Neutralization avoidance and naturalness in artificial language learning

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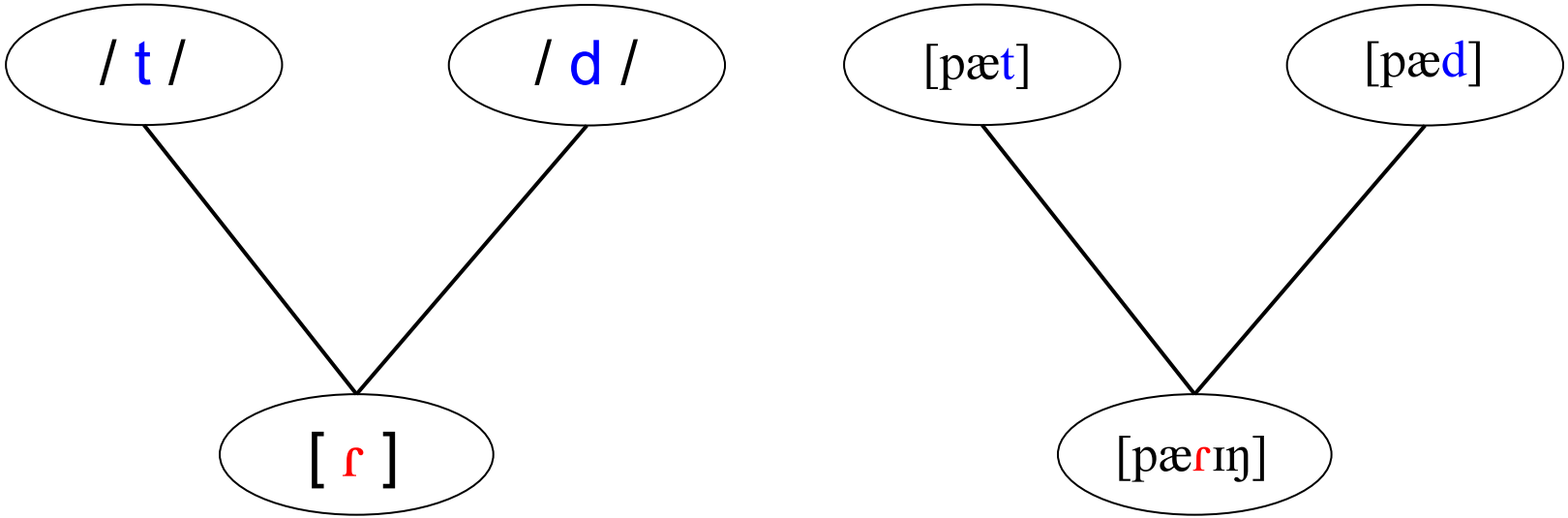
Neutralization



Neutralization avoidance (contrast preservation)

- Previous studies have appealed to neutralization avoidance in analyses of phonological patterns:
  - Diachronic perspective: selection process against neutralizing patterns, especially those resulting in ambiguous speech; functional load hypothesis. (e.g., Wedel, 2006; Silverman, 2010; Wedel et al., 2013)
  - Synchronic perspective:
    - MAXIMIZE CONTRASTS (Flemming, 1996, 2004)
    - *NEUT (Bolognesi, 1998)
    - *MERGE (Padgett, 2003, 2009)
    - PRESERVECONTRAST (Lubowicz 2007)

Research questions

- A lot of work discussing the role of the speaker and listener in neutralization avoidance. (see Silverman 2012 for an overview)
  - But not much work looking at the role of the learner.

- Questions:
  - Are learners biased against neutralizing alternations in comparison with non-neutralizing ones?
  - If so, what is the basis for such a bias?

- Artificial language approach:
  - Present equal input for neutralizing and non-neutralizing alternations.
  - Test how well learners acquire the two types of alternation.

Main points

- Experiment 1: Neutralizing alternations are harder to learn than non-neutralizing alternations.

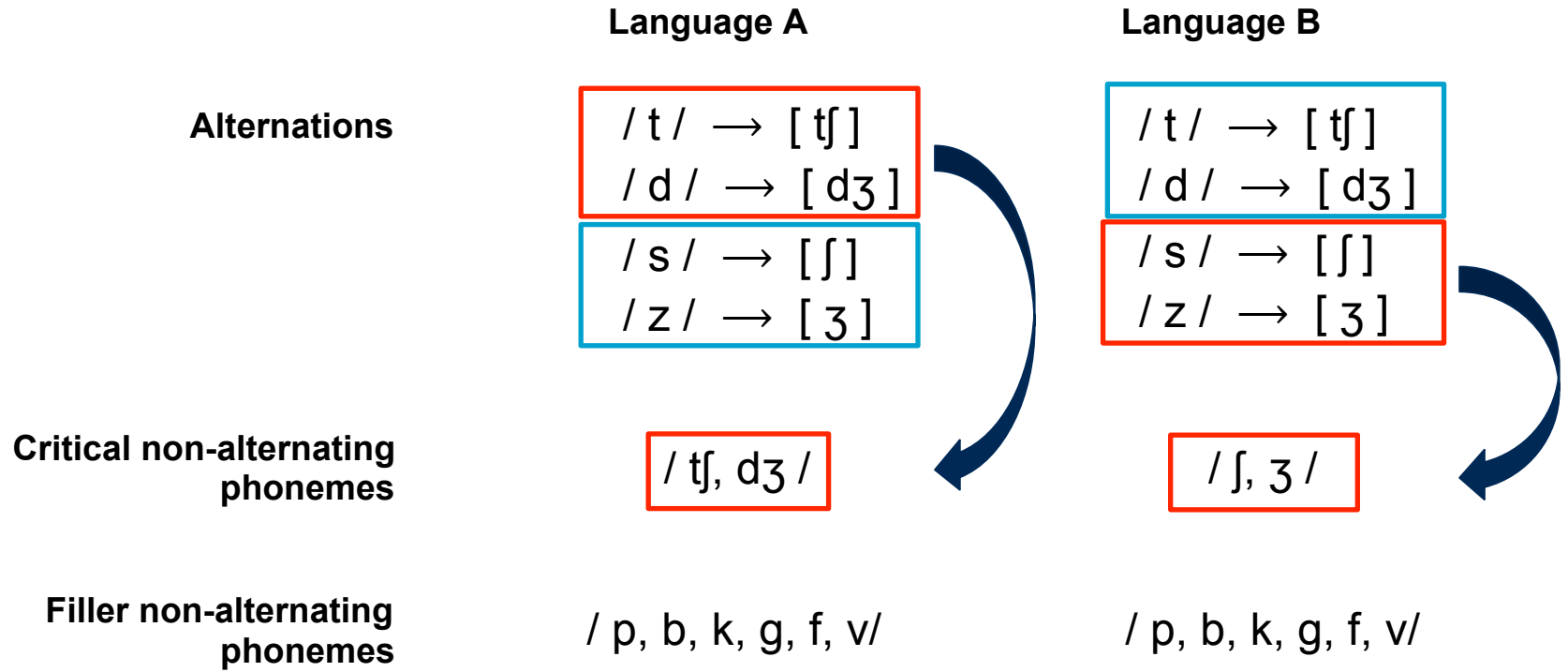
- Experiment 2: Neutralization avoidance effect during learning is driven by homophony avoidance.

