LI2035
Experimental Phonetics and Speech Science

An analysis of the vowel system of the Wexford variety of
Hiberno-English, and a comparison with the Standard
Southern English variety of British English

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08.04.2019

Abstract

This study is an acoustic and durational investigation of the vowels of a male speaker of the Wexford variety of Hiberno English. Pure vowels, diphthongs, and vowels in a rhotic context were analysed by way of obtaining formant values from speech spectrograms in a semi-automatic manner using the computer software *Praat*. The study also compares the results obtained from the Wexford English study with the Standard Southern English variety of British English, on which investigations have already been carried out and for which literature has been published.

1. Introduction

This study had three aims as follows: (i) to provide an acoustic and durational analysis of the modern vowel system of the Wexford variety of Hiberno English, (ii) to comment on how vowels in this variety are influenced by the rhotic context, and (iii) to compare this vowel system with that of another variety of English – the Standard Southern English variety of British English was chosen. The computer program *Praat* was used for speech analysis by extracting formant values and durations from spectrograms of the recorded material on three of the five total recording repetitions. Averages of the formant values were then calculated and closely analysed by way of graphs and tables. Using the data collected, aim (i) will firstly focus on the phonological system of the variety and determining the set of contrasts. Secondly, striking features of the phonetic realisation of the vowel system will then also be determined. Finally, the vowel length can also be studied and conclusions may be drawn which determine the extent of the role that vowel length plays on the system. With regard to aim (ii), the vowel system was analysed in the rhotic context. Steady states, transitions, and final values in /ɹ/ were all considered to understand whether the /ɹ/ spreads to the entire vowel. For aim (iii), the findings of the two preceding aims are referred to for comparison between the two varieties of English at both the phonological and phonetic level.

2. Methods

Using the *Praat* software, one of the provided recordings is opened with a text grid with the tiers: 'word', 'vowel', and 'formant'. The 'formant' tier should be defined as a point tier, the other two are interval tiers. The spectrogram of the recording is carefully analysed and the segment of the word in question from the word list is found and an interval created on the first tier, then on the second tier the vowel is isolated (or in the case of a vowel in a rhotic context, the vowel and the following /ɹ/). Finally, the formant points are be chosen depending on the vowel. In the case of a pure vowel, one central formant point should be chosen. In the case of a diphthong, two points should be positioned, one for the steady state of the initial vowel and one for the steady state of the following vowel. In the rhotic case, three points must be positioned within the vowel interval. One for the initial steady state of the vowel, one at the midpoint of the transition from the pure vowel to /ɹ/, and one in the full rhotic context.

The positioning of these formant points was done manually for each of the three chosen sound files. A script was written for *Praat* which automatically extracted the F1, F2, and F3 values from these formant points and the extracted values were exported into a comma- separated values (.csv) file. The script used in this study can be found at Appendix C. This file type was edited with a spreadsheet editor and tables and figures were created from the collected data.

These tables and figures were analysed, and trends were identified. The formalised results can be viewed below under the results heading.

Figure 0 (below) shows a labelled screenshot of the *Praat* software with a spectrogram of the word *heed*.

Fig. 0: Vowel Segmentation Example Using Praat
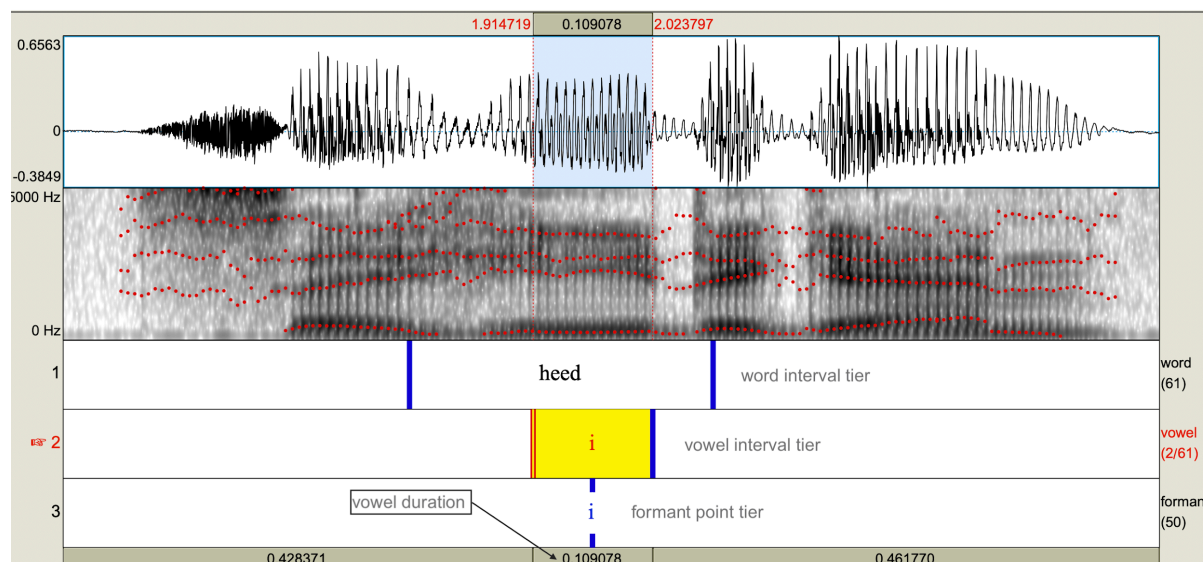
3.   Materials

