Analysis - Butera (2022)

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 (7 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 $(X(6) = 18.03; p < 0.006)$

`Point of Articulation` - **no** main effect $(X(2) = 1.6; p < 0.45)$

`Sonority` - main effect $(X(1) = 1800; p < 0)$

`Stress` - main effect $(X(1) = 395.17; p < 0)$

`Horizontal Position` - main effect $(X(2) = 29.7; p < 0)$

`Vertical Position` - main effect $(X(1) = 78.15; p < 0)$
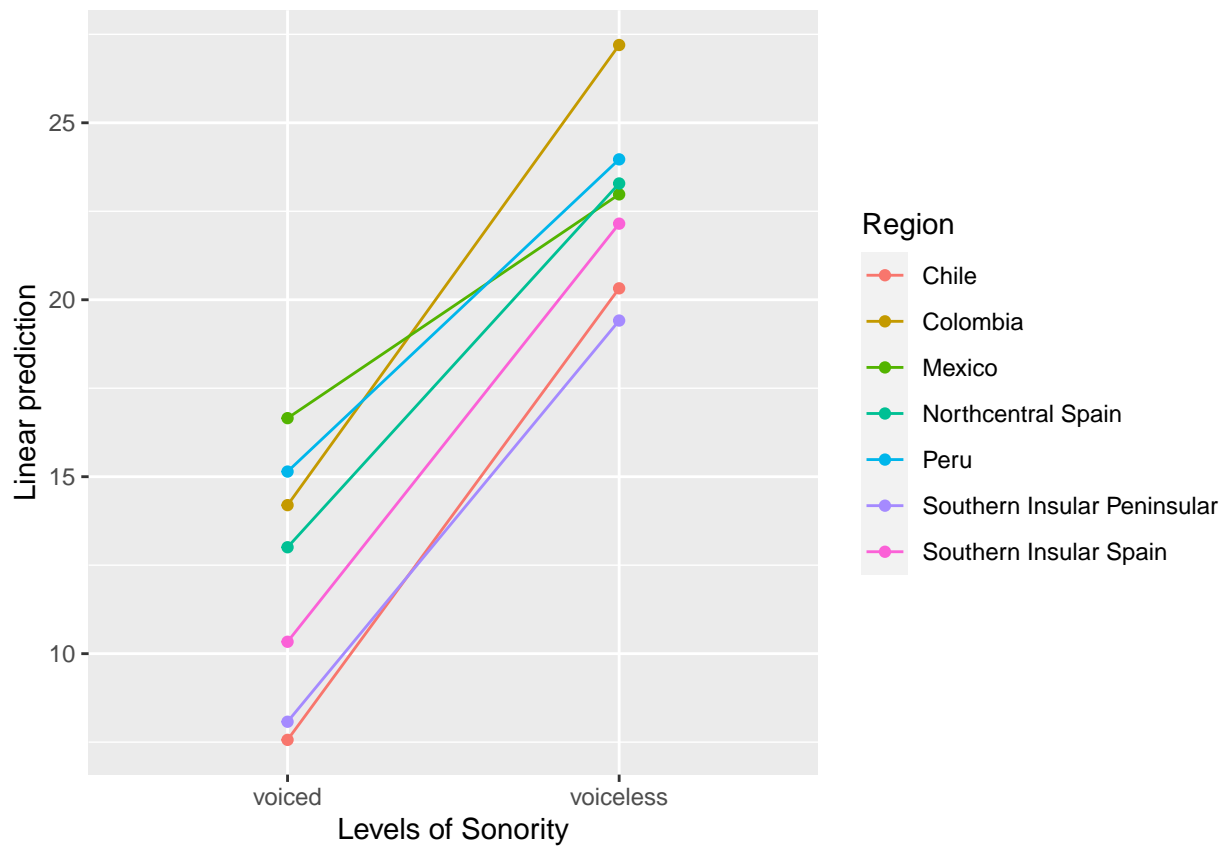
Interactions

