

1290 **Supplementary information for *Persson (2024)*. *The***
1291 ***acoustic characteristics of Central Swedish***

1292 Both the main text and these supplementary information (SI) are derived from the same R
1293 markdown document available via OSF at <https://osf.io/7uvj4/>.

1294 **S1.1 Required software**

1295 The document was compiled using `knitr` (Xie, 2023a) in RStudio with R:

```
1296 -
1297 platform      aarch64-apple-darwin20
1298 arch          aarch64
1299 os            darwin20
1300 system        aarch64, darwin20
1301 status
1302 major         4
1303 minor         4.0
1304 year          2024
1305 month         04
1306 day           24
1307 svn rev       86474
1308 language       R
1309 version.string R version 4.4.0 (2024-04-24)
1310 nickname       Puppy Cup
```

1311 The following R packages were used to create this document: R (Version 4.4.0; R
1312 Core Team, 2022) and the R-packages `brms` (Version 2.21.0; Bürkner, 2023), `curl` (Version
1313 5.2.1; Ooms, 2023), `dplyr` (Version 1.1.4; Wickham, François, Henry, Müller, & Vaughan,

1314 2023), *forcats* (Version 1.0.0; Wickham, 2023a), *ggforce* (Version 0.4.2; Pedersen, 2022),
 1315 *ggplot2* (Version 3.5.1; Wickham, Chang, et al., 2023), *glue* (Version 1.7.0; Hester & Bryan,
 1316 *gtsummary* (Version 1.7.2; Sjoberg et al., 2023), *kableExtra* (Version 1.4.0; Zhu,
 1317 2021), *knitr* (Version 1.47; Xie, 2023b), *linguisticsdown* (Version 1.2.0; Liao, 2019), *lme4*
 1318 (Version 1.1.35.3; Bates, Maechler, Bolker, & Walker, 2023), *lubridate* (Version 1.9.3; Spinu,
 1319 Gromelund, & Wickham, 2023), *magrittr* (Version 2.0.3; Bache & Wickham, 2022), *Matrix*
 1320 (Version 1.7.0; Bates, Maechler, & Jagan, 2023), *modelr* (Version 0.1.11; Wickham, 2023b),
 1321 *modelsummary* (Version 2.1.1; Arell-Bundock, 2024), *mvtnorm* (Version 1.2.5; Genz, Bretz,
 1322 Miwa, Mi, & Hothorn, 2023), *nlme* (Version 3.1.164; Pinheiro, Bates, & R Core Team,
 1323 2023), *papaja* (Version 0.1.2.9000; Aust & Barth, 2023), *patchwork* (Version 1.2.0; Pedersen,
 1324 2023), *plotfunctions* (Version 1.4; van Rij, 2020), *plotly* (Version 4.10.4; Sievert et al., 2023),
 1325 *purrr* (Version 1.0.2; Wickham & Henry, 2023), *Rcpp* (Version 1.0.12; Eddelbuettel et al.,
 1326 2023), *readr* (Version 2.1.5; Wickham, Hester, & Bryan, 2023), *rlang* (Version 1.1.4; Henry
 1327 & Wickham, 2023), *stringr* (Version 1.5.1; Wickham, 2023c), *tibble* (Version 3.2.1; Müller
 1328 & Wickham, 2023), *tidyrr* (Version 1.3.1; Wickham, Vaughan, & Girlich, 2023), *tidyverse*
 1329 (Version 2.0.0; Wickham, 2023d), and *tinylabels* (Version 0.2.4; Barth, 2023)

1330 **S1.2 Neutralization of short /e/ and /ɛ/**

1331 Figure S1 demonstrates that the short allophones of /e/ and /ɛ/ neutralize as [ɛ] in Central
 1332 Swedish.

1333 **S1.3 The effect of different measurement points**

1334 Figure S2 visualizes the SwehVd vowel space under four different assumptions about
 1335 measurement points. The figure suggests that the use of different measurement points
 1336 primarily affects vowels for which formant dynamics are particularly important, e.g., [e:]
 1337 and [o:].

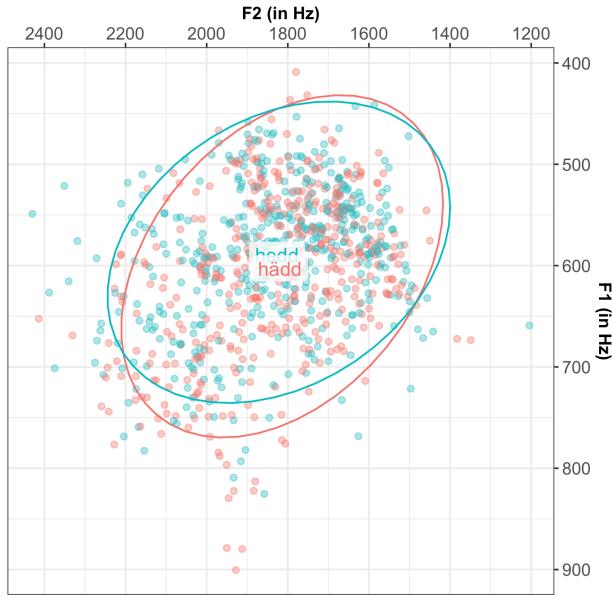


Figure S1. The *hedd* and *hädd* words in the SwehVd vowel data in F1-F2 space. Points show recordings of the *hedd* and *hädd* words ([ɛ]) by 48 native talkers in the database, averaged across the five measurement points within each vowel segment. Word labels indicate word means across talkers. Since *hädd* and *hedd* resulted in the same allophone, all *hädd* words are excluded from the subset used in this study. This facilitates comparison of, for example, densities across vowels (see diagonal of Figure 3).

¹³³⁸ **S1.4 Mean cue values across talkers**

¹³³⁹ The overall mean cue values for the long and short vowels are presented in Tables S1 and
¹³⁴⁰ S2, respectively.

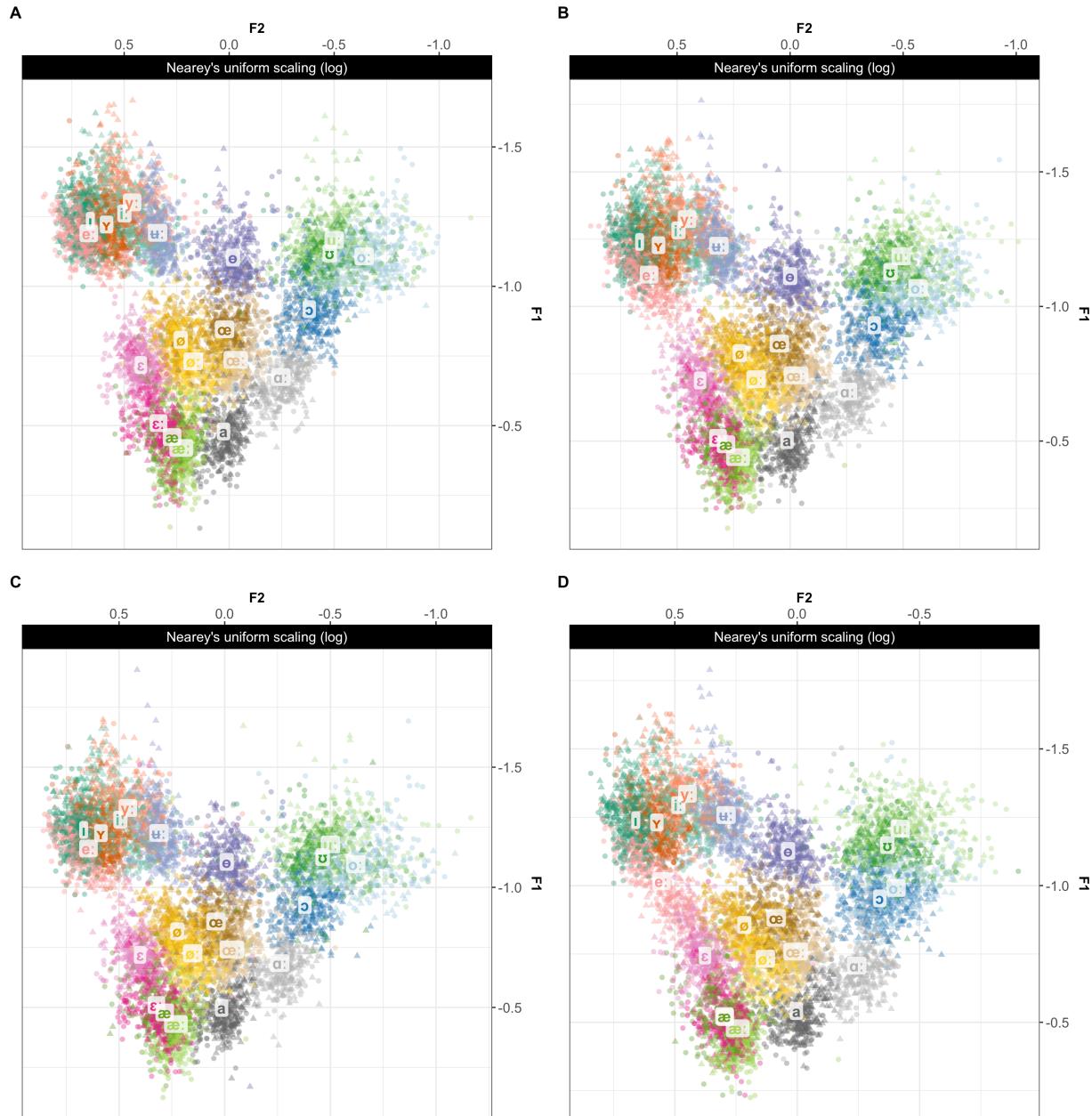


Figure S2. The SwehVd vowel data in F1-F2 space, faceted by the time points used for measuring formants: averaging across the first three time-points (at 20, 35, and 50% into the vowel; **panel A**), averaging across the mid three time-points (at 35, 50, and 65% into the vowel; **panel B**), taking the mid time-point (at 50%; **panel C**), and averaging across the final three mid-points (at 50, 65, and 80% into the vowel; **panel D**). Points show recordings of each of the 21 Central Swedish vowels, vowel labels indicate vowel means across talkers. Long vowels are boldfaced. Vowels that mismatched intended label are excluded (1.21% of all recordings).

Table S1

The spectral and temporal properties of the long vowels (averaged across talkers, by gender in Hertz)

Cue	Gender	[i:]	[y:]	[ɯ:]	[e:]	[ɛ:]	[æ:]	[ø:]	[œ:]	[ɑ:]	[ɔ:]	[ʊ:]
Duration F	F	0.22 (SD=0.05)	0.24 (SD=0.04)	0.23 (SD=0.05)	0.25 (SD=0.05)	0.25 (SD=0.04)	0.25 (SD=0.05)	0.25 (SD=0.04)	0.25 (SD=0.05)	0.23 (SD=0.05)	0.25 (SD=0.05)	0.23 (SD=0.05)
		0.2 (SD=0.05)	0.21 (SD=0.05)	0.22 (SD=0.06)	0.23 (SD=0.05)	0.23 (SD=0.05)	0.25 (SD=0.06)	0.23 (SD=0.05)	0.23 (SD=0.06)	0.24 (SD=0.06)	0.24 (SD=0.05)	0.21 (SD=0.05)
F0	F	202.26 (SD=26.14)	197.51 (SD=29.77)	197.48 (SD=25.48)	195.77 (SD=24.6)	190.62 (SD=23.72)	190.29 (SD=24.88)	190.94 (SD=24.49)	191.83 (SD=24.97)	194.12 (SD=25.23)	196.05 (SD=26.78)	200.21 (SD=25.91)
		118.12 (SD=21.56)	113.46 (SD=20.17)	115.04 (SD=21.02)	114.87 (SD=19.3)	108.51 (SD=18.94)	110.06 (SD=20.16)	109.15 (SD=21.28)	113.48 (SD=25.12)	111.96 (SD=20.08)	118.94 (SD=21.93)	115.61 (SD=18.52)
F1	F	379.73 (SD=40.28)	365.11 (SD=33.21)	394.43 (SD=29.37)	428.32 (SD=43.19)	789.24 (SD=98.65)	840.84 (SD=122.92)	641 (SD=76.26)	615.78 (SD=74.78)	652.24 (SD=84.95)	443.45 (SD=46.98)	398.69 (SD=37.25)
		310.53 (SD=36.19)	298.85 (SD=35.72)	332.16 (SD=39.26)	393.81 (SD=41.04)	683.73 (SD=65.1)	727.05 (SD=62.18)	543.16 (SD=44.26)	548.09 (SD=45.31)	578.64 (SD=57.42)	423.07 (SD=28.97)	350.19 (SD=33.43)
F2	F	2070.82 (SD=200.88)	1997.58 (SD=175.05)	1776.61 (SD=114.1)	2406.57 (SD=310.74)	1801.31 (SD=128.8)	1648.55 (SD=88.26)	1529.59 (SD=94.52)	1304.61 (SD=114.89)	1055.28 (SD=107.03)	770.11 (SD=93.38)	786.72 (SD=105.56)
		1937.17 (SD=184.55)	1864.78 (SD=169.32)	1602.27 (SD=81.54)	2106.4 (SD=150.09)	1573.55 (SD=111.05)	1469.25 (SD=109.55)	1335.38 (SD=118.33)	1136.89 (SD=88.89)	883.2 (SD=81.81)	712.57 (SD=78.05)	768.6 (SD=73.48)
F3	F	3148.44 (SD=360.71)	3273.13 (SD=139.43)	2658.86 (SD=173.38)	3063.51 (SD=168.32)	2764.53 (SD=243.69)	2726.22 (SD=273.58)	2681.93 (SD=144.12)	2746.77 (SD=138.83)	2860.06 (SD=197.94)	2921.52 (SD=187.61)	2844.49 (SD=185.93)
		2937.13 (SD=115.16)	2821.75 (SD=107.5)	2368.81 (SD=119.22)	2693.68 (SD=138.95)	2492.35 (SD=176.49)	2498.89 (SD=163.73)	2375.36 (SD=204.2)	2401.73 (SD=160.65)	2671.62 (SD=219.92)	2653.25 (SD=170.04)	2548.81 (SD=148.75)

