

## Appendix C. Mixed Effects Models

Table 1. F1 Frequency linear mixed effects regression - Intercept /i/

Predictors	Estimates	SE	F1 CI: lower	CI: upper	p
(Intercept)	438.00	16.07	406.50	469.50	< 0.001*
vowel [a]	280.51	8.75	263.35	297.67	< 0.001*
vowel [e]	29.18	10.62	8.38	49.99	0.006*
vowel [o]	78.76	10.08	58.99	98.52	< 0.001*
vowel [u]	43.01	12.06	19.37	66.64	0.002*
sex [m]	-62.80	19.92	-101.85	-23.75	0.002*
syllable [Closed_Final]	-10.21	15.31	-40.21	19.79	0.505
syllable [Open]	-5.57	5.76	-16.85	5.72	0.334
syllable [Open_Final]	-5.03	7.55	-19.82	9.77	0.505
stress [Unstressed]	-1.32	6.14	-13.35	10.70	0.829
style [WordList]	10.46	7.57	-4.39	25.30	0.167
vowel [a] * sex [m]	-90.54	13.03	-116.07	-65.00	< 0.001*
vowel [e] * sex [m]	-22.92	14.49	-51.33	5.49	0.114
vowel [o] * sex [m]	-38.12	13.69	-64.94	-11.29	0.005*
vowel [u] * sex [m]	-8.50	15.88	-39.63	22.63	0.593
<b>Random Effects</b>					
$\sigma^2$	4161.30				
$\tau_{00}$ word	796.26				
$\tau_{00}$ speaker	2377.81				
ICC	0.43				
$N_{\text{speaker}}$	26				
$N_{\text{word}}$	616				
Observations	1202				
Marginal $R^2$ / Conditional $R^2$	0.630 / 0.790				

Table 2. F1 Frequency linear mixed effects regression - Intercept /u/

Predictors	Estimates	SE	F1 CI: lower	CI: upper	p
(Intercept)	481.01	16.28	449.10	512.92	< 0.001*
vowel [a]	237.51	11.04	215.87	259.14	< 0.001*
vowel [e]	-13.83	12.04	-37.43	9.78	0.251
vowel [i]	-43.01	12.06	-66.64	-19.37	< 0.001*
vowel [o]	35.75	11.96	12.31	59.19	0.003*
sex [m]	-71.30	20.41	-111.31	-31.29	< 0.001*
syllable [Closed_Final]	-10.21	15.31	-40.21	19.79	0.505
syllable [Open]	-5.57	5.76	-16.85	5.72	0.334
syllable [Open_Final]	-5.03	7.55	-19.82	9.77	0.505
stress [Unstressed]	-1.32	6.14	-13.35	10.70	0.829
style [WordList]	10.46	7.57	-4.39	25.30	0.167
vowel [a] * sex [m]	-82.04	14.78	-111.01	-53.07	< 0.001*
vowel [e] * sex [m]	-14.42	15.96	-45.70	16.85	0.366
vowel [i] * sex [m]	8.50	15.88	-22.63	39.63	0.593
vowel [o] * sex [m]	-29.62	15.41	-59.82	0.57	0.055
<b>Random Effects</b>					
$\sigma^2$	4161.30				
$\tau_{00}$ word	796.26				
$\tau_{00}$ speaker	2377.80				
ICC	0.43				
$N_{\text{speaker}}$	26				
$N_{\text{word}}$	616				
Observations	1202				
Marginal R <sup>2</sup> / Conditional R <sup>2</sup>	0.630 / 0.790				