Experiment 1

Experiment 1: method

- Participants: native English speakers (n=30)
- 3 phases:
  - Exposure phase
  - Test phase 1: trained items
  - Test phase 2: novel items
- 4 novel alternations involving palatalization /t, d, s, z/ ⟶ [tʃ, dʒ, ʃ, ʒ]
- 2 counterbalancing groups: Language A vs. Language B

Experiment 1: design



Experiment 1: stimuli

- Exposure stimuli: 48 CVCVC singular nonwords with CVCVC-i plural forms:
  - 8 alternating [t ~ tʃ] and [d ~ dʒ] (Neutralizing in Language A)
    [tusut] ⟶ [tusutʃi]
  - 8 alternating [s ~ ʃ] and [z ~ ʒ] (Neutralizing in Language B)
    [duvis] ⟶ [duviʃi]
  - 8 critical non-alternating trials ending in [tʃ, dʒ] (Language A) or [ʃ, ʒ] (Language B)
    [buvatʃ] ⟶ [buvatʃi]
  - 24 non-alternating filler trials ending in [p, b, k, g, f, v].
    [vatuk] ⟶ [vatuki]

Experiment 1: stimuli

- ‘Illegal’ sequences never presented.
  - *[ti, di] in Language A.
  - *[si, zi] in Language B.

- Otherwise, consonant and vowel distribution roughly balanced across positions.

Experiment 1: exposure phase

Experiment 1: test phases

- 2 test phases: 24 trained items, then 48 untrained items.
- Forced-choice task: choose the correct plural form between an alternating option and a non-alternating option.

Experiment 1: test phase options

- Incorrect changing options for non-alternating phonemes:

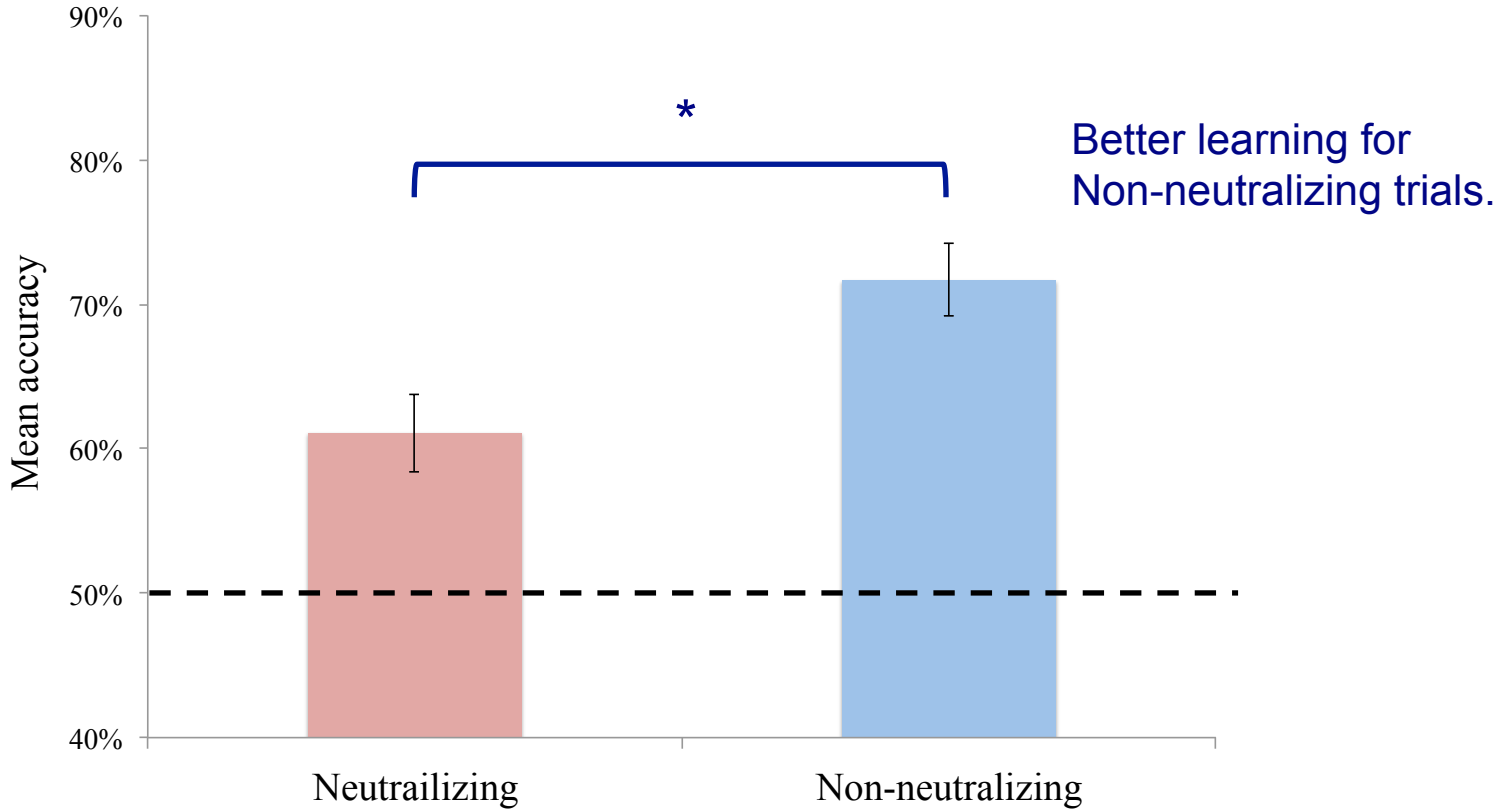
/ tʃ / ⟶ [ʃ]
/ dʒ / ⟶ [ʒ]
/ ʃ / ⟶ [tʃ]
/ ʒ / ⟶ [dʒ]

