Variable phonological phenomena in speech perception:

Regressive voicing assimilation and the perception of voicing contrasts in Spanish

Rebeka Campos-Astorkiza (she/her)

campos-astorkiza.1@osu.edu

THE OHIO STATE UNIVERSITY

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Goal of the Study

- Examine the role of assimilation in speech perception in cases where the assimilated feature is not contrastive but allophonic:
  - Focus on regressive voicing assimilation of /s/ in Spanish.

Speech Perception & Phonological knowledge

- Speech perception as integration of acoustic/auditory cues and language-dependent phonological knowledge (Mitterer et. 2013, Durvasula et al. 2018, Cavirani and Hamann 2022):
  - Phonological processes can (i) resolve ambiguities in the acoustic signal and (ii) determine perception, despite conflicting acoustic cues.

Speech Perception & Assimilation

- Role of assimilation in perception:
  - Perceptual compensation for assimilation allows listeners to retrieve underlying form of assimilated target sound.
  - Assimilation can determine perception of a given sound, even if the acoustic signal corresponds to a different one (Meunier 1999, Snoeren et al. 2005, Mitterer et al. 2013, Cavirani and Hamann 2022).

Speech Perception & Assimilation

- Mitterer et al. (2013) examine regressive place assimilation in Korean (labial-to-velar):
  - [ŋ # k] => /m # k/ or /ŋ # k/ BUT [ŋ # s] => /ŋ # s/
  - *RQ*: Is the perception of [**ŋ** # k] & [**ŋ** # s] /m/ or /ŋ/?
  - *Methods*: Spoken word recognition task in eye-tracking paradigm and categorization task
  - *Finding*: Korean listeners are more likely to perceive velar sound as underlying labial in an assimilation-triggering context ([ŋ # k]) than a non-triggering one ([ŋ # s]).
    - Korean listeners apply knowledge of place assimilation in perception.

Speech Perception & Assimilation

- Cavirani & Hamann (2022) assess regressive voicing assimilation (RVA) in Gallo-Italic varieties of N. Italy:
  - Obstruents agree in voicing with following obstruent.
  - *RQ:* Is a non-assimilated obstruent perceived as assimilated?
    - E.g., is bilabial in [a**p**da] perceived as /**p**/ or /**b**/ ?
  - *Methods:* forced-choice segment detection task
  - *Finding*: Listeners perceive the obstruent as voiced more than half of the time.
    - RVA influences perception but acoustic cues also play role => integration of auditory cues and phonological knowledge.

Speech Perception & Assimilation

- Previous studies focus on:
  - Perception of target sound where assimilated feature is contrastive for that sound
- Less is known about:
  - What happens when assimilation results in allophonic alternations?
  - What is the impact of assimilation on perception of trigger sound?

Speech Perception & Assimilation

- Meunier (1997,1999) explores assimilation of non-contrastive feature for target sound in French:
  - Progressive voicing assimilation in obstruent+liquid:
    - [**gl**as] “ice” vs. [**kl̥**as] “class”
  - *RQ*: Does liquid voicing affect obstruent perception?
  - *Methods:* segment retrieval and forced-choice identification tasks
  - *Finding*: perception of obstruent as voiced/voiceless is determined by liquid voicing, plus acoustic cues.
    - Listeners apply progressive assimilation in perception.
    - Allophonic variation includes info on surrounding sounds.

Regressive Voicing Assimilation in Spanish

- RVA of /s/ to following consonant in Spanish:

i[z]la	'island'	de[z]de	'from'
ra[z]go	vs.	ra[s]ko	'feature, I scratch'
la[z] gamas	vs.	la[s] camas	'the ranges, the beds'
mi[z] manos	vs.	mi[s] piernas	'my hands, my legs'

- Fun facts about RVA of /s/ and Spanish:
  - /s/ is not contrastive for voicing but stops are.
  - RVA is gradient and variable (Schmidt & Willis 2010)
  - Dialectal differences in RVA: less voicing in Basque Country Spanish than other dialects (Campos-Astorkiza 2019, 2017, Sedó et al. 2020).

