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Developmental trajectory of L2 and L3 vowel perception: Acoustic and perceptual similarity of English and Norwegian vowels to Polish vowel categories

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The role of language experience in non-native speech perception

- PAM (Best 1995), SLM (Flege 1995) and NGTA (Dziubalska-Kołaczyk & Wrembel 2022) state that adult listeners assimilate non-native sounds to native categories.

- The SLM (Flege 1995, Flege and Bohn 2021): in order to establish a new category for an L2 sound, learners need to detect differences between L1 and L2 sounds.

- The more experienced the L2/L3 learners are, the more likely they should be to discern the differences between the L1 and L2 sounds.

- Longitudinal experiments are challenging.

Previous research on the role of experience in non-native speech perception

- Usually experienced vs. inexperienced listeners, some heightened awareness of phonetic differences between L1 and L2 revealed: Flege 1991, Flege, Bohn and Jang 1997.

- Little support for the effect of experience in L2 vowel identification or categorization: Cerbian (2002), Cerbian (2006) found some effect on L1 vowel identification, but no effect on L2 vowel categorization (but the two groups actually differed in the character of exposure: immersion vs. formal setting).

Previous research on the role of experience in non-native speech perception

- In a challenging oddity discrimination task: Rallo Fabra and Romero (2012)

- Better effects of vowel identification than discrimination training in Carlet and Cebrian (2019).

- L2 identification and discrimination improved while perception of cross-linguistic similarity remained unchanged (Cebrian, Carlet, Gorba and Gavalda 2019), in line with a cross-sectional study by Flege, Munro and Fox (1994)

- Increased experience with the target language can influence the perceptual similarity between L1 and target language vowels (Flege 1991, Ingram and Park 1997)

- Iverson and Evans (2009): learners with a larger vowel inventory in L1 are initially at an advantage, learners with a smaller vowel inventory require more training to achieve similar results.

The perception of non-native lip rounding

- Strange, Bohn and Nishi (2004) examined acoustic and perceptual similarity of North German and American English vowels. They found that acoustic similarity did not always predict perceptual similarity, especially for front rounded vowels.

- Alispahic, Mulak and Escudero (2017) showed that detailed acoustic comparisons between native (Peruvian Spanish and Australian English) and non-native (Dutch) vowels predicted perception patterns more accurately than overall comparisons of inventory size.

- Although both Strange et al. (2004) and Alispahic et al. (2017) included front rounded vowels and observed peculiar assimilation patterns, they did not specifically investigate the role of lip rounding or F3 in the perceptuo-acoustic relationship.

- We are aiming at addressing this issue.

Study

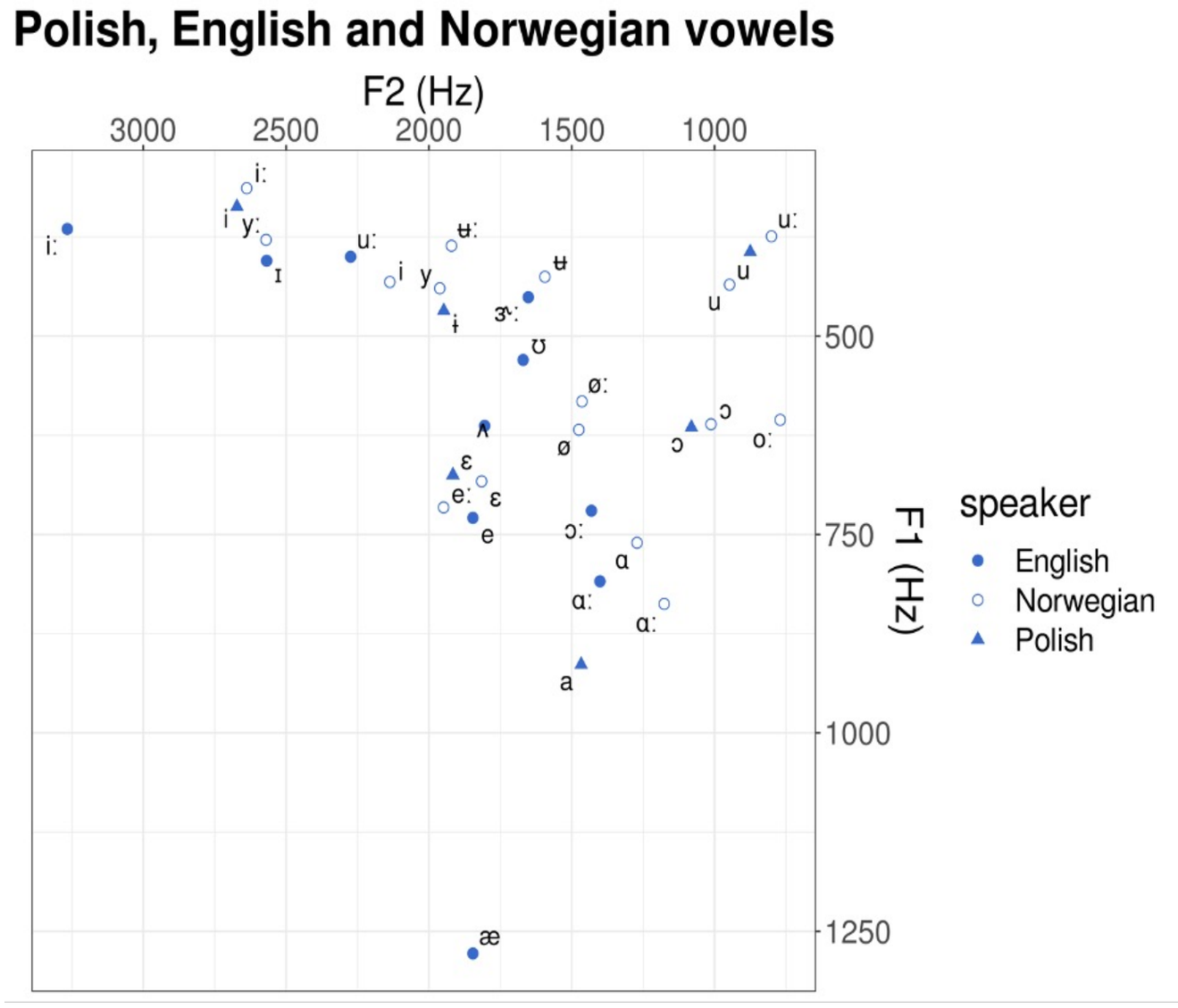
Vowel inventories

- Polish: /i ɨ ɛ a ɔ u/
- English: /iː ɪ e æ ʌ ɑː ɒ ɔː ʊ uː ɜː ə/
- Norwegian: long vowels /iː, yː, ʉː, uː, eː, øː, oː, ɑː/ and short vowels /i, y, ʉ, u, e, ø, o, ɑ/ (Kristoffersen 2000)

Euclidean distance

- Euclidean distance between vowels: the distance between two points in vowel space (Hz)

- It may be two-dimensional or three-dimensional: F1-F2 or F1-F2-F3.



Research questions

- RQ1: Do assimilation patterns of L2/L3 vowels depend on the Euclidean distance between a given non-native vowel and a target category?

- RQ2: Do the relationships between assimilations of L2/L3 vowels to native categories and their Euclidean distances change over time?

- RQ3: Does the Euclidean distance predict assimilation better in L2 or L3?

