Analysis - Butera (2022)

Note: Wherever p > 0, the reporting standard may vary. I would recommend simply putting p > .005 (as opposed to .05). The actual values are very small and the I specified rounding function used to only give a few digits for space reasons. (Some of the values have 15+ zeroes).

Statistical Analysis

The data were analyzed using generalized mixed effects models in which the outcome variable Relative Intensity (RI) in decibels was predicted by Region (6 regions total), point of articulation (velar, bilabial or dental), sonority (voiced or voiceless), stress (stressed or unstressed), horizontal position (anterior, central or posterior), vertical position (high, mid or low). Several interactions were also assessed. Three total 2-way interactions included a region by point of articulation, region by sonority, and a stress by region. Four total 3-way interactions were assessed: region by place of articulation and sonority, stress by region and sonority, region by sonority by horizontal vowel and finally region by sonority by vertical position. Random intercepts by participant were included to take into account the nested structure of the data. The normality of residuals were determined by visual inspections of a Q-Q and residual versus fitted plots. Main effects and interactions were determined by carrying out nested model comparisons. Finally, model fit was determined by marginal and conditional R squared.

Results

Main effects

`Region` - main effect $(X(5) = 16.31; p < 0.006)$ overall, there were regional differences in RI.

`Point of Articulation` - **no** main effect $(X(2) = 1.6; p < 0.45)$ - there was not a main effect for PoA, suggesting that the model could not detect a difference in RI between each PoA overall.

`Sonority` - main effect $(X(1) = 1800; p < 0)$ - overall, voiceless and voiced consonants, were produced with distinct RI.

`Stress` - main effect $(X(1) = 395.17; p < 0)$ - overall, the voiced and voiceless consonants were realized with distinct RI.

`Horizontal Position` - main effect $(X(2) = 29.7; p < 0)$ - overall, there were differences in RI between anterior, central, and posterior vowels.

`Vertical Position` - main effect $(X(1) = 78.15; p < 0)$ - - overall, there were differences in RI between high, central and low vowels.

Interactions

`Region*sonority` - 2-way interaction $(X(5) = 82.64; p < 0)$ - The effect of sonority (the difference in RI between voiced and voiceless consonants) depended on/differed by Region.

`Region*poa` - 2-way interaction $(X(10) = 22.88; p < 0.011)$ - The effect of Point of Articulation (the difference in RI in dental, bilabial and velar points of articulation) depended on/differed by Region.

`Region*stress` - **No** 2-way interaction $(X(5) = 6.94; p < 0.225)$ - The effect of stress on RI depended on/differed by Region.

`Region*poa*sonority` - 3-way interaction $(X(6) = 27.38; p < 0)$ - The difference in RI between stressed and unstressed positions varied by whether the consonant was voiced or voiceless and by Region.

