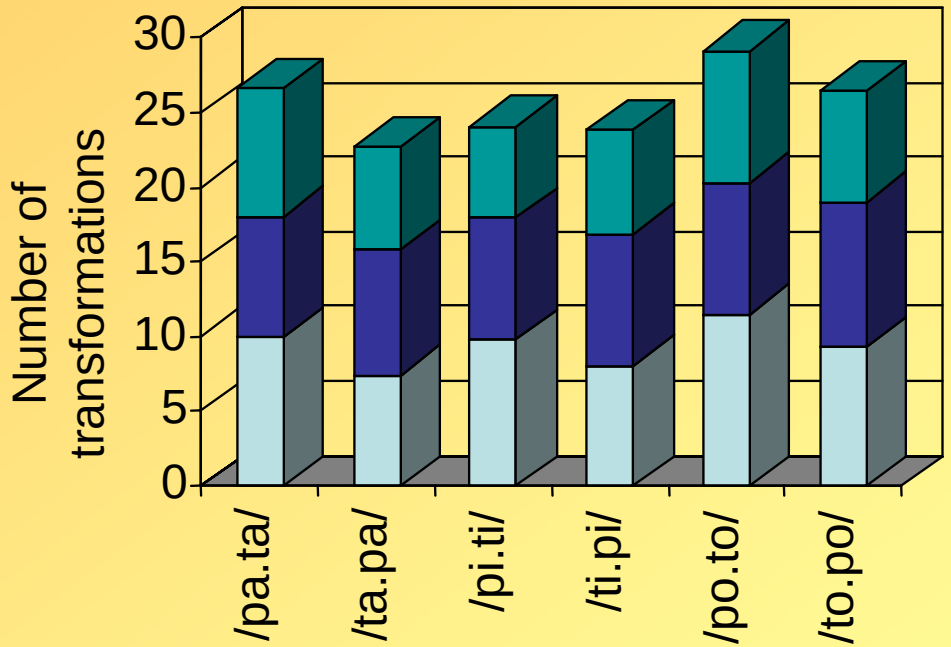
- No significant effect of number of forms

Labial-Coronal experiment

Results

Form subanalysis - Pairwise coupling

The main organization of the perceptual transformations:
A pairwise coupling between the veridical and the couple-based forms of each reversible stimulus, representing on average 71% of the observed transformations



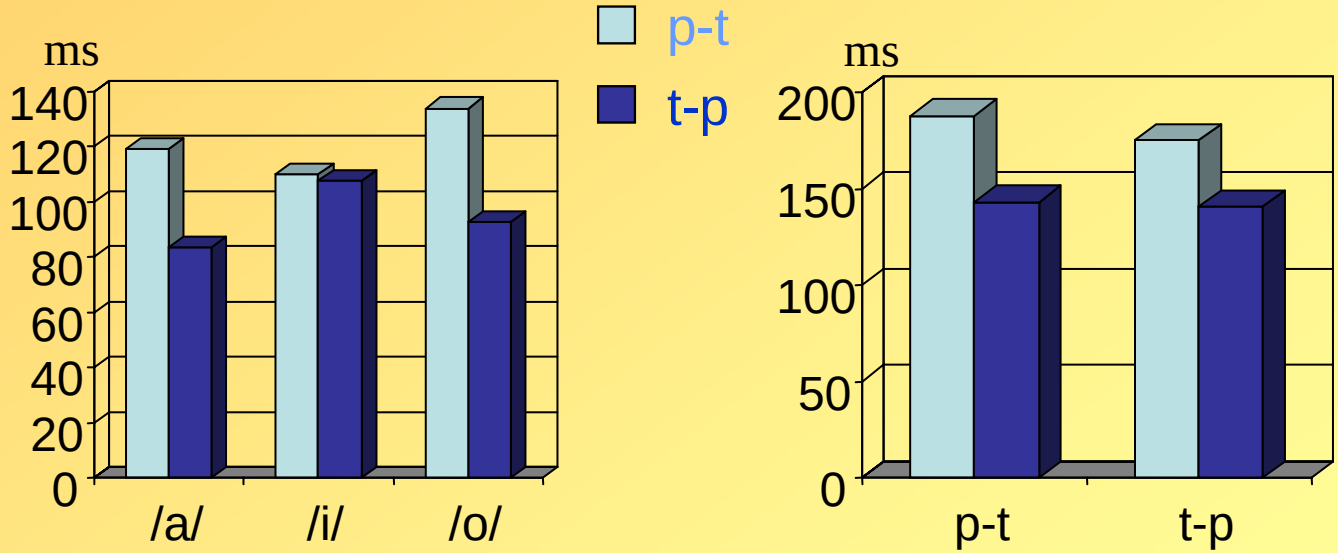
Number of veridical, couple-based and nonveridical transformations reported as a function of the stimulus