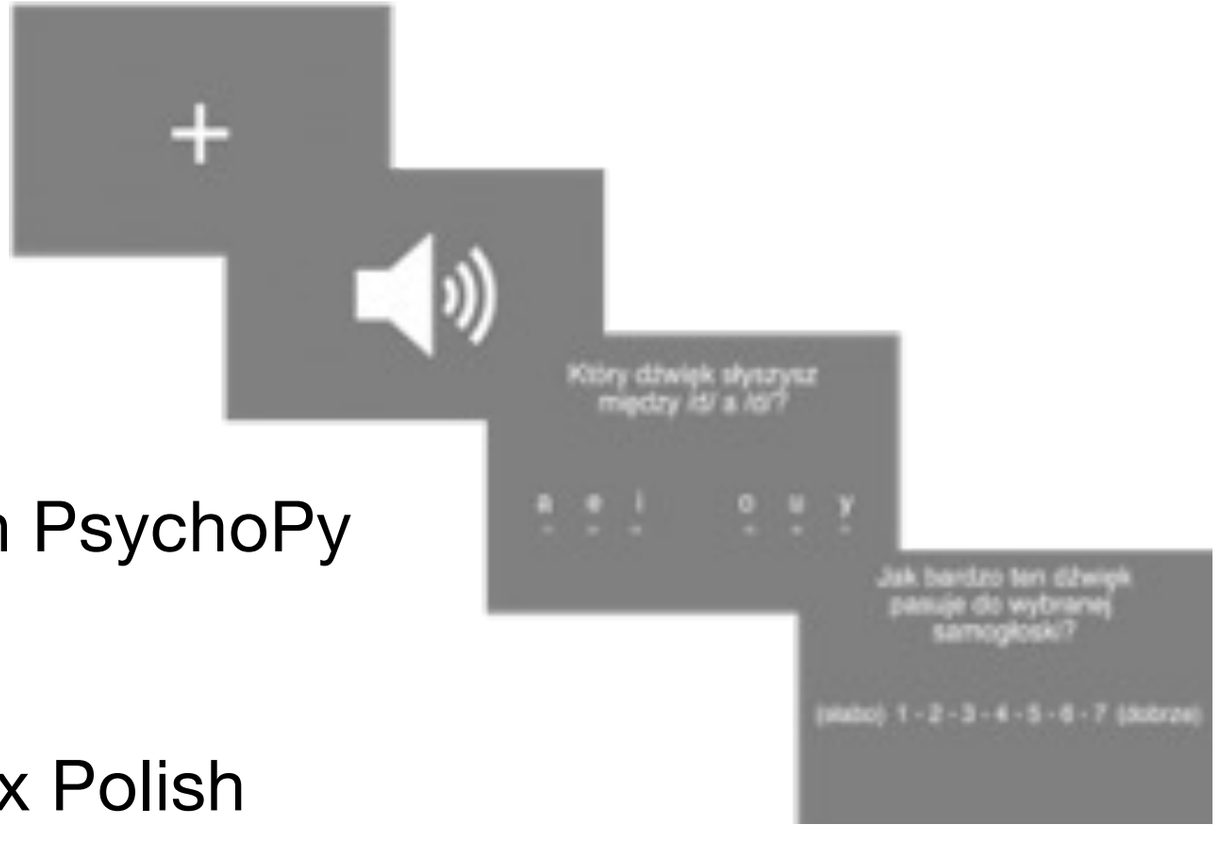
- RQ4: If we take into account the Euclidean distance, are L2 or L3 vowels perceived as worse exemplars of L1 categories?

- RQ5: Does lip rounding influence assimilation patterns?

Methodology: Participants

- 15 participants (9 females, 6 males), out of original pool N=24
- L1 Polish
- L2 English (advanced, mean of language learning duration: 12 yrs)
- L3 Norwegian (2 months of intensive instruction)
- Mean age: 20
- Instructed setting
- Three testing times after the onset of L3 Norwegian learning:
  - T1 -- two months, T2 -- five months and T3 -- nine months.

Procedure



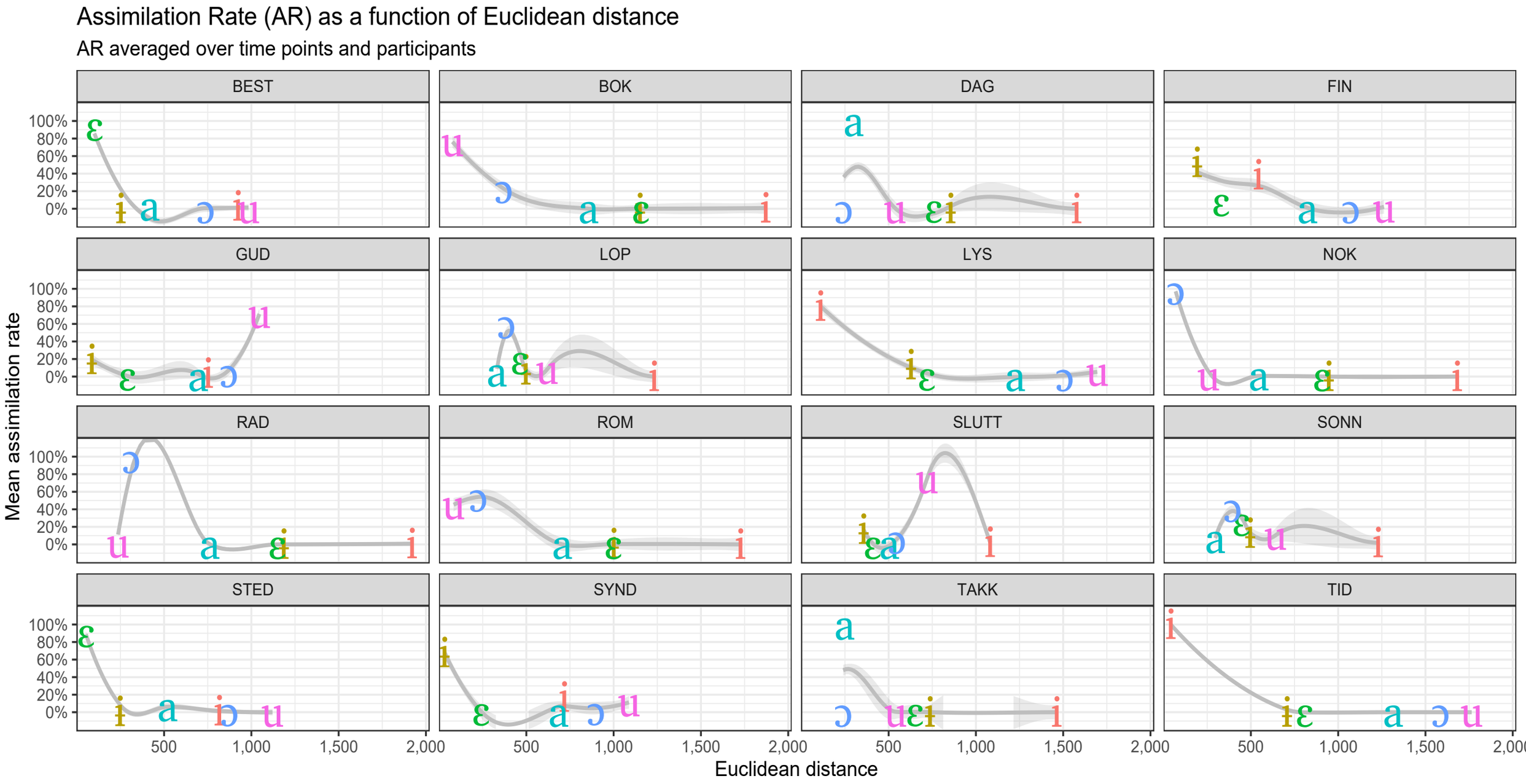
- **Perceptual assimilation task** in PsychoPy (Peirce et al. 2019)
- 10 English and 16 Norwegian monophthongs assimilated to six Polish vowel categories
- Orthographic labels used for six Polish vowel categories /i, ɨ, e, a, ɔ, u/
- The stimuli in /dVd/ nonce words
- Randomised, 3x each (e.g., dåd, did)
- Tested in separate blocks, on separate days
- **Goodness of fit ratings** of each non-native vowel to the chosen L1 category, on a Likert scale: 1 (weak fit) -- 7 (good fit)