Table 3. F2 Frequency linear mixed effects regression - Intercept /i/

Predictors	Estimates	SE	F2 CI: lower	CI: upper	p
(Intercept)	2360.07	34.74	2291.99	2428.15	< 0.001*
vowel [a]	-596.35	24.65	-644.66	-548.04	< 0.001*
vowel [e]	-150.70	29.80	-209.12	-92.28	< 0.001*
vowel [o]	-912.19	28.43	-967.91	-856.47	< 0.001*
vowel [u]	-1066.07	33.02	-1130.78	-1001.35	< 0.001*
sex [m]	-368.60	42.59	-452.07	-285.13	< 0.001*
syllable [Closed_Final]	-119.21	43.31	-204.11	-34.32	0.006*
syllable [Open]	-1.39	16.37	-33.47	30.68	0.932
syllable [Open_Final]	17.81	21.32	-23.97	59.59	0.403
stress [Unstressed]	-41.00	17.18	-74.66	-7.33	0.017
style [WordList]	35.35	20.89	-5.59	76.29	0.091
vowel [a] * sex [m]	123.15	36.74	51.14	195.15	0.001*
vowel [e] * sex [m]	40.90	40.95	-39.36	121.16	0.318
vowel [o] * sex [m]	150.10	38.64	74.37	225.82	< 0.001*
vowel [u] * sex [m]	228.22	44.15	141.68	314.76	< 0.001*
<b>Random Effects</b>					
$\sigma^2$	32038.01				
$\tau_{00}$ word	8261.45				
$\tau_{00}$ speaker	4637.05				
ICC	0.29				
$N_{\text{speaker}}$	26				
$N_{\text{word}}$	616				
Observations	1202				
Marginal R <sup>2</sup> / Conditional R <sup>2</sup>	0.765 / 0.832				

Table 4. F2 Frequency linear mixed effects regression - Intercept /u/

Predictors	Estimates	SE	F2 CI: lower	CI: upper	p
(Intercept)	1294.00	34.47	1226.44	1361.57	< 0.001*
vowel [a]	469.71	30.04	410.84	528.59	< 0.001*
vowel [e]	915.37	32.91	850.85	979.88	< 0.001*
vowel [i]	1066.07	33.02	1001.35	1130.78	< 0.001*
vowel [o]	153.88	32.81	89.57	218.18	< 0.001*
sex [m]	-140.38	43.26	-225.17	-55.60	0.001*
syllable [Closed_Final]	-119.21	43.31	-204.11	-34.32	0.006*
syllable [Open]	-1.39	16.37	-33.47	30.68	0.932
syllable [Open_Final]	17.81	21.32	-23.97	59.59	0.403
stress [Unstressed]	-41.00	17.18	-74.66	-7.33	0.017*
style [WordList]	35.35	20.89	-5.59	76.29	0.091
vowel [a] * sex [m]	-105.07	40.73	-184.90	-25.24	0.010*
vowel [e] * sex [m]	-187.32	44.31	-274.16	-100.48	< 0.001*
vowel [i] * sex [m]	-228.22	44.15	-314.76	-141.68	< 0.001*
vowel [o] * sex [m]	-78.12	42.66	-161.74	5.50	0.067
<b>Random Effects</b>					
$\sigma^2$	32038.01				
$\tau_{00}$ word	8261.45				
$\tau_{00}$ speaker	4637.05				
ICC	0.29				
$N_{\text{speaker}}$	26				
$N_{\text{word}}$	616				
Observations	1202				
Marginal $R^2$ / Conditional $R^2$	0.765 / 0.832				

Table 5. F3 Frequency linear mixed effects regression - Intercept /i/

Predictors	Estimates	SE	F3		p
			CI: lower	CI: upper	
(Intercept)	3072.74	52.86	2969.14	3176.35	< 0.001*
vowel [a]	−242.40	37.90	−316.67	−168.12	< 0.001*
vowel [e]	−120.36	45.73	−209.99	−30.72	0.008*
vowel [o]	−335.84	43.60	−421.28	−250.39	< 0.001*
vowel [u]	−366.71	50.51	−465.72	−267.71	< 0.001*
sex [m]	−404.09	64.51	−530.53	−277.64	< 0.001*
syllable [Closed_Final]	−88.03	66.05	−217.48	41.43	0.183
syllable [Open]	−22.08	24.82	−70.74	26.57	0.374
syllable [Open_Final]	−30.75	32.51	−94.47	32.96	0.344
stress [Unstressed]	16.36	26.41	−35.40	68.12	0.536
style [WordList]	−0.96	30.75	−61.22	59.31	0.975
vowel [a] * sex [m]	0.04	56.15	−110.01	110.08	0.999
vowel [e] * sex [m]	53.53	62.48	−68.92	175.99	0.392
vowel [o] * sex [m]	32.81	59.06	−82.93	148.56	0.578
vowel [u] * sex [m]	6.13	67.19	−125.56	137.83	0.927
<b>Random Effects</b>					
$\sigma^2$	80133.05				
$\tau_{00}$ word	12056.78				
$\tau_{00}$ speaker	9476.69				
ICC	0.20				
$N_{\text{speaker}}$	27				
$N_{\text{word}}$	616				
Observations	1202				
Marginal R <sup>2</sup> / Conditional R <sup>2</sup>	0.348 / 0.481				