/ p / ⟶ [tʃ]
/ b / ⟶ [dʒ]

/ k / ⟶ [tʃ]
/ g / ⟶ [dʒ]

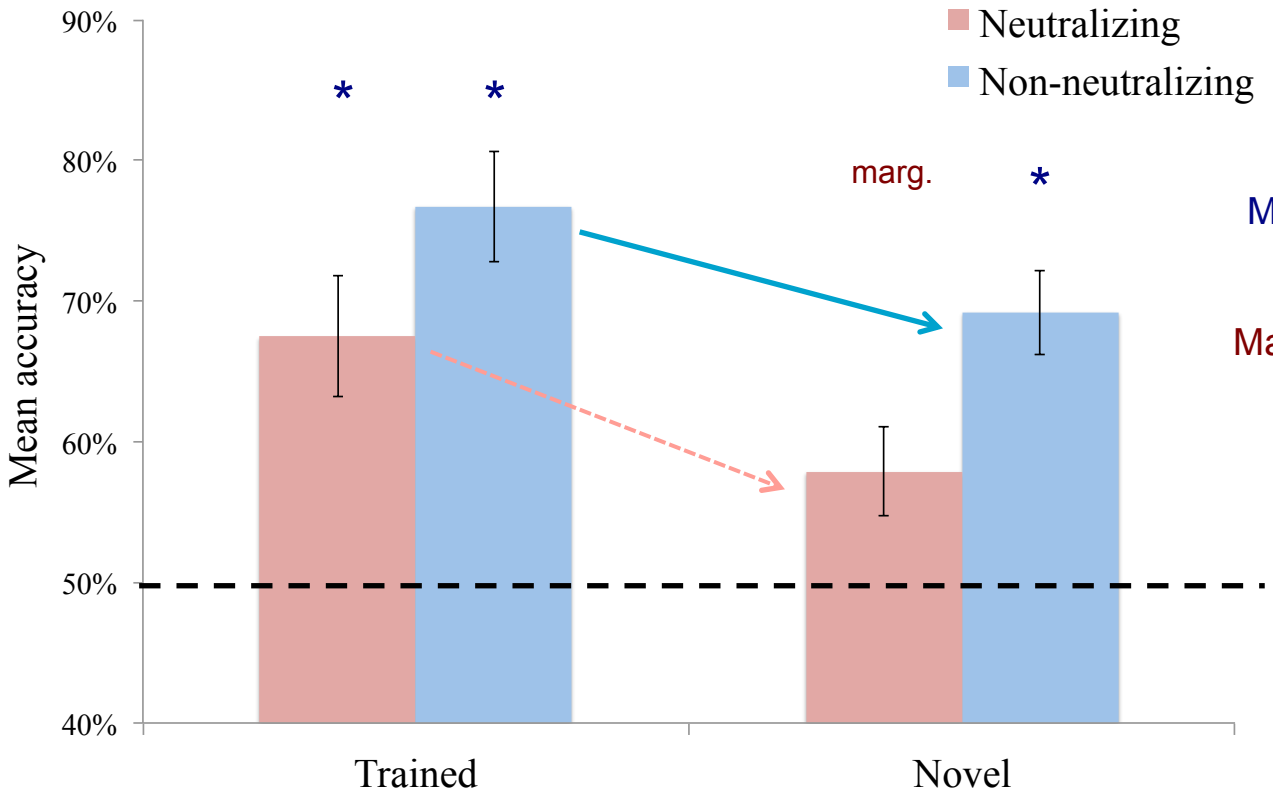
/ f / ⟶ [ʃ]
/ v / ⟶ [ʒ]

Experiment 1: results (Neut. vs. Non-neut. overall)



Better learning for
Non-neutralizing trials.