`Region*sonority` - 2-way interaction $(X(6) = 83.02; p < 0)$

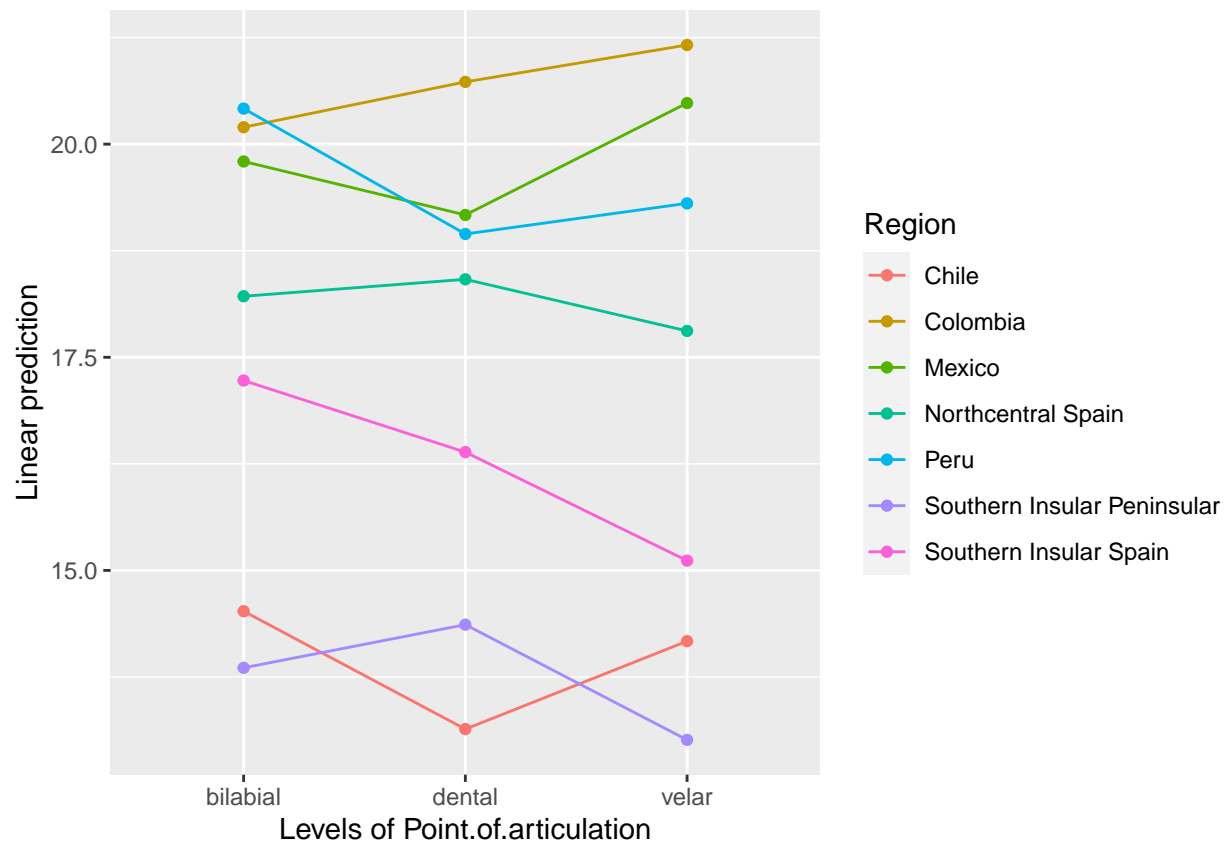`Region*poa` - 2-way interaction $(X(12) = 24.88; p < 0.015)$