Results

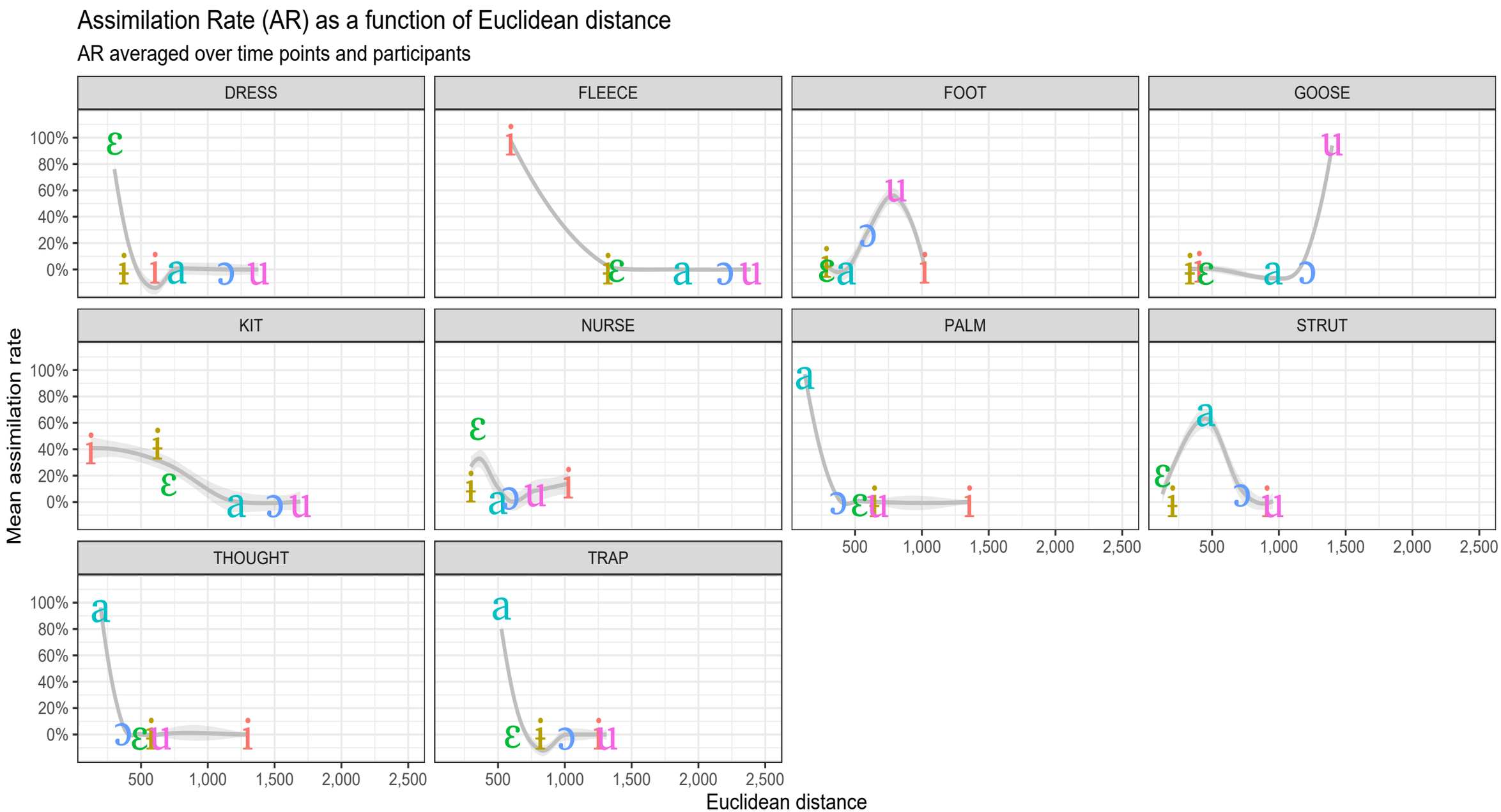
Norwegian stimulus	Polish vowel targets						
	/i/ <i>	/ɨ/ <y>	/ɛ/ <e>	/a/ <a>	/ɔ/ <o>	/u/ <u>	NA
/iː/ TID	100% (5.77)						
/i/ FIN	33.33% (5)	37.50% (5.41)	26.39% (5.21)			1.39% (3)	1.39% (4)
/yː/ LYS	70.83% (4.59)	23.61% (5)	1.39% (1)			4.17% (4.33)	
/y/ SYND	16.67% (5.25)	62.50% (4.64)	8.33% (5.17)		2.78% (5)	8.33% (2.33)	1.39%
/eː/ STED			88.89% (5.14)	6.94% (5.6)	1.39% (2)		2.78% (4)
/e/ BEST	1.39% (2)		93.06% (5.9)	5.56% (5)			
/øː/ LØP		9.72% (3.57)	19.44% (5.14)	5.56% (3.75)	58.33% (4.45)	6.94% (3.2)	
/ø/ SØNN		11.11% (3.25)	36.11% (4.35)	8.33% (5)	33.33% (4.29)	6.94% (3.2)	4.17% (5.33)
/ɑː/ DAG				100% (5.53)			
/ɑ/ TAKK				98.61% (5.69)			1.39% (4)
/oː/ RÅD	1.39% (5)				97.22% (5.25)	1.39% (7)	
/o/ NOK					98.61% (5.58)		1.39%
/uː/ BOK					38.89% (5.43)	61.11% (5.02)	
/u/ ROM					72.22% (5.08)	27.78% (4.9)	
/ʉː/ GUD	2.78% (7)	18.06% (4.23)	1.39% (1)		1.39% (5)	75% (4.72)	1.39% (5)
/ʉ/ SLUTT	1.39% (3)	23.61% (4.12)			9.72% (5)	63.89% (4.65)	1.39% (7)

English stimulus	Polish vowel targets						
	/i/ <i>	/ɨ/ <y>	/ɛ/ <e>	/a/ <a>	/ɔ/ <o>	/u/ <u>	NA
/iː/ FLEECE	100% (5.81)						
/ɪ/ KIT	37.5% (5.04)	34.72% (5.84)	27.78% (6.15)				
/e/ DRESS			98.61% (6.03)	1.39% (5)			
/æ/ TRAP				100% (5.75)			
/ʌ/ STRUT			13.89% 5.3	75% (5.13)	11.11% (4.5)		
/ɑː/ PALM				97.22% 5.53	1.39% (6)	1.39[illegible](4)	
/ɔː/ THOUGHT				97.22% (5.67)	1.39 (3)	1.39 (5)	
/uː/ GOOSE						100% (5.15)	
/ʊ/ FOOT	1.39% (7)	4.17% (4.67)			43.06% (4.61)	51.39% (3.86)	
/ɜː/ NURSE	15.28% (4.09)	15.28% (2.64)	54.17% (4.62)	4.17% (1.33)	6.94% (4.8)	4.17% (6)	