Experiment 1: results (trained and new items)



Main effect of training.
Trained > New

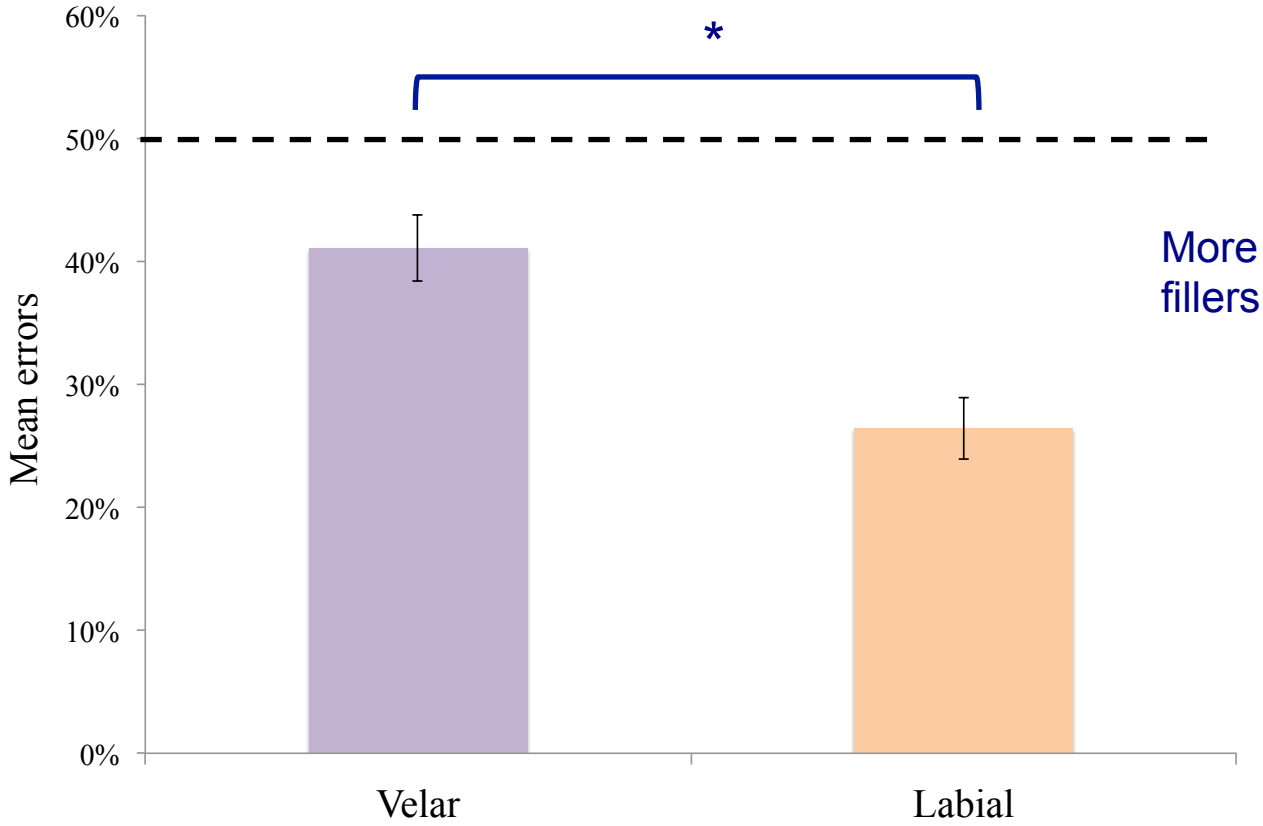
Main effect of Trial Type.
Non-neut. > neut.

No interaction.

Summary

- Neutralizing alternations dispreferred relative to Non-neutralizing alternations, despite equal evidence for both.
  - Independent of which alternations were being learned.

A second interesting result: velar vs. labial fillers



More errors on velar fillers than labial fillers!

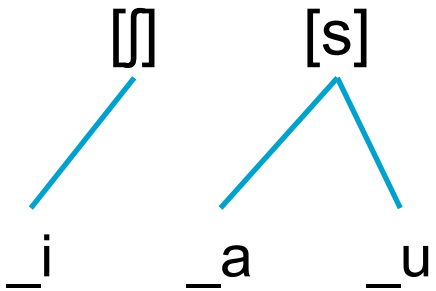
Accounting for the anti-neutralization effect

- Why are neutralizing rules more difficult to learn?

- We consider two possibilities:
  - pure distributional learning
  - learning bias

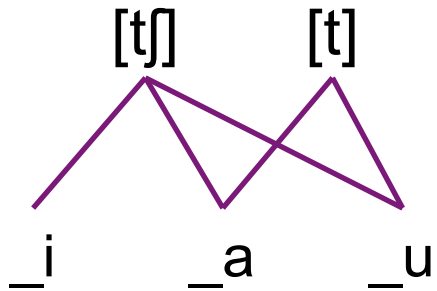
Just distributional learning?

Non-neutralizing alternation



Fully complementary distribution

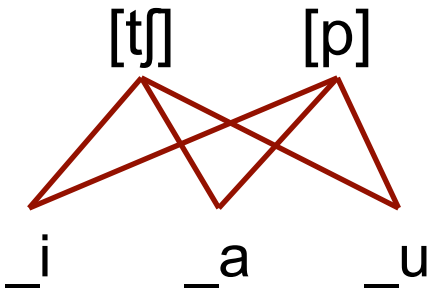
Neutralizing alternation



Partially overlapping distribution

Harder to learn?

Non-alternating fillers

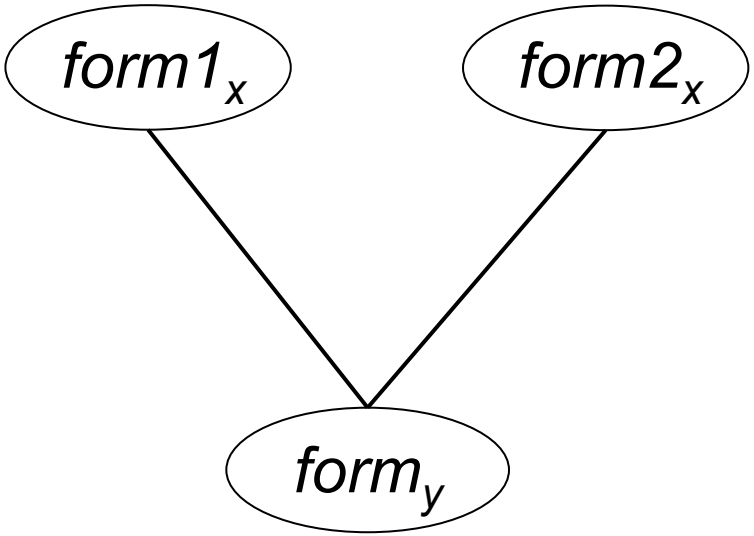


Fully overlapping distribution

Anti-neutralization learning bias?