`Region*stress*sonority` - 2-way interaction $(X(13) = 49.09; p < 0)$

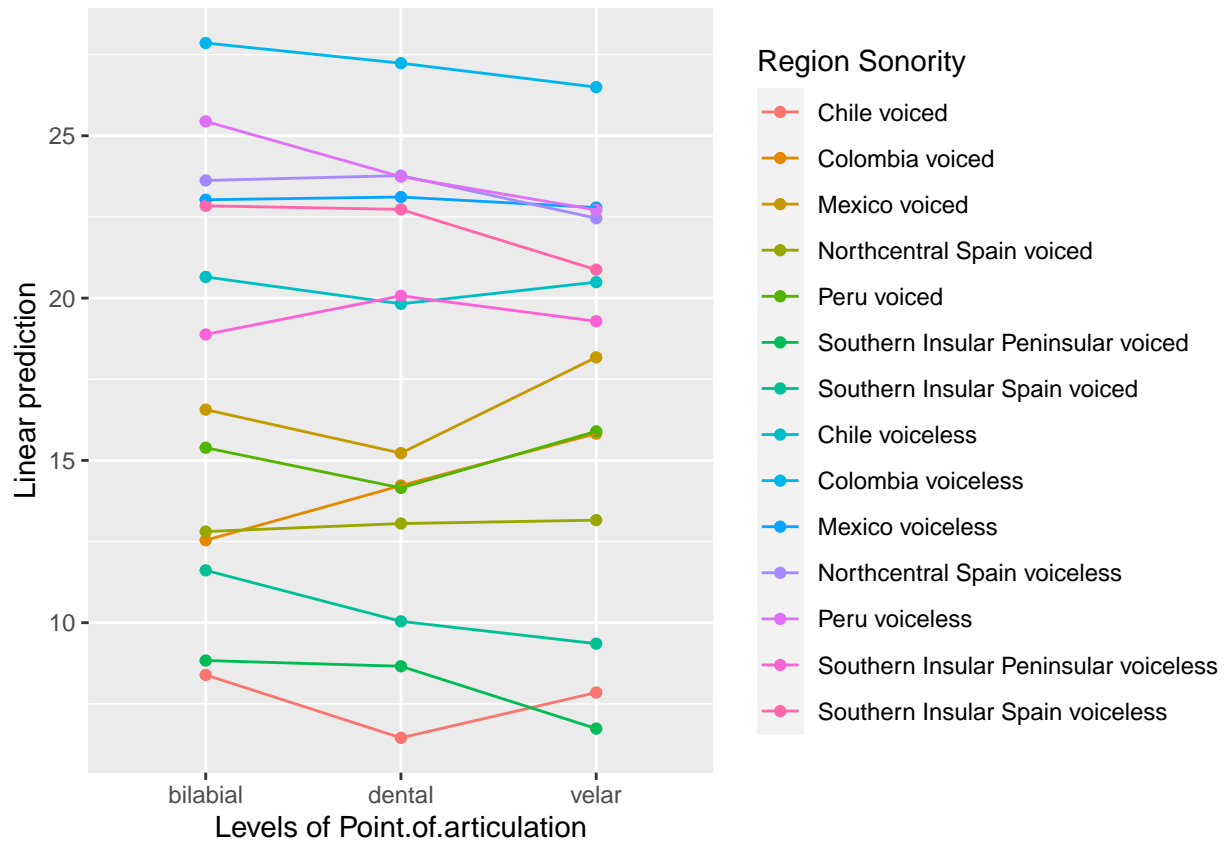`Region*poa*sonority` - 2-way interaction $(X(7) = 28.33; p < 0)$

