Results: the FOOT-STRUT split

Caitlin Halfacre

November 13, 2021

Contents

1. Introduction

As summarised in chapter the FOOT and STRUT vowels were measured once, at one third of the duration (Rosenfelder et al., 2014).

In order to prevent over fitting of models the various possible linguistic predictors (particularly phonological environment) were plotted with F1 and F2 and only included if variation was seen between the levels of the predictor . Then the stepCAIC() function from the cAIC4 package (Saefken and Ruegamer, 2018) was used to determine the model with the best fit. For model reporting categorical some predictors were sum coded in order to understand the intercept in real terms rather than at a combination of single levels of the predictors Winter (2019), those that were sum-coded are marked in the model tables.

2. The Split

2.1. CoRP-SE speakers

The CoRP-SE speakers are assumed to have the prototypical southern FOOT-STRUT split. Three is no attestation in the literature that the split in the South East is affected by social class. Analysis of their vowels shows that the split is found mostly in height (F1: 199Hz) and very slightly in frontness (F2: -86Hz), as discussed below and in section 2.1.2, the frontness is a difference in mean but there is full overlap between the ranges. From figure 1 (a plot of F1 against F2, ellipses drawn at 0.67 of the standard deviation) it can be seen that there is overlap of individual tokens but the average position of the STRUT, words is lower in the vowel space than the FOOT words. They are also on average further back but the range falls within a subsection of the total F2 range of the FOOT words, which are more spread out. Full analysis of the F1 and F2 difference is in sections 2.1.1 and 2.1.2.

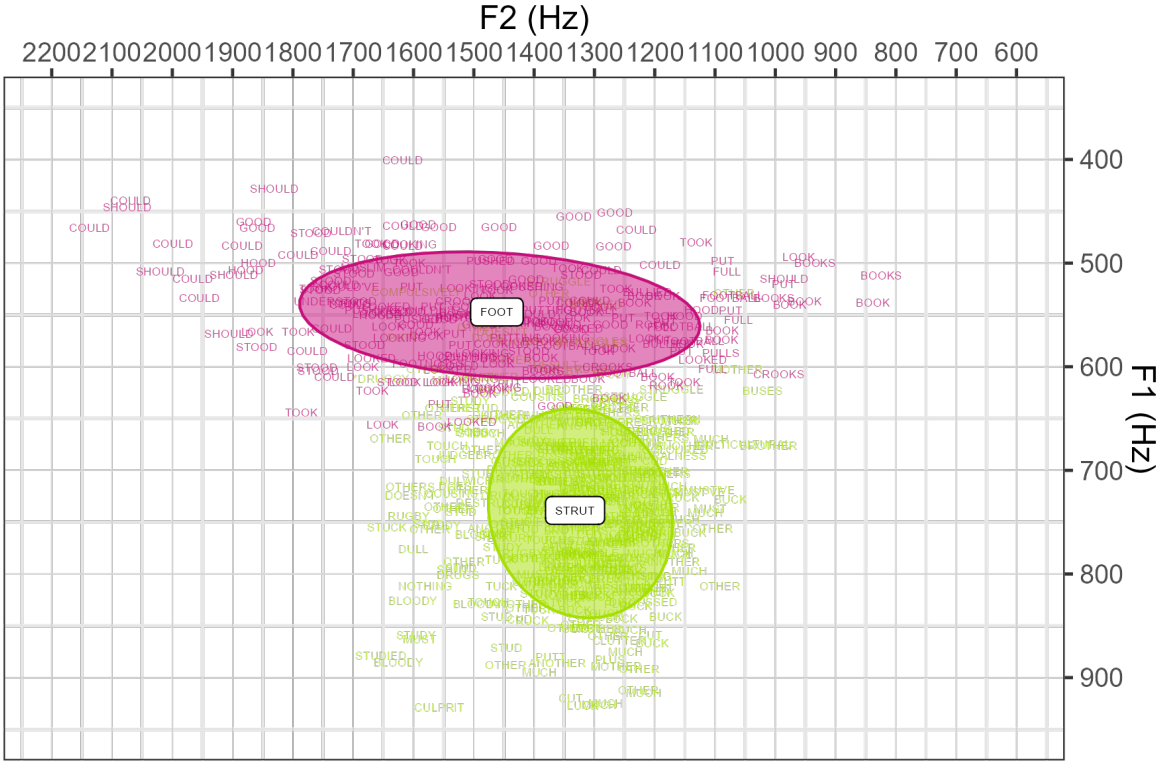

Figure 1: Vowel Space plot of FOOT and STRUT in the CoRP-SE speakers

2.1.1. F1

The model of the normalised F1 of the FOOT and STRUT words is shown in table 1; the model also includes random intercepts for speaker and word. The model intercept is 536Hz, which is the mean F1 of the FOOT words. The effect size of lexical Set is 199Hz (t=17.28). Therefore, the mean F1 for the vowels in the STRUT words is 735Hz. There is an effect of speakers sex (t=3.77) but the effect size is only 21Hz, which is not large in the context of the lexical set variation. This model demonstrates that the vowels of the two lexical sets are distinct in height in CoRP-SE speakers, with the mean of the STRUT lexical set lower in the mouth than the mean of the FOOT lexical set, by 199Hz. The difference is visualised in figure 2 (based on raw data, not the model predictions), where the distinction between the vowel measurements in the two lexical sets can be seen clearly, with no overlap between the interquartile ranges.

fixedeffect	estimate	tvalue
(Intercept)	536.37	35.36
lexSetSTRUT	199.08	17.28
sexSum1	20.57	3.77
ageGroupSum1	3.82	0.71
folManSum1	12.17	0.76
folManSum2	0.15	0.02
folManSum3	-20.85	-1.56
preSeg_smallSum1	19.32	1.50
preSeg_smallSum2	11.43	1.32
preSeg_smallSum3	-12.04	-0.96
preSeg_smallSum4	-19.77	-0.95
freq.zipf_z	0.61	0.11
styleSum1	-16.14	-2.18
styleSum2	7.27	0.79
time_z	1.55	0.43