- Learners have a neutralization avoidance bias when learning alternations.

Dispreferred relationship:



Anti-neutralization learning bias?

- Learners have a neutralization avoidance bias when learning alternations.
- What type of bias?
  - Relevant to contrasts at phonological level or lexical level?

→ Does homophony play a role?

Experiment 2

Experiment 2: Is neutralization avoidance driven by homophony avoidance?

- Phonologically neutralizing alternations tolerated when they result in little lexical neutralization. (e.g. Silverman 2010 on Korean)
- Existing neutralizing rules in a language create far fewer homophones than similar, non-existing neutralizing rules would. (Kaplan, 2011)
- Diachronically, mergers less likely when they would result in high amounts of homophony. (Wedel et al. 2013)
- Synchronically, stochastic processes may occur less frequently when they result in potential homophones. (e.g. Kaplan & Muratani 2015 on Japanese nasal contraction)

Experiment 2: design

Exp. 1: Half lexical neutralization

t-final	tusut	tusutʃi
	buvat	buvatʃi
	tʃuzat	tʃuzatʃi
	faput	faputʃi
tʃ-final	tusutʃ	tusutʃi
	buvatʃ	buvatʃi
	pifitʃ	pifitʃi
	gizutʃ	gizutʃi

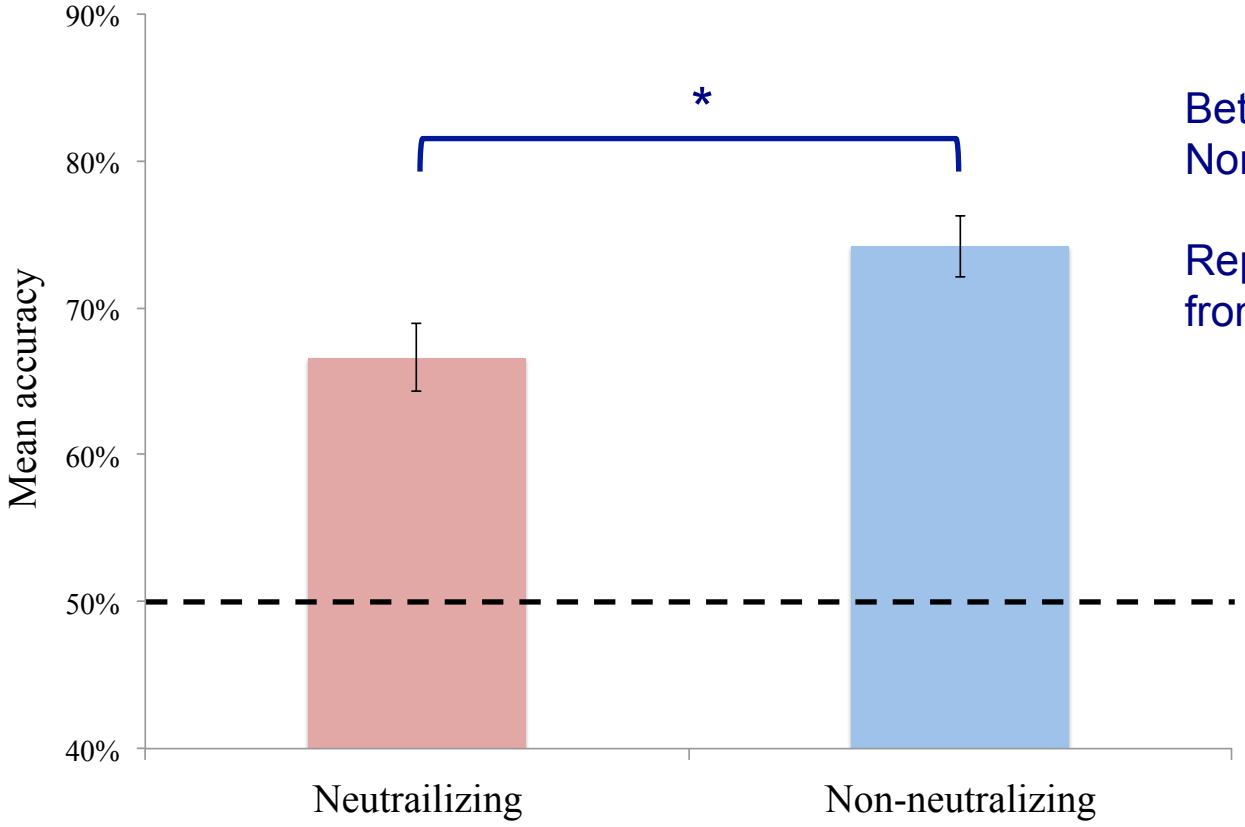
Exp. 2: Homophony Condition

t-final	tusut	tusutʃi
	buvat	buvatʃi
	tʃuzat	tʃuzatʃi
	faput	faputʃi
tʃ-final	tusutʃ	tusutʃi
	buvatʃ	buvatʃi
	tʃuzatʃ	tʃuzatʃi
	faputʃ	faputʃi

Exp. 2: No Homophony Condition

t-final	tusut	tusutʃi
	buvat	buvatʃi
	tʃuzat	tʃuzatʃi
	faput	faputʃi
tʃ-final	busutʃ	busutʃi
	tavutʃ	tavutʃi
	pifitʃ	pifitʃi
	gizutʃ	gizutʃi