2-way Region x Sonority interaction
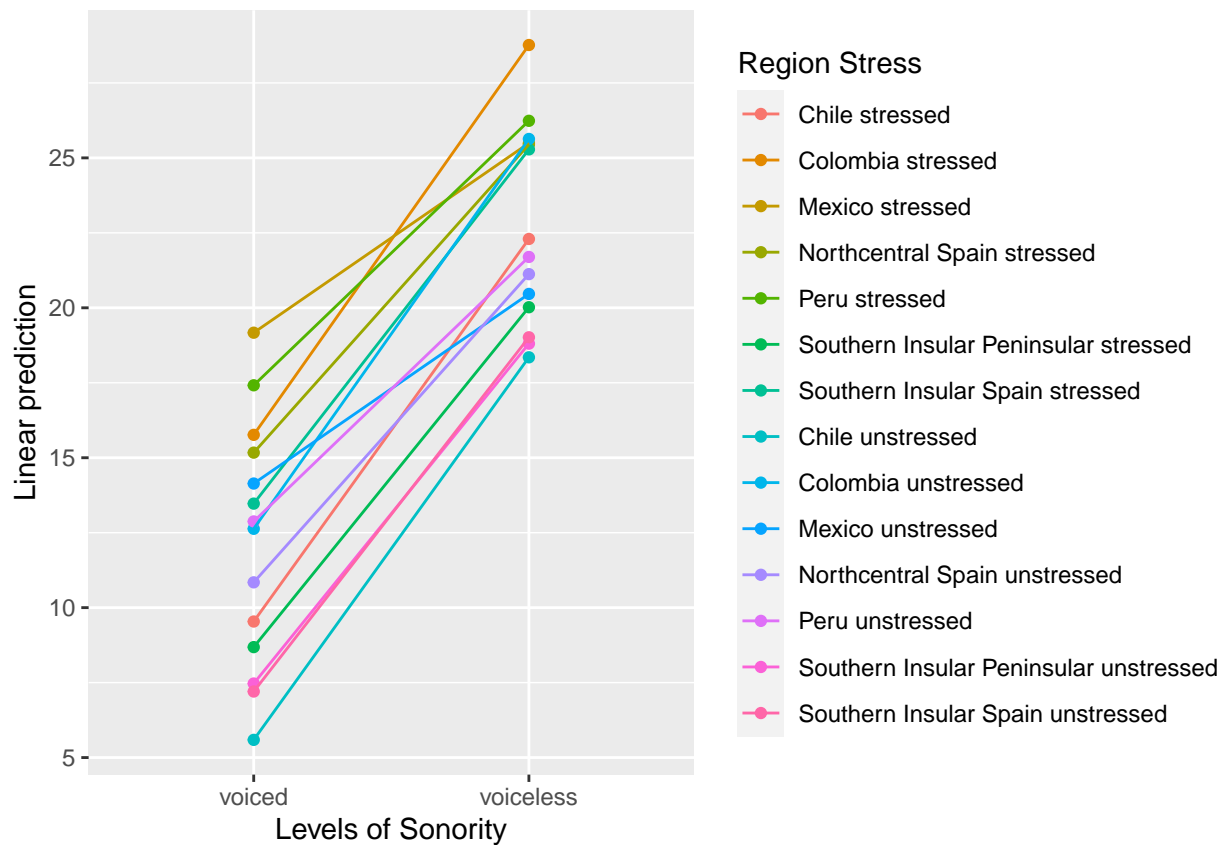
2-way Region x PoA interaction

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	14985.70
BIC	15405.61
Pseudo-R² (fixed effects)	0.60
Pseudo-R² (total)	0.69

