Analysis & Results: the TRAP-BATH split

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Contents

0.1. Introduction

Formant measurements for the below analysis were taken from the normalised FAVE (Rosenfelder et al., 2014) output, which is taken at one third duration (see chapter 5), and normalised using the Lobanov method. The syllable information used was produced using the transcriptions from MFA/FAVE and the syllabifyr package (Fruehwald, 2020).

In order to prevent over fitting of models the linguistic predictors were plotted with F1 and F2, and only included if variation was seen between the levels of the predictor. Models were compared using CAIC, including using the stepCAIC() function from the cAIC4 package (Saefken and Ruegamer, 2018) to determine the model with the best fit. Unless involved in an interaction, categorical predictors were sum coded (suing contr.sum() from the stats package R Core Team 2021) in order to understand the intercept as a mean 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 as 'predictor*Sum*'. Continuous predictors were scaled to a z-score using the scale() function (R Core Team, 2021). Duration is measured by FAVE in seconds, but was converted to milliseconds (x1000) for readability and log10 transformed to remove positive skew Winter (2019).

how to defend this better - ask Dan?

The origins of the BATH lexical set are described as lengthening and backing, and it is generally considered to be merged with the PALM (and START) sets in southern varieties of

English (see chapter 3). Therefore, two approaches to modelling were taken. First, within each corpus group models included TRAP, BATH, and PALM (start words were coded as PALM since there is no difference in non-rhotic speakers) lexical sets to ascertain the pattern of BATH in relation to the other two sets of words. This analysis included F1 (to check for vowel height difference), F2 (to understand the reported difference in frontness), and duration. For vowels of the same quality **?** say that a difference of 50msec is needed to form a change in vowel category. However, since BATH moving from TRAP to PALM is also a change in vowel quality, a smaller difference in duration may contribute to a change in category. The second part of the analysis will take the BATH words alone and look at the effects on their realisation by both speakers group and morpho-phonological environment. Since the BATH set is backed on phonological environment (pre-fricative, and occasionally pre-nasal), following manner was not included in the models to avoid collinearity.

0.2. The Split

0.2.1. The Split in CoRP-SE speakers

The TRAP-BATH split as seen in the South East speakers is confirmed as the vowel in BATH words patterning with PALM rather than TRAP. This is seen in an F1 difference of 98Hz and an F2 difference of 363Hz. The BATH (and PALM) words have vowels that are higher and further back than the vowels in TRAP words. There was also some interaction between speakers sex and lexical set in the F1 dimension, full analysis of the split is found below.

Figure 0.1.: Vowel Space plot of TRAP,BATH and PALM in the CoRP-SE speakers

F1 of the CoRP-SE speakers

The best fit model of F1 of TRAP, BATH, and PALM in the CoRP-SE speakers is shown in table 0.1, which includes an interaction effect of lexical set and speaker sex. The calculation of the interaction can be seen in table 0.2 (note, the cells in grey are marked to show that none of the effects that distinguish the PALM values from the BATH values had a t-value greater than 1.4 so could be considered negligible). This demonstrates that BATH patterns with PALM and the TRAP-BATH split in the South East speakers has an overall higher vowel in TRAP than in BATH (see figure 0.2). A mean F1 difference of +98Hz (calculated between BATH and TRAP, excluding the PALM effect). This is larger in female speakers (+117Hz) due to a lower BATH and higher TRAP, and lower in the male speakers (+79Hz) due to a higher BATH and lower TRAP. Overral the mean F1 for vowels in BATH words is 740Hz, for PALM words 755Hz, and for TRAP words 857Hz.

fixedeffect	estimate	tvalue
(Intercept)	739.50	61.88
lexSetPALM	15.90	1.40
lexSetTRAP	117.49	12.25
sexMale	13.94	0.81
ageGroupSum1	-0.60	-0.09
freq.zipf_z	0.44	0.14
styleminimalpair	42.22	2.04
stylewordlist	32.41	3.38
has_codaSum1	2.42	0.71
lexSetPALM:sexMale	-9.63	-0.61
lexSetTRAP:sexMale	-38.95	-2.93

Table 0.1.: Linear Mixed Effects Model of F1 of TRAP,BATH, and PALM in CoRP-SE speakers

	BATH	PALM	TRAP	TRAP-BATH difference
Female	764.37	780.27	881.86	117.49
Male	778.31	784.58	856.85	78.54
Mean	771.34	782.43	869.36	98.02