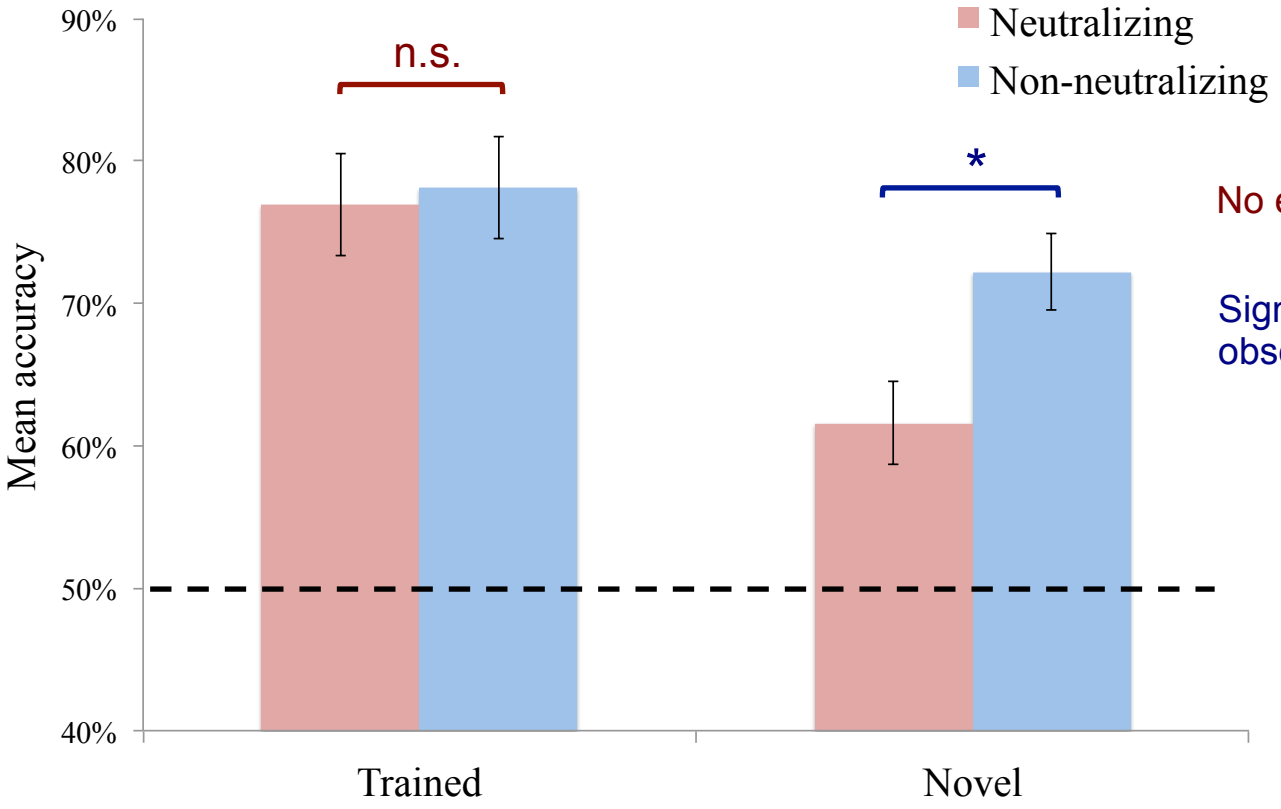
Experiment 2: results (Neut. vs. Non-neut. overall)



Better performance for Non-neutralizing trials.

Replicated main effect from Exp. 1.

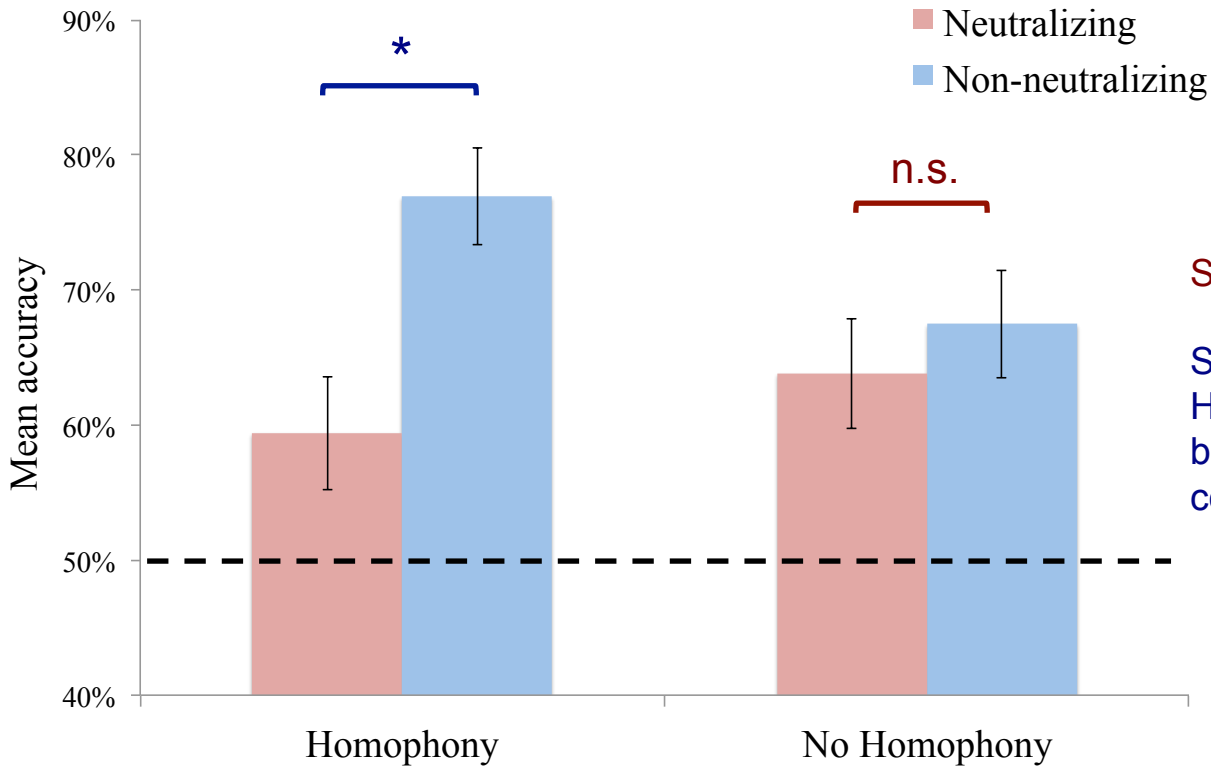
Experiment 2: results (trained vs. novel items)



No effect of Trial Type for trained items.