Table S2

The spectral and temporal properties of the short vowels (averaged across talkers, by gender in Hertz)

Cue	Gender	[i]	[y]	[e]	[ɛ]	[æ]	[ø]	[œ]	[a]	[ɔ]	[o]
Duration	F	0.12 (SD=0.02)	0.12 (SD=0.02)	0.13 (SD=0.02)	0.12 (SD=0.02)	0.16 (SD=0.03)	0.12 (SD=0.03)	0.17 (SD=0.03)	0.13 (SD=0.03)	0.13 (SD=0.02)	0.13 (SD=0.03)
	M	0.11 (SD=0.02)	0.11 (SD=0.03)	0.13 (SD=0.02)	0.12 (SD=0.02)	0.13 (SD=0.03)	0.12 (SD=0.03)	0.14 (SD=0.03)	0.13 (SD=0.02)	0.12 (SD=0.02)	0.12 (SD=0.03)
F0	F	218.55 (SD=29.41)	221.58 (SD=27.82)	219.72 (SD=28.7)	213.5 (SD=26.46)	203.8 (SD=28.32)	214.19 (SD=26.7)	206.31 (SD=26.72)	208.47 (SD=26.74)	214.02 (SD=28.06)	224.89 (SD=28.4)
	M	128.98 (SD=19.73)	130.12 (SD=18.44)	128.58 (SD=19.22)	119.25 (SD=21.69)	119.05 (SD=20.05)	125.29 (SD=17.45)	123.63 (SD=19.27)	117.74 (SD=19.19)	123.68 (SD=19.17)	132.89 (SD=18.48)
F1	F	385.31 (SD=38.08)	387.64 (SD=36.94)	424.93 (SD=36.49)	635.03 (SD=69.25)	799.8 (SD=100.22)	573.8 (SD=64.24)	532.76 (SD=55.58)	788.18 (SD=99.76)	501.44 (SD=54.57)	418.49 (SD=37.01)
	M	330.61 (SD=30.04)	334.94 (SD=31.31)	379.7 (SD=35.54)	547.46 (SD=41.76)	703.17 (SD=51.91)	494.75 (SD=38.76)	499.02 (SD=37.88)	687.54 (SD=55.08)	459.94 (SD=40.86)	371.24 (SD=28.89)
F2	F	2511.76 (SD=288.04)	2376.37 (SD=157.36)	1329.55 (SD=115.67)	1946.83 (SD=181.2)	1755.92 (SD=143.49)	1666.86 (SD=114.75)	1405.18 (SD=156.48)	1372.95 (SD=99.7)	937.21 (SD=97.85)	854.39 (SD=109.9)
	M	2242.23 (SD=124.13)	2012.84 (SD=105.02)	1166.35 (SD=87.07)	1720.93 (SD=112.77)	1517.06 (SD=113.71)	1417.46 (SD=136.96)	1205.86 (SD=90.4)	1134.2 (SD=86.67)	793.65 (SD=75.38)	768.48 (SD=76.95)
F3	F	3081.21 (SD=171.41)	2804.95 (SD=166.88)	2780.03 (SD=197.87)	2735 (SD=247.64)	2791.93 (SD=262.46)	2704.28 (SD=162.68)	2781.63 (SD=175.79)	2844.63 (SD=268.99)	3035.1 (SD=189.32)	2940.08 (SD=182.4)
	M	2757.15 (SD=137.69)	2462.19 (SD=109.26)	2442.7 (SD=138.25)	2501.48 (SD=153.16)	2532.25 (SD=157.51)	2426.6 (SD=140.27)	2440.67 (SD=159.42)	2662.24 (SD=207.5)	2724.42 (SD=184.96)	2605.44 (SD=146.73)

S1.5 Cue matrix plot in unnormalized Hertz

Figure S3 displays the pairwise combinations of the five spectral and temporal cues—F0, F1, F2, F3 and duration—in raw Hertz. For F0, there are two overlapping but separated peaks, reflecting the overall difference in vocal tract size for the two groups of female and male talkers in the database.

S1.6 Talker differences in the [i:] - [y:] contrast

Figure S4 visualizes two example talkers that differ in their phonetic realization of [i:] - [y:] when F3 is considered.

S1.7 Additional information concerning static analyses**S1.7.1 Summary tables of LMMs predicting category separability from cue**

space

Table S3
LMMs predicting category separability from cue space

<i>unrounded vs. outrounded</i>			
	[i:] vs. [y:]	[e:] vs. [y:]	[ɪ] vs. [Y]
(Intercept)	0.091 se = 0.008 t-value = 10.765 p.value = <0.001	0.319 se = 0.013 t-value = 25.329 p.value = <0.001	0.145 se = 0.0097 t-value = 15.0 p.value = <0.001
cue space F1F2F3	0.032 se = 0.01 t-value = 3.191 p.value = <0.003	0.012 se = 0.002 t-value = 5.916 p.value = <0.001	0.045 se = 0.004 t-value = 11.57 p.value = <0.001
SD (Intercept Talker)	0.028	0.08	0.059
SD (Observations)	0.046	0.009	0.018

<i>outrounded vs. inrounded</i>			
	[y:] vs. [ɯ:]	[o:] vs. [u:]	[ɔ] vs. [ʊ]
(Intercept)	0.191 se = 0.013 t-value = 15.2 p.value = <0.001	0.1999 se = 0.012 t-value = 17.2 p.value = <0.001	0.244 se = 0.012 t-value = 19.98 p.value = <0.001
cue space F1F2F3	0.099 se = 0.008 t-value = 13.02 p.value = <0.001	0.014 se = 0.0016 t-value = 8.95 p.value = <0.001	0.01 se = 0.0017 t-value = 6.29 p.value = <0.001
SD (Intercept Talker)	0.073	0.074	0.077
SD (Observations)	0.034	0.007	0.0078

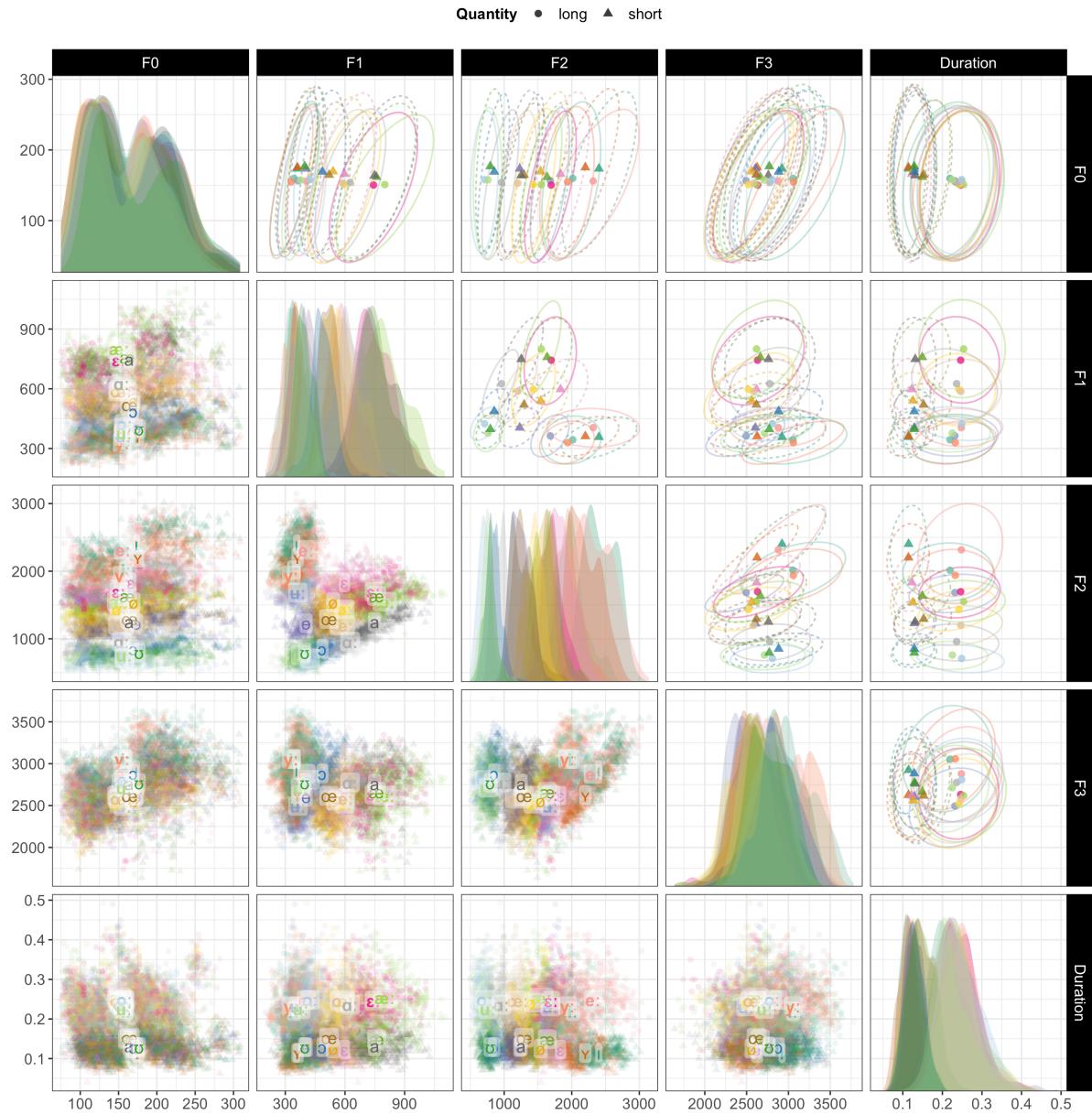


Figure S3. The SwehVd vowels in unnormalized Hertz space. Points show recordings of each of the 21 Central Swedish vowels by the talkers in the database in all five cue spaces, averaged across the three midpoints. Vowel labels indicate vowel means across talkers. Ellipses show bivariate Gaussian 95% confidence interval of vowel means. Note that, unlike in Figure 1, axis directions are not reversed. Vowels that mismatched the intended label are excluded (1.21% of all recordings).

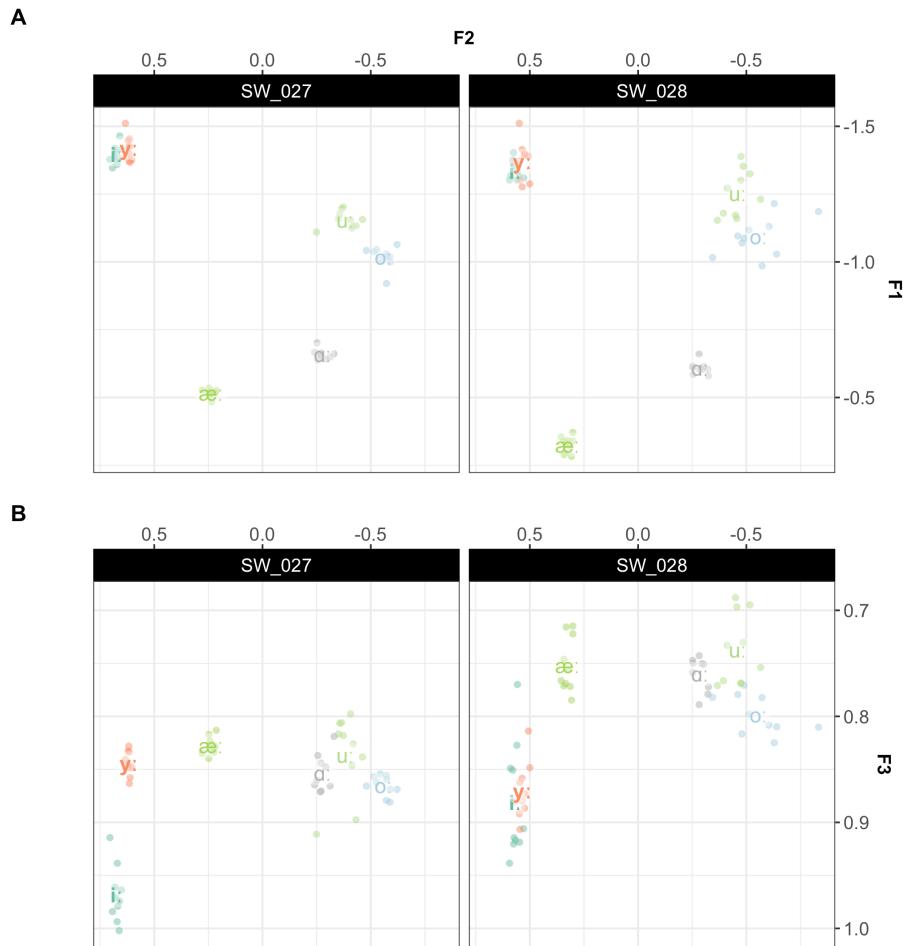


Figure S4. The effect of including F3 for the [i:] - [y:] distinction, illustrated in a reduced vowel space. **Panel A** shows two example talkers with overlapping [i:] - [y:] in F1-F2 space. **Panel B** shows how considering F3 affects the space: for talker SW_028, there is very little effect of F3, thus maintained [i:] - [y:] overlap, while for talker SW_027, separability increases.