Table 6. F3 Frequency linear mixed effects regression - Intercept /u/

Predictors	Estimates	SE	F3 CI: lower	CI: upper	p
(Intercept)	2706.03	52.58	2602.97	2809.09	< 0.001*
vowel [a]	124.32	45.98	34.21	214.43	0.007*
vowel [e]	246.36	50.24	147.89	344.82	< 0.001*
vowel [i]	366.71	50.51	267.71	465.72	< 0.001*
vowel [o]	30.88	50.18	-67.47	129.22	0.538
sex [m]	-397.95	65.64	-526.60	-269.30	< 0.001*
syllable [Closed_Final]	-88.03	66.05	-217.48	41.43	0.183
syllable [Open]	-22.08	24.82	-70.74	26.57	0.374
syllable [Open_Final]	-30.75	32.51	-94.47	32.96	0.344
stress [Unstressed]	16.36	26.41	-35.40	68.12	0.536
style [WordList]	-0.96	30.75	-61.22	59.31	0.975
vowel [a] * sex [m]	-6.10	62.19	-127.98	115.78	0.922
vowel [e] * sex [m]	47.40	67.33	-84.56	179.36	0.481
vowel [i] * sex [m]	-6.13	67.19	-137.83	125.56	0.927
vowel [o] * sex [m]	26.68	65.05	-100.81	154.17	0.682
<b>Random Effects</b>					
$\sigma^2$	80133.05				
$\tau_{00}$ word	12056.78				
$\tau_{00}$ speaker	11021.20				
ICC	0.22				
N <sub>speaker</sub>	26				
N <sub>word</sub>	616				
Observations	1202				
Marginal R <sup>2</sup> / Conditional R <sup>2</sup>	0.342 / 0.489				

Table 7. Vowel pitch linear mixed effects regression - Intercept /i/

Predictors	Estimates	SE	<b>pitch</b> CI: lower	CI: upper	<i>p</i>
(Intercept)	248.96	9.75	229.86	268.06	< 0.001*
vowel [a]	−3.86	3.50	−10.72	3.01	0.271
vowel [e]	1.82	4.29	−6.59	10.24	0.671
vowel [o]	3.05	4.05	−4.89	10.99	0.452
vowel [u]	7.22	4.95	−2.47	16.92	0.144
sex [m]	−127.91	11.52	−150.50	−105.33	< 0.001*
syllable [Closed_Final]	−16.71	6.22	−28.91	−4.51	0.007*
syllable [Open]	1.70	2.40	−3.00	6.40	0.478
syllable [Open_Final]	−6.77	3.11	−12.85	−0.68	0.029*
stress [Unstressed]	−9.10	2.48	−13.97	−4.24	< 0.001*
style [WordList]	19.19	3.40	12.53	25.86	< 0.001*
vowel [a] * sex [m]	−0.78	5.33	−11.23	9.68	0.884
vowel [e] * sex [m]	−2.31	5.95	−13.96	9.35	0.698
vowel [o] * sex [m]	−5.36	5.61	−16.35	5.62	0.338
vowel [u] * sex [m]	−8.14	6.66	−21.19	4.91	0.222
<b>Random Effects</b>					
$\sigma^2$	598.66				
$\tau_{00}$ word	260.81				
$\tau_{00}$ speaker	1380.39				
ICC	0.73				
$N_{\text{speaker}}$	26				
$N_{\text{word}}$	604				
Observations	1173				
Marginal $R^2$ / Conditional $R^2$	0.670 / 0.912				