Labial-Coronal experiment

Results

Form subanalysis – Preferential syllabic structure

Whichever the stimulus, the stability durations of /pV.tV/ were always greater than that of /tV.pV/ with an average of 1.40 more /pV.tV/ than /tV.pV/



Stability durations of Labial-Coronal transformations and Coronal-Labial transformations as a function of stimuli condition (left) and paircoupling condition (right) (one-sided t-test, [t(1,143) = 3,73, p < 0,005])

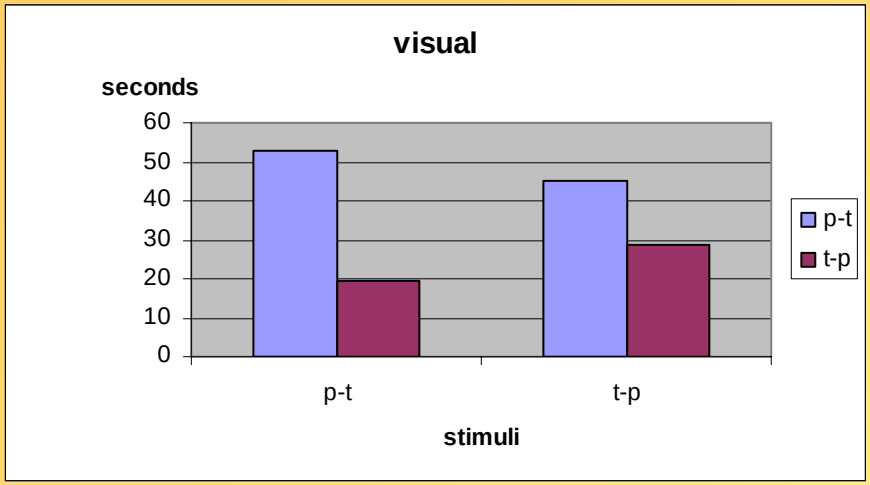
Labial-Coronal: Further experiment

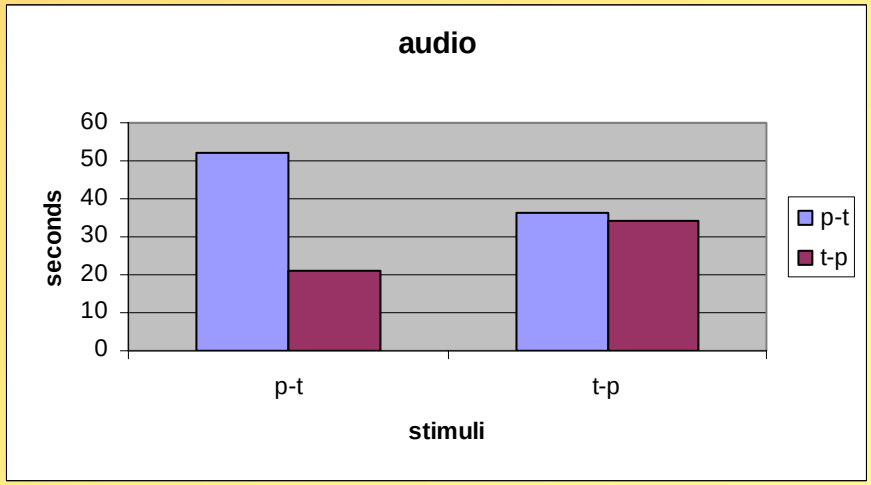
Basirat (2005)