Table S4

LMMs predicting category separability from cue space for all long-short contrasts

	[i:] vs. [ɪ]	[y:] vs. [ʏ]	[ɯ:] vs. [œ]	[ɛ:] vs. [ε]	[ε:] vs. [ɛ]	[æ:] vs. [æ]
<i>long vs. short</i>						
(Intercept)	0.23 se = 0.012 t-value = 18.584 p.value = <0.001	0.201 se = 0.01 t-value = 20.899 p.value = <0.001	0.348 se = 0.014 t-value = 24.974 p.value = <0.001	0.468 se = 0.018 t-value = 26.61 p.value = <0.001	0.243 se = 0.016 t-value = 15.375 p.value = <0.001	0.12 se = 0.014 t-value = 8.853 p.value = <0.001
cue space F1F2F3	0.025 se = 0.005 t-value = 5.444 p.value = <0.0001	0.058 se = 0.004 t-value = 14.004 p.value = <0.001	0.008 se = 0.002 t-value = 4.049 p.value = 0.00012	0.015 se = 0.003 t-value = 5.381 p.value = <0.001	0.01 se = 0.004 t-value = 2.678 p.value = 0.009	0.025 se = 0.007 t-value = 3.473 p.value = 0.0008
cue space F1F2Duration	0.028 se = 0.005 t-value = 6.27 p.value = <0.001	0.037 se = 0.004 t-value = 8.956 p.value = <0.001	0.019 se = 0.002 t-value = 9.882 p.value = <0.001	0.019 se = 0.003 t-value = 7.074 p.value = <0.001	0.038 se = 0.004 t-value = 9.806 p.value = <0.001	0.049 se = 0.007 t-value = 6.814 p.value = <0.001
SD (Intercept Talker)	0.076	0.059	0.089	0.112	0.1	0.081
SD (Observations)	0.02	0.019	0.008	0.012	0.017	0.033
<i>long vs. short</i>						
	[œ] vs. [ø]	[æ:] vs. [æ]	[ɑ:] vs. [a]	[ɔ:] vs. [ɔ]	[ɯ:] vs. [ʊ]	
(Intercept)	0.154 se = 0.011 t-value = 13.765 p.value = <0.001	0.169 se = 0.013 t-value = 12.851 p.value = <0.001	0.334 se = 0.013 t-value = 25.325 p.value = <0.001	0.257 se = 0.016 t-value = 15.713 p.value = <0.001	0.146 se = 0.01 t-value = 14.013 p.value = <0.001	
cue space F1F2F3	0.011 se = 0.004 t-value = 2.924 p.value = 0.00449	0.009 se = 0.003 t-value = 2.636 p.value = 0.0101	0.011 se = 0.003 t-value = 3.756 p.value = 0.0003	0.0085 se = 0.003 t-value = 3.162 p.value = 0.0022	0.014 se = 0.003 t-value = 4.183 p.value = <0.001	
cue space F1F2Duration	0.0476 se = 0.004 t-value = 12.292 p.value = <0.001	0.0313 se = 0.003 t-value = 9.074 p.value = <0.001	0.011 se = 0.003 t-value = 6.197 p.value = <0.001	0.033 se = 0.003 t-value = 12.279 p.value = <0.001	0.037 se = 0.003 t-value = 11.177 p.value = <0.001	
SD (Intercept Talker)	0.069	0.083	0.083	0.104	0.064	
SD (Observations)	0.0175	0.0156	0.013	0.012	0.015	

S1.7.2 Category separability indices for additional cue combinations

Mirroring results from Figure 6, Figure S5 indicates that the F1-F2-duration combination generates the highest category separability for all vowel pairs besides the [y:] - [y] contrast, for which F1-F2-F3 achieves higher separability. The second highest separability is overall achieved by F1-F2-F3, besides for the [ε:] - [ε], [æ:] - [æ], [ø:] - [ø] and [œ:] - [œ] contrasts where F1-duration achieves the second best separability, and for [u:] - [u], for which F2-duration is second-best. This would seem to suggest duration dependencies for these contrasts. Interestingly, for several contrasts, the category separability combining one spectral cue with duration decreases relative to F1-F2, highlighting the reliance on spectral cues for these quantity contrasts (e.g., [u:] - [ø], [ε:] - [ε], [o:] - [ɔ], [æ:] - [a]).

For the [i:] - [ɪ], [u:] - [ø], [o:] - [ɔ], [u:] - [v] and [æ:] - [a] vowel pairs, the F1-F3 cue combination decreases separability most relative to F1-F2 baseline, which would seem to suggest the informativity of F2 for distinguishing between these pairs. For the allophones to /ε/ and /ø/: [ε:] - [ε], [ε:] - [ε], [æ:] - [æ], [ø:] - [ø] and [œ:] - [œ], the F2-F3 cue combination produces the lowest separability, presumably highlighting the importance of F1.

S1.7.3 Category separability assuming talker-independent representations

The category separability index presented in the main paper assumed talker-specific category representations. Given that the data is normalized using Nearey's uniform scaling, one might instead argue talker-independent representations. Figures S6 and S7 visualize the category separability index for both the rounding and the quantity evaluations while assuming talker-independent representations. As indicated in Figures S6 and S7, the overall results replicate in both evaluations. Of note, Figure S6 suggests that the relative increase in category separability for the [i:] - [y:] contrast when including F3 might possibly be driven by between-talker differences in the realizations of these vowels. There is further a smaller relative benefit of including duration comparing to F3 for the [æ:] - [æ] and [ø:] - [ø] contrasts when talker-independent representations are assumed.

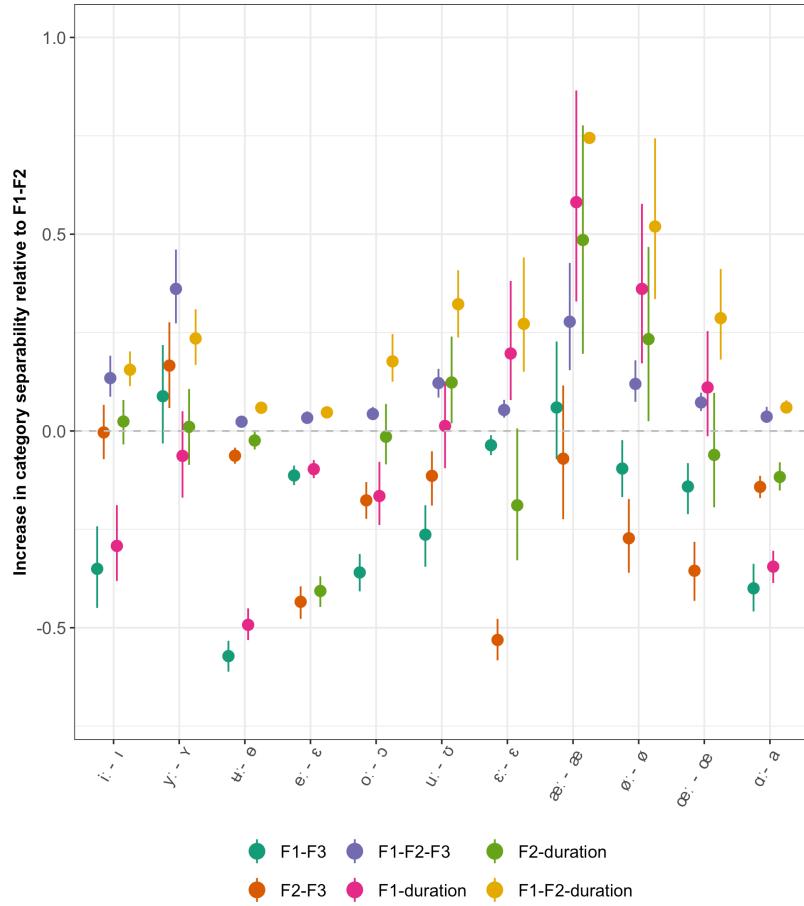


Figure S5. The increase in category separability relative to F1-F2-baseline for different cue combinations and the long-short vowel pairs. Pointranges indicate mean and 95% bootstrapped CIs of the category separability summarized across talkers for each cue combination.

¹³⁷⁸ S1.8 Additional information concerning dynamic analyses

¹³⁷⁹ S1.8.1 Summary tables of GAMMs

¹³⁸⁰ S1.8.2 Visualizations of GAMMs

¹³⁸¹ Figures S8, S9, S10, S11, S12, and S13 visualize the GAMMs fit to the long-short vowel
¹³⁸² pairs.

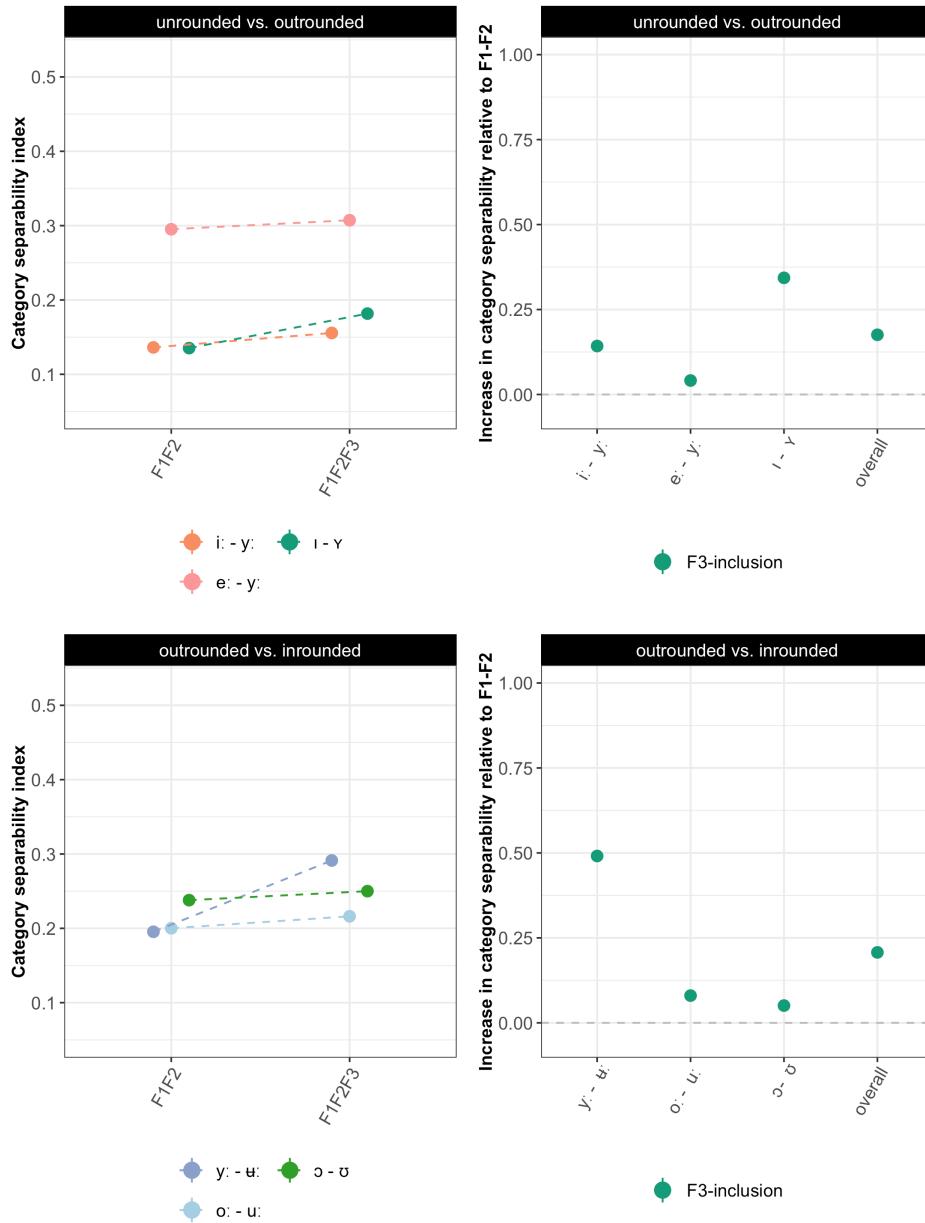


Figure S6. The effect of including F3 in measures of category separability for the distinction between neighboring unrounded vs. outrounded vowels (**top row**), and outrounded vs. inrounded vowels (**bottom row**), under the assumption of talker-independent representations. **Left panels** plot the category separability for F1-F2 and F1-F2-F3 cue combinations. **Right panels** plot the proportional increase in category separability relative to F1-F2-baseline. Axis ranges are held constant across columns.