Table 1: Linear Mixed Effects Model of F1 of FOOT and STRUT in the South East

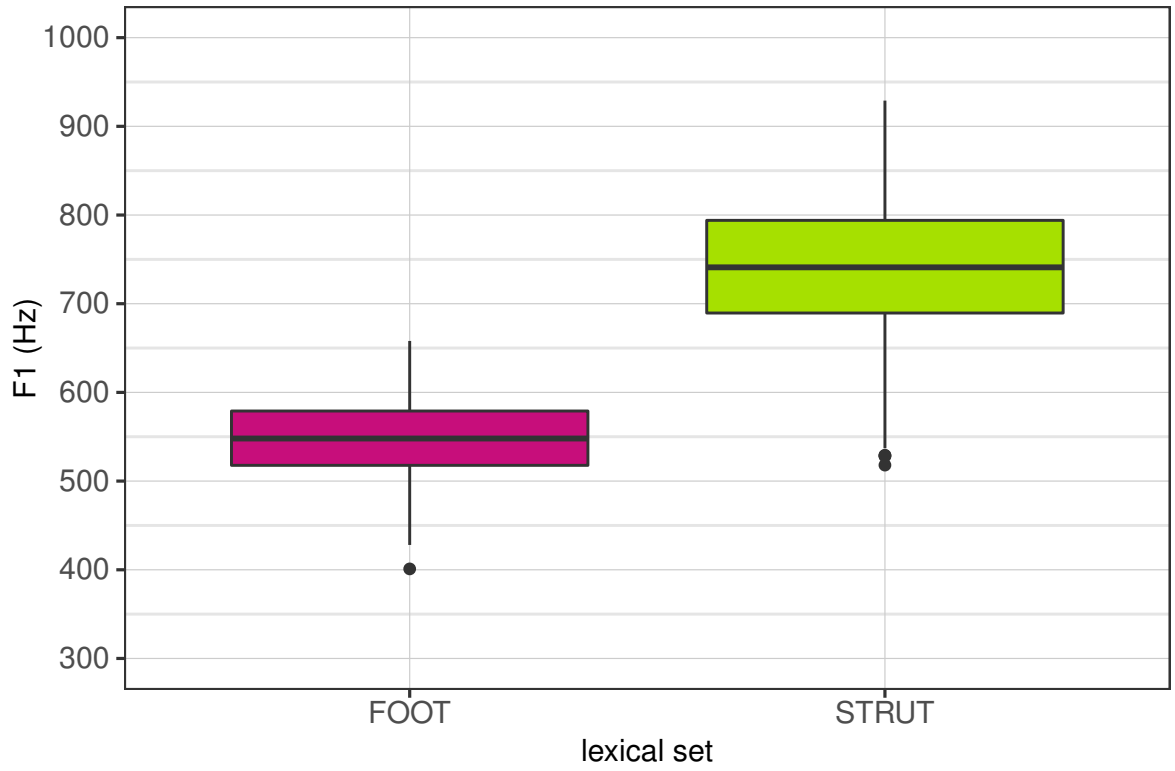

Figure 2: F1 of FOOT and STRUT in CoRP-SE speakers

2.1.2. F2

Modelling F2 (see table 11) showed an intercept of 1383Hz, the mean of the FOOT() lexical set, and while there is a lot less variation according to lexical set than seen in F1, there is a difference of -86Hz (t =-2.58) implying that the STRUT vowel is slightly further back than the FOOT vowel in south-eastern speakers, this can be seen in figure 3. This difference is not large and it can be seen in figure 3 that the inter-quartile range is almost completely overlapping; the STRUT words merely have a smaller range of F2 than the FOOT words. There is also a small but significant effect of style .

A further model was run including STRUT, THOUGHT, and schwa, to check the frontness of the STRUT vowel of in comparison to other vowels at a similar height in the English vowel space. The model summary can be found in appendix A; it shows that the STRUT vowel in these speakers is significantly further forward than the THOUGHT vowel (-399Hz, t=-13.50) and also significantly further back than the schwa (305Hz, t=8.16), placing it between the two in the vowel space but closer to schwa (see figure 4).

fixedeffect	estimate	tvalue
(Intercept)	1386.41	29.16
lexSetSTRUT	-85.98	-2.58
sexSum1	-13.82	-0.56
ageGroupSum1	-20.93	-0.84
folManSum1	10.77	0.23
folManSum2	-1.30	-0.05
folManSum3	-52.11	-1.37
preSeg_smallSum1	-26.20	-0.69
preSeg_smallSum2	-15.12	-0.60
preSeg_smallSum3	-62.95	-1.74
preSeg_smallSum4	107.84	1.81
freq.zipf_z	-2.61	-0.17
styleSum1	62.19	3.24
styleSum2	-43.60	-1.88
time_z	15.37	1.67