- The perceptual stability of the LC pattern /pata/ was tested in three modalities: audio, visual and audiovisual, during a verbal transformation task
- Using identical method and procedure as Rousset *et al.* (2004)
- Results confirm:
  - More transformations for p-t than for t-p
  - Greater significant stability duration for the LC pattern /pata/ than the reverse /tapa/ in A (+ 8 sec mean), V (+27.7 sec mean) and AV (+16.7 sec mean) modalities, with a stronger “LC effect” in visual modality ([$F(2,26) = 5$, $p < 0{,}05$])

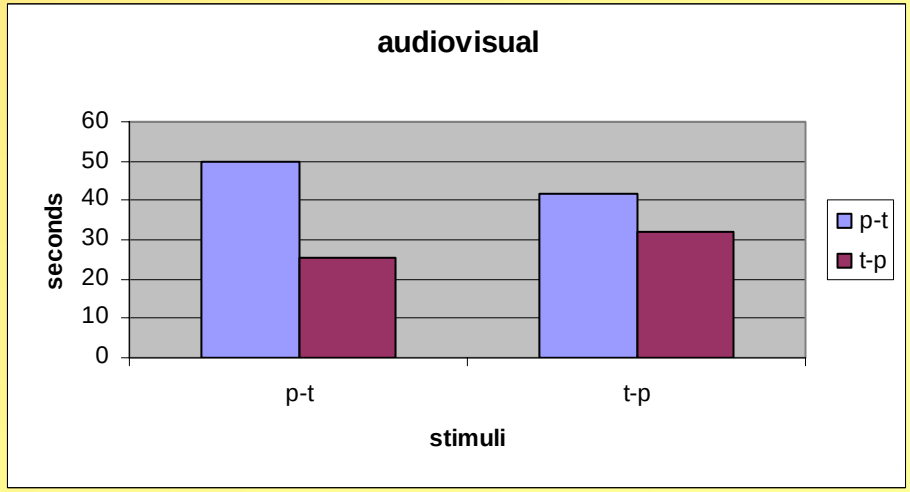
Labial-Coronal: Results in V, A and AV modalities

Basirat (2005)





Stability durations of Labial-Coronal transformations and Coronal-Labial transformations as a function of paircoupling condition