Table 0.2.: Interactions effects of lexical set and speaker sex on F1 of TRAP, BATH, and PALM in CoRP-SE speakers (calculated from interactions in table 0.1)

Figure 0.2.: F1 of BATH, PALM, and TRAP in CoRP-SE speakers

F2 of the CoRP-SE speakers

The best fit model for the F2 of TRAP, BATH, and PALM, can be seen in table 0.3. Similar to the model of F1 there is a difference between BATH and TRAP (+363Hz, t=18.97) but little to none between BATH and PALM (-39Hz, t = -1.81), again supporting past evidence that BATH patterns with PALM in the South East, this difference is shown in figure 0.3. The mean F2 for vowels in the BATH lexical set is 1215Hz, for PALM 1175Hz, and for TRAP 1578Hz; there is no other significant variation.

fixedeffect	estimate	tvalue
(Intercept)	1214.63	46.57
lexSetPALM	-39.41	-1.81
lexSetTRAP	363.19	18.97
sexSum1	1.80	0.13
ageGroupSum1	25.92	1.85
freq.zipf_z	3.80	0.59
styleSum1	-25.27	-1.59
styleSum2	23.53	0.90
has_codaSum1	-1.73	-0.25
time_z	-6.25	-1.46

Table 0.3.: Linear Mixed Effects Model of F2 of TRAP,BATH, and PALM in CoRP-SE speakers

Figure 0.3.: F2 of BATH, PALM, and TRAP in CoRP-SE speakers

Duration of the CoRP-SE speakers

The model for duration of the TRAP, BATH, and PALM vowels is shown in table **??**. The best fit model included an interaction between lexical set and presence of coda, as shown in table 0.5. The mean duration of the vowel in the BATH words is 123msec However, the only significant effect seen is that of TRAP, which is 28msec shorter than PALM and BATH. This shows that BATH words are broadly the same length as PALM words and different to TRAP words, demonstrating that the TRAP-BATH split is also found in duration.

Without perception data it is difficult to tell if this length difference is contributing to the status of the BATH words.

fixedeffect	estimate	tvalue
(Intercept)	2.09	30.02
lexSetPALM	0.06	0.78
lexSetTRAP	-0.12	-2.08
has_codaTRUE	0.03	0.44
sexSum1	0.02	2.48
ageGroupSum1	0.00	0.33
freq.zipf_z	-0.00	-0.03
styleSum1	-0.05	-1.19
styleSum2	-0.04	-0.47
time_z	0.04	1.93
folVcSum1	0.01	0.82
lexSetPALM:has_codaTRUE	-0.01	-0.15
lexSetTRAP:has_codaTRUE	0.05	0.74
styleSum1:time_z	-0.03	-1.36
styleSum2:time_z	0.02	0.52

Table 0.4.: Linear Mixed Effects Model of log10(duration) of TRAP,BATH, and PALM in CoRP-SE speakers

	BATH	PALM	TRAP	TRAP-bath difference	PALM-BATH difference	T
has_codaFALSE	123.0269	141.2538	95.49926	-27.53	18.23	
has_codaTRUE	131.8257	147.9108	114.8154	-17.01	16.09	
average	127.4263	144.5823	105.1573	-22.27	17.16	

Table 0.5.: Interaction effects of lexical set and presence of coda on TRAP, BATH, and PALM in CoRP-SE speakers (converted to msec)

Figure 0.4.: Duration of BATH, PALM, and TRAP in CoRP-SE speakers

0.2.2. The Split in DECTE speakers

In models of F1, F2, and duration, the DECTE speakers do not show any difference between TRAP and BATH words. The difference between TRAP and PALM is 70Hz in F1 and 205Hz in F2. These speakers show a more spread out PALM distribution than the CoRP-SE speakers but they show no difference between TRAP and BATH; there is no evidence of a TRAP-BATH split, the models demonstrating this can be seen below.