Table 2: Linear Mixed Effects Model of F2 of FOOT and STRUT in the South East

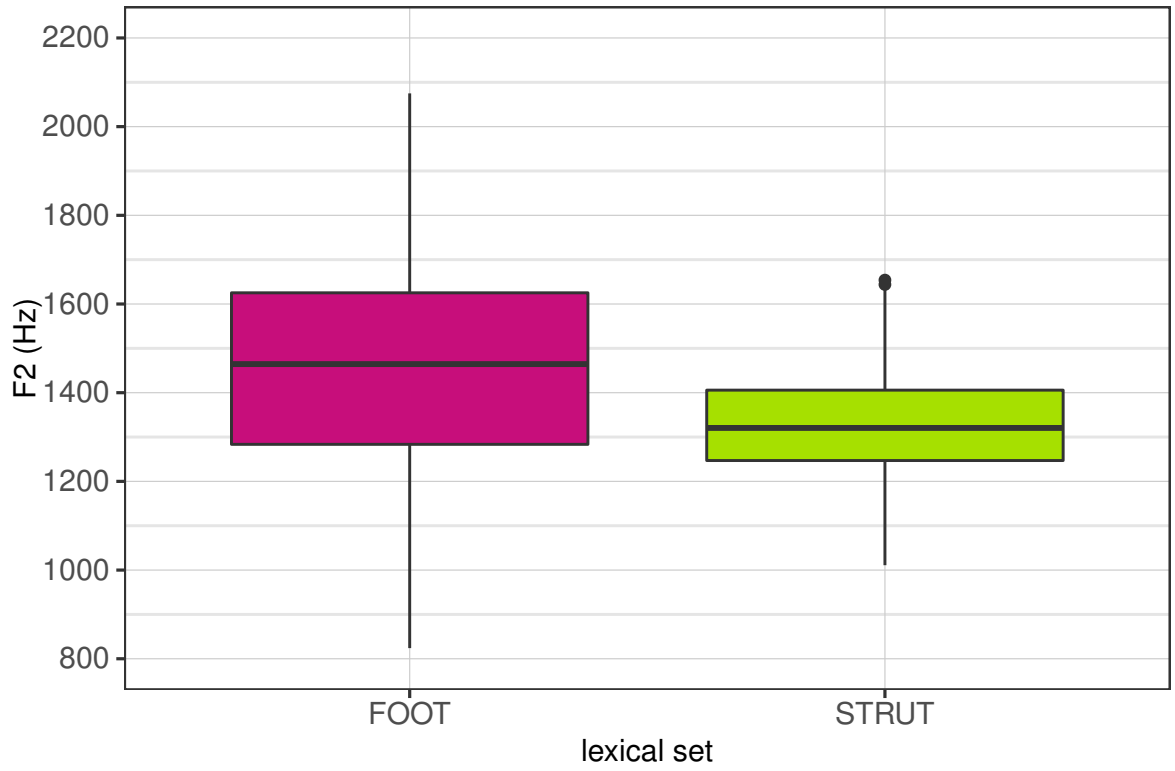

Figure 3: F2 of FOOT and STRUT in CoRP-SE speakers

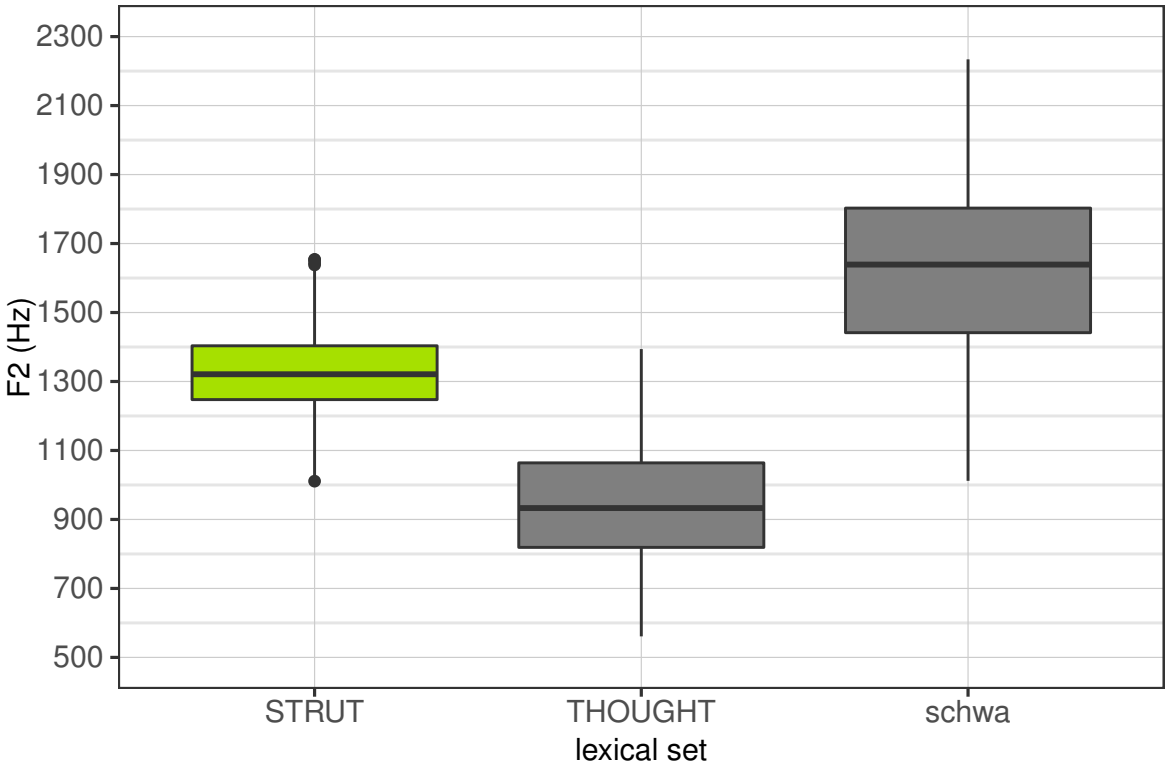

Figure 4: F2 of STRUT, THOUGHT, and schwa in CoRP-SE speakers

2.2. DECTE speakers

The DECTE speakers do not show a split in height, as measured by F1. They show some F2 differences between FOOT and STRUT, particularly in the old age group. This pattern is clearly different to that found in the CoRP-SE speakers and it can be concluded that according to this sample, the majority of state-educated speakers in the North East do not show FOOT-STRUTsplit as is found in the CoRP-SE speakers.