`Region*stress*sonority` - **No** 3-way interaction $(X(6) = 6.04; p < 0.418)$ - The difference in RI between stressed and unstressed positions varied by whether the consonant was voiced or voiceless and by Region.
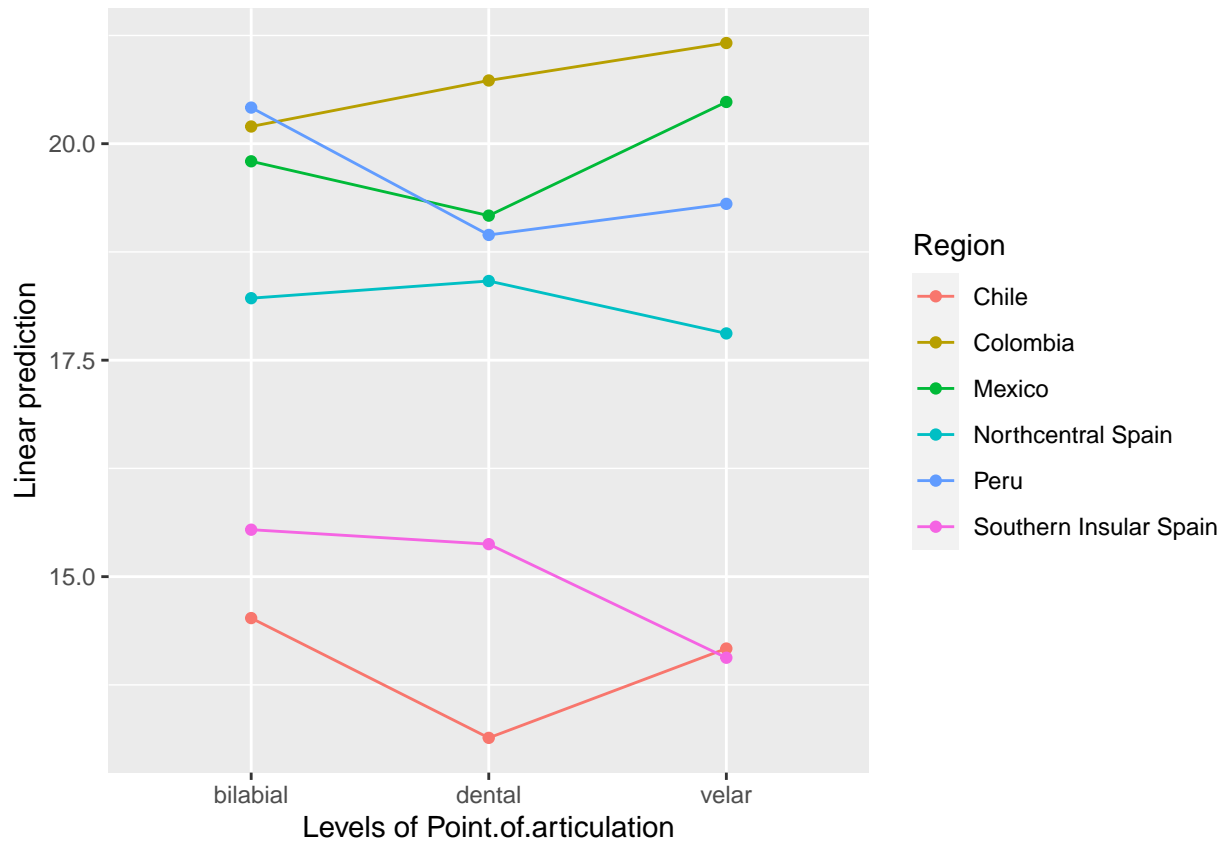
`Region*horizontal position` - **No** 2-way interaction $(X(10) = 6.32; p < 0.787)$ - The model could not detect differences in horizontal position per region

`Region*vertical postion` - **No** 2-way interaction $(X(5) = 4.51; p < 0.479)$ - The model could not detect differences in vertical position per region