Figure 0.5.: Vowel Space plot of TRAP,BATH and PALM in the DECTE speakers

F1 of the DECTE speakers

Table 0.6 shows the best fit model for F1 of the TRAP, BATH, and PALM words in the DECTE speakers. The mean F2 of the vowel in the BATH words is shown to be 842Hz, 70Hz higher (lower in the mouth) than the PALM words, which have a mean of 771 Hz and almost identical to the TRAP words (mean = 841Hz). As would be expected from speakers in the North of England, the DECTE speakers are not showing an evidence of a TRAP-BATH split in F1.

fixedeffect	estimate	tvalue
(Intercept)	841.89	65.90
lexSetPALM	-70.43	-4.26
lexSetTRAP	-0.90	-0.07
sexMale	-45.42	-2.39
ageGroupSum1	23.54	6.07
freq.zipf_z	8.10	1.69
has_codaSum1	2.41	0.48
time_z	-4.42	-0.85
lexSetPALM:sexMale	-9.28	-0.35
lexSetTRAP:sexMale	-1.91	-0.09

Table 0.6.: Linear Mixed Effects Model of F1 of TRAP,BATH, and PALM in DECTE-NE speakers

Figure 0.6.: F1 of TRAP, BATH and PALM in DECTE speakers

F2 of the DECTE speakers

The best fit model for the F2 of the TRAP, BATH, and PALM words is shown in table 0.7. The vowels in the BATH words have a mean of 1505Hz and in PALM words, 1324 Hz (difference of 181Hz), showing that BATH is further forward in the vowel space. This is supported by the negligible difference between the BATH and TRAP words, which have a mean of 1530 Hz. The difference between PALM and TRAP/BATH is also smaller than in CoRP-SE speakers.

fixedeffect	estimate	tvalue
(Intercept)	1504.91	37.87
lexSetPALM	-180.69	-6.42
lexSetTRAP	24.61	1.06
sexSum1	36.40	1.12
ageGroupSum1	-17.55	-0.53
freq.zipf_z	0.74	0.08
has_codaSum1	-5.21	-0.57
time_z	-18.10	-1.99

Table 0.7.: Linear Mixed Effects Model of F2 of TRAP,BATH, and PALM in DECTE-NE speakers

Figure 0.7.: F2 of TRAP, BATH and PALM in DECTE speakers

Duration of the DECTE speakers

The best fit model of duration in the DECTE speakers can be seen in table 0.8 and the interaction calculation (converted to msec) is shown in table 0.9. The model shows that the mean vowel length in the BATH words is 94msec long. Those with a coda are approximately the same length as the TRAP words with codas (4Hz difference), though in the words without codas the difference is larger (-22msec). There is a difference between TRAP and PALM (-20msec), however, all of these values are closer to the value for the TRAP words in the CoRP-SE speakers than to the PALM and BATH values in the CoRP-SE speakers demonstrating that not only do the DECTE speakers not show a TRAP-BATH split in duration, they also broadly do not have a long PALM vowel. This supports the conclusion drawn from the variation found in F2 that the PALM vowel is not consistently the same in DECTE speakers as in the CoRP-SE speakers.

say more about the interaction and codas?

fixedeffect	estimate	tvalue
(Intercept)	1.99	33.16
lexSetPALM	-0.04	-0.40
lexSetTRAP	-0.11	-1.86
has_codaTRUE	-0.03	-0.46
sexSum1	0.00	0.06
ageGroupSum1	-0.01	-0.87
freq.zipf_z	-0.00	-0.21
time_z	-0.00	-0.16
folVcSum1	0.01	0.44
lexSetPALM:has_codaTRUE	0.14	1.26
lexSetTRAP:has_codaTRUE	0.09	1.33

Table 0.8.: Linear Mixed Effects Model of duration of TRAP,BATH, and PALM in DECTE-NE speakers

	BATH	PALM	TRAP	TRAP-BATH diff	PALM-BATH diff	TRAP-PALM diff
no coda	97.72372	89.12509	75.85776	-21.87	-8.60	-13.27
coda	91.20108	114.8154	87.09636	-4.10	23.61	-27.72
mean	94.4624	101.9702	81.47706	-12.99	7.51	-20.49

Table 0.9.: Interaction effects of lexical set and presence of coda on TRAP, BATH, and PALM in DECTE speakers

Figure 0.8.: Duration of TRAP, BATH and PALM in DECTE speakers

0.2.3. The Split in CoRP-NE speakers

The CoRP-NE speakers show little to no difference in F1 or F2 that could be evidence for a TRAP-BATH split (though F2 is a little more complex, details below). The difference between TRAP and PALM in F1 is 86Hz and in F2 is 329Hz.