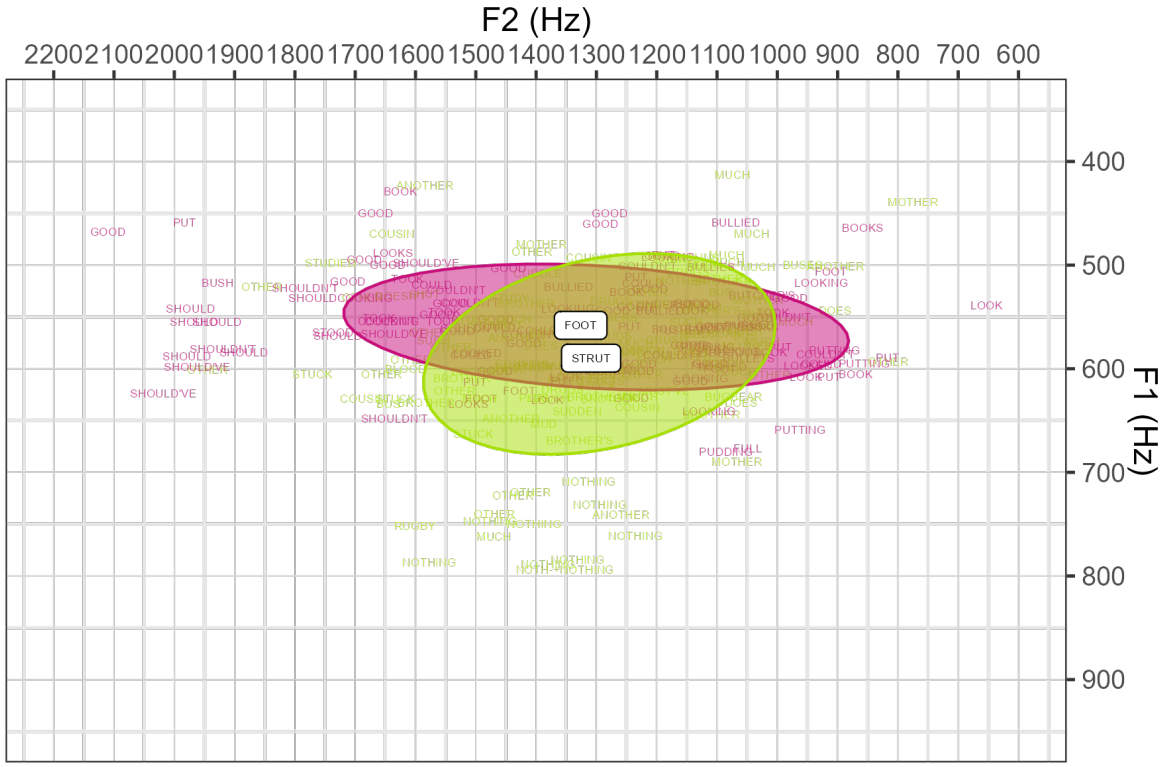

Figure 5: Vowel Space plot of FOOT and STRUT in the DECTE speakers

2.2.1. F1

Modelling F1 of the FOOT and STRUT words in the DECTE speakers gives an intercept of 572Hz (table 3), which is the mean of the FOOT words, and no significant effect of lexical set (seen in figure 5). However, when looking at individual speakers, as shown in figure 6, it does appear that some speakers have a small difference. Since the best fit model did not include random effect for speaker it is not possible to investigate this further.