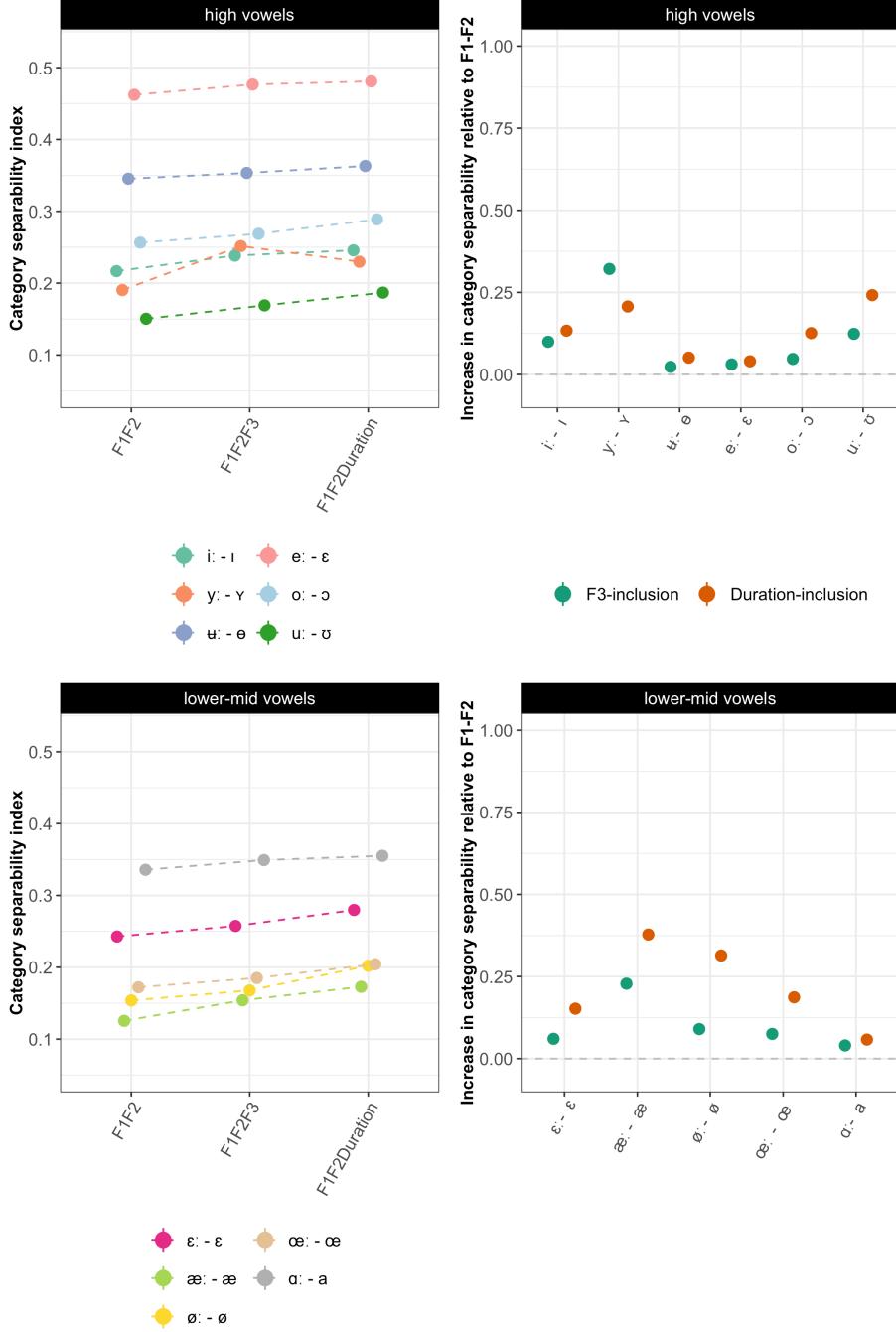


Figure S7. The effect of including F3 and duration in measures of category separability for long-short vowel pair distinctions, under the assumption of talker-independent representations. For visualization purposes, the pairs are split into high vowels (**top row**), and lower-mid vowels (**bottom row**). **Left panels** plot the category separability for F1-F2, F1-F2-F3 and F1-F2-duration cue combinations. **Right panels** plot the increase in category separability relative to F1-F2-baseline. Axis ranges are held constant across columns.

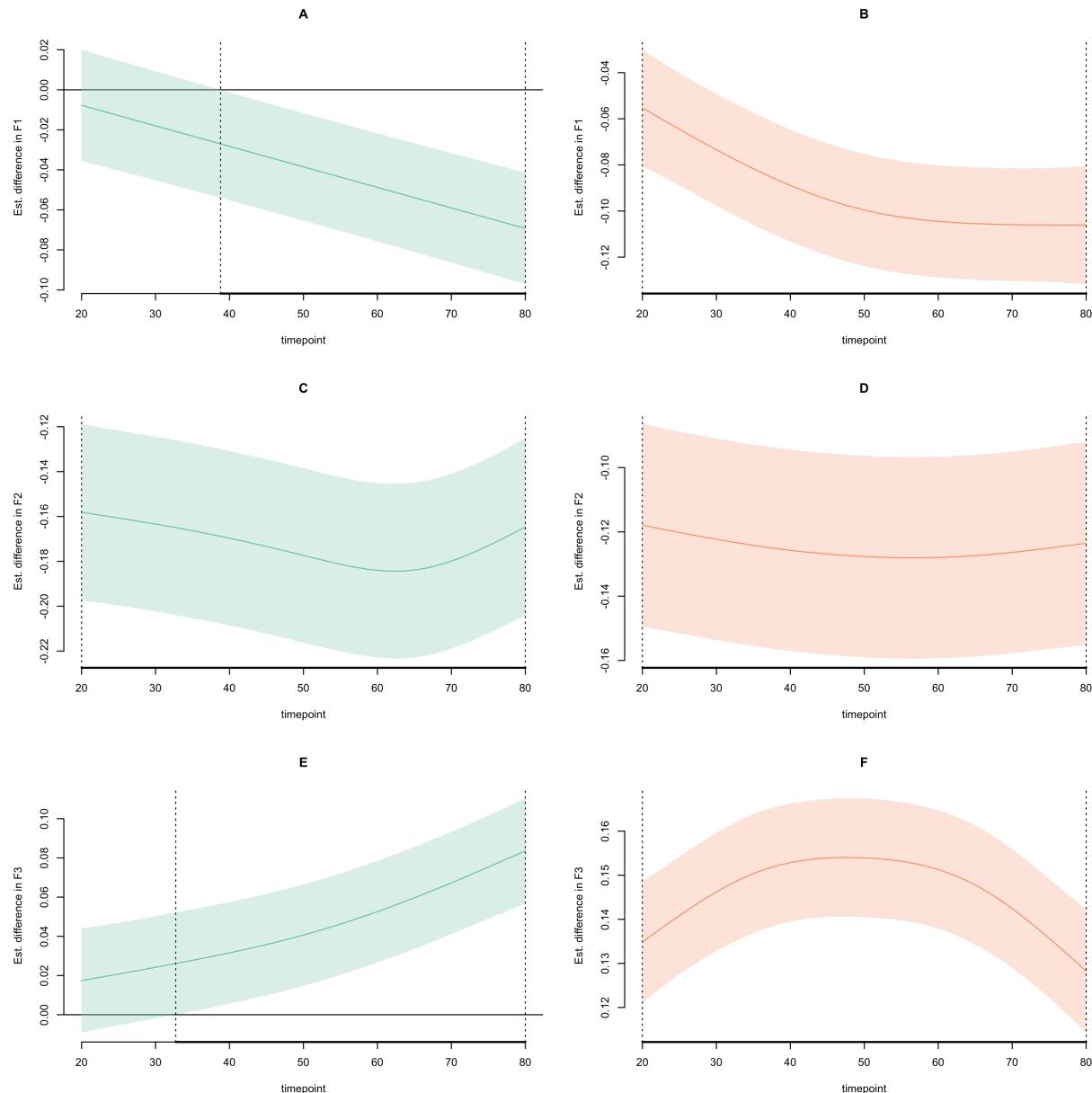


Figure S8. Fitted smooths of GAMM for predicting F1-F2-F3 and 95% confidence intervals for the [i]-[ɪ] (**left**) and [y]-[ʏ] (**right**) vowel pairs.

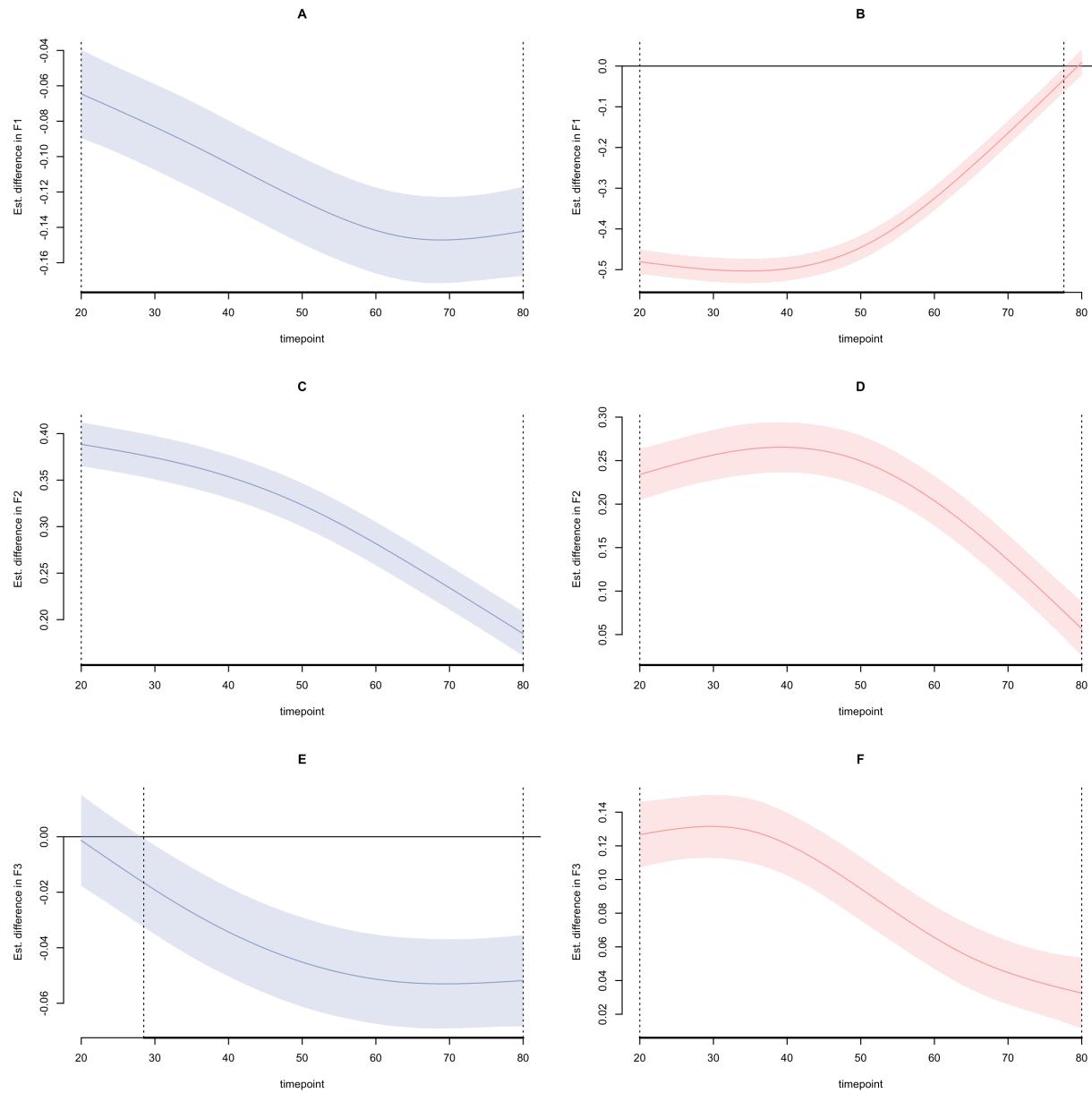


Figure S9. Fitted smooths of GAMM for predicting F1-F2-F3 and 95% confidence intervals for the [ɛ]-[ø] (**left**) and [e:]-[ɛ] (**right**) vowel pairs.