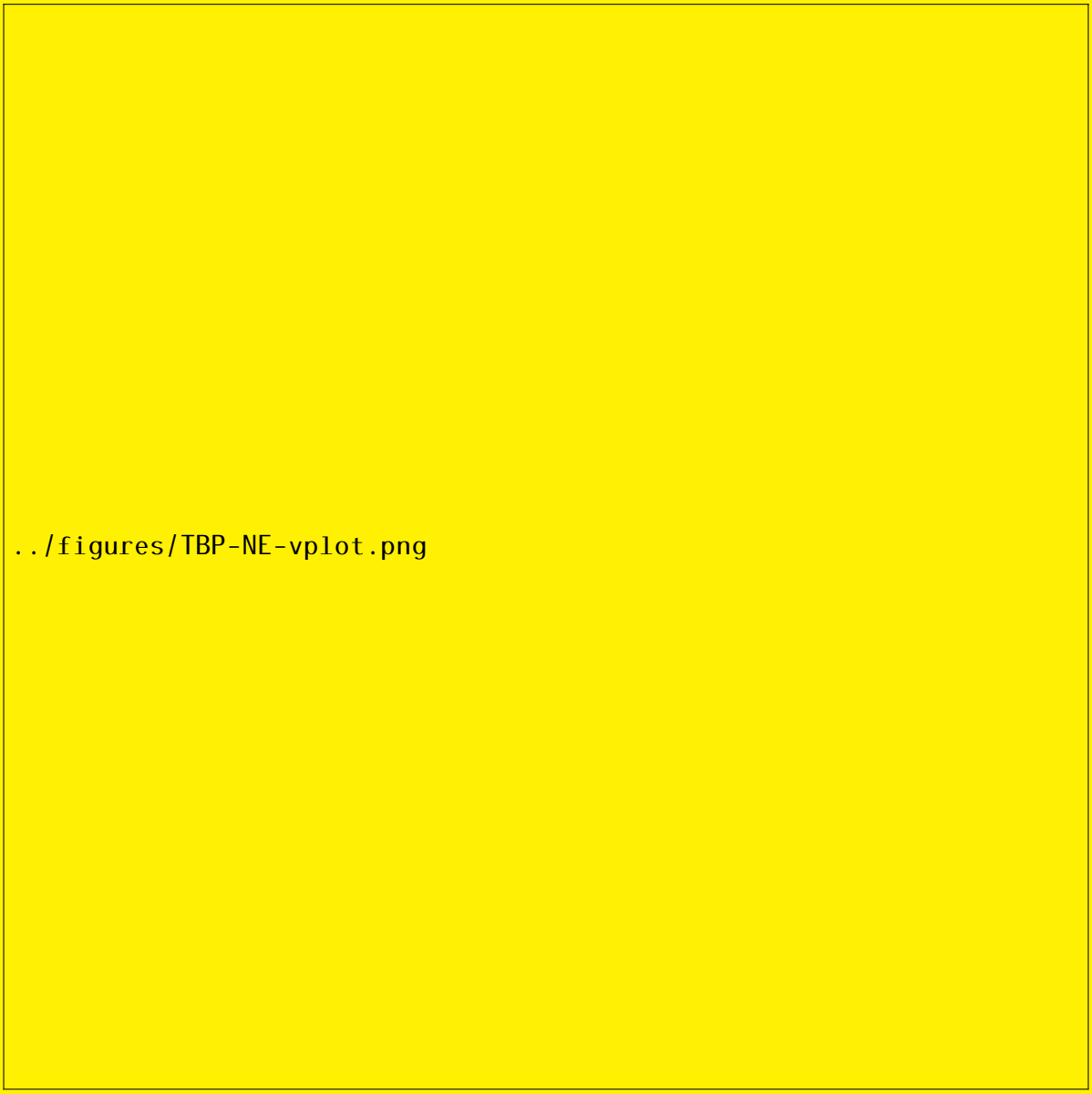

Figure 0.9.: Vowel Space plot of TRAP,BATH and PALM in the CoRP-NE speakers

F1 of the CoRP-NE speakers

Table 0.10 shows the best fit model for the CoRP-NE speakers. There is a three way interaction between lexical set, speaker sex, and speaker age group, which is summarised in table 0.11. This table shows that the largest TRAP-BATH difference is found in the Old Male group (which is only one speaker, who has spent more time in the south of England than other speakers)