Assimilation rate as a function of ED: L3 Norwegian



Assimilation rate as a function of ED: L2 English



Euclidean distance & assimilation count

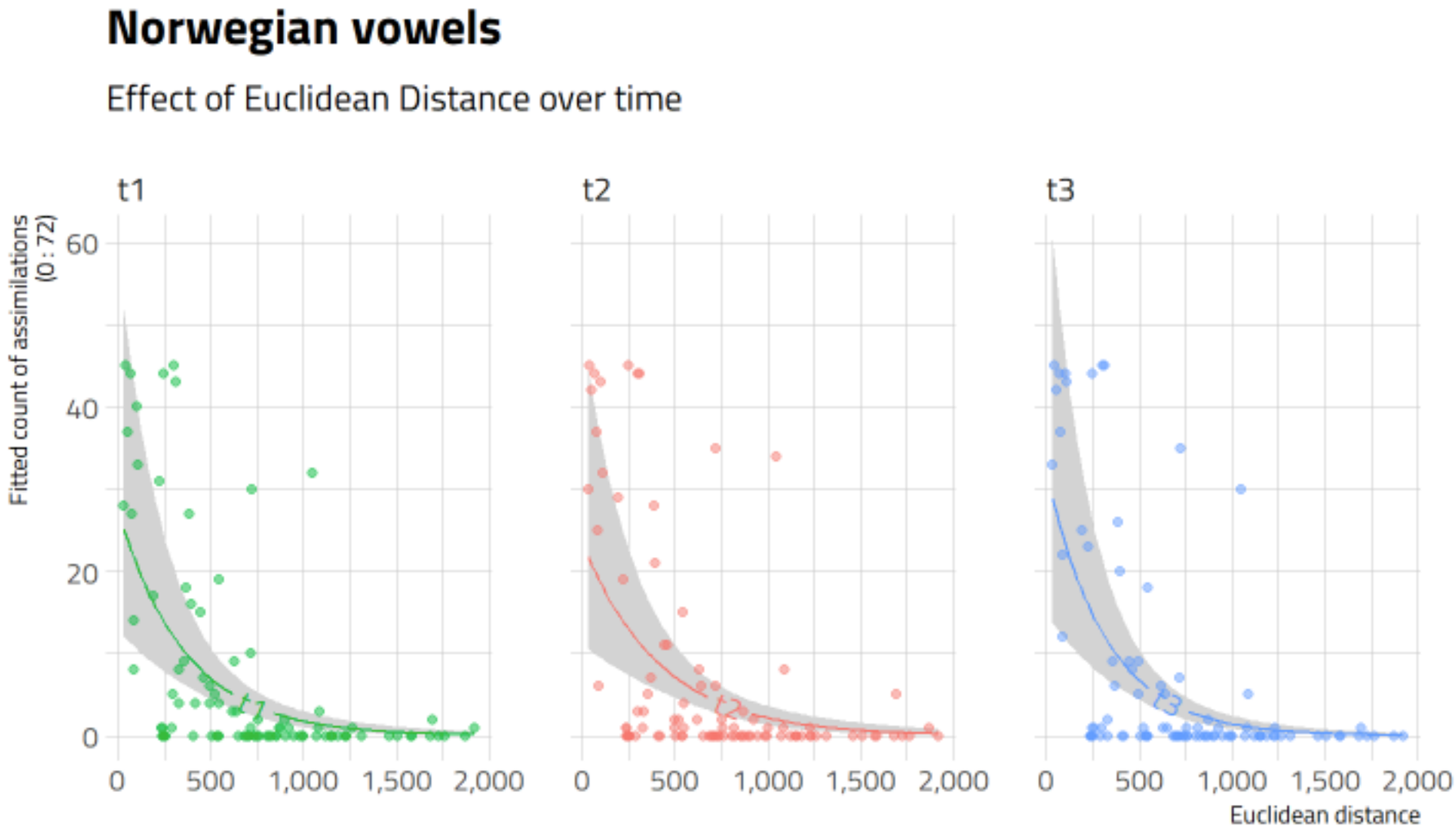
- A negative binomial model was used to capture whether the F1-F2 Euclidean distance is related to how often a given Norwegian vowel is assimilated to a given Polish vowel.

- ED is negative and significant (z = -6.751, Pr(>|z|) = 1.46e-11***)

- Similar results for English and for all the three testing times.

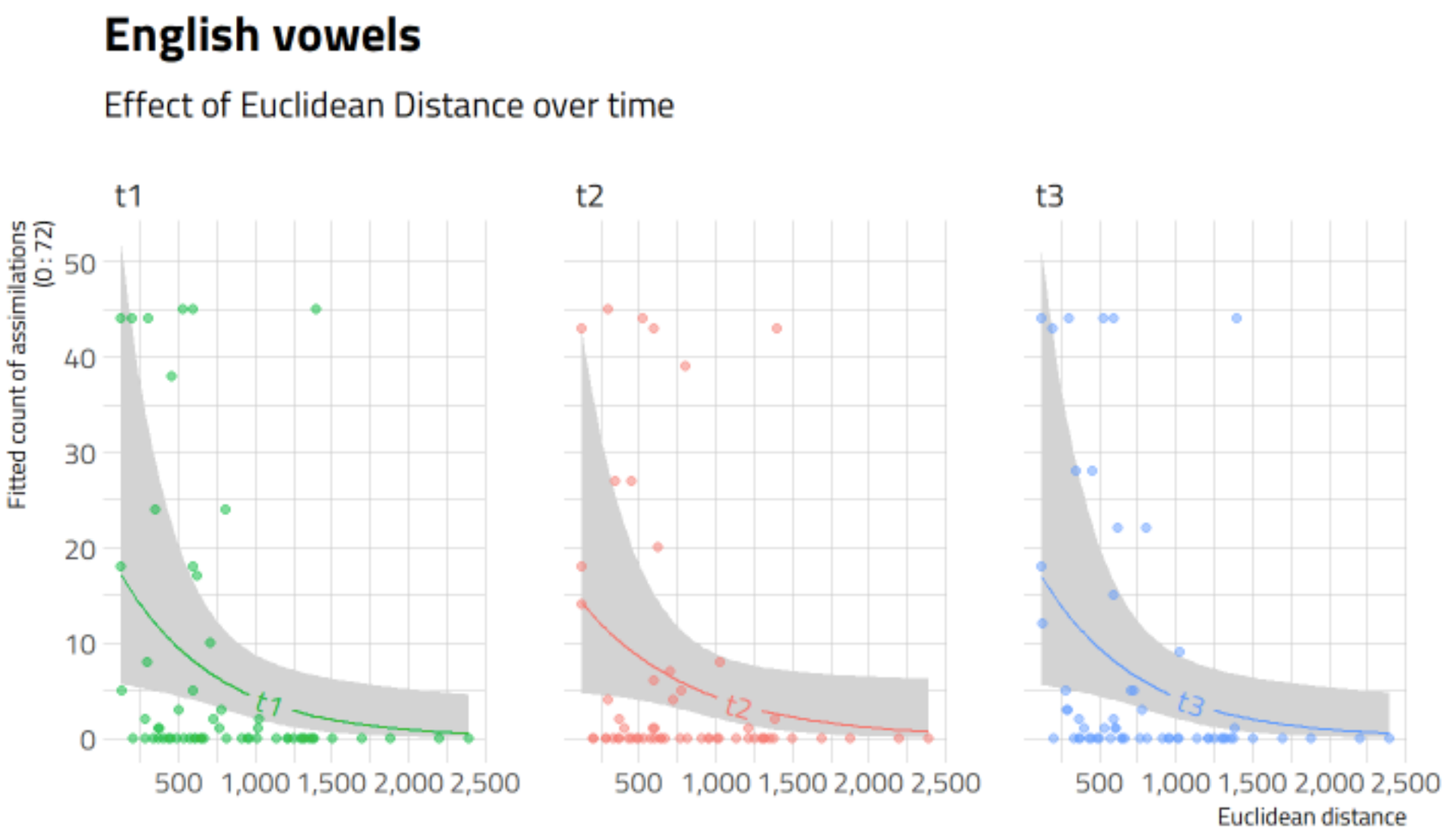
- **RQ 1: YES** -> The larger the Euclidean distance, the fewer assimilations are predicted.

Effect of ED on assimilation over time: L3 Norwegian



RQ 2A: NO -> Weak and insignificant differences between testing times.