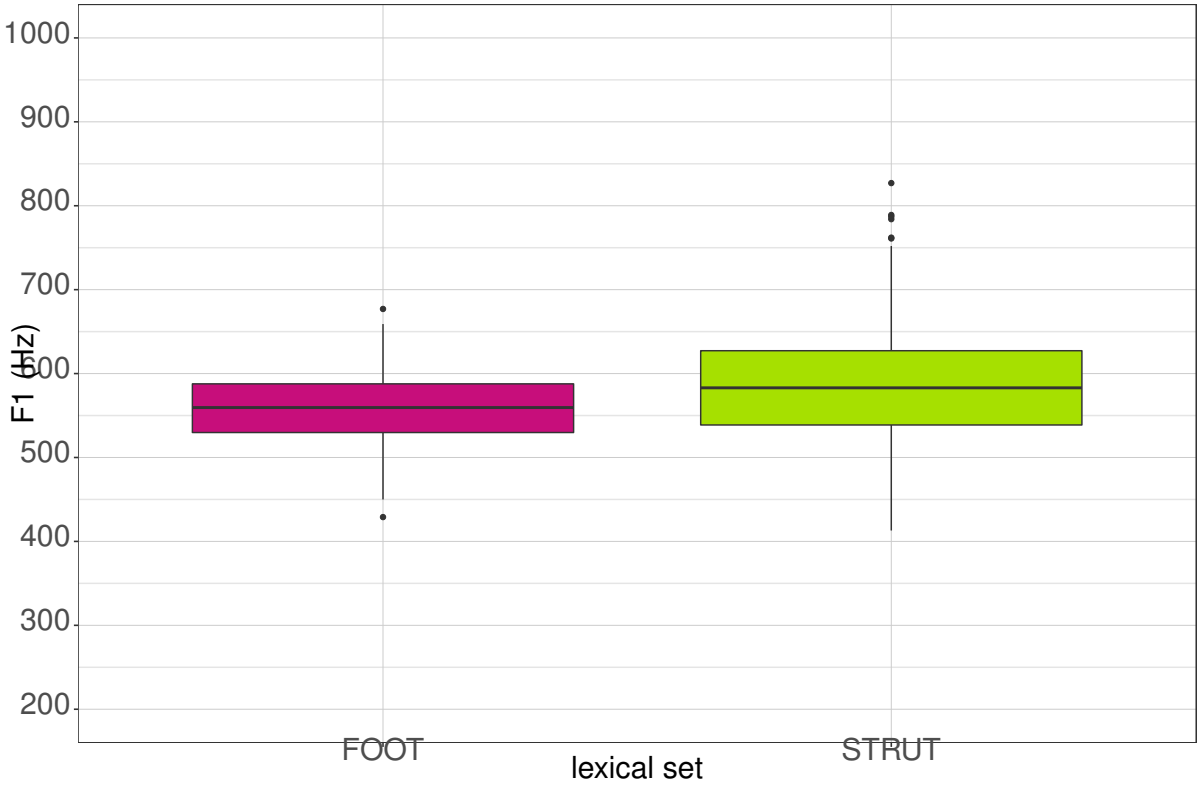

Figure 6: F1 of FOOT and STRUT in DECTE speakers

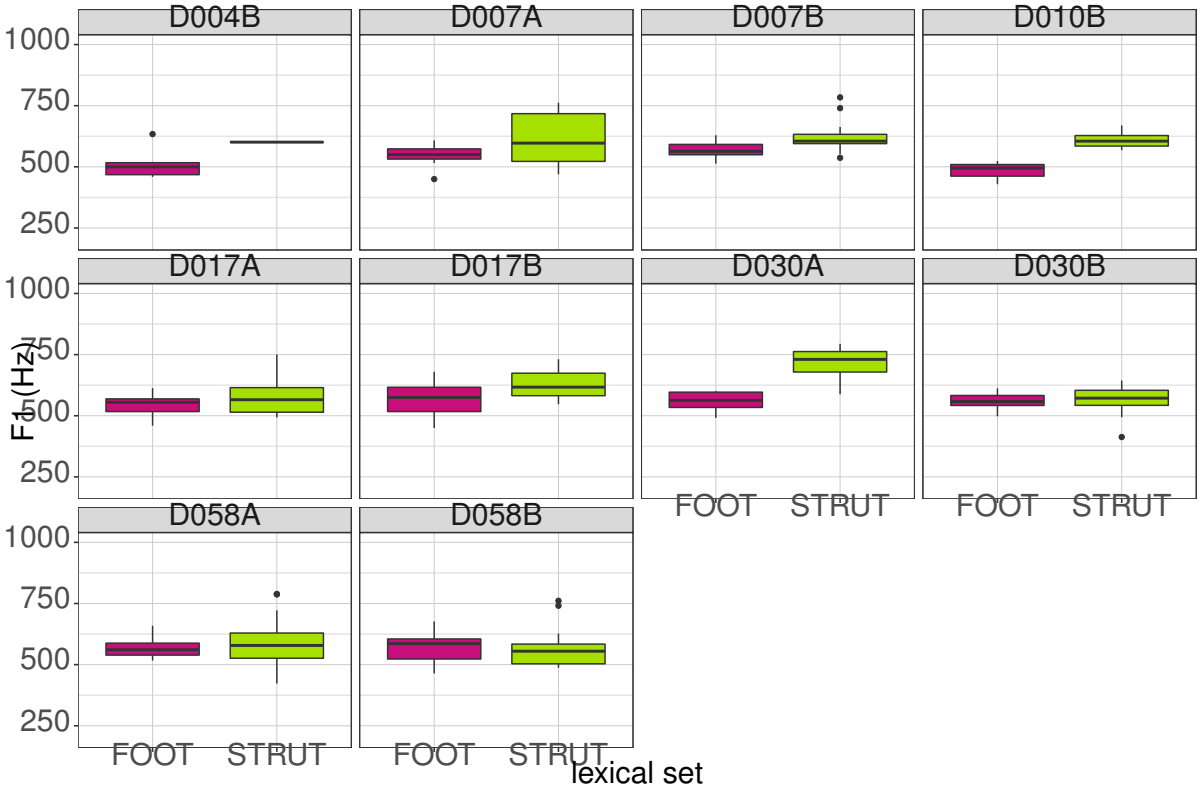

Figure 7: F1 of FOOT and STRUT in DECTE speakers, by speaker

fixedeffect	estimate	tvalue
(Intercept)	571.28	27.70
lexSetSTRUT	27.12	1.47
sexSum1	3.53	0.72
ageGroupSum1	-8.55	-1.70
folManSum1	-19.81	-0.86
folManSum2	5.81	0.41
folManSum3	14.90	0.69
preSeg_smallSum1	24.82	1.14
preSeg_smallSum2	-4.07	-0.30
preSeg_smallSum3	1.52	0.07
preSeg_smallSum4	-19.53	-0.65
freq.zipf_z	7.14	0.75
time_z	11.41	1.84

Table 3: Linear Mixed Effects Model of F1 of FOOT and STRUT in DECTE speakers

2.2.2. F2

The best fit model of F2 of the FOOT and STRUT words in the DECTE speakers (table 4) includes an interaction of lexical set and age group. The intercept (mean of FOOT words in old speakers) is 1232Hz, the mean of FOOT words in young speakers is 1638Hz. The split in the old age group is +147Hz whereas in the young age group it is -26Hz (negligible). It is possible that the split in the younger speakers is affected by the due to the Tyneside phenomenon of FOOT merging with GOOSE, which seems to be more prevalent in the younger speakers in this age group (figure 7).