2-way Region x Sonority interaction
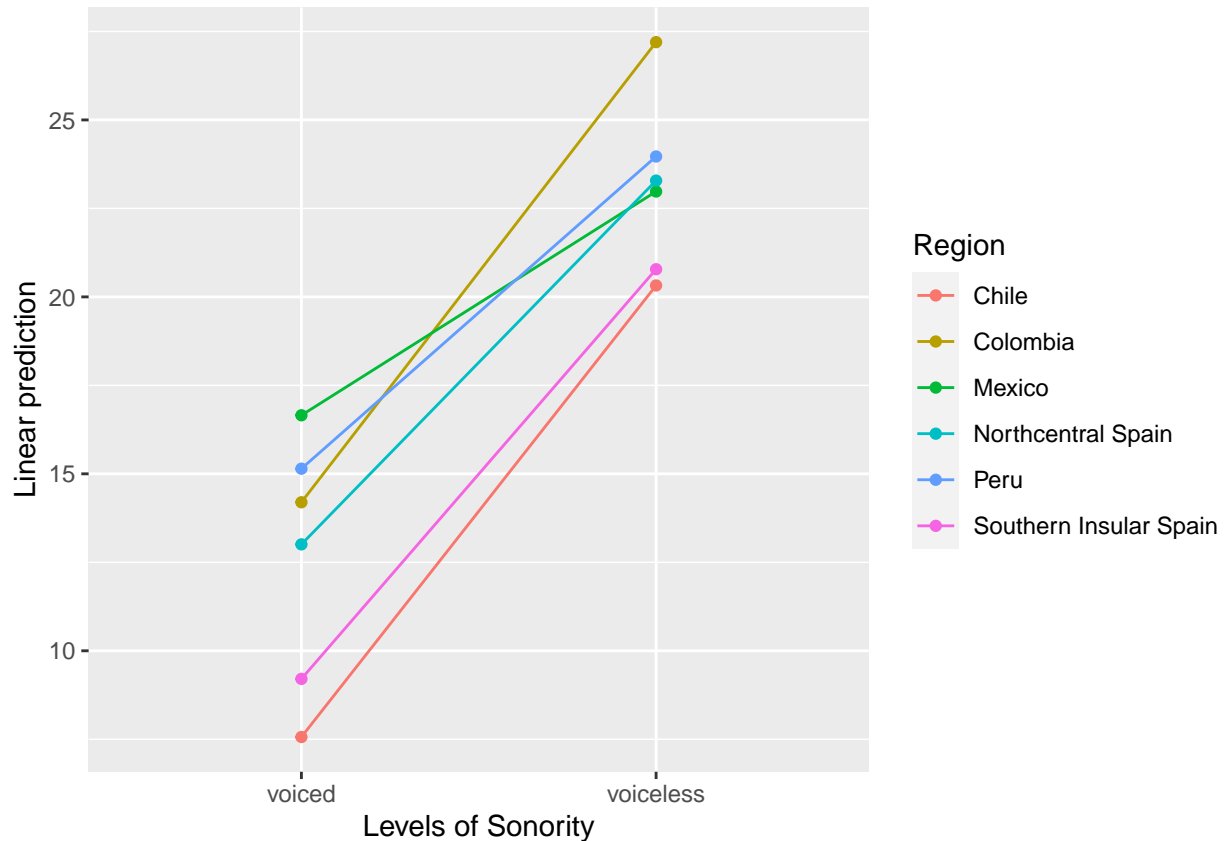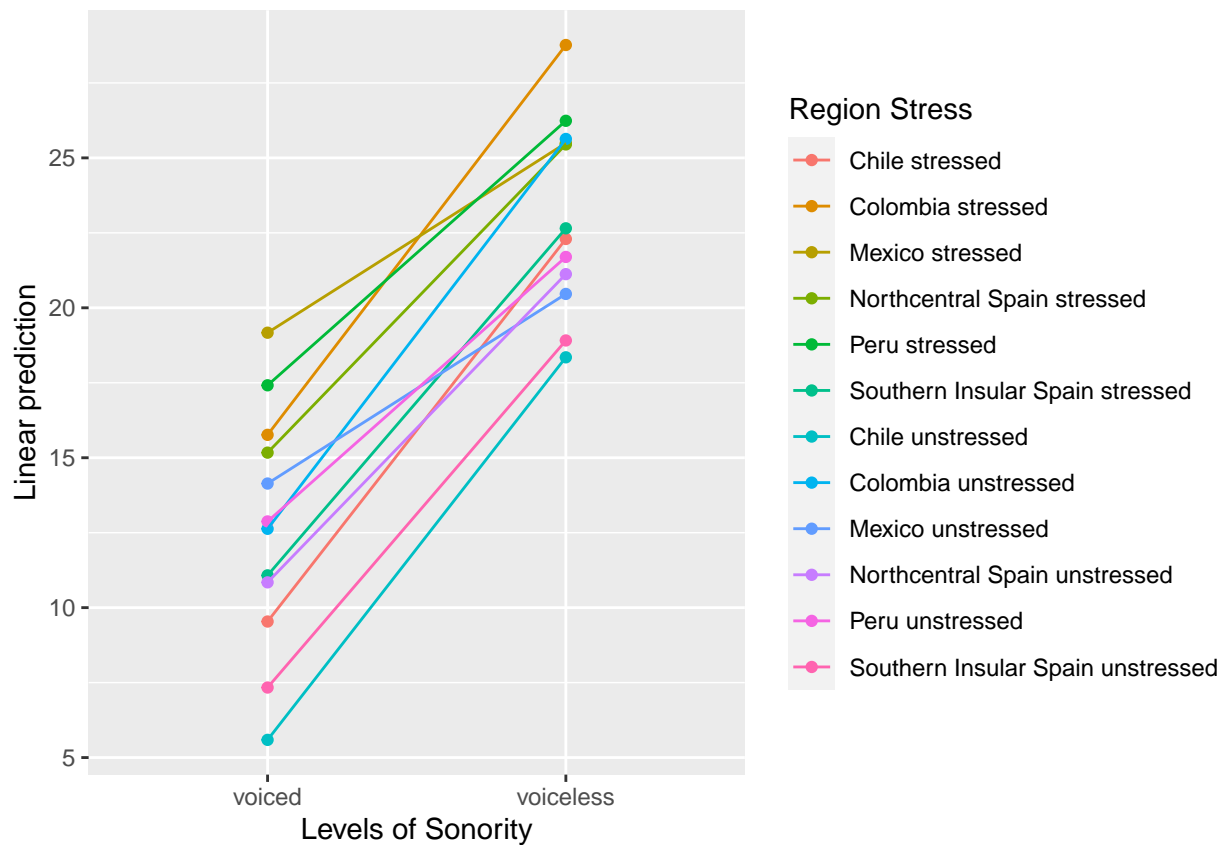