Effect of ED on assimilation over time: L2 English



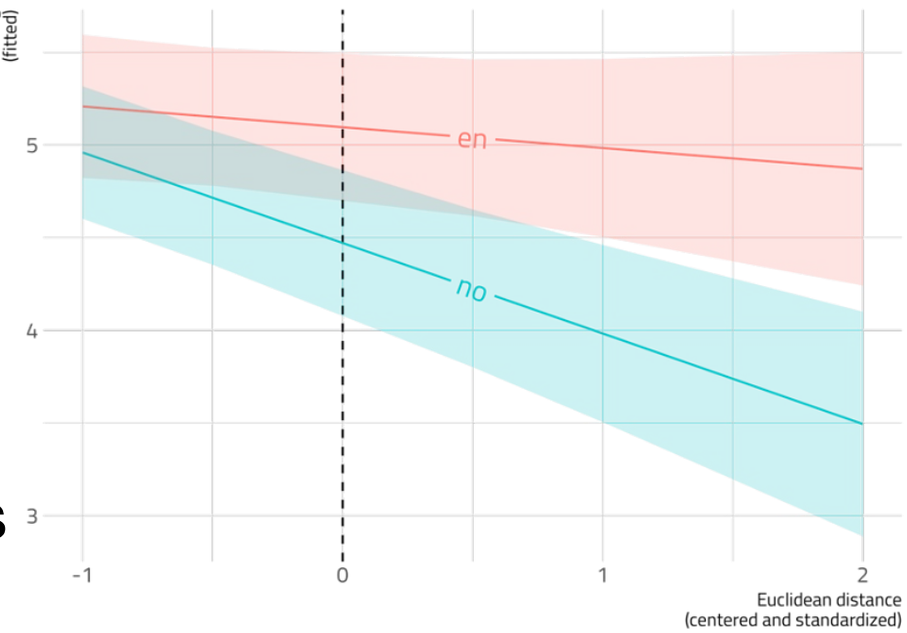
RQ 2B: NO -> Weak and insignificant differences between testing times.

Euclidean distance as predictor of assimilation in L2 vs. L3

- Stronger effect of the ED in L3 than in L2
  - coefficient in Norwegian ed_z = -1.7 > English ed_z= - 0.61
  - assimilations in the better-known L2 English have stabilized
  - Due to more experience in L2 than L3, the learners discern the differences between the L1 and foreign sounds
- **RQ 3:** The Euclidean distance predicts assimilation better in L3 than L2.

Goodness of fit in L2 vs. L3

- Mixed effects linear model of Likert rating as a function of ED, language (L2, L3) and their interaction; by-participant random intercept.
  - Larger Euclidean distance means lower goodness of fit ratings in both languages.
- Significant effect of language; L2 > L3
  - L2 English vowels seem more similar to L1 Polish vowels than L3 Norwegian vowels



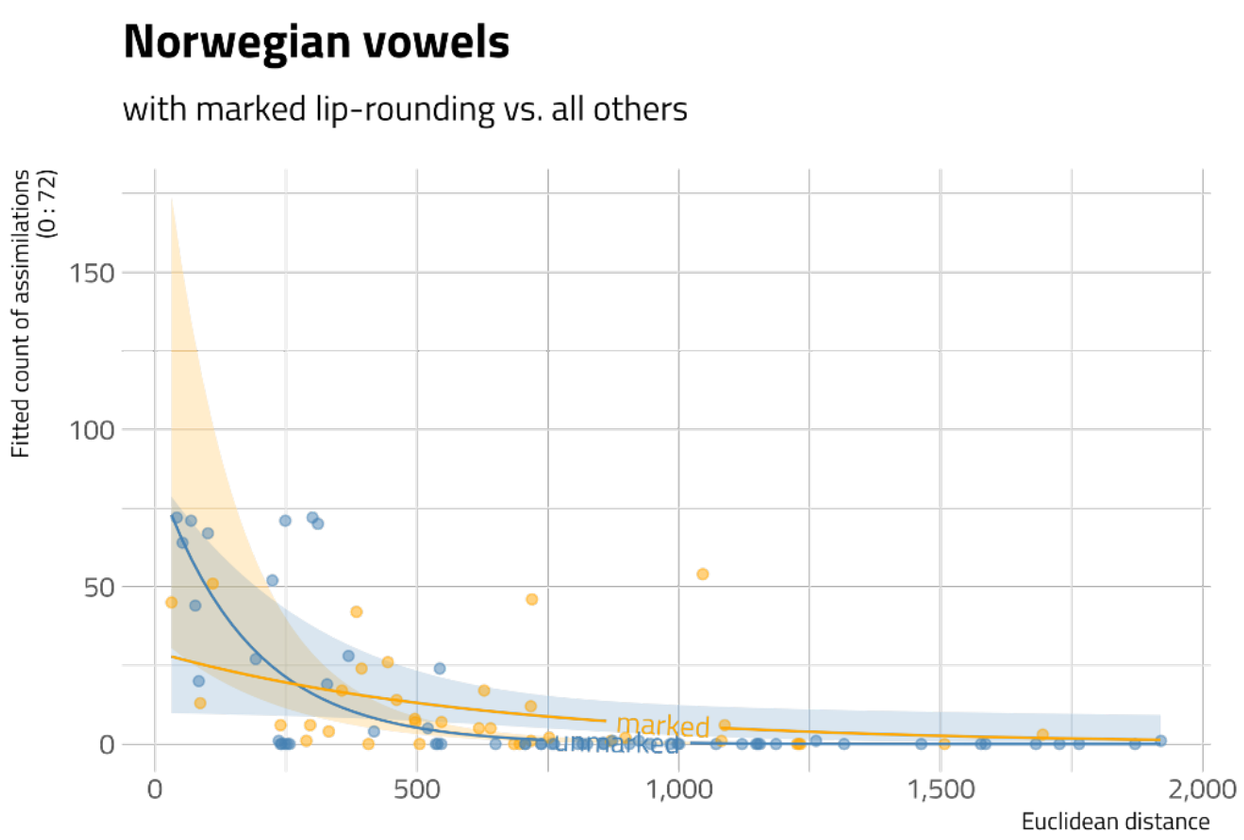
- **RQ 4:** L2 English vowels rated as better exemplars of L1 categories than L3 Norwegian vowels