Research Questions

1. Does allophonic voicing of Spanish /s/ play a role in the perception of the voicing contrast of a following obstruent (/p, t, k/ vs. /b, d, g/)?

2. Are there perceptual differences depending on the place of articulation of the obstruent and on voiced vs. voiceless /s/ allophones?

METHODOLOGY

LISTENING TASK

- Forced-choice Identification Task:
  - Listen to a 2-word sequence with assimilation context, /s/+obstruent, across words:
    - Examples: /la**s** **g**otas/, /mi**s** **p**arkas/

      ‘the drops, my coats’
  - Decide what words they are according to obstruent’s voicing:
    - Example: ¿Mi**s** **p**arcas o mi**s** **b**arcas?

      ‘my coats or my boats?’

STIMULI

- 4 versions of a word sequence constituting a minimal pair for voicing – Examples:
  - /las **b**ekas/ ~ /las **p**ekas/ ‘the scholarhips, the freckles’
  - /las **d**unas/ ~ /las **t**unas/ ‘the dunes, the music groups’
  - /las **k**alas/ ~ /las **g**alas/ ‘the coves, the galas’
- **2 voicing matching versions**:
  - [s] + voiceless obstruent
  - [z] + voiced obstruent
- **2 voicing non-matching versions**:
  - [s] + voiced obstruent
  - [z] + voiceless obstruent

STIMULI

- Creating the stimuli:
  - Recordings of a Castilian Spanish speaker reading the word sequences were manipulated in Praat:
    - Voiced and voiceless productions of /s/ were spliced to create the 4 versions mentioned earlier.
- Stimuli examples:

Matching

la[s] calas

la[z] galas

Non-matching

la[z] calas

la[s] galas

STIMULI

- 40 test items:
  - 10 word sequences x 4 versions
- 40 distractors with other minimal pairs:
  - Example: /mis ka**n**as/ vs. /mis ka**m**as/

‘my white hairs, my beds’

PROCEDURE

- Online survey via Qualtrics:
  - Linguistic background questionnaire
  - Perception task:
    - Randomized stimuli and distractors

Fig.1 Qualtrics survey

PARTICIPANTS

- 120 listeners from Madrid and Basque Country, Spain:
  - Dialectal difference in production of RVA (Campos-Astorkiza 2017)
- Age range: 21-73

DATA ANALYSIS

- 2,400 tokens
- Dependent variable:
  - ***Accuracy rate*** according to voicing of obstruent
- Independent variables:
  - stimuli structure:
    - [s]+voiceless, [s]+voiced, [z]+voiceless & [z]+voiced
  - place of articulation of obstruent (/b, d, g/)
  - participants' origin (M vs. BC)
  - interaction bt. stimuli structure & other factors
- Logistic regression; pairwise comparisons for interactions in R.

RESULTS

Statistical Results

Table 1. Best-fit regression model

	estimate	std. error	z value	p value
(Intercept)	-2.0748	0.2042	-10.162	< 2e-16
Stimuli structure (ref=[s]+voiced)				
[s]+voiceless	-0.2697	0.3064	-0.880	0.37863
[z]+voiced	-3.4058	1.0208	-3.336	<0.001
[z]+voiceless	0.6034	0.2627	2.297	0.02164
Place of articulation (ref=b/p)				
d/t	-0.8784	0.4659	-1.885	0.05938
g/k	-0.0816	0.2938	-0.278	0.78121
Structure*POA (ref=[z]+voiced:b/p)				
[s]+voiceless:d/t	0.9295	0.6077	1.529	0.12615
[z]+voiced:d/t	3.8377	1.1565	3.318	<0.001
[z]+voiceless:d/t	2.1006	0.5272	3.984	<0.001
[s]+voiceless:g/k	-0.6184	0.4835	-1.279	0.20088
[z]+voiced:g/k	1.1928	1.1934	0.999	0.31758
[z]+voiceless:g/k	1.0178	0.3626	2.807	0.0041