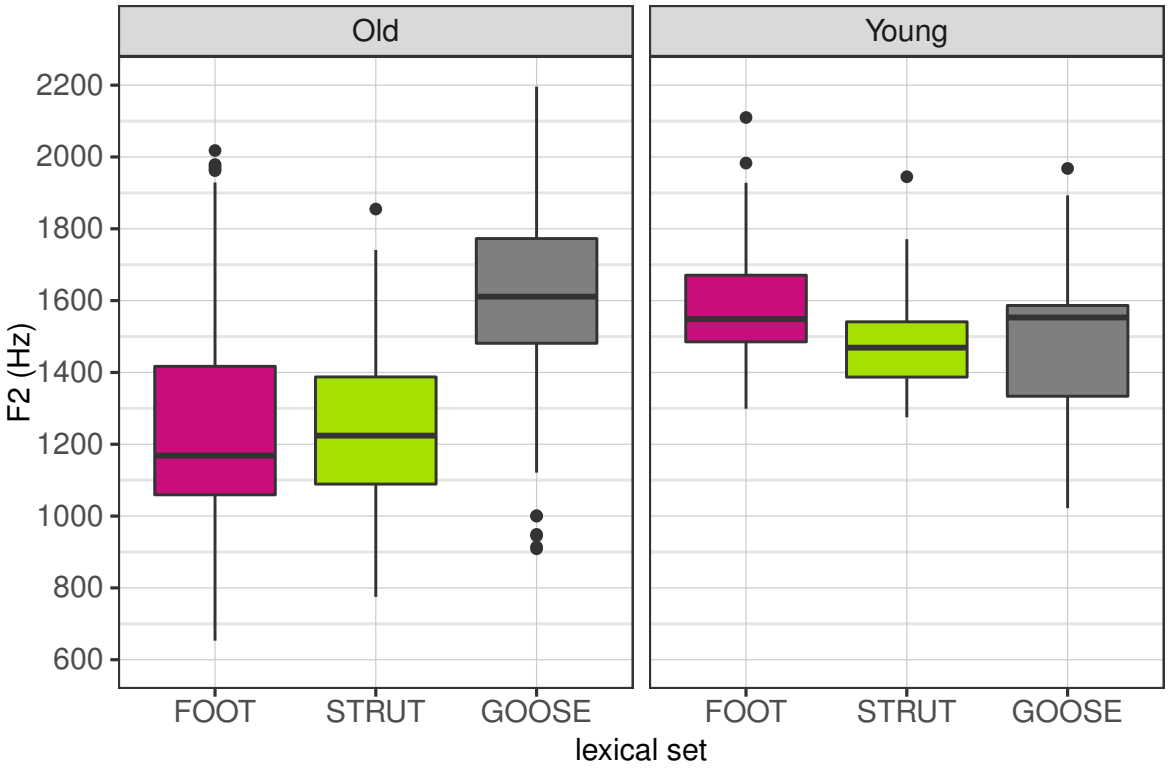

Figure 8: F2 of FOOT, STRUT, and GOOSE in DECTE speakers, by age group

fixedeffect	estimate	tvalue
(Intercept)	1232.05	19.07
lexSetSTRUT	146.67	2.67
ageGroupYoung	405.58	6.41
sexSum1	-48.29	-1.80
folManSum1	-73.52	-1.13
folManSum2	-12.44	-0.31
folManSum3	11.04	0.18
preSeg_smallSum1	-150.48	-2.42
preSeg_smallSum2	-139.84	-3.60
preSeg_smallSum3	-148.60	-2.36
preSeg_smallSum4	458.85	5.36
freq.zipf_z	25.87	0.95
time_z	-37.39	-1.96
lexSetSTRUT:ageGroupYoung	-172.85	-2.88

Table 4: Linear Mixed Effects Model of F2 of FOOT and STRUT in DECTE speakers

2.3. CoRP-NE speakers

CoRP-NE speakers show some evidence of a FOOT-STRUT split, particularly in F1 (on average 110Hz, higher in female speakers) but little evidence of an F2 split except in one speaker. Further analysis of the F1 and F2 differences can be seen in sections 2.3.1 and 2.3.2, but from the vowel space plot in figure it can be seen that the FOOT words have a similar distribution to the CoRP-SE speakers. The STRUT words are lower than the FOOT words (with some overlap) but have similar frontness.