Table 8. Vowel pitch linear mixed effects regression - Intercept /u/

Predictors	Estimates	SE	<b>pitch</b> CI: lower	CI: upper	<i>p</i>
(Intercept)	256.18	9.88	236.81	275.56	< 0.001*
vowel [a]	-11.08	4.53	-19.97	-2.19	0.015*
vowel [e]	-5.40	4.98	-15.16	4.36	0.278
vowel [i]	-7.22	4.95	-16.92	2.47	0.144
vowel [o]	-4.18	4.90	-13.78	5.43	0.394
sex [m]	-136.05	11.78	-159.15	-112.96	< 0.001*
syllable [Closed_Final]	-16.71	6.22	-28.91	-4.51	0.007*
syllable [Open]	1.70	2.40	-3.00	6.40	0.478
syllable [Open_Final]	-6.77	3.11	-12.85	-0.68	0.029*
stress [Unstressed]	-9.10	2.48	-13.97	-4.24	< 0.001*
style [WordList]	19.19	3.40	12.53	25.86	< 0.001*
vowel [a] * sex [m]	7.36	6.21	-4.81	19.54	0.236
vowel [e] * sex [m]	5.83	6.74	-7.37	19.03	0.387
vowel [i] * sex [m]	8.14	6.66	-4.91	21.19	0.222
vowel [o] * sex [m]	2.77	6.47	-9.92	15.46	0.668
<b>Random Effects</b>					
$\sigma^2$	598.66				
$\tau_{00}$ word	260.81				
$\tau_{00}$ speaker	1380.39				
ICC	0.73				
$N_{\text{speaker}}$	26				
$N_{\text{word}}$	604				
Observations	1173				
Marginal $R^2$ / Conditional $R^2$	0.670 / 0.912				



Table 9. Vowel duration linear mixed effects regression - Intercept /i/

Predictors	Estimates	SE	duration		p
			CI: lower	CI: upper	
(Intercept)	88.26	7.43	73.70	102.82	< 0.001*
vowel [a]	12.25	6.31	-0.11	24.61	0.052
vowel [e]	-12.55	7.49	-27.23	2.12	0.094
vowel [o]	-13.05	7.24	-27.25	1.15	0.072
vowel [u]	-16.78	7.76	-32.00	-1.57	0.031*
sex [m]	-10.82	8.33	-27.15	5.50	0.194
syllable [Closed_Final]	1.90	10.93	-19.51	23.31	0.862
syllable [Open]	-1.92	4.10	-9.95	6.11	0.639
syllable [Open_Final]	24.05	5.35	13.56	34.54	< 0.001*
stress [Unstressed]	2.23	4.34	-6.28	10.74	0.608
style [WordList]	-16.14	4.51	-24.98	-7.30	< 0.001*
vowel [a] * sex [m]	4.46	9.26	-13.70	22.61	0.631
vowel [e] * sex [m]	17.74	10.28	-2.40	37.88	0.084
vowel [o] * sex [m]	17.05	9.77	-2.10	36.20	0.081
vowel [u] * sex [m]	8.48	10.59	-12.27	29.23	0.423
<b>Random Effects</b>					
$\sigma^2$	2353.34				
$\tau_{00}$ word	183.33				
$\tau_{00}$ speaker	44.65				
ICC	0.09				
$N_{\text{speaker}}$	26				
$N_{\text{word}}$	616				
Observations	1202				
Marginal $R^2$ / Conditional $R^2$	0.097 / 0.177				

Table 10. Vowel duration linear mixed effects regression - Intercept /u/

Predictors	Estimates	SE	duration		p
			CI: lower	CI: upper	
(Intercept)	71.47	7.03	57.69	85.26	< 0.001*
vowel [a]	29.04	6.96	15.40	42.68	< 0.001*
vowel [e]	4.23	7.62	-10.70	19.17	0.579
vowel [i]	16.78	7.76	1.57	32.00	0.031*
vowel [o]	3.74	7.74	-11.44	18.92	0.630
sex [m]	-2.35	8.19	-18.40	13.71	0.775
syllable [Closed_Final]	1.90	10.93	-19.51	23.31	0.862
syllable [Open]	-1.92	4.10	-9.95	6.11	0.639
syllable [Open_Final]	24.05	5.35	13.56	34.54	< 0.001*
stress [Unstressed]	2.23	4.34	-6.28	10.74	0.608
style [WordList]	-16.14	4.51	-24.98	-7.30	< 0.001*
vowel [a] * sex [m]	-4.02	9.65	-22.94	14.89	0.677
vowel [e] * sex [m]	9.26	10.52	-11.35	29.87	0.378
vowel [i] * sex [m]	-8.48	10.59	-29.23	12.27	0.423
vowel [o] * sex [m]	8.57	10.18	-11.39	28.52	0.400
<b>Random Effects</b>					
$\sigma^2$	2353.34				
$\tau_{00}$ word	183.33				
$\tau_{00}$ speaker	44.65				
ICC	0.09				
$N_{\text{speaker}}$	26				
$N_{\text{word}}$	616				
Observations	1202				
Marginal $R^2$ / Conditional $R^2$	0.097 / 0.177				