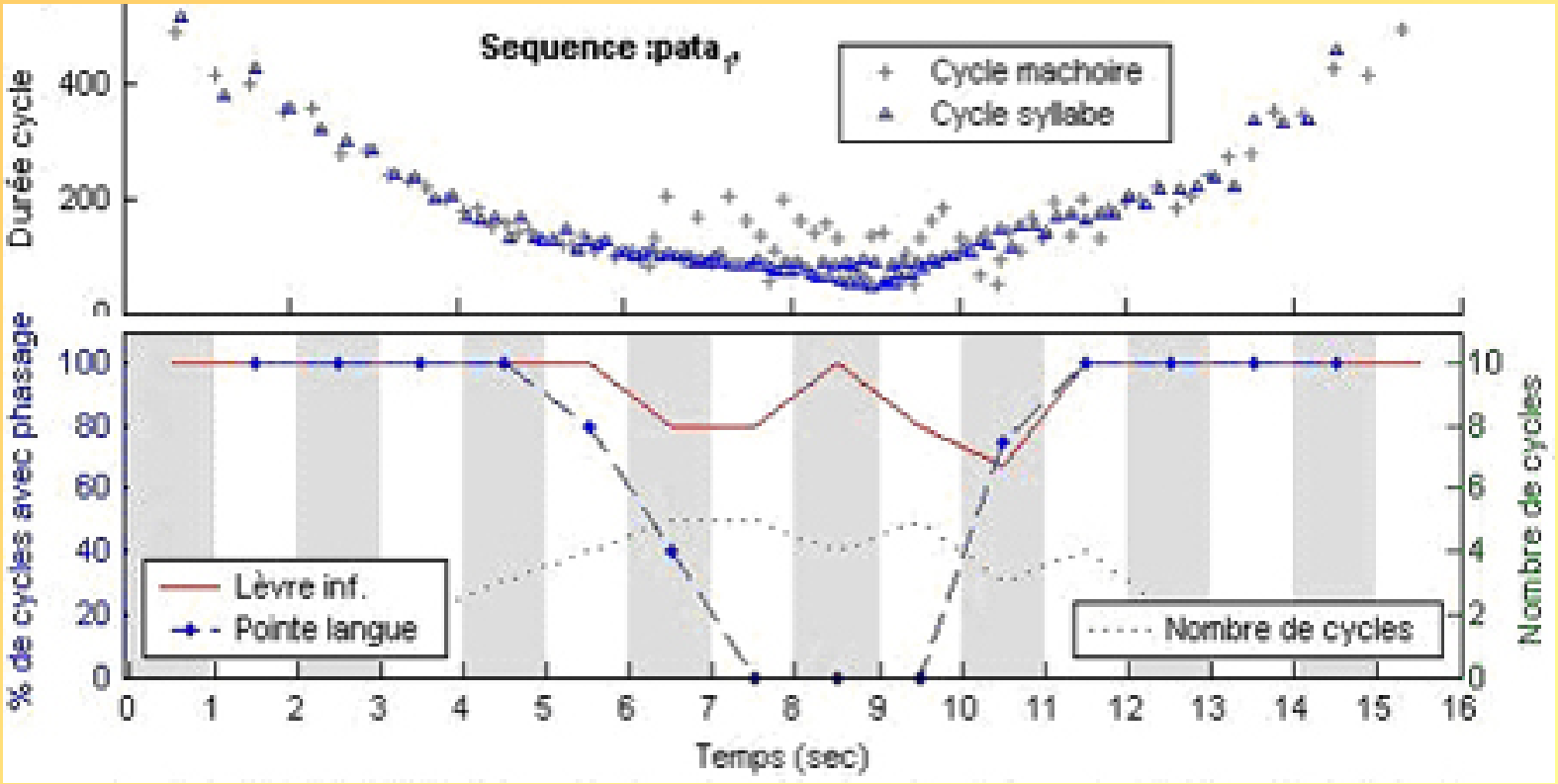


Labial-Coronal experiments
Conclusion

- The transformation analysis and the perceptual stability duration analysis provide a nice perceptual correlate of the LC effect: Whichever the stimulus or the measure used, we always observed a perceptual preference for the /pV.tV/ forms over the /tV.pV/ forms.
- However questions remain:
  - Might the larger proportion of /p/ in word initial positions than the proportion of /t/ in French bias transformations towards the LC pattern? The bada-daba experiment in progress may get round this problem.
  - Might this effect be due to articulatory properties of the speech apparatus? LC pattern seems articulate with a stronger articulatory cohesiveness than the CL pattern (Rochet-Capellan, current PhD). May then explain the higher perceptual stability/attractivity of /pV.tV/ forms?
  - How then can reconcile this hypothetical articulatory explanation of the LC effect and its perceptual validity during the verbal transformation task? Is it a motor-perceptual unit?
  - Why might tendencies in the reported perceptual changes reflect tendencies in the phonologies of the world's languages?

Labial_Coronal sequence: An economical gesture

Rochet-Capellan (2004)



- A preliminary study has shown that Labial_Coronal sequence is in phase with a single jaw-opening gesture: The labial fits in with the phase of preparation or launching and the coronal fits in with the phase of jaw lowering

General conclusion

- This set of results reveals that languages do not construct sound sequences within syllables and within lexical units from random selections among a set of possible speech sounds
- Our main objectives are:

  To keep on with studies relevant to relationship between sensory-motor capacities and phonology

  To understand how syllables emerge as units of sound organization in language

  To identify phonological and phonetic patterns that form the basis of syllable perception

  To integrate these knowledge in the ICP ACI-project Complex Systems in SHS ***“Pati papa?”*** regarding the modeling of emergence of a language in a community of sensori-motor agents in interaction

The end