Effect of Stimuli Structure

- Lowest accuracy for non-matching stimuli
- Non-matching [z]+vlss => **lowest accuracy** ($p<0.05$)
- Matching [z]+vd => **highest accuracy** ($p<0.05$)
- Compare: Fillers' accuracy rate is 98%

Table 2. Accuracy rate by stimuli structure

	Stimuli structure	% Correct
Matching	[s]+voiceless obst.	92.83%
	[z]+voiced obst.	**97.83%**
Non-matching	[s]+voiced obst.	90.33%
	[z]+voiceless obst.	**69.00%**

Effect of Place of Articulation

- Dental => lowest accuracy rate ($p<0.05$)

Table 3. Accuracy rate by POA

b/p	d/t	g/k
90.21%	83.75%	86.67%

EFFECT OF STRUCTURE*POA

- For b/p and g/k:
  - Non-matching stimuli => lower accuracy than matching ones ($p<0.05$)
- For d/t:
  - Non-matching [s]+voiced => highest accuracy

Table 4. Accuracy rate by stimuli structure and POA

	Stimuli structure	**b/p**	**d/t**	**g/k**
matching	[s]+voiceless obst.	91.25%	90.83%	95.42%
	[z]+voiced obst.	99.58%	92.5%	98.75%
non-matching	[s]+voiced obst.	**88.75%**	**95%**	**89.58%**
	[z]+voiceless obst.	**81.25%**	56.66%	**62.92%**

Discussion

Role of RVA in Perception

- Results show /s/ voicing plays role in the perception of voicing contrast for following obstruent:
  - Higher accuracy for stimuli matching for voicing.
  - For non-matching stimuli, lower accuracy stems from listeners perceiving stop according to /s/ voicing, i.e., use their knowledge of RVA to perceive stop.

Asymmetry According to Allophone

- Asymmetry among non-matching stimuli – accuracy is higher for [s]+voiced than [z]+voiceless.
- Pattern might stem from variable nature of RVA in Spanish (Campos-Astorkiza 2019, Sedó et al. 2020):
  - [s]+voiced may occur in production.
  - [z]+voiceless is very rare.
    - Importance of listeners' experience (cf. Mitterer et al. 2013)

POA Effect

- Dental POA shows highest accuracy for non-matching [s]+voiced:
  - Dental production might be different from bilabial and velar => less constriction:
    - /d/ in Spanish tends to show more weakening (Colantoni & Marinescu 2010)
    - More weakening corresponds with higher intensity (ej. Carrasco et al. 2012) => more cues for voicing.
  - Dentals are more frequent in Spanish.

Conclusions

- New evidence of the role of assimilation on speech perception by focusing on RVA:
  - Variable RVA that results in allophonic alternations can impact perception.
  - RVA can impact the voicing perception of the trigger consonant.
- Findings align with approaches to speech perception as integration of phonological knowledge and acoustic/auditory cues:
  - Emphasizing the relationship between allophonic processes and perception of contrastive features.

Next Steps

- Theoretical formalization of the phenomenon:
  - BiPhon-OT (Boersma 2011, Cavirani and Hamman 2022)
- Broader empirical study with more data:
  - Shadowing task
  - Dialectal variation

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Eskerrik asko!

Thank you!

¡Muchas gracias!

STIMULI

1. /las **b**atas/ ~ /las **p**atas/ ‘the robes, the legs’
2. /las **b**arkas/ ~ /las **p**arkas/ ‘the boats, the parkas’
3. /las **b**ekas/ ~ /las **p**ekas/ ‘the scholarships, the freckles’
4. /los **b**o̰jos/ ~ /los **p**o̰jos/ ‘the pastries, the chickens’
5. /las **d**unas/ ~ /las **t**unas/ ‘the dunes, the music groups’
6. /las **d**omas/ ~ /las **t**omas/ ‘you tame them, you take them’
7. /las **k**omas/ ~ /las **g**omas/ ‘you eat them, the erasers’
8. /las **k**otas/ ~ /las **g**otas/ ‘the levels, the drops’
9. /las **k**alas/ ~ /las **g**alas/ ‘the coves, the galas’
10. /las **k**asas/ ~ /las **g**asas/ ‘the houses, the gauzes’