Significant difference observed for novel items.

Experiment 2: results (novel items by condition)



Significant interaction.

Significant difference in Homophony condition, but not in No Homophony condition.

General discussion

Distributional learning or learning bias?

- Effect not just due to distributional learning at a segmental level.
  - Could explain why neutralizing alternations are harder to learn (Exp. 1).
  - But does not explain why this effect is only seen when it leads to homophony (Exp. 2).

- Learning likely paradigm-based, but more complicated than just learning rules.
  - Rules were completely regular.
  - Should be no problem learning rules like $Xt_{[sing]} \rightarrow Xtʃi_{[plur]}$ from pairs like [tusut]…[tusutʃi]. (e.g. MGL; Albright & Hayes, 2002)
  - Yet learning impaired if the rule leads to neutralization, and especially homophony.

→ Suggests an anti-neutralization learning bias, sensitive to lexical neutralization.

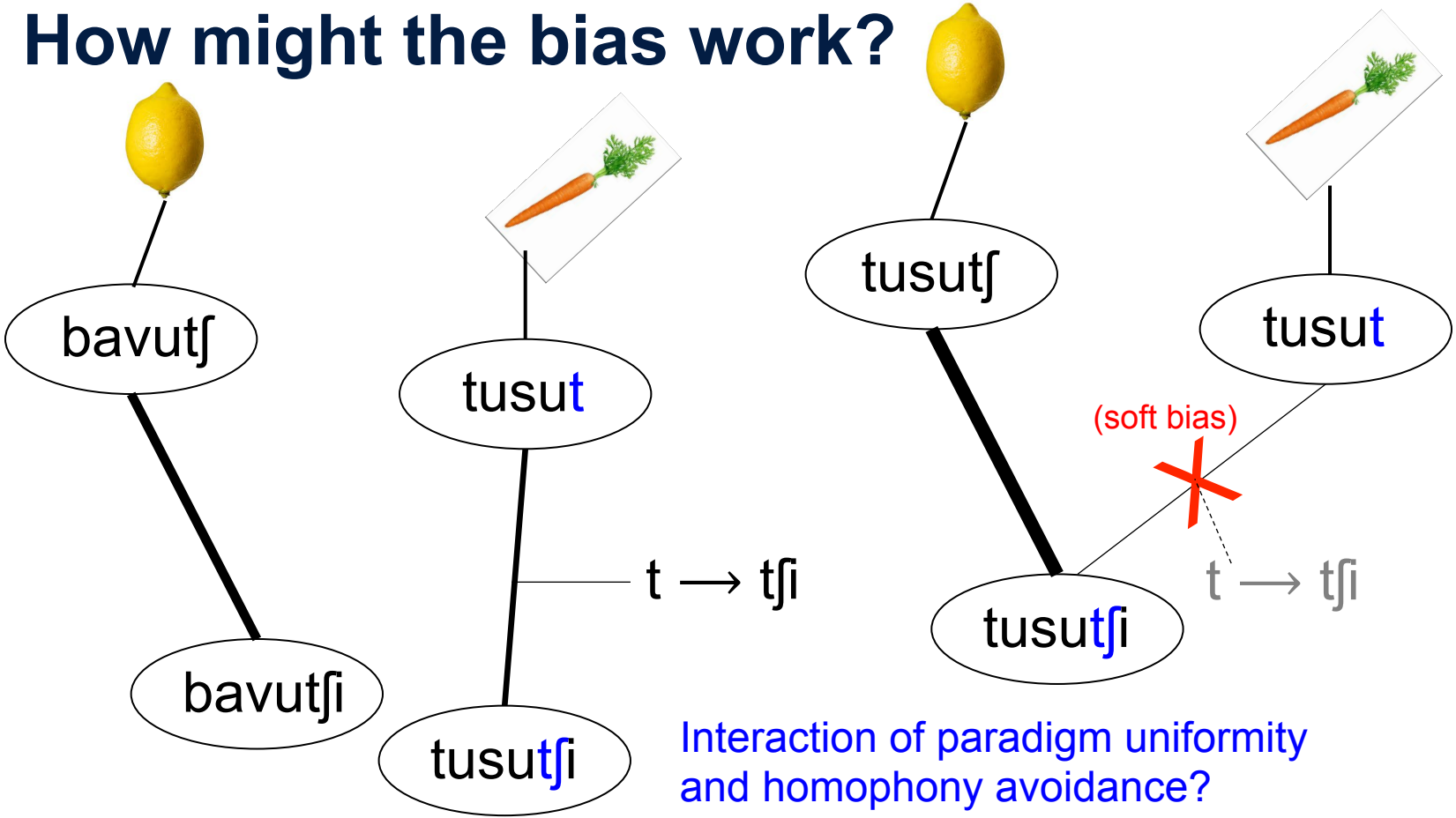
Interaction between lexical/semantic learning and phonological learning

- Learners must track homophones that they encounter during learning.
  - Otherwise, amount of homophony in the input would have no effect on learning.

- But, homophony avoidance (Exp. 2) was found in novel items, where there was no actual homophony.