Effect of lip rounding

- The interaction ed:marked_rounding is positive and significant,

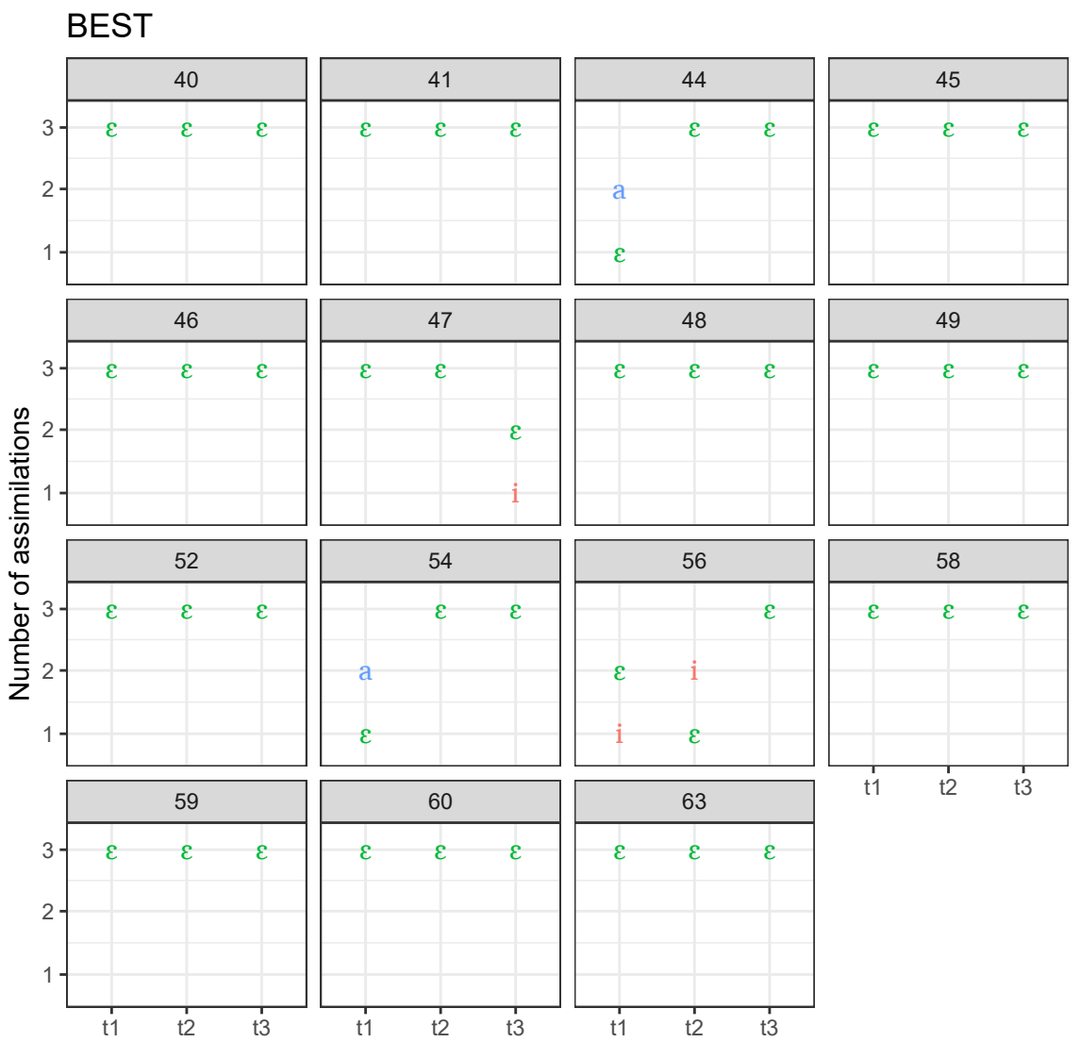
- but the effect of marked_rounding is not significant

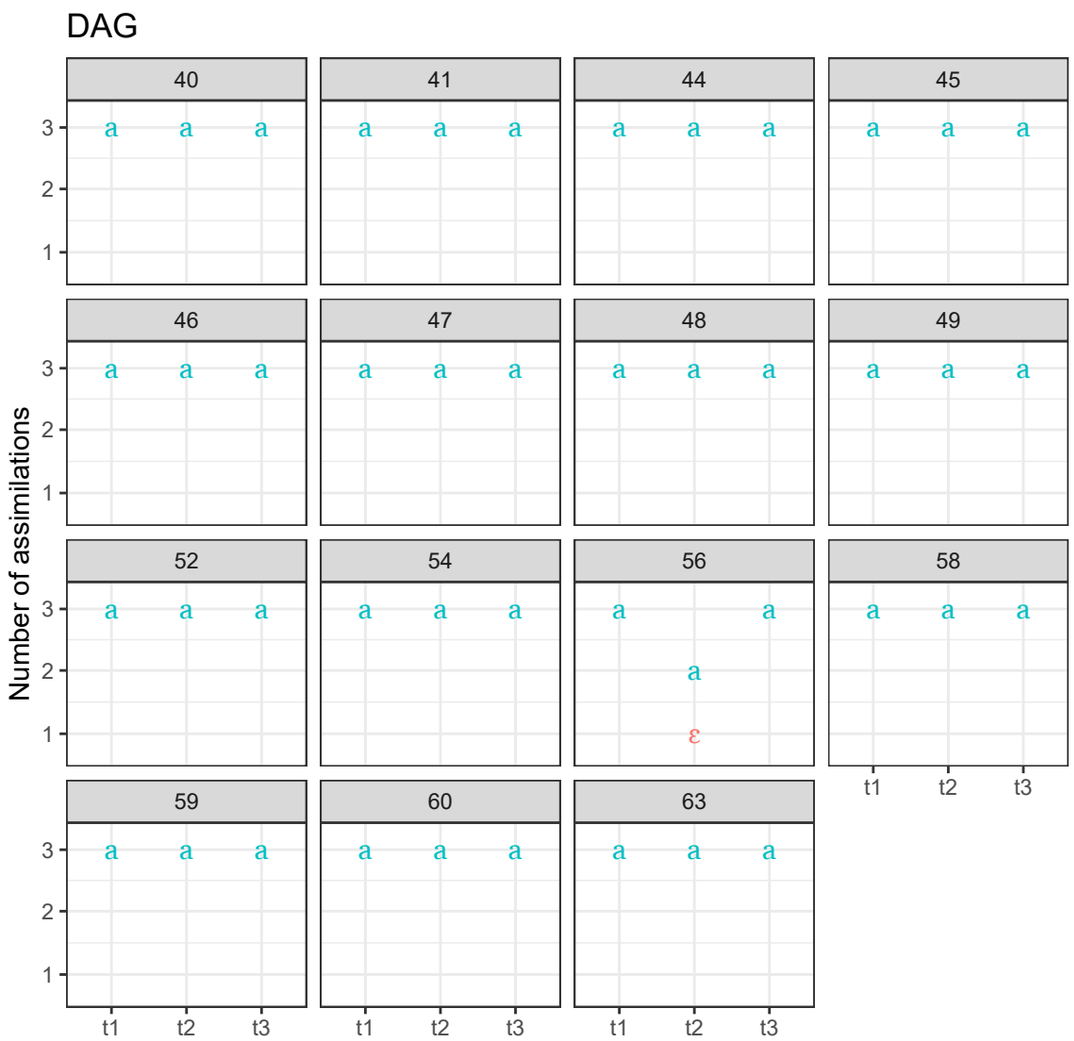
- **RQ 5**: hard to interpret



Individual variation: developmental trajectories (1)