fixedeffect	estimate	tvalue
(Intercept)	814.30	43.81
lexSetPALM	-52.55	-2.88
lexSetTRAP	78.88	4.97
sexMale	10.88	0.40
ageGroupYoung	45.78	2.41
freq.zipf_z	1.58	0.53
styleSum1	-16.23	-2.16
styleSum2	-4.94	-0.39
has_codaSum1	1.69	0.52
time_z	1.50	0.64
lexSetPALM:sexMale	15.55	0.55
lexSetTRAP:sexMale	-55.72	-2.34
lexSetPALM:ageGroupYoung	-9.22	-0.48
lexSetTRAP:ageGroupYoung	-74.15	-4.47
sexMale:ageGroupYoung	-33.80	-1.10
lexSetPALM:sexMale:ageGroupYoung	-30.44	-0.98
lexSetTRAP:sexMale:ageGroupYoung	59.93	2.25

Table 0.10.: Linear Mixed Effects Model of F1 of TRAP,BATH, and PALM in CoRP-NE speakers

	BATH	PALM	TRAP	TRAP-BATH diff	PALM-BATH diff	TRAP-PALM diff
Old Female	814.30	761.75	893.18	78.88	-52.55	131.43
Old Male	825.18	788.18	848.34	23.16	-37.00	60.16
Young Female	860.08	798.31	864.81	4.73	-61.77	66.50
Young Male	837.16	760.50	846.10	8.94	-76.66	85.60
Mean	834.18	777.19	863.11	28.93	-57.00	85.92

Table 0.11.: Interaction effects of lexical set, speaker sex and speaker age group on F1 of TRAP, BATH, and PALM in CoRP-NE speakers (calculated from interactions in table 0.10)

Figure 0.10.: F1 of TRAP, BATH and PALM in DECTE speakers

F2 of the CoRP-NE speakers

Table 0.12 shows the best fit model for F2 of the CoRP-NE speakers; the model included a three way interaction between lexical set, speaker sex, and speaker age group, the results of which are shown in table 0.13. Despite the interaction effects, it can be seen that the majority of speakers show a very small TRAP-BATH difference (mean = 90Hz). The largest TRAP-BATH difference (and smallest PALM-BATH difference) is seen in the old male group, which is only one speaker, who has spent more time in the south than the other speakers. The F2 values could be interpreted as a BATH target that is slightly further back than TRAP, however, it is also possible that the difference is due to some individual BATH words having a PALM target. Further analysis on the BATH vowel will be presented below.

fixedeffect	estimate	tvalue
(Intercept)	1334.28	29.30
lexSetPALM	-214.93	-5.86
lexSetTRAP	80.85	2.52
sexMale	5.92	0.08
ageGroupYoung	45.92	0.92
has_codaSum1	5.25	0.73
freq.zipf_z	-1.75	-0.26
time_z	-2.45	-0.58
lexSetPALM:sexMale	24.34	0.46
lexSetTRAP:sexMale	106.53	2.36
lexSetPALM:ageGroupYoung	-28.76	-0.79
lexSetTRAP:ageGroupYoung	-26.68	-0.84
sexMale:ageGroupYoung	39.27	0.46
lexSetPALM:sexMale:ageGroupYoung	-89.44	-1.52
lexSetTRAP:sexMale:ageGroupYoung	-124.64	-2.48

Table 0.12.: Linear Mixed Effects Model of F2 of TRAP,BATH, and PALM in CoRP-NE speakers

	BATH	PALM	TRAP	TRAP-BATH difference	PALM-BATH difference
Old Female	1334.28	1119.35	1415.13	80.85	-214.93
Old Male	1343.20	1152.61	1530.58	187.38	-190.59
Young Female	1380.20	1136.51	1434.37	54.17	-243.69
Young Male	1428.39	1119.60	1464.45	36.06	-308.79
Mean	1371.52	1132.02	1461.13	89.61	-239.50

Table 0.13.: Interaction effects of lexical set, speaker sex and speaker age group on F2 of TRAP, BATH, and PALM in CoRP-NE speakers (calculated from interactions in table 0.12)

Duration of the CoRP-NE speakers

Table 0.12 shows the best fit model for duration in the CoRP-NE speakers. An interaction effect is seen between lexical set and presence of a coda. This interaction is summarised in table 0.15. TRAP and PALM are on average 62 msec apart, and the PALM length is closer to the length found in the CoRP-SE speakers, implying that CoRP-NE speaker do not have the shorter PALM vowel found in the DECTE speakers. There is a TRAP-BATHdifference present in the words with a coda (-20msec) but none in words without a coda. The difference is less than the difference between TRAP-PALM, and while the mean duration of the BATH (136msec) words is longer than the TRAP words (126msec) it is not as long as the PALM words (189msec). In a form similar to the F2 results above, the duration

of the BATH values could be interpreted as a target that is slightly further back than TRAP, or as some individual BATH words having a PALM target and so pulling the mean duration higher.