Table 11. Vowel intensity linear mixed effects regression - Intercept /i/

Predictors	Estimates	SE	intensity		p
			CI: lower	CI: upper	
(Intercept)	71.25	1.44	68.43	74.06	< 0.001*
vowel [a]	0.39	0.50	-0.59	1.37	0.437
vowel [e]	-0.34	0.62	-1.55	0.88	0.586
vowel [o]	-0.36	0.59	-1.51	0.79	0.542
vowel [u]	-0.32	0.72	-1.73	1.09	0.654
sex [m]	0.75	1.80	-2.79	4.28	0.679
syllable [Closed_Final]	-1.22	0.93	-3.05	0.61	0.191
syllable [Open]	0.77	0.37	0.05	1.49	0.035*
syllable [Open_Final]	-0.39	0.46	-1.29	0.50	0.390
stress [Unstressed]	-0.59	0.36	-1.29	0.11	0.099
style [WordList]	-0.49	0.59	-1.63	0.66	0.406
vowel [a] * sex [m]	-0.06	0.79	-1.60	1.49	0.940
vowel [e] * sex [m]	0.70	0.88	-1.02	2.42	0.426
vowel [o] * sex [m]	0.33	0.82	-1.28	1.94	0.687
vowel [u] * sex [m]	-0.07	1.00	-2.03	1.89	0.943
<b>Random Effects</b>					
$\sigma^2$		10.46			
$\tau_{00}$ word		14.70			
$\tau_{00}$ speaker		27.14			
ICC		0.80			
$N_{\text{speaker}}$		26			
$N_{\text{word}}$		616			
Observations		1201			
Marginal R <sup>2</sup> / Conditional R <sup>2</sup>	0.013 / 0.803				

Table 12. Vowel intensity linear mixed effects regression - Intercept /u/

Predictors	Estimates	SE	intensity		p
			CI: lower	CI: upper	
(Intercept)	70.92	1.45	68.09	73.76	< 0.001*
vowel [a]	0.71	0.66	-0.58	2.01	0.281
vowel [e]	-0.02	0.73	-1.46	1.42	0.983
vowel [i]	0.32	0.72	-1.09	1.73	0.654
vowel [o]	-0.03	0.72	-1.44	1.38	0.962
sex [m]	0.67	1.83	-2.91	4.26	0.712
syllable [Closed_Final]	-1.22	0.93	-3.05	0.61	0.191
syllable [Open]	0.77	0.37	0.05	1.49	0.035*
syllable [Open_Final]	-0.39	0.46	-1.29	0.50	0.390
stress [Unstressed]	-0.59	0.36	-1.29	0.11	0.099
style [WordList]	-0.49	0.59	-1.63	0.66	0.406
vowel [a] * sex [m]	0.01	0.91	-1.77	1.80	0.989
vowel [e] * sex [m]	0.77	1.00	-1.20	2.74	0.443
vowel [i] * sex [m]	0.07	1.00	-1.89	2.03	0.943
vowel [o] * sex [m]	0.40	0.95	-1.47	2.27	0.673
<b>Random Effects</b>					
$\sigma^2$		10.46			
$\tau_{00}$ word		14.70			
$\tau_{00}$ speaker		27.14			
ICC		0.80			
$N_{\text{speaker}}$		26			
$N_{\text{word}}$		616			
Observations		1201			
Marginal R <sup>2</sup> / Conditional R <sup>2</sup>	0.013 / 0.803				