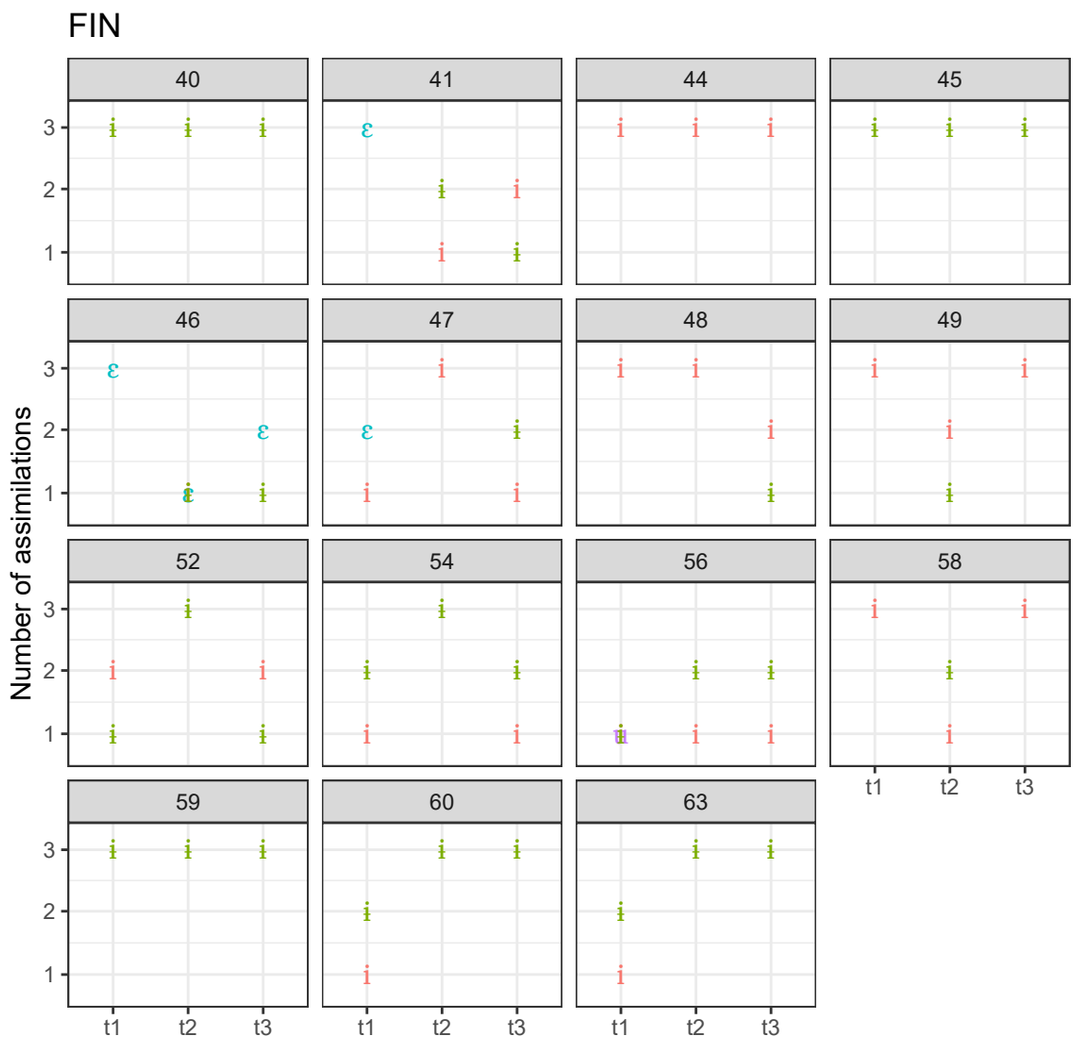
- Examples of vowels with relatively stable assimilations over time across participants

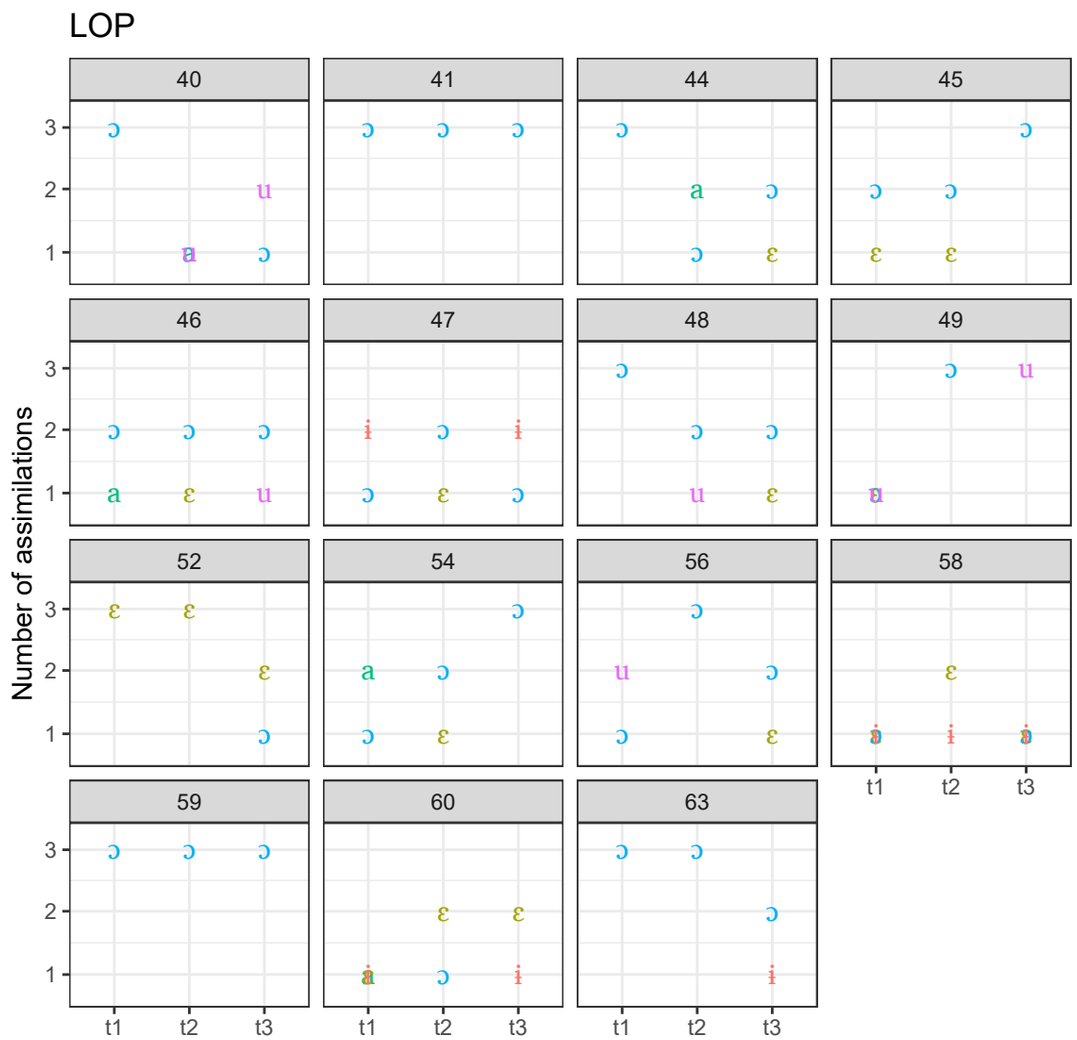




Individual variation: developmental trajectories (2)