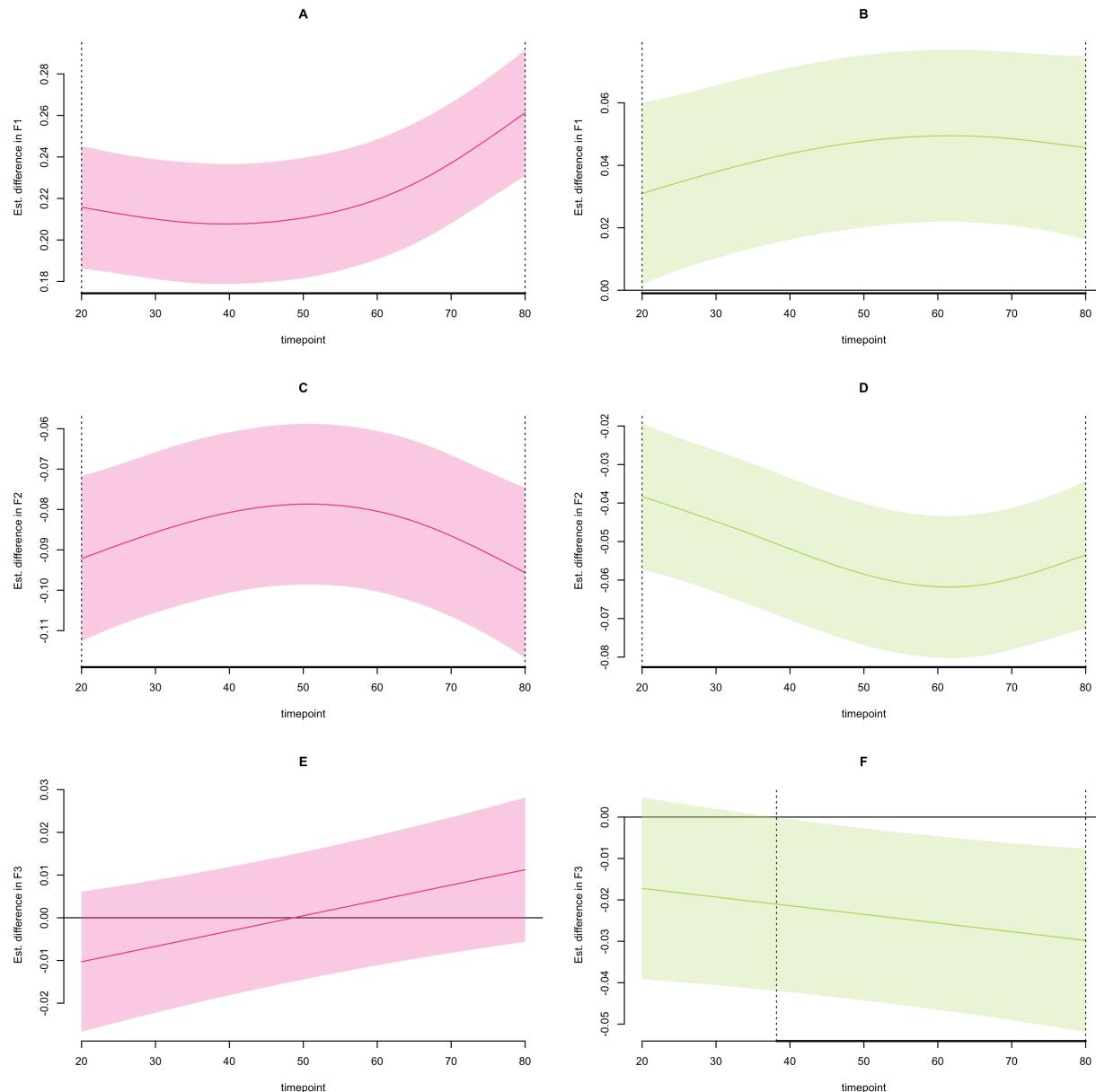


Figure S10. Fitted smooths of GAMM for predicting F1-F2-F3 and 95% confidence intervals for the [ε:]-[ɛ] (**left**) and [æ:]-[æ] (**right**) vowel pairs.

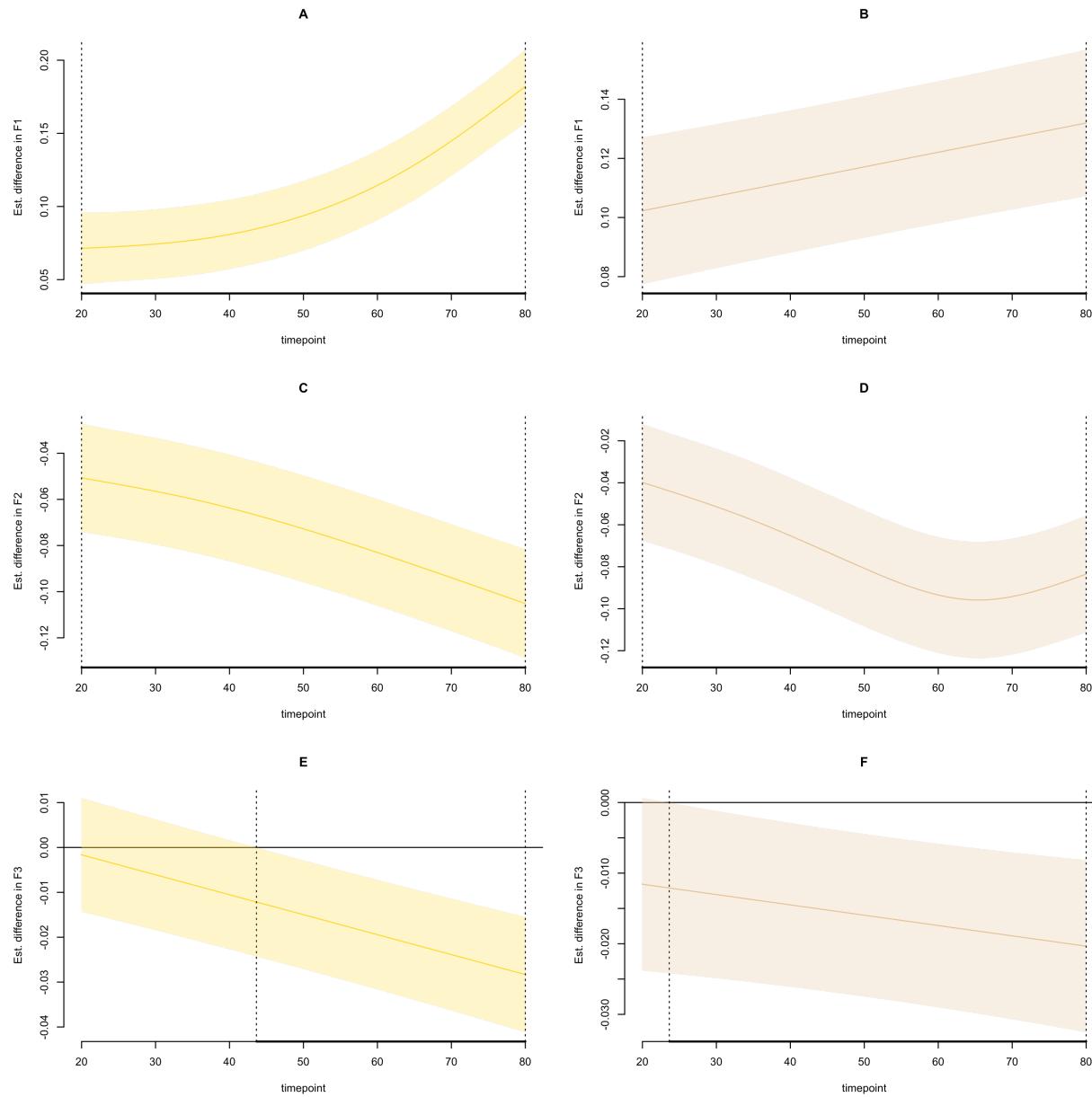


Figure S11. Fitted smooths of GAMM for predicting F1-F2-F3 and 95% confidence intervals for the [ø:]-[ø] (**left**) and [œ:]-[œ] (**right**) vowel pairs.

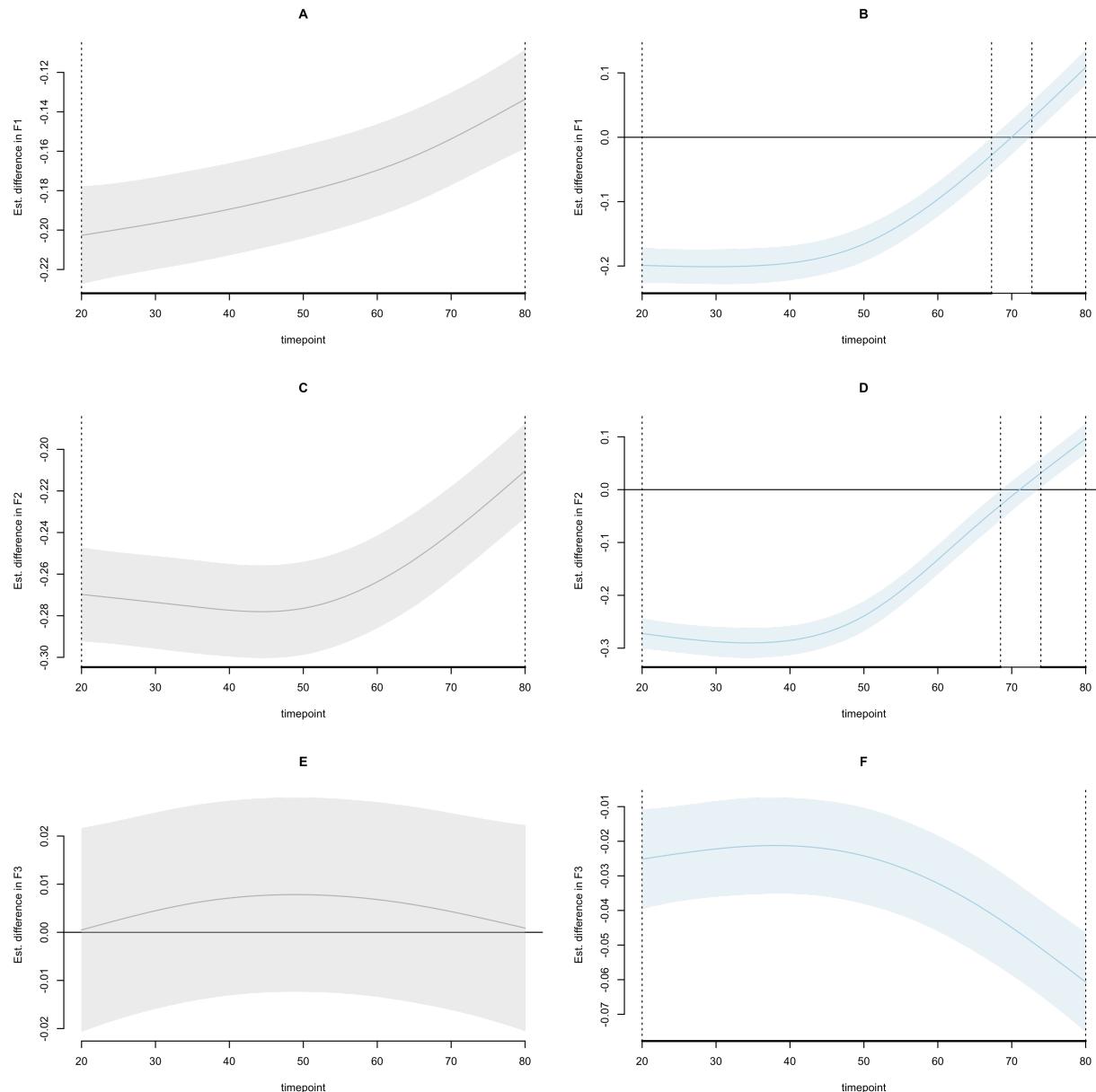


Figure S12. Fitted smooths of GAMM for predicting F1-F2-F3 and 95% confidence intervals for the [ɑ:]-[a] (**left**) and [o:]-[œ] (**right**) vowel pairs.

Table S5

Model summary, coefficients for parametric and smooth terms for [i:] - [y:] predicting F1

A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	-1.2505	0.0175	-71.6225	< 0.0001
category [y:]	-0.0290	0.0051	-5.6460	< 0.0001
Gendermale	-0.0793	0.0244	-3.2529	0.0012
B. smooth terms	edf	Ref.df	F-value	p-value
s(timepoint)	3.0168	3.4940	49.7632	< 0.0001
s(timepoint):category [y:]	1.8190	2.2251	1.0603	0.4002
s(Talker)	35.5354	39.0000	519.3428	< 0.0001
s(Talker,category)	37.2811	79.0000	22.0717	0.0987

Table S6

Model summary, coefficients for parametric and smooth terms for [i:] - [y:] predicting F2

A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	0.4445	0.0185	24.0769	< 0.0001
category [y:]	-0.0259	0.0038	-6.7647	< 0.0001
Gendermale	0.0539	0.0258	2.0876	0.0369
B. smooth terms	edf	Ref.df	F-value	p-value
s(timepoint)	2.4321	2.9246	26.6703	< 0.0001
s(timepoint):category [y:]	1.5879	1.9288	1.0032	0.4309
s(Talker)	37.2737	39.0000	3559.5780	< 0.0001
s(Talker,category)	38.4339	79.0000	69.9332	0.3622

Table S7

Model summary, coefficients for parametric and smooth terms for [i:] - [y:] predicting F3

A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	0.8997	0.0119	75.8438	< 0.0001
category [y:]	-0.0021	0.0102	-0.2023	0.8397
Gendermale	0.0163	0.0166	0.9830	0.3257
B. smooth terms	edf	Ref.df	F-value	p-value
s(timepoint)	1.0001	1.0002	19.2566	< 0.0001
s(timepoint):category [y:]	2.7282	3.2476	6.8551	0.0001
s(Talker)	9.5569	39.0000	216.3509	0.0605
s(Talker,category)	68.0168	79.0000	347.3984	< 0.0001

Table S8

Model summary, coefficients for parametric and smooth terms for [i:] - [ɯ:] predicting F1

A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	-1.2127	0.0161	-75.3482	< 0.0001
category [ɯ:]	0.0336	0.0081	4.1184	< 0.0001
Gendermale	-0.0663	0.0225	-2.9509	0.0032
B. smooth terms	edf	Ref.df	F-value	p-value
s(timepoint)	3.0241	3.4728	46.6752	< 0.0001
s(timepoint):category [ɯ:]	3.0198	3.4684	21.0872	< 0.0001
s(Talker)	28.7465	39.0000	709.6758	< 0.0001
s(Talker,category)	47.3292	79.0000	121.4009	0.0251

Table S9

Model summary, coefficients for parametric and smooth terms for [i:] - [ɯ:] predicting F2

A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	0.3865	0.0131	29.4871	< 0.0001
category [ɯ:]	-0.1204	0.0091	-13.1598	< 0.0001
Gendermale	0.0368	0.0183	2.0105	0.0445
B. smooth terms	edf	Ref.df	F-value	p-value
s(timepoint)	1.8214	2.2273	29.9642	< 0.0001
s(timepoint):category [ɯ:]	2.9817	3.4626	81.3483	< 0.0001
s(Talker)	19.5350	39.0000	2205.8452	0.0017
s(Talker,category)	58.5627	79.0000	1071.5104	0.0019