fixedeffect	estimate	tvalue
(Intercept)	2.14	35.52
lexSetPALM	0.16	1.49
lexSetTRAP	-0.07	-1.25
has_codaTRUE	-0.01	-0.22
sexSum1	0.02	1.68
ageGroupSum1	0.00	0.28
freq.zipf_z	0.01	1.27
styleSum1	-0.11	-5.35
styleSum2	0.06	1.74
time_z	0.00	0.38
folVcSum1	-0.01	-0.85
lexSetPALM:has_codaTRUE	-0.04	-0.34
lexSetTRAP:has_codaTRUE	0.07	1.14

Table 0.14.: Linear Mixed Effects Model of duration of TRAP,BATH, and PALM in CoRP-NE speakers

	BATH	PALM	TRAP	TRAP-BATH diff	PALM-BATH diff	TRAP-PALM diff
no coda	138.0384	199.5262	117.4898	-20.55	61.49	-82.04
coda	134.8963	177.8279	134.8963	0.00	42.93	-42.93
mean	136.4674	188.6771	126.193	-10.27	52.21	-62.48

Table 0.15.: Interaction effects of lexical set and presence of coda on duration of TRAP, BATH, and PALM in CoRP-NE speakers.

Figure 0.11.: Duration of TRAP, BATH and PALM in CoRP-NE speakers

0.3. BATH vowel alone

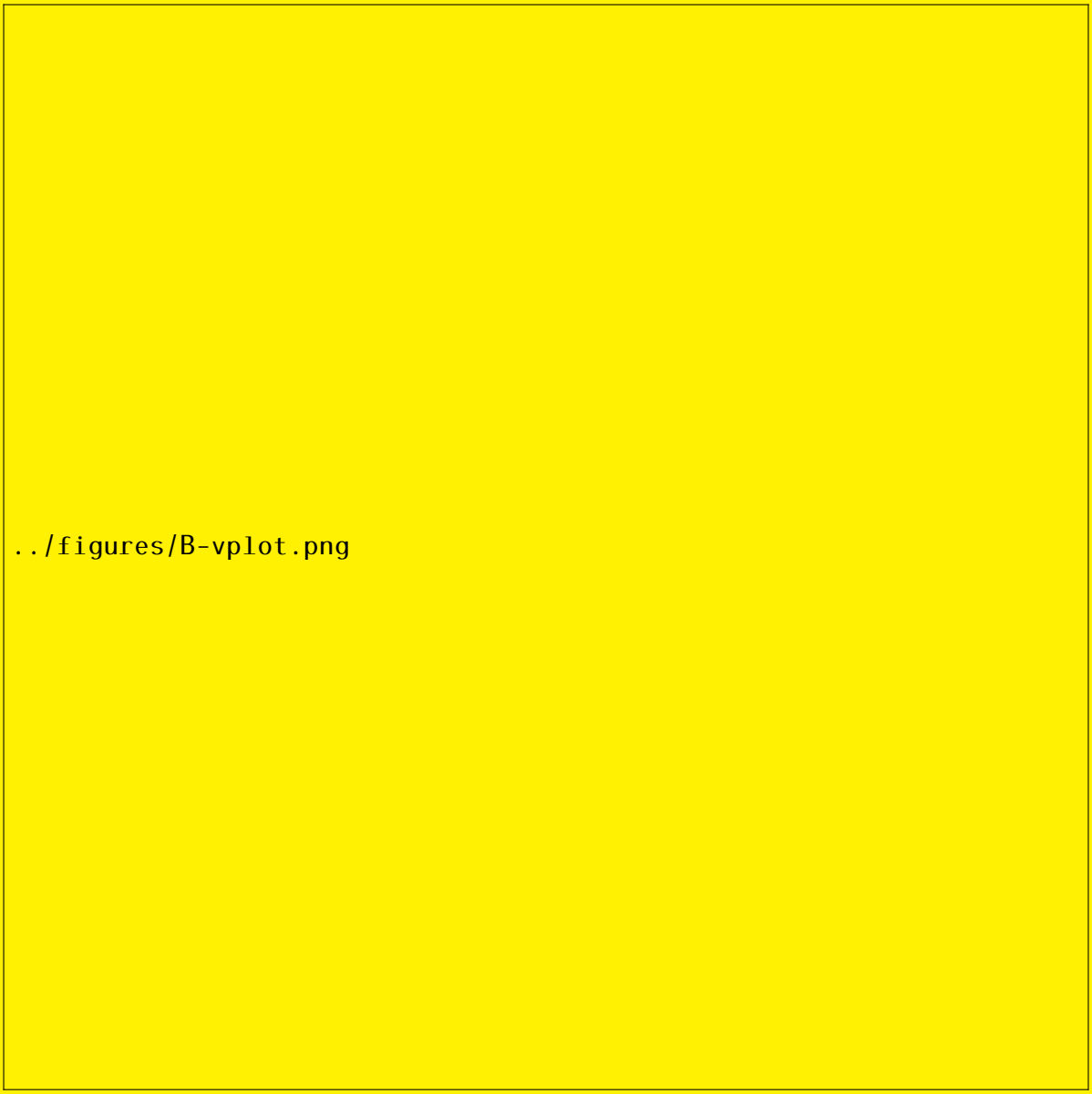

Figure 0.12.: BATH

0.3.1. F1

The best fit model of BATH in all speaker groups is shown in table 0.16. There is a three way interaction between sex, age group and corpus, shown in table **??**. It can be seen that overall the CoRP-NE speakers have a BATH vowel at 828Hz, very similar to the height of the DECTE speakers (837Hz), whereas the CoRP-SE speakers have a higher vowel, at 762Hz. While there is variation between male and female, and old and young, none of this variation reaches overlap between the lower vowels (CoRP-NE and DECTE), and the higher vowels (CoRP-SE).

fixedeffect	estimate	tvalue
(Intercept)	815.06	38.48
relevel(corpus, "CoRP-NE")DECTE-NE	61.18	2.53