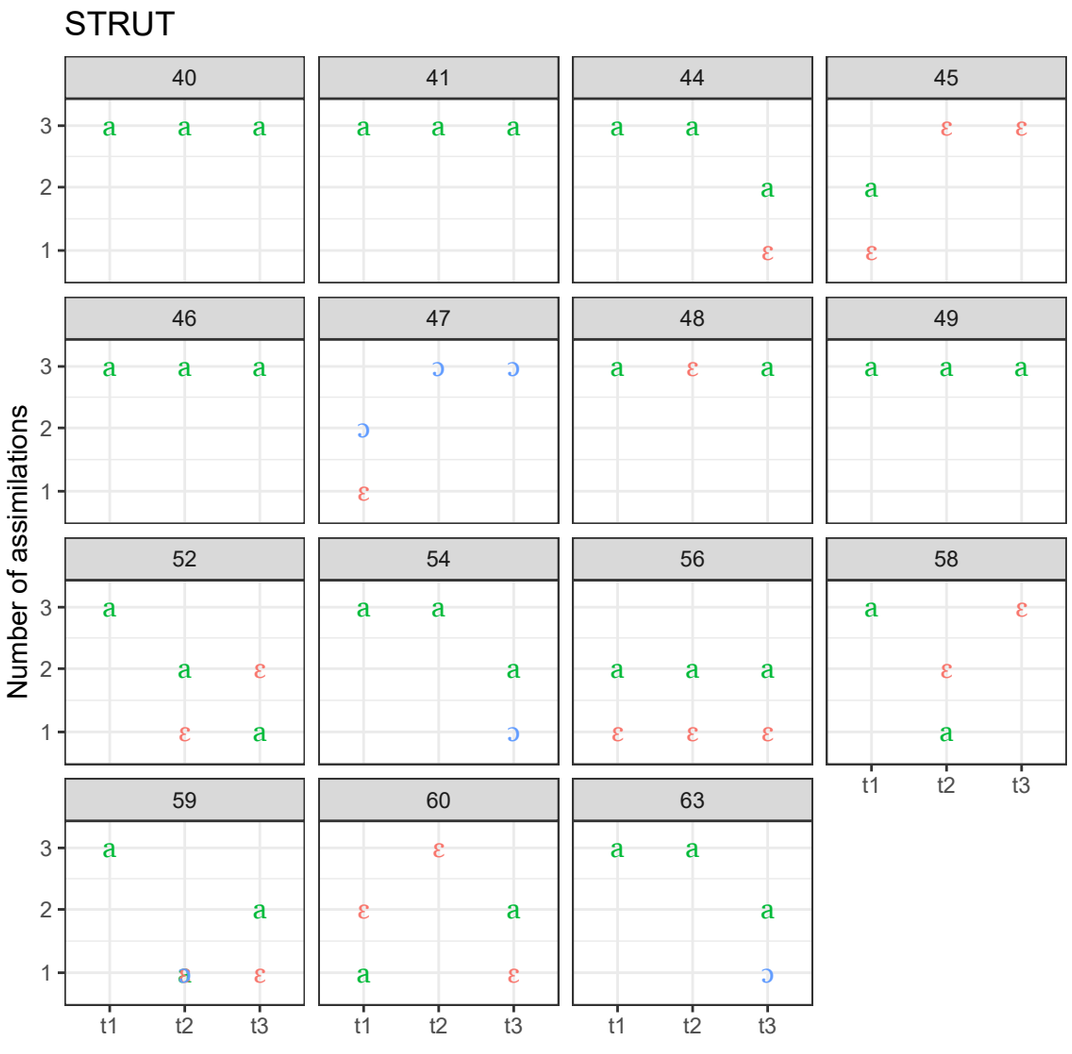
- Examples of vowels with considerable variability in assimilations over time across participants – L3 NORWEGIAN

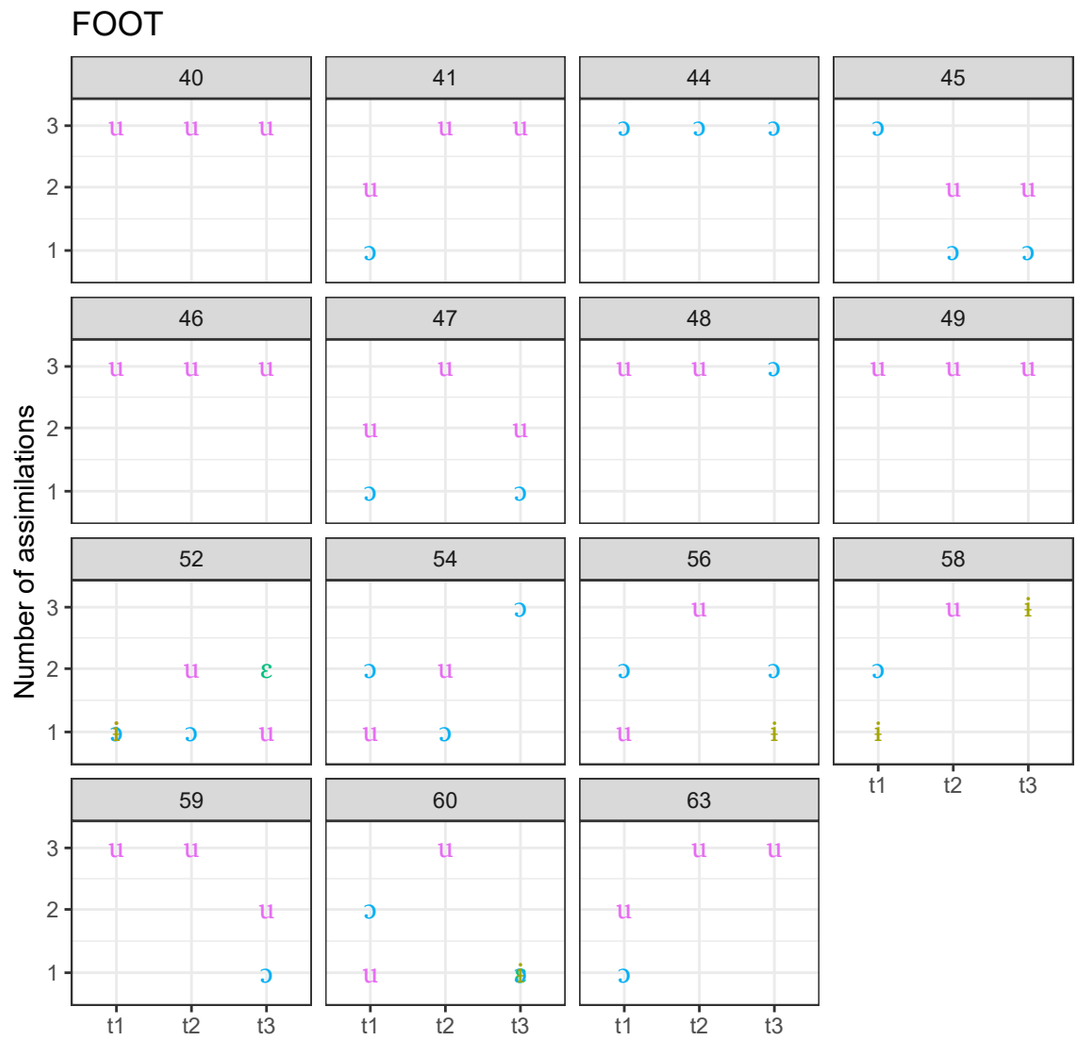




Individual variation: developmental trajectories (3)

- Examples of vowels with considerable variability in assimilations over time across participants – L2 ENGLISH





Discussion

- Perceptual targets in L3 phonology are largely modulated by Euclidean distance, but they are influenced by other phonetic features -> these factors/factor combinations need further investigation.

- The perceptuo-acoustic similarity patterns, based on PAT and ED, are not substantially restructured during the first year of L3 learning.

- ED influences perception more in L3 Norwegian than in L2 English.

- With regard to the comparison of goodness of fit ratings, in the present language combination, L3 Norwegian has more marked vowels than the L2 English. Languages with comparable vowel inventories/less marked vowels should be examined (e.g. L1 Polish, L2 English, L3 Spanish?).

- Some indication that marked lip rounding may influence assimilation patterns.

Discussion

- The perception of cross-linguistic similarity remained unchanged over time – in line with Cebrian et al. (2019), Flege et al. (1994)

- The character of exposure may play a role (cf. Cebrian 2006) – here: formal setting not immersion

- L1 Polish learners with a small vowel inventory may be at a disadvantage (cf. Iverson and Evans 2009)

- For front rounded vowels more peculiar assimilation patterns were observed (as in Strange et al. 2004 and Alispahic et al. 2017)

Conclusions

- We aimed to trace developmental trajectory on 2 levels:

  (1) L2 vs. L3

- Macro level (across languages) –> differences attested as a function of language experience, in the expected direction (L2 categories more established, L3 more reliance on ED)

- (2) T1-T2-T3

- Micro level (within language, across-participants) –> little/no visible restructuring over time, maybe too short a time window (7 months); -> individual trajectories of development for some vowels

- Longitudinal experiment proved challenging (high drop-out rate)

Further research

- Future research should also investigate the relationship between L2 and L3 vowel assimilation and production development (cf. Wrembel et al. 2022).

- More challenging oddity discrimination task, rather than perceptual assimilation task, could shed further light.

- Free classification (Daidone et al. 2023), suitable for L1s with few vowels.

- Fit index as an additional measure in the statistical analysis, in addition to the assimilation count and goodness of fit.

- Calculating overlap between pairs of vowels.

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