2-way Region x PoA interaction

3-way Region x PoA x Sonority interaction
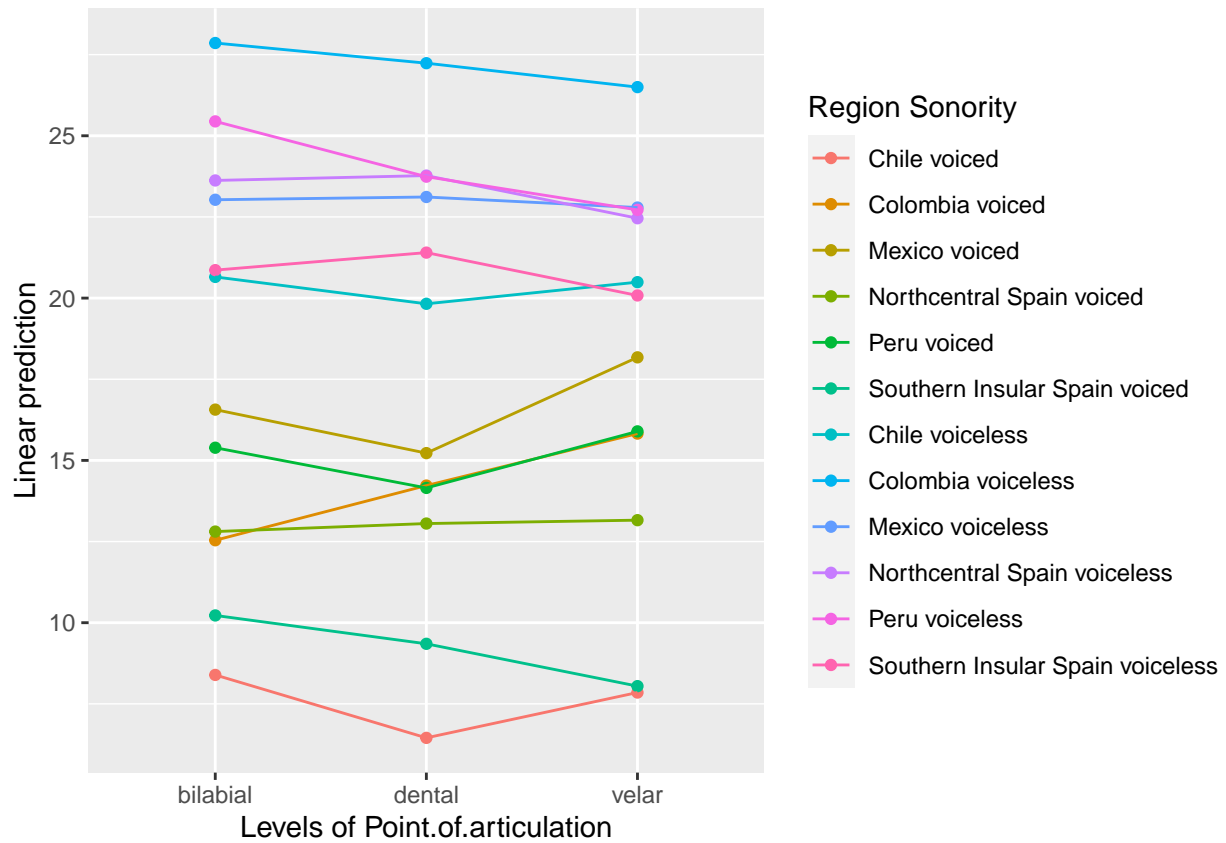
3-way Region x Stress x Sonority interaction

Full model

Observations	2520
Dependent variable	Relative.intensity
Type	Mixed effects linear regression