Table S10

Model summary, coefficients for parametric and smooth terms for [i:] - [ɯ:] predicting F3

A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	0.7963	0.0113	70.5968	< 0.0001
category [ɯ:]	-0.1368	0.0111	-12.2835	< 0.0001
Gendermale	0.0321	0.0158	2.0365	0.0418
B. smooth terms	edf	Ref.df	F-value	p-value
s(timepoint)	1.6940	2.0710	8.8735	0.0001
s(timepoint):category [ɯ:]	2.9234	3.4138	10.9632	< 0.0001
s(Talker)	0.0001	39.0000	0.0000	0.7681
s(Talker,category)	77.4959	79.0000	54.7815	< 0.0001

Table S11

Model summary, coefficients for parametric and smooth terms for [i:] - [e:] predicting F1

A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	-1.1692	0.0139	-84.2519	< 0.0001
category [e:]	0.1307	0.0119	10.9686	< 0.0001
Gendermale	-0.0176	0.0194	-0.9067	0.3646
B. smooth terms	edf	Ref.df	F-value	p-value
s(timepoint)	2.7489	3.2572	46.3007	< 0.0001
s(timepoint):category [e:]	3.8695	3.9748	790.8174	< 0.0001
s(Talker)	9.5453	39.0000	87.1163	0.0580
s(Talker,category)	67.0920	79.0000	162.7500	< 0.0001

Table S12

Model summary, coefficients for parametric and smooth terms for [i:] - [e:] predicting F2

A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	0.5364	0.0145	36.9465	< 0.0001
category [e:]	0.0800	0.0143	5.5759	< 0.0001
Gendermale	0.0209	0.0203	1.0278	0.3041
B. smooth terms	edf	Ref.df	F-value	p-value
s(timepoint)	1.2386	1.4340	16.9517	< 0.0001
s(timepoint):category [e:]	3.7960	3.9729	264.2232	< 0.0001
s(Talker)	0.0019	39.0000	0.0001	0.4672
s(Talker,category)	77.3206	79.0000	52.8965	< 0.0001

Table S13

Model summary, coefficients for parametric and smooth terms for [i:] - [e:] predicting F3

A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	0.8664	0.0131	66.0824	< 0.0001
category [e:]	-0.0417	0.0096	-4.3198	< 0.0001
Gendermale	0.0265	0.0183	1.4446	0.1487
B. smooth terms	edf	Ref.df	F-value	p-value
s(timepoint)	1.0001	1.0001	14.3112	0.0002
s(timepoint):category [e:]	3.5533	3.8876	63.5281	< 0.0001
s(Talker)	17.3913	39.0000	366.7896	0.0004
s(Talker,category)	59.3862	79.0000	225.6487	< 0.0001

Table S14

Model summary, coefficients for parametric and smooth terms for the high front short vowels predicting F1

A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	-1.2153	0.0127	-95.5924	< 0.0001
category [Y]	0.0075	0.0067	1.1083	0.2678
Gendermale	-0.0254	0.0178	-1.4318	0.1523
B. smooth terms	edf	Ref.df	F-value	p-value
s(timepoint)	2.3979	2.9060	3.3187	0.0175
s(timepoint):category [Y]	1.0000	1.0000	4.2695	0.0389
s(Talker)	27.7413	39.0000	468.5362	< 0.0001
s(Talker,category)	47.9833	79.0000	90.8256	0.0206

Table S15

Model summary, coefficients for parametric and smooth terms for the high front short vowels predicting F2

A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	0.6273	0.0128	48.8949	< 0.0001
category [Y]	-0.0586	0.0116	-5.0568	< 0.0001
Gendermale	-0.0149	0.0179	-0.8331	0.4048
B. smooth terms	edf	Ref.df	F-value	p-value
s(timepoint)	3.3278	3.7567	13.3047	< 0.0001
s(timepoint):category [Y]	1.0000	1.0001	3.1409	0.0764
s(Talker)	6.3833	39.0000	86.6745	0.1901
s(Talker,category)	71.1834	79.0000	263.8538	< 0.0001

Table S16

Model summary, coefficients for parametric and smooth terms for the high front short vowels predicting F3

A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	0.8120	0.0094	86.7831	< 0.0001
category [Y]	-0.0727	0.0050	-14.5131	< 0.0001
Gendermale	0.0044	0.0131	0.3376	0.7357
B. smooth terms	edf	Ref.df	F-value	p-value
s(timepoint)	2.7760	3.2549	65.5966	< 0.0001
s(timepoint):category [Y]	3.0148	3.4704	52.0579	< 0.0001
s(Talker)	27.5301	39.0000	645.2514	< 0.0001
s(Talker,category)	48.8674	79.0000	133.6283	0.0486

Table S17

Model summary, coefficients for parametric and smooth terms for the high back long vowels predicting F1

A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	-1.1296	0.0124	-91.4148	< 0.0001
category [u:]	-0.1061	0.0091	-11.6801	< 0.0001
Gendermale	0.0329	0.0173	1.9054	0.0568
B. smooth terms	edf	Ref.df	F-value	p-value
s(timepoint)	3.7637	3.9505	416.3048	< 0.0001
s(timepoint):category [u:]	3.6849	3.9255	369.2896	< 0.0001
s(Talker)	17.3835	39.0000	94.2355	0.0032
s(Talker,category)	57.6310	79.0000	63.2542	< 0.0001

Table S18

Model summary, coefficients for parametric and smooth terms for the high back long vowels predicting F2

A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	-0.5157	0.0174	-29.5961	< 0.0001
category [u:]	0.0398	0.0103	3.8663	0.0001
Gendermale	0.0682	0.0243	2.8031	0.0051
B. smooth terms	edf	Ref.df	F-value	p-value
s(timepoint)	3.8784	3.9843	884.3931	< 0.0001
s(timepoint):category [u:]	3.7862	3.9658	174.8411	< 0.0001
s(Talker)	25.0350	39.0000	134.7690	< 0.0001
s(Talker,category)	48.6357	79.0000	36.1400	0.0058

Table S19

Model summary, coefficients for parametric and smooth terms for the high back long vowels predicting F3

A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	0.7881	0.0120	65.5786	< 0.0001
category [u:]	-0.0236	0.0051	-4.6657	< 0.0001
Gendermale	0.0267	0.0168	1.5887	0.1122
B. smooth terms	edf	Ref.df	F-value	p-value
s(timepoint)	3.2571	3.6883	15.2473	< 0.0001
s(timepoint):category [u:]	1.6521	2.0207	19.1269	< 0.0001
s(Talker)	31.8986	39.0000	812.7661	< 0.0001
s(Talker,category)	43.8638	79.0000	89.2372	0.1221

Table S20

Model summary, coefficients for parametric and smooth terms for the high back short vowels predicting F1

A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	-1.0462	0.0116	-89.8077	< 0.0001
category [u]	-0.1386	0.0097	-14.2818	< 0.0001
Gendermale	0.0232	0.0162	1.4336	0.1518
B. smooth terms	edf	Ref.df	F-value	p-value
s(timepoint)	3.0603	3.5497	75.9391	< 0.0001
s(timepoint):category [u]	1.0002	1.0003	5.4461	0.0197
s(Talker)	10.9301	39.0000	104.7983	0.0852
s(Talker,category)	64.8352	78.0000	148.9877	< 0.0001

Table S21

Model summary, coefficients for parametric and smooth terms for the high back short vowels predicting F2

A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	-0.3769	0.0156	-24.2012	< 0.0001
category [u]	-0.0424	0.0088	-4.8025	< 0.0001
Gendermale	-0.0112	0.0217	-0.5154	0.6063
B. smooth terms	edf	Ref.df	F-value	p-value
s(timepoint)	3.5562	3.8467	76.9066	< 0.0001
s(timepoint):category [u]	2.7071	3.1932	71.2364	< 0.0001
s(Talker)	26.0859	39.0000	272.0183	< 0.0001
s(Talker,category)	48.0521	78.0000	66.7823	0.0096

Table S22

Model summary, coefficients for parametric and smooth terms for the high back short vowels predicting F3

A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	0.8255	0.0113	73.0739	< 0.0001
category [u]	-0.0292	0.0056	-5.2185	< 0.0001
Gendermale	0.0124	0.0157	0.7887	0.4303
B. smooth terms	edf	Ref.df	F-value	p-value
s(timepoint)	1.0001	1.0002	95.7868	< 0.0001
s(timepoint):category [u]	1.9991	2.4488	6.2454	0.0015
s(Talker)	29.1275	39.0000	2403.7161	< 0.0001
s(Talker,category)	47.3171	78.0000	374.0028	0.0998

Table S23

Model summary, coefficients for parametric and smooth terms for the lower-mid front long vowels predicting F1

A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	-0.4664	0.0205	-22.7936	< 0.0001
category [æ:]	0.0460	0.0084	5.4424	< 0.0001
Gendermale	-0.0209	0.0286	-0.7300	0.4655
B. smooth terms	edf	Ref.df	F-value	p-value
s(timepoint)	2.3985	2.8801	5.5492	0.0009
s(timepoint):category [æ:]	2.9271	3.4029	42.2298	< 0.0001
s(Talker)	32.1863	39.0000	852.9541	< 0.0001
s(Talker,category)	43.1275	79.0000	89.3690	0.0311

Table S24

Model summary, coefficients for parametric and smooth terms for the lower-mid front long vowels predicting F2

A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	0.2778	0.0099	28.0182	< 0.0001
category [æ:]	-0.0559	0.0065	-8.6094	< 0.0001
Gendermale	-0.0062	0.0139	-0.4452	0.6562
B. smooth terms	edf	Ref.df	F-value	p-value
s(timepoint)	3.4254	3.7885	244.3314	< 0.0001
s(timepoint):category [æ:]	3.6101	3.8806	242.5392	< 0.0001
s(Talker)	21.8765	39.0000	1052.7781	< 0.0001
s(Talker,category)	55.3558	79.0000	410.4479	0.0004

Table S25

Model summary, coefficients for parametric and smooth terms for the lower-mid front long vowels predicting F3

A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	0.7418	0.0160	46.4515	< 0.0001
category [æ:]	-0.0063	0.0071	-0.8957	0.3705
Gendermale	0.0264	0.0223	1.1837	0.2366
B. smooth terms	edf	Ref.df	F-value	p-value
s(timepoint)	2.5570	3.0749	18.5927	< 0.0001
s(timepoint):category [æ:]	1.0000	1.0001	13.8709	0.0002
s(Talker)	31.1397	39.0000	914.4816	< 0.0001
s(Talker,category)	44.5499	79.0000	99.2827	0.0933

Table S26

Model summary, coefficients for parametric and smooth terms for the lower-mid front short vowels predicting F1

A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	-0.6015	0.0130	-46.3345	< 0.0001
category [æ]	0.1726	0.0104	16.5493	< 0.0001
Gendermale	-0.0163	0.0181	-0.8991	0.3687
B. smooth terms	edf	Ref.df	F-value	p-value
s(timepoint)	3.4917	3.8332	51.7731	< 0.0001
s(timepoint):category [æ]	1.9327	2.3680	45.2830	< 0.0001
s(Talker)	13.1542	39.0000	160.7058	0.0705
s(Talker,category)	63.7164	79.0000	177.0030	< 0.0001

Table S27

Model summary, coefficients for parametric and smooth terms for the lower-mid front short vowels predicting F2

A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	0.3499	0.0113	31.0690	< 0.0001
category [æ]	-0.0797	0.0082	-9.6873	< 0.0001
Gendermale	-0.0123	0.0157	-0.7810	0.4349
B. smooth terms	edf	Ref.df	F-value	p-value
s(timepoint)	1.1719	1.3066	365.5786	< 0.0001
s(timepoint):category [æ]	2.3852	2.8844	208.8811	< 0.0001
s(Talker)	17.6245	39.0000	429.5987	0.0028
s(Talker,category)	59.5197	79.0000	269.1815	< 0.0001

Table S28

Model summary, coefficients for parametric and smooth terms for the lower-mid front short vowels predicting F3

A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	0.7520	0.0128	58.8018	< 0.0001
category [æ]	0.0099	0.0055	1.7964	0.0725
Gendermale	0.0297	0.0179	1.6637	0.0963
B. smooth terms	edf	Ref.df	F-value	p-value
s(timepoint)	2.7661	3.2897	4.4730	0.0025
s(timepoint):category [æ]	1.0001	1.0001	0.8789	0.3486
s(Talker)	31.6397	39.0000	296.4814	< 0.0001
s(Talker,category)	41.9894	79.0000	30.9853	0.0725

Table S29

Model summary, coefficients for parametric and smooth terms for the mid center long vowels predicting F1

A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	-0.7265	0.0169	-42.9651	< 0.0001
category [œ:]	-0.0098	0.0073	-1.3412	0.1799
Gendermale	-0.0176	0.0236	-0.7457	0.4559
B. smooth terms	edf	Ref.df	F-value	p-value
s(timepoint)	2.9469	3.4536	4.4850	0.0033
s(timepoint):category [œ:]	1.0001	1.0001	39.1344	< 0.0001
s(Talker)	31.5576	39.0000	1258.5044	< 0.0001
s(Talker,category)	44.6301	79.0000	145.9365	0.0505