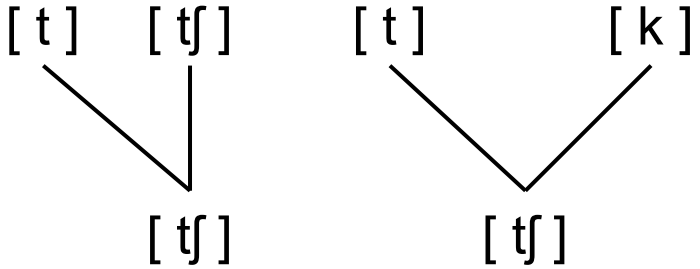
→ The observed homophony affected the generalization to novel items, i.e. the ability to induce the phonological rule.

How might the bias work?



Interaction of paradigm uniformity and homophony avoidance?

Future directions



- What happens if paradigm uniformity is taken out of the picture?
- More implicit experiment (pairs of the paradigm less explicit).
- Does the amount of homophony have a gradient effect?
  - Test with multiple homophony levels.
- Do we see the same effect with infants?
- Implemented learning model.

Conclusions

- Neutralizing alternations dispreferred relative to non-neutralizing alternations.

- This neutralization avoidance seems to be driven by homophony avoidance, suggesting an interaction between lexical/semantic learning and phonological learning.

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References:

Bolognesi, R. (1998). *The phonology of Campidanian Sardinian: A unitary account of a self-organizing structure*. NOR.

Bybee, J. L., & Slobin, D. I. (1982). Rules and schemas in the development and use of the English past tense. *Language*, 265-289.

Calamaro, S., & Jarosz, G. (2015). Learning General Phonological Rules From Distributional Information: A Computational Model. *Cognitive science*, *39*(3), 647-666.

Flemming, E. (1996). Evidence for constraints on contrast: The dispersion theory of contrast. *UCLA Working Papers in Phonology*, *1* (pp. 86-106).

Flemming, E. (2004). Contrast and perceptual distinctiveness. In B. Hayes, R. Kirchner, and D. Steriade (Eds.) *Phonetically-Based Phonology* (pp. 232-276).

Halle, M. (2005). Palatalization/velar softening: What it is and what it tells us about the nature of language. *Linguistic Inquiry*, *36*(1), 23-41.

Kapatsinski, V. (2013). Conspiring to mean: Experimental and computational evidence for a usage-based harmonic approach to morphophonology. *Language*, *89*(1), 110-148.

Kaplan, A. (2011). How much homophony is normal?. *Journal of linguistics*, *47*(03), 631-671.

Kaplan, A., & Muratani, Y. (2015). Categorical and gradient homophony avoidance: Evidence from Japanese. *Laboratory Phonology*, *6*(2), 167-195.

Kochetov, A. (2011). Palatalisation. In M. Oostendrop, C. Ewen, B. Hume, & K. Rice (Eds.). *Companion to Phonology*. (pp.1666-1690). Oxford: Wiley Blackwell.

Labrune, L. (2012). *The phonology of Japanese*. Oxford: Oxford University Press.

Łubowicz, A. (2007). Paradigmatic contrast in Polish. *Journal of Slavic linguistics*, *15*(2).

References:

Mattys, S. L., Jusczyk, P. W., Luce, P. A., & Morgan, J. L. (1999). Phonotactic and prosodic effects on word segmentation in infants. *Cognitive psychology*, *38*(4), 465-494.

Merriman, W., Bowman, L., & MacWhinney, B. (1989). The Mutual Exclusivity Bias in Children's Word Learning. *Monographs Of The Society For Research In Child Development*, *54*(3/4), i.

Moreton, E., & Pater, J. (2012a). Structure and Substance in Artificial-phonology Learning, Part I: Structure. *Language And Linguistics Compass*, *6*(11), 686-701.

Moreton, E., & Pater, J. (2012b). Structure and Substance in Artificial-Phonology Learning, Part II: Substance. *Language And Linguistics Compass*, *6*(11), 702-718.

Ngon, C., Martin, A., Dupoux, E., Cabrol, D., Dutat, M., & Peperkamp, S. (2013). (Non) words,(non) words,(non) words: evidence for a protolexicon during the first year of life. *Developmental Science*, *16*(1), 24-34.

Padgett, J. (2003). Contrast and post-velar fronting in Russian. *Natural Language & Linguistic Theory*, *21*(1), 39-87.

Padgett, J. (2009). Systemic contrast and Catalan rhotics. *The Linguistic Review,* 26(4), 431-463.

Peperkamp, S. & Dupoux, E. (2007). Learning the mapping from surface to underlying representations in an artificial language. In J. Cole & J. Hualde (Eds.). *Laboratory phonology* (Vol. 9, pp. 315-338). Berlin: Mouton de Gruyter.

Silverman, D. (2010). Neutralization and anti-homophony in Korean. *J. Ling.*, *46*(02), 453-482.

Silverman, D. (2012). *Neutralization*. Cambridge: Cambridge University Press.

Skoruppa, K., & Peperkamp, S. (2011). Adaptation to novel accents: Feature-based learning of context-sensitive phonological regularities. *Cognitive Science*. 35, 348-366.

Steriade, D. (2001). Directional asymmetries in place assimilation: a perceptual account. *The role of speech perception in phonology*, 219-250.

References:

Wedel, A. (2006). Exemplar models, evolution and language change. *The Linguistic Review*, *23*(3).

Wedel, A., Jackson, S., & Kaplan, A. (2013). Functional load and the lexicon: Evidence that syntactic category and frequency relationships in minimal lemma pairs predict the loss of phoneme contrasts in language change. *Language and speech*, 0023830913489096.

White, J. (2014). Evidence for a learning bias against saltatory phonological alternations. *Cognition*, *130*(1), 96-115.

White, J., & Sundara, M. (2014). Biased generalization of newly learned phonological alternations by 12-month-old infants. *Cognition*, *133*(1), 85-90.

Wilson, C. (2006). Learning phonology with substantive bias: An experimental and computational study of velar palatalization. *Cognitive Science*, *30*(5), 945-982.