AIC	15031.80
BIC	15393.39
Pseudo-R² (fixed effects)	0.59
Pseudo-R² (total)	0.68

Fixed Effects					
	Est.	S.E.	t val.	d.f.	p
(Intercept)	9.35	1.64	5.72	23.51	0.00
RegionColombia	2.72	2.31	1.17	23.51	0.25
RegionMexico	7.07	3.27	2.16	23.51	0.04
RegionNorthcentral Spain	4.13	1.96	2.11	23.51	0.05
RegionPeru	5.99	2.31	2.59	23.48	0.02
RegionSouthern Insular Spain	1.35	2.16	0.62	23.51	0.54
Point.of.articulationdental	-1.94	0.86	-2.25	2445.00	0.02
Point.of.articulationvelar	-0.54	0.86	-0.63	2445.00	0.53
Sonorityvoiceless	12.26	0.86	14.26	2445.00	0.00
Stressunstressed	-3.95	0.50	-7.95	2445.00	0.00
Horizontal.positioncentral	1.76	0.73	2.40	2445.00	0.02
Horizontal.positionposterior	0.01	0.55	0.02	2445.00	0.99
Vertical.Positionmid	1.27	0.55	2.30	2445.00	0.02
RegionColombia:Point.of.articulationdental	3.62	1.22	2.98	2445.00	0.00
RegionMexico:Point.of.articulationdental	0.60	1.72	0.35	2445.00	0.73
RegionNorthcentral Spain:Point.of.articulationdental	2.19	1.03	2.13	2445.00	0.03
RegionPeru:Point.of.articulationdental	0.70	1.22	0.58	2445.00	0.56
RegionSouthern Insular Spain:Point.of.articulationdental	1.06	1.14	0.94	2445.00	0.35
RegionColombia:Point.of.articulationvelar	3.83	1.22	3.15	2445.00	0.00
RegionMexico:Point.of.articulationvelar	2.15	1.72	1.25	2445.00	0.21
RegionNorthcentral Spain:Point.of.articulationvelar	0.89	1.03	0.87	2445.00	0.39
RegionPeru:Point.of.articulationvelar	1.05	1.22	0.86	2445.00	0.39
RegionSouthern Insular Spain:Point.of.articulationvelar	-1.64	1.14	-1.44	2445.00	0.15
RegionColombia:Sonorityvoiceless	3.06	1.22	2.51	2445.00	0.01
RegionMexico:Sonorityvoiceless	-5.80	1.72	-3.37	2445.00	0.00
RegionNorthcentral Spain:Sonorityvoiceless	-1.45	1.03	-1.41	2445.00	0.16
RegionPeru:Sonorityvoiceless	-2.21	1.22	-1.82	2445.00	0.07
RegionSouthern Insular Spain:Sonorityvoiceless	-1.62	1.14	-1.43	2445.00	0.15
RegionColombia:Stressunstressed	0.81	0.70	1.16	2445.00	0.25
RegionMexico:Stressunstressed	-1.08	0.99	-1.09	2445.00	0.28
RegionNorthcentral Spain:Stressunstressed	-0.38	0.59	-0.64	2445.00	0.52
RegionPeru:Stressunstressed	-0.59	0.70	-0.85	2445.00	0.40
RegionSouthern Insular Spain:Stressunstressed	0.21	0.66	0.31	2445.00	0.75
RegionColombia:Horizontal.positioncentral	1.08	1.04	1.04	2445.00	0.30
RegionMexico:Horizontal.positioncentral	1.82	1.47	1.24	2445.00	0.22
RegionNorthcentral Spain:Horizontal.positioncentral	0.42	0.88	0.48	2445.00	0.63
RegionPeru:Horizontal.positioncentral	1.51	1.04	1.46	2445.00	0.15
RegionSouthern Insular Spain:Horizontal.positioncentral	0.16	0.97	0.16	2445.00	0.87
RegionColombia:Horizontal.positionposterior	1.04	0.78	1.32	2445.00	0.19
RegionMexico:Horizontal.positionposterior	2.29	1.11	2.07	2445.00	0.04
RegionNorthcentral Spain:Horizontal.positionposterior	0.61	0.66	0.93	2445.00	0.35
RegionPeru:Horizontal.positionposterior	0.94	0.78	1.20	2445.00	0.23
RegionSouthern Insular Spain:Horizontal.positionposterior	0.34	0.73	0.47	2445.00	0.64
RegionColombia:Vertical.Positionmid	0.96	0.78	1.23	2445.00	0.22
RegionMexico:Vertical.Positionmid	0.82	1.11	0.73	2445.00	0.46
RegionNorthcentral Spain:Vertical.Positionmid	0.38	0.66	0.57	2445.00	0.57
RegionPeru:Vertical.Positionmid	1.46	0.78	1.86	2445.00	0.06
RegionSouthern Insular Spain:Vertical.Positionmid	0.64	0.73	0.87	2445.00	0.38
RegionChile:Point.of.articulationdental:Sonorityvoiceless	1.11	1.22	0.91	2445.00	0.36
RegionColombia:Point.of.articulationdental:Sonorityvoiceless	-2.31	1.22	-1.90	2445.00	0.06
RegionMexico:Point.of.articulationdental:Sonorityvoiceless	1.43	2.11	0.68	2445.00	0.50
RegionNorthcentral Spain:Point.of.articulationdental:Sonorityvoiceless	-0.10	0.80	-0.12	2445.00	0.90
RegionPeru:Point.of.articulationdental:Sonorityvoiceless	-0.47	1.22	-0.38	2445.00	0.70

Random Effects		
Group	Parameter	Std. Dev.
Speaker	(Intercept)	2.50
Residual		4.71

Grouping Variables		
Group	# groups	ICC
Speaker	21	0.22