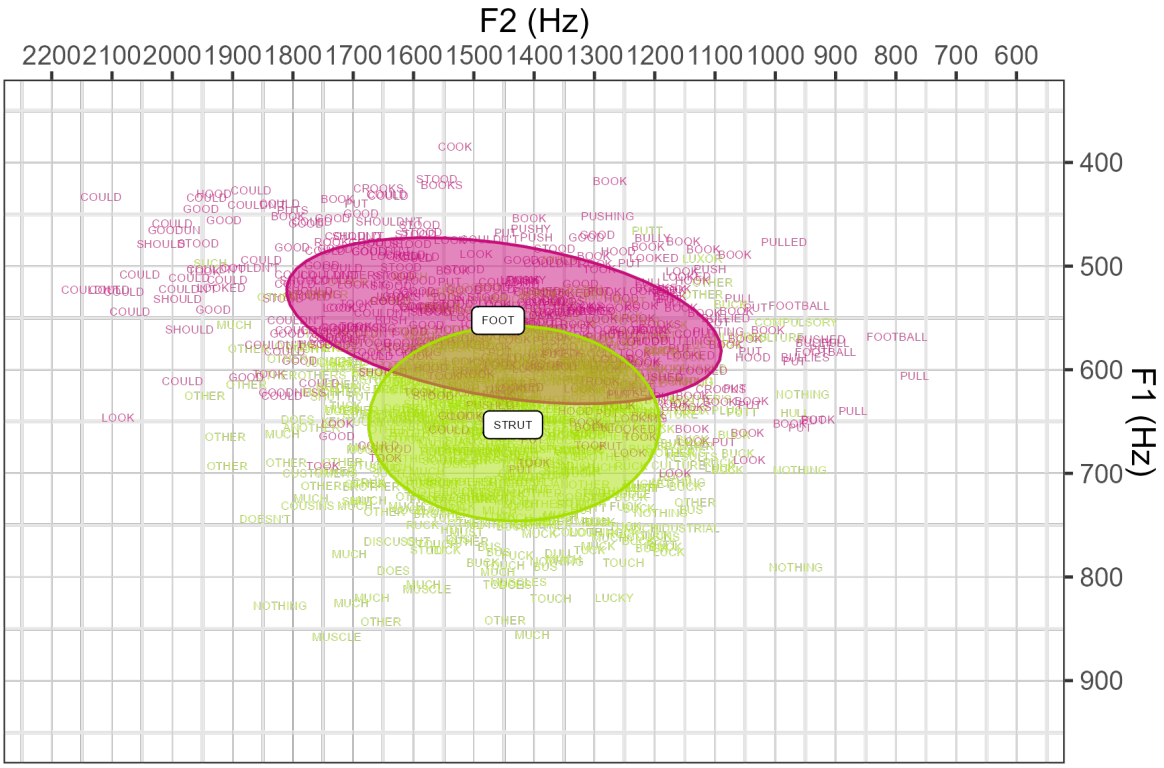

Figure 9: Vowel Space plot of FOOT and STRUT in the CoRP-NE speakers

2.3.1. F1

The best fit model for F1 of the CoRP-NE speakers can be seen in table 5 and shows a FOOT-STRUT split in F1 that interacts with both speaker sex and age group. The mean value of FOOT is 541.53 and the mean value of STRUT is 651Hz, showing an average split of 110Hz. However, this split is overall higher for female speakers (mean=142Hz) compared to male speakers (mean=78Hz) (64 Hz difference), there is also a slightly larger split in older speakers. Overall the size of split is ranked: OF, Yf, OM, YM.

fixedeffect	estimate	tvalue
(Intercept)	516.30	27.03
lexSetSTRUT	172.92	14.45
sexMale	32.17	1.22
ageGroupYoung	36.03	1.88
folManSum1	-12.31	-1.08
folManSum2	11.62	1.59
folManSum3	-5.03	-0.52
preSeg_smallSum1	24.05	2.49
preSeg_smallSum2	12.59	1.82
preSeg_smallSum3	-22.43	-2.08
preSeg_smallSum4	-9.66	-0.56
freq.zipf_z	2.55	0.61
styleSum1	-12.35	-2.17
styleSum2	5.40	0.78
lexSetSTRUT:sexMale	-89.79	-5.32
lexSetSTRUT:ageGroupYoung	-61.66	-5.40
sexMale:ageGroupYoung	-36.95	-1.18
lexSetSTRUT:sexMale:ageGroupYoung	50.89	2.53

Table 5: Linear Mixed Effects Model of F1 of FOOT and STRUT in the North East

	FOOT	STRUT	*size of split*
Old Female	516.3	689.22	*172.92*
Old Male	548.47	631.6	*83.13*
Young Female	553.07	664.33	*111.26*
Young Male	548.29	620.65	*72.36*
Mean	541.53	651.45	*109.92*

Table 6: table showing effects of speaker age group and sex on F1 of FOOT and STRUT in CoRP-NE speakers (calculated from table 5)

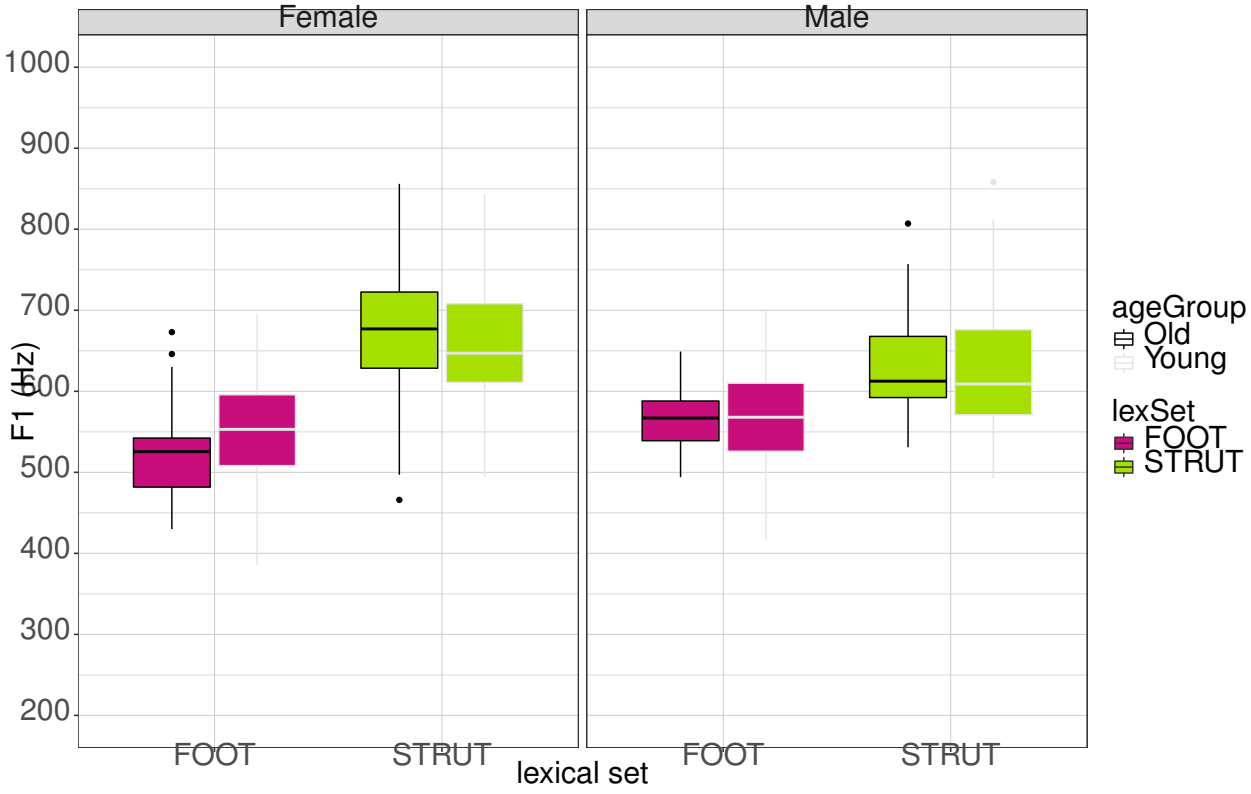
Female
Male
1000
900
800
700
600
500
400
300
200
F1 (Hz)
FOOT
STRUT
FOOT
STRUT
lexical set
ageGroup
Old
Young
lexSet
FOOT
STRUT