Five separate recordings of the entire word list were provided and three were chosen for the project. For the recordings, a male Wexford English speaker of approximately twenty years old was instructed to read the words from the provided word list in a "say ___ again" context. The second, third, and fourth recordings were chosen, and thirty of the thirty-seven words were used from each recording. In total, ninety samples (with a few exceptions) underwent spectral analysis and the formant values were extracted at various points in the articulations. The entire word list can be viewed at Appendix A. The majority of the words are minimal pairs in the /h-d/ environment, where the middle sound is a vowel. The words which were used for the study are as follows:

TABLE A											
1	heed	6	Pam	11	aunt	16	hood	21	petite	26	hard
2	hid	7	matter	12	hod	17	who'd	22	beard	27	horticulture
3	hayed	8	ant	13	hawed	18	hide	23	gird	28	lord
4	head	9	palm	14	hoed	19	Hoyd	24	bared	29	hoard
5	had	10	Mater	15	Hudd	20	how'd	25	heard	30	Hurd

4.   Results

4.1.   The vowel system of Wexford English

4.1.1.   Pure vowels

The pure vowels of the Wexford variety of Hiberno English were analysed to determine the set of contrasts. The word list (see Appendix A) drew attention to the following word pairs:

    a.   *Hudd / hood*
    b.   *Pam / palm*
    c.   *aunt / ant*
    d.   *matter / Mater*

a. The *Hudd - hood* pair is differentiated as two separate vowels in some varieties of English i.e.: [hʌd] / [hʊd], however it was determined to be articulated as the same vowel /ʊ/ in Wexford English. The formant values showed no significant differences. The difference in duration was also negligible. Given the similarities of the two articulations, this is not a contrasting pair of vowels.

b. The *Pam - palm* pair showed very small formant value differences at F1, F2, and F3 - less than or equal to 40 Hz. Based on this small difference, the vowel quality is considered the same. The duration of the *Pam /* [a] utterance was 98ms, compared with 145ms for *palm / [aː].* The durations are at a ratio of roughly 2:3. This is a significant durational difference.

c. The *aunt - ant* pair showed an insignificant difference in duration. The F1 and F3 values also showed very little difference, however there was variability of 100 Hz in the F2 values of the vowels. This may just be a measuring discrepancy as after relistening to the sound file there was an indiscernible audio difference. More research is needed to make a complete declaration on the vowels' qualities.

d. In the case of *matter - Mater,* the vowels were determined to have the same quality as the difference in formant values was 40 Hz or less for F1, F2, and F3. There was a miniscule variance in duration, so it was considered insignificant.

The other minimal pairs in the /h-d/ context were verified to have significant enough differences in the obtained formant values to be labelled as distinct vowels.

Figure 1 (overleaf) is a plot of the averages of the formant values of the pure vowels extracted from three of the recordings. Figure 2 shows the pure vowels from figure 1 plotted as a vowel chart with F1 and F2 values. The figure shows a distinct vowel quadrilateral.

See Appendix B tables 1 to 4 for the complete numeric results of the pure vowels in table form.
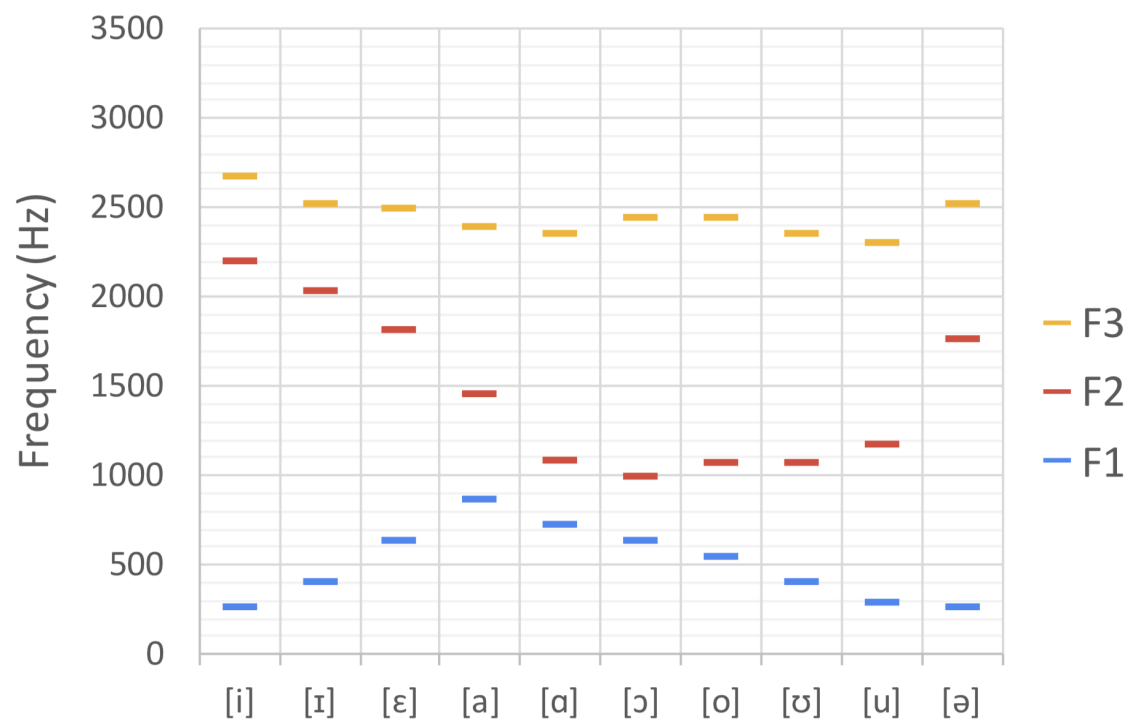