relevel(corpus, "CoRP-NE")CoRP-SE	-68.19	-2.82
ageGroupYoung	40.96	1.96
sexMale	2.08	0.07
freq.zipf_z	0.78	0.12
styleSum1	-23.64	-2.19
styleSum2	1.15	0.06
has_codaSum1	-12.15	-1.69
time_z	-4.63	-1.05
relevel(corpus, "CoRP-NE")DECTE-NE:ageGroupYoung	-78.54	-2.30
relevel(corpus, "CoRP-NE")CoRP-SE:ageGroupYoung	-21.00	-0.70
relevel(corpus, "CoRP-NE")DECTE-NE:sexMale	-40.70	-1.05
relevel(corpus, "CoRP-NE")CoRP-SE:sexMale	19.85	0.52
ageGroupYoung:sexMale	-25.99	-0.78
relevel(corpus, "CoRP-NE")DECTE-NE:ageGroupYoung:sexMale	-8.42	-0.15
relevel(corpus, "CoRP-NE")CoRP-SE:ageGroupYoung:sexMale	-7.77	-0.15

Table 0.16.: Linear Mixed Effects Model of F1 of BATH

0.3.2. F2

Table 0.17 shows the best fit model for F2 of the vowel in BATH words in all three speaker groups. Modelling the BATH words alone shows that the CoRP-NE speakers have a vowel with F2 between the CoRP-SE speakers (-144Hz lower) and DECTE speakers (173Hz higher). From this model it is difficult to tell if this is truly a vowel with a mean in between or the effect of both positions existing with the set of tokens.

fixedeffect	estimate	tvalue
(Intercept)	1346.66	38.65
relevel(corpus, "CoRP-NE")DECTE-NE	173.11	3.62
relevel(corpus, "CoRP-NE")CoRP-SE	-143.53	-3.12
sexMale	40.09	0.92
ageGroupSum1	-5.17	-0.32
freq.zipf_z	26.29	1.58
has_codaSum1	-24.64	-1.27
time_z	-5.45	-0.72
relevel(corpus, "CoRP-NE")DECTE-NE:sexMale	-148.92	-2.07
relevel(corpus, "CoRP-NE")CoRP-SE:sexMale	-50.06	-0.69

Table 0.17.: Linear Mixed Effects Model of F2 of BATH

Figure 0.13.: F2 of BATH

0.3.3. Duration

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