Figure 10

2.3.2. F2

The best fit model for F2 of the CoRP-NE speakers (see table **??**) also includes a three way interaction between lexical set, sex, and age group (summarised in figure 8). The mean value of FOOT is 1339Hz and the mean value of STRUT is 1380Hz, showing very little distinction. This is held up in all speaker groups except OM, however this group is only one speaker, Alexander, who has spent more time in the South than the other speakers (attending a specialist state boarding school in Warwick before returning to a private day sixth form in Newcastle) so it is possible that he has a larger split than the others. If this this speaker is not included it is reasonable to conclude that the CoRP-NE speakers do not have a FOOT-STRUT split in frontness.

fixedeffect	estimate	tvalue
(Intercept)	1468.01	25.11
lexSetSTRUT	-27.34	-0.68
sexMale	-261.86	-3.42
ageGroupYoung	-77.10	-1.45
folManSum1	81.82	1.71
folManSum2	52.98	1.89
folManSum3	-209.68	-5.95
preSeg_smallSum1	-45.91	-1.21
preSeg_smallSum2	-28.81	-1.10
preSeg_smallSum3	-68.50	-1.71
preSeg_smallSum4	161.72	2.57
freq.zipf_z	28.41	1.74
styleSum1	56.67	3.08
styleSum2	-30.87	-1.52
time_z	-6.79	-0.83
lexSetSTRUT:sexMale	203.82	4.34
lexSetSTRUT:ageGroupYoung	52.55	1.67
sexMale:ageGroupYoung	162.76	1.84
lexSetSTRUT:sexMale:ageGroupYoung	-240.35	-4.31

Table 7: Linear Mixed Effects Model of F2 of FOOT and STRUT in the North East

	FOOT	STRUT	*size of split*
Old Female	1468.01	1440.67	*-27.34*
Old Male	1206.15	1382.63	*176.48*
Young Female	1390.91	1416.12	*25.21*
Young Male	1291.81	1280.49	*-11.32*
Mean	1339.22	1379.98	*40.76*

Table 8: table showing effects of speaker age group and sex on F2 of FOOT and STRUT in CoRP-NE speakers (calculated from table 7)

2.4. Conclusions on the Split

If CoRP-SE speakers are assumed to have a prototypical FOOT-STRUT split then the split is characterised by difference in F1 (around 190Hz) and a small F2 (around 70Hz), making the vowel in STRUT words lower and slightly further back than in FOOT words. In CoRP-NE speakers we see a small F1 difference and no F2 difference, suggesting that while they have *a* split, it is not necessarily the same. In order to understand the nature of this difference between speaker groups the FOOT and STRUT words were modelled separately, results of this are discussed in section 3.

3. STRUT VOWEL ONLY

3.1. F1

Modelling the STRUT vowel alone shows that the CoRP-NE speakers are significantly different in F1 from both the CoRP-SE and the DECTE speakers. This means that the CoRP-NE speakers are producing a vowel that's height is in between the two other groups .

fixedeffect	estimate	tvalue
(Intercept)	655.69	24.22
relevel(corpus, "CoRP-NE")DECTE-NE	-52.45	-3.66
relevel(corpus, "CoRP-NE")CoRP-SE	95.84	7.29
sexMale	-29.61	-2.68
ageGroupYoung	-6.37	-0.55
folManfricative	16.98	0.86
folManlateral	-17.24	-0.74
folManstop	15.79	0.77
preSeg_smallstop	2.51	0.15
preSeg_smallobstruent-liquid	-31.09	-1.61
preSeg_smallSH/JH	-34.09	-1.06
preSeg_smallnone	-2.82	-0.11
freq.zipf_z	6.59	1.08
styleminimalpair	34.58	1.98
stylewordlist	26.02	2.16

Table 9: Linear Mixed Effects Model of F1 of STRUT

3.2. F2

fixedeffect	estimate	tvalue
(Intercept)	1432.78	19.02
relevel(corpus, "CoRP-NE")DECTE-NE	-57.45	-1.14
relevel(corpus, "CoRP-NE")CoRP-SE	-85.31	-1.67
sexMale	-15.36	-0.38
ageGroupYoung	24.43	0.57
folManfricative	-36.83	-0.76
folManlateral	-169.04	-3.02
folManstop	-43.68	-0.87
preSeg_smallstop	33.96	0.83
preSeg_smallobstruent-liquid	2.89	0.06
preSeg_smallSH/JH	185.52	2.45
preSeg_smallnone	56.13	0.95
freq.zipf_z	12.17	0.84
styleminimalpair	-29.86	-0.76
stylewordlist	-10.90	-0.38
time_z	1.94	0.32

Table 10: Linear Mixed Effects Model of F2 of STRUT

References

Rosenfelder, I., Fruehwald, J., Evanini, K., Seyfarth, S., Gorman, K., Prichard, H. and Yuan, J. (2014), 'FAVE (Forced Alignment and Vowel Extraction) Program Suite'.

Saefken, B. and Ruegamer, D. (2018), 'cAIC4: Conditional Akaike information criterion for lme4'.
URL: https://arxiv.org/abs/1803.05664

Winter, B. (2019), *Statistics for Linguists: An Introduction Using R*, Routledge.

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fixedeffect	estimate	tvalue
(Intercept)	1296.45	37.71
lexSetTHOUGHT	-399.00	-13.50
lexSetschwa	305.19	8.16
sexSum1	-12.72	-0.77
ageGroupSum1	-4.21	-0.26
folManSum1	37.03	0.98
folManSum2	17.13	0.86
folManSum3	-102.64	-5.05
preSeg_smallSum1	-55.23	-1.80
preSeg_smallSum2	-16.17	-0.92
preSeg_smallSum3	-69.59	-2.41
preSeg_smallSum4	68.11	1.52
freq.zipf_z	-1.90	-0.16
styleSum1	59.22	3.20
styleSum2	-47.13	-2.04

Table 11: Linear Mixed Effects Model of F2 of STRUT, THOUGHT, and schwa in the South East