Table S30

Model summary, coefficients for parametric and smooth terms for the mid center long vowels predicting F2

A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	0.0744	0.0117	6.3573	< 0.0001
category [œ:]	-0.1171	0.0114	-10.2512	< 0.0001
Gendermale	-0.0104	0.0163	-0.6372	0.5241
B. smooth terms	edf	Ref.df	F-value	p-value
s(timepoint)	3.2941	3.7089	193.6028	< 0.0001
s(timepoint):category [œ:]	3.7297	3.9282	381.5898	< 0.0001
s(Talker)	0.8813	39.0000	6.9354	0.4171
s(Talker,category)	77.3538	79.0000	254.5904	< 0.0001

Table S31

Model summary, coefficients for parametric and smooth terms for the mid center long vowels predicting F3

A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	0.7323	0.0108	67.6613	< 0.0001
category [œ:]	0.0104	0.0052	1.9782	0.0480
Gendermale	-0.0025	0.0151	-0.1681	0.8665
B. smooth terms	edf	Ref.df	F-value	p-value
s(timepoint)	3.3374	3.7227	59.1292	< 0.0001
s(timepoint):category [œ:]	3.4294	3.7772	67.9323	< 0.0001
s(Talker)	29.6535	39.0000	1744.4730	< 0.0001
s(Talker,category)	47.2299	79.0000	260.6346	0.0391

Table S32

Model summary, coefficients for parametric and smooth terms for the mid center short vowels predicting F1

A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	-0.8545	0.0123	-69.4714	< 0.0001
category [œ]	-0.0158	0.0097	-1.6344	0.1023
Gendermale	0.0125	0.0172	0.7262	0.4678
B. smooth terms	edf	Ref.df	F-value	p-value
s(timepoint)	3.5796	3.8588	173.3591	< 0.0001
s(timepoint):category [œ]	2.9340	3.4113	16.0463	< 0.0001
s(Talker)	14.1702	39.0000	302.4206	0.0380
s(Talker,category)	63.1586	79.0000	279.1835	< 0.0001

Table S33

Model summary, coefficients for parametric and smooth terms for the mid center short vowels predicting F2

A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	0.1595	0.0141	11.3009	< 0.0001
category [œ]	-0.1191	0.0114	-10.4280	< 0.0001
Gendermale	-0.0344	0.0197	-1.7436	0.0813
B. smooth terms	edf	Ref.df	F-value	p-value
s(timepoint)	2.2604	2.7351	34.5559	< 0.0001
s(timepoint):category [œ]	3.4647	3.8071	349.8467	< 0.0001
s(Talker)	12.8319	39.0000	2243.9486	0.0298
s(Talker,category)	65.5976	79.0000	2258.5568	< 0.0001

Table S34

Model summary, coefficients for parametric and smooth terms for the mid center short vowels predicting F3

A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	0.7432	0.0098	75.6290	< 0.0001
category [œ]	0.0114	0.0056	2.0340	0.0420
Gendermale	0.0062	0.0137	0.4523	0.6511
B. smooth terms	edf	Ref.df	F-value	p-value
s(timepoint)	3.2841	3.6832	149.3740	< 0.0001
s(timepoint):category [œ]	3.3298	3.7122	106.1946	< 0.0001
s(Talker)	25.9119	39.0000	1422.1973	< 0.0001
s(Talker,category)	51.4251	79.0000	345.2444	0.0184

Table S35

Model summary, coefficients for parametric and smooth terms for /i/ predicting F1

A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	-1.2427	0.0157	-78.9328	< 0.0001
category [I]	0.0371	0.0137	2.7134	0.0067
Gendermale	-0.0545	0.0198	-2.7534	0.0059
B. smooth terms	edf	Ref.df	F-value	p-value
s(timepoint)	2.9563	3.4642	55.3871	< 0.0001
s(timepoint):category [I]	1.0000	1.0001	68.4212	< 0.0001
s(Talker)	20.3749	39.0000	505.9699	0.0001
s(Talker,category)	56.5165	79.0000	231.1143	0.0002

Table S36

Model summary, coefficients for parametric and smooth terms for /i/ predicting F2

A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	0.4737	0.0174	27.1554	< 0.0001
category [I]	0.1704	0.0196	8.6881	< 0.0001
Gendermale	0.0327	0.0202	1.6233	0.1046
B. smooth terms	edf	Ref.df	F-value	p-value
s(timepoint)	1.3830	1.6530	18.0138	< 0.0001
s(timepoint):category [I]	3.2796	3.7133	6.7933	0.0001
s(Talker)	2.0415	39.0000	11.9241	0.4174
s(Talker,category)	75.7153	79.0000	171.1447	< 0.0001

Table S37

Model summary, coefficients for parametric and smooth terms for /i/ predicting F3

A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	0.8922	0.0147	60.5368	< 0.0001
category [I]	-0.0441	0.0130	-3.3795	0.0007
Gendermale	0.0337	0.0185	1.8258	0.0680
B. smooth terms	edf	Ref.df	F-value	p-value
s(timepoint)	1.0001	1.0003	15.5226	0.0001
s(timepoint):category [I]	2.3498	2.8529	35.7660	< 0.0001
s(Talker)	19.5361	39.0000	568.5014	0.0003
s(Talker,category)	57.6016	79.0000	289.8411	0.0001

Table S38

Model summary, coefficients for parametric and smooth terms for /y/ predicting F1

A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	-1.2862	0.0149	-86.2412	< 0.0001
category [Y]	0.0889	0.0120	7.4271	< 0.0001
Gendermale	-0.0502	0.0191	-2.6311	0.0085
B. smooth terms	edf	Ref.df	F-value	p-value
s(timepoint)	3.1766	3.6029	65.3943	< 0.0001
s(timepoint):category [Y]	2.5556	3.0388	19.2641	< 0.0001
s(Talker)	23.6319	39.0000	469.8048	< 0.0001
s(Talker,category)	52.8112	79.0000	152.3845	0.0026

Table S39

Model summary, coefficients for parametric and smooth terms for /y/ predicting F2

A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	0.4507	0.0144	31.2079	< 0.0001
category [Y]	0.1242	0.0159	7.8100	< 0.0001
Gendermale	0.0062	0.0168	0.3656	0.7147
B. smooth terms	edf	Ref.df	F-value	p-value
s(timepoint)	2.9464	3.4178	47.4311	< 0.0001
s(timepoint):category [Y]	2.3870	2.8642	3.4414	0.0162
s(Talker)	4.2101	39.0000	365.6413	0.3015
s(Talker,category)	74.3386	79.0000	1645.4089	< 0.0001

Table S40

Model summary, coefficients for parametric and smooth terms for /y/ predicting F3

A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	0.9134	0.0086	106.0065	< 0.0001
category [Y]	-0.1439	0.0066	-21.8142	< 0.0001
Gendermale	-0.0130	0.0111	-1.1686	0.2427
B. smooth terms	edf	Ref.df	F-value	p-value
s(timepoint)	3.2360	3.6465	17.5977	< 0.0001
s(timepoint):category [Y]	3.3754	3.7403	16.9235	< 0.0001
s(Talker)	25.2775	39.0000	949.5166	< 0.0001
s(Talker,category)	51.8369	79.0000	249.7645	0.0314

Table S41

Model summary, coefficients for parametric and smooth terms for /ɛ/ predicting F1

A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	-1.2142	0.0147	-82.7945	< 0.0001
category [ɛ]	0.1134	0.0118	9.6084	< 0.0001
Gendermale	-0.0200	0.0188	-1.0662	0.2864
B. smooth terms	edf	Ref.df	F-value	p-value
s(timepoint)	3.5016	3.8160	173.2009	< 0.0001
s(timepoint):category [ɛ]	3.0360	3.4928	43.2258	< 0.0001
s(Talker)	23.5404	39.0000	442.8618	< 0.0001
s(Talker,category)	52.8094	79.0000	145.9149	0.0019

Table S42

Model summary, coefficients for parametric and smooth terms for /ɛ/ predicting F2

A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	0.3157	0.0122	25.9013	< 0.0001
category [ɛ]	-0.3064	0.0116	-26.3315	< 0.0001
Gendermale	0.0068	0.0150	0.4535	0.6502
B. smooth terms	edf	Ref.df	F-value	p-value
s(timepoint)	2.9953	3.4585	298.3962	< 0.0001
s(timepoint):category [ɛ]	3.4809	3.8035	584.4777	< 0.0001
s(Talker)	15.3919	39.0000	773.9038	0.0152
s(Talker,category)	62.4428	79.0000	579.9508	< 0.0001

Table S43

Model summary, coefficients for parametric and smooth terms for /ɛ/ predicting F3

A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	0.7145	0.0106	67.3415	< 0.0001
category [ɛ]	0.0352	0.0079	4.4349	< 0.0001
Gendermale	0.0033	0.0137	0.2431	0.8079
B. smooth terms	edf	Ref.df	F-value	p-value
s(timepoint)	3.4854	3.8067	27.2527	< 0.0001
s(timepoint):category [ɛ]	3.0080	3.4685	59.1125	< 0.0001
s(Talker)	25.9963	39.0000	1478.7326	< 0.0001
s(Talker,category)	51.3885	79.0000	377.1923	0.0153

Table S44

Model summary, coefficients for parametric and smooth terms for /e/ predicting F1

A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	-1.0969	0.0134	-81.6369	< 0.0001
category [ε]	0.3621	0.0141	25.6152	< 0.0001
Gendermale	0.0082	0.0160	0.5169	0.6053
B. smooth terms	edf	Ref.df	F-value	p-value
s(timepoint)	3.9225	3.9937	1197.4189	< 0.0001
s(timepoint):category [ε]	3.8937	3.9906	921.5105	< 0.0001
s(Talker)	8.3683	39.0000	39.6280	0.1113
s(Talker,category)	67.6617	79.0000	89.3655	< 0.0001

Table S45

Model summary, coefficients for parametric and smooth terms for /e/ predicting F2

A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	0.6114	0.0163	37.4577	< 0.0001
category [ε]	-0.2070	0.0138	-14.9844	< 0.0001
Gendermale	-0.0066	0.0207	-0.3172	0.7511
B. smooth terms	edf	Ref.df	F-value	p-value
s(timepoint)	3.8022	3.9591	425.7994	< 0.0001
s(timepoint):category [ε]	3.6306	3.9048	123.7554	< 0.0001
s(Talker)	21.5500	39.0000	365.0006	< 0.0001
s(Talker,category)	54.5449	79.0000	145.6635	0.0001

Table S46

Model summary, coefficients for parametric and smooth terms for /e/ predicting F3

A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	0.8436	0.0116	72.5287	< 0.0001
category [ε]	-0.0916	0.0088	-10.3843	< 0.0001
Gendermale	0.0157	0.0150	1.0448	0.2962
B. smooth terms	edf	Ref.df	F-value	p-value
s(timepoint)	3.5769	3.8592	82.3482	< 0.0001
s(timepoint):category [ε]	3.4562	3.7990	61.6135	< 0.0001
s(Talker)	25.5586	39.0000	250.4581	< 0.0001
s(Talker,category)	49.3150	79.0000	61.7838	0.0098

Table S47

Model summary, coefficients for parametric and smooth terms for /ɛ/ predicting F1

A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	-0.4979	0.0168	-29.5536	< 0.0001
category [ɛ]	-0.2217	0.0144	-15.4139	< 0.0001
Gendermale	-0.0221	0.0213	-1.0374	0.2996
B. smooth terms	edf	Ref.df	F-value	p-value
s(timepoint)	2.8687	3.3403	8.5123	< 0.0001
s(timepoint):category [ɛ]	3.0057	3.4615	14.7926	< 0.0001
s(Talker)	21.1842	39.0000	753.9500	< 0.0001
s(Talker,category)	55.9935	79.0000	305.7499	0.0017

Table S48

Model summary, coefficients for parametric and smooth terms for /ɛ/ predicting F2

A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	0.3201	0.0122	26.1441	< 0.0001
category [ɛ]	0.0857	0.0099	8.6797	< 0.0001
Gendermale	-0.0090	0.0157	-0.5780	0.5633
B. smooth terms	edf	Ref.df	F-value	p-value
s(timepoint)	3.3495	3.7247	157.0077	< 0.0001
s(timepoint):category [ɛ]	2.6391	3.1272	3.9379	0.0076
s(Talker)	23.4744	39.0000	728.9755	< 0.0001
s(Talker,category)	53.3979	79.0000	252.7058	0.0014

Table S49

Model summary, coefficients for parametric and smooth terms for /ɛ/ predicting F3

A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	0.7461	0.0139	53.8644	< 0.0001
category [ɛ]	0.0003	0.0076	0.0447	0.9643
Gendermale	0.0267	0.0186	1.4333	0.1519
B. smooth terms	edf	Ref.df	F-value	p-value
s(timepoint)	2.7718	3.2960	17.0974	< 0.0001
s(timepoint):category [ɛ]	1.0000	1.0001	8.1519	0.0043
s(Talker)	32.4840	39.0000	382.3264	< 0.0001
s(Talker,category)	41.0810	79.0000	32.9008	0.0589

Table S50

Model summary, coefficients for parametric and smooth terms for /æ/ predicting F1

A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	-0.4389	0.0196	-22.3632	< 0.0001
category [æ]	-0.0430	0.0136	-3.1549	0.0016
Gendermale	-0.0151	0.0257	-0.5872	0.5571
B. smooth terms	edf	Ref.df	F-value	p-value
s(timepoint)	3.3641	3.7547	108.3002	< 0.0001
s(timepoint):category [æ]	1.8893	2.3113	1.9999	0.1150
s(Talker)	28.0353	39.0000	586.8502	< 0.0001
s(Talker,category)	47.7162	79.0000	115.2095	0.0079