Fixed Effects					
	Est.	S.E.	t val.	d.f.	p
(Intercept)	9.35	1.63	5.75	21.94	0.00
RegionColombia	2.72	2.30	1.18	21.94	0.25
RegionMexico	7.07	3.25	2.18	21.94	0.04
RegionNorthcentral Spain	4.13	1.94	2.13	21.94	0.04
RegionPeru	5.99	2.30	2.61	21.91	0.02
RegionSouthern Insular Peninsular	-1.32	2.57	-0.51	21.94	0.61
RegionSouthern Insular Spain	4.02	2.57	1.56	21.94	0.13
Point.of.articulationdental	-1.94	0.85	-2.27	2436.00	0.02
Point.of.articulationvelar	-0.54	0.85	-0.63	2436.00	0.53
Sonorityvoiceless	12.26	0.85	14.36	2436.00	0.00
Stressunstressed	-3.95	0.49	-8.01	2436.00	0.00
Horizontal.positioncentral	1.76	0.73	2.41	2436.00	0.02
Horizontal.positionposterior	0.01	0.55	0.02	2436.00	0.99
Vertical.Positionmid	1.27	0.55	2.31	2436.00	0.02
RegionColombia:Point.of.articulationdental	3.62	1.21	3.00	2436.00	0.00
RegionMexico:Point.of.articulationdental	0.60	1.71	0.35	2436.00	0.73
RegionNorthcentral Spain:Point.of.articulationdental	2.19	1.02	2.14	2436.00	0.03
RegionPeru:Point.of.articulationdental	0.70	1.21	0.58	2436.00	0.56
RegionSouthern Insular Peninsular:Point.of.articulationdental	1.76	1.35	1.30	2436.00	0.19
RegionSouthern Insular Spain:Point.of.articulationdental	0.37	1.35	0.27	2436.00	0.78
RegionColombia:Point.of.articulationvelar	3.83	1.21	3.17	2436.00	0.00
RegionMexico:Point.of.articulationvelar	2.15	1.71	1.26	2436.00	0.21
RegionNorthcentral Spain:Point.of.articulationvelar	0.89	1.02	0.87	2436.00	0.38
RegionPeru:Point.of.articulationvelar	1.05	1.21	0.87	2436.00	0.39
RegionSouthern Insular Peninsular:Point.of.articulationvelar	-1.56	1.35	-1.15	2436.00	0.25
RegionSouthern Insular Spain:Point.of.articulationvelar	-1.72	1.35	-1.27	2436.00	0.20
RegionColombia:Sonorityvoiceless	3.06	1.21	2.53	2436.00	0.01
RegionMexico:Sonorityvoiceless	-5.80	1.71	-3.39	2436.00	0.00
RegionNorthcentral Spain:Sonorityvoiceless	-1.45	1.02	-1.42	2436.00	0.16
RegionPeru:Sonorityvoiceless	-2.21	1.21	-1.83	2436.00	0.07
RegionSouthern Insular Peninsular:Sonorityvoiceless	-2.22	1.35	-1.64	2436.00	0.10
RegionSouthern Insular Spain:Sonorityvoiceless	-1.03	1.35	-0.76	2436.00	0.44
RegionColombia:Stressunstressed	0.81	0.70	1.17	2436.00	0.24
RegionMexico:Stressunstressed	-1.08	0.99	-1.10	2436.00	0.27
RegionNorthcentral Spain:Stressunstressed	-0.38	0.59	-0.64	2436.00	0.52
RegionPeru:Stressunstressed	-0.59	0.70	-0.85	2436.00	0.39
RegionSouthern Insular Peninsular:Stressunstressed	2.73	0.78	3.51	2436.00	0.00
RegionSouthern Insular Spain:Stressunstressed	-2.32	0.78	-2.98	2436.00	0.00
RegionColombia:Horizontal.positioncentral	1.08	1.03	1.05	2436.00	0.30
RegionMexico:Horizontal.positioncentral	1.82	1.46	1.25	2436.00	0.21
RegionNorthcentral Spain:Horizontal.positioncentral	0.42	0.87	0.48	2436.00	0.63
RegionPeru:Horizontal.positioncentral	1.51	1.03	1.47	2436.00	0.14
RegionSouthern Insular Peninsular:Horizontal.positioncentral	0.81	1.15	0.71	2436.00	0.48
RegionSouthern Insular Spain:Horizontal.positioncentral	-0.49	1.15	-0.43	2436.00	0.67
RegionColombia:Horizontal.positionposterior	1.04	0.78	1.33	2436.00	0.18
RegionMexico:Horizontal.positionposterior	2.29	1.10	2.08	2436.00	0.04
RegionNorthcentral Spain:Horizontal.positionposterior	0.61	0.66	0.93	2436.00	0.35
RegionPeru:Horizontal.positionposterior	0.94	0.78	1.21	2436.00	0.23
RegionSouthern Insular Peninsular:Horizontal.positionposterior	0.11	0.87	0.12	2436.00	0.90
RegionSouthern Insular Spain:Horizontal.positionposterior	0.58	0.87	0.66	2436.00	0.51
RegionColombia:Vertical.Positionmid	0.96	0.78	1.24	2436.00	0.22
RegionMexico:Vertical.Positionmid	0.82	1.10	0.74	2436.00	0.46
RegionNorthcentral Spain:Vertical.Positionmid	0.38	0.66	0.58	2436.00	0.56

Random Effects		
Group	Parameter	Std. Dev.
Speaker	(Intercept)	2.48
Residual		4.68

Grouping Variables		
Group	# groups	ICC
Speaker	21	0.22