Table S51

Model summary, coefficients for parametric and smooth terms for /æ/ predicting F2

A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	0.2405	0.0119	20.2467	< 0.0001
category [æ]	0.0521	0.0091	5.7258	< 0.0001
Gendermale	-0.0093	0.0153	-0.6040	0.5459
B. smooth terms	edf	Ref.df	F-value	p-value
s(timepoint)	3.3987	3.7515	43.0948	< 0.0001
s(timepoint):category [æ]	2.7770	3.2571	8.0074	< 0.0001
s(Talker)	25.2241	39.0000	1125.4241	< 0.0001
s(Talker,category)	51.7897	79.0000	314.6290	0.0025

Table S52

Model summary, coefficients for parametric and smooth terms for /æ/ predicting F3

A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	0.7357	0.0163	45.2652	< 0.0001
category [æ]	0.0233	0.0106	2.2046	0.0276
Gendermale	0.0297	0.0215	1.3819	0.1671
B. smooth terms	edf	Ref.df	F-value	p-value
s(timepoint)	2.3374	2.8366	3.2304	0.0391
s(timepoint):category [æ]	1.0001	1.0001	2.8277	0.0927
s(Talker)	29.5293	39.0000	739.5767	< 0.0001
s(Talker,category)	46.3596	79.0000	104.4224	0.0879

Table S53

Model summary, coefficients for parametric and smooth terms for /ø/ predicting F1

A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	-0.7103	0.0156	-45.5354	< 0.0001
category [ø]	-0.1058	0.0117	-9.0252	< 0.0001
Gendermale	-0.0351	0.0202	-1.7397	0.0820
B. smooth terms	edf	Ref.df	F-value	p-value
s(timepoint)	2.3099	2.7827	1.6642	0.1254
s(timepoint):category [ø]	3.2258	3.6473	75.5103	< 0.0001
s(Talker)	25.8634	39.0000	911.2704	< 0.0001
s(Talker,category)	51.0366	79.0000	221.2125	0.0176

Table S54

Model summary, coefficients for parametric and smooth terms for /ø/ predicting F2

A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	0.1670	0.0152	10.9938	< 0.0001
category [ø]	0.0734	0.0117	6.2872	< 0.0001
Gendermale	-0.0267	0.0196	-1.3656	0.1721
B. smooth terms	edf	Ref.df	F-value	p-value
s(timepoint)	3.2560	3.6754	207.5789	< 0.0001
s(timepoint):category [ø]	2.1014	2.5558	64.4651	< 0.0001
s(Talker)	25.1208	39.0000	4944.0262	< 0.0001
s(Talker,category)	53.0234	79.0000	1358.2399	0.0109

Table S55

Model summary, coefficients for parametric and smooth terms for /ø/ predicting F3

A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	0.7172	0.0109	65.8742	< 0.0001
category [ø]	0.0141	0.0062	2.2891	0.0221
Gendermale	0.0105	0.0146	0.7168	0.4736
B. smooth terms	edf	Ref.df	F-value	p-value
s(timepoint)	3.4723	3.8446	75.4970	< 0.0001
s(timepoint):category [ø]	1.0001	1.0002	41.4930	< 0.0001
s(Talker)	32.0273	39.0000	1485.3644	< 0.0001
s(Talker,category)	44.4773	79.0000	160.7187	0.0545

Table S56

Model summary, coefficients for parametric and smooth terms for /œ/ predicting F1

A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	-0.7590	0.0157	-48.2066	< 0.0001
category [œ]	-0.1173	0.0122	-9.6135	< 0.0001
Gendermale	0.0300	0.0203	1.4771	0.1397
B. smooth terms	edf	Ref.df	F-value	p-value
s(timepoint)	2.9969	3.4959	37.6112	< 0.0001
s(timepoint):category [œ]	1.0000	1.0001	20.8779	< 0.0001
s(Talker)	24.8639	39.0000	927.1593	< 0.0001
s(Talker,category)	52.0699	79.0000	266.9870	0.0088

Table S57

Model summary, coefficients for parametric and smooth terms for /œ/ predicting F2

A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	-0.0023	0.0171	-0.1343	0.8931
category [œ]	0.0721	0.0139	5.2018	< 0.0001
Gendermale	-0.0181	0.0218	-0.8276	0.4079
B. smooth terms	edf	Ref.df	F-value	p-value
s(timepoint)	3.8523	3.9696	266.9332	< 0.0001
s(timepoint):category [œ]	3.4298	3.8031	44.3554	< 0.0001
s(Talker)	23.2700	39.0000	5567.4541	< 0.0001
s(Talker,category)	54.9619	79.0000	1835.2586	0.0081

Table S58

Model summary, coefficients for parametric and smooth terms for /œ/ predicting F3

A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	0.7415	0.0117	63.5705	< 0.0001
category [œ]	0.0160	0.0059	2.7304	0.0064
Gendermale	-0.0065	0.0158	-0.4126	0.6799
B. smooth terms	edf	Ref.df	F-value	p-value
s(timepoint)	2.9308	3.4371	19.7617	< 0.0001
s(timepoint):category [œ]	1.0000	1.0001	4.4916	0.0341
s(Talker)	33.5974	39.0000	1500.4023	< 0.0001
s(Talker,category)	42.3813	79.0000	109.4314	0.1543

Table S59

Model summary, coefficients for parametric and smooth terms for /ɑ/ predicting F1

A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	-0.6845	0.0176	-38.8058	< 0.0001
category [a]	0.1755	0.0114	15.4202	< 0.0001
Gendermale	-0.0061	0.0233	-0.2621	0.7933
B. smooth terms	edf	Ref.df	F-value	p-value
s(timepoint)	2.9673	3.4347	41.8548	< 0.0001
s(timepoint):category [a]	2.2977	2.7647	22.1895	< 0.0001
s(Talker)	29.7089	39.0000	488.5858	< 0.0001
s(Talker,category)	45.6542	79.0000	70.3904	0.0658

Table S60

Model summary, coefficients for parametric and smooth terms for /ɑ/ predicting F2

A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	-0.2110	0.0134	-15.7262	< 0.0001
category [a]	0.2581	0.0110	23.3829	< 0.0001
Gendermale	-0.0598	0.0171	-3.4988	0.0005
B. smooth terms	edf	Ref.df	F-value	p-value
s(timepoint)	3.7570	3.9380	61.3738	< 0.0001
s(timepoint):category [a]	3.3958	3.7743	56.2100	< 0.0001
s(Talker)	22.7061	39.0000	1721.6117	< 0.0001
s(Talker,category)	54.9854	79.0000	604.0724	0.0016

Table S61

Model summary, coefficients for parametric and smooth terms for /ɑ/ predicting F3

A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	0.7854	0.0152	51.7589	< 0.0001
category [a]	-0.0043	0.0101	-0.4226	0.6726
Gendermale	0.0569	0.0200	2.8485	0.0044
B. smooth terms	edf	Ref.df	F-value	p-value
s(timepoint)	1.0000	1.0001	14.9221	0.0001
s(timepoint):category [a]	2.0927	2.5609	1.6685	0.1931
s(Talker)	29.0459	39.0000	743.3069	< 0.0001
s(Talker,category)	47.0456	79.0000	122.1371	0.0246

Table S62

Model summary, coefficients for parametric and smooth terms for /o/ predicting F1

A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	-1.0655	0.0137	-77.5512	< 0.0001
category [ɔ]	0.1012	0.0127	7.9773	< 0.0001
Gendermale	0.0554	0.0170	3.2524	0.0012
B. smooth terms	edf	Ref.df	F-value	p-value
s(timepoint)	3.8116	3.9665	520.6087	< 0.0001
s(timepoint):category [ɔ]	3.7159	3.9400	428.5582	< 0.0001
s(Talker)	17.3746	39.0000	126.5860	0.0095
s(Talker,category)	58.3434	79.0000	81.3096	0.0001

Table S63

Model summary, coefficients for parametric and smooth terms for /o/ predicting F2

A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	-0.5081	0.0180	-28.2486	< 0.0001
category [ɔ]	0.1549	0.0129	11.9984	< 0.0001
Gendermale	0.0006	0.0235	0.0273	0.9782
B. smooth terms	edf	Ref.df	F-value	p-value
s(timepoint)	3.9347	3.9940	1679.1649	< 0.0001
s(timepoint):category [ɔ]	3.8070	3.9740	512.5442	< 0.0001
s(Talker)	27.1884	39.0000	408.4524	< 0.0001
s(Talker,category)	48.3598	79.0000	84.9479	0.0194

Table S64

Model summary, coefficients for parametric and smooth terms for /o/ predicting F3

A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	0.8060	0.0127	63.3878	< 0.0001
category [ɔ]	0.0339	0.0067	5.0600	< 0.0001
Gendermale	0.0244	0.0171	1.4220	0.1551
B. smooth terms	edf	Ref.df	F-value	p-value
s(timepoint)	3.3570	3.7273	19.6656	< 0.0001
s(timepoint):category [ɔ]	2.9268	3.3935	26.7933	< 0.0001
s(Talker)	33.0410	39.0000	1704.5743	< 0.0001
s(Talker,category)	43.4334	79.0000	132.6541	0.2583

Table S65

Model summary, coefficients for parametric and smooth terms for /u/ predicting F1

A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	-1.1881	0.0139	-85.1839	< 0.0001
category [u]	0.0563	0.0089	6.3124	< 0.0001
Gendermale	0.0000	0.0185	0.0017	0.9986
B. smooth terms	edf	Ref.df	F-value	p-value
s(timepoint)	2.5083	3.0028	85.9692	< 0.0001
s(timepoint):category [u]	1.6891	2.0617	7.9543	0.0004
s(Talker)	29.9150	39.0000	253.4452	< 0.0001
s(Talker,category)	42.8163	78.0000	35.4706	0.0246

Table S66

Model summary, coefficients for parametric and smooth terms for /u/ predicting F2

A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	-0.4820	0.0187	-25.8430	< 0.0001
category [u]	0.0378	0.0123	3.0855	0.0020
Gendermale	0.0581	0.0247	2.3574	0.0185
B. smooth terms	edf	Ref.df	F-value	p-value
s(timepoint)	3.7956	3.9618	140.2768	< 0.0001
s(timepoint):category [u]	1.9794	2.4184	10.1612	< 0.0001
s(Talker)	29.3475	39.0000	119.5479	< 0.0001
s(Talker,category)	41.3514	78.0000	17.6264	0.0200

Table S67

Model summary, coefficients for parametric and smooth terms for /u/ predicting F3

A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	0.7765	0.0125	62.3403	< 0.0001
category [u]	0.0239	0.0058	4.1451	< 0.0001
Gendermale	0.0169	0.0169	0.9999	0.3175
B. smooth terms	edf	Ref.df	F-value	p-value
s(timepoint)	2.8207	3.3106	19.9309	< 0.0001
s(timepoint):category [u]	2.0381	2.4777	2.5524	0.0505
s(Talker)	34.4885	39.0000	721.2592	< 0.0001
s(Talker,category)	39.3159	78.0000	45.0897	0.2425

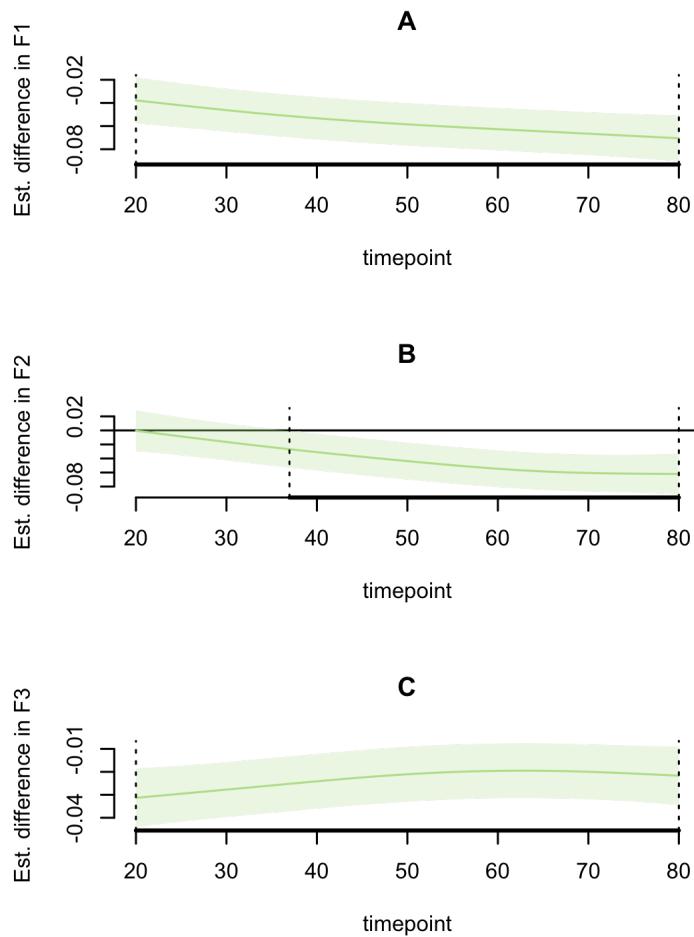


Figure S13. Fitted smooths of GAMM for predicting F1-F2-F3 and 95% confidence intervals for the [u:]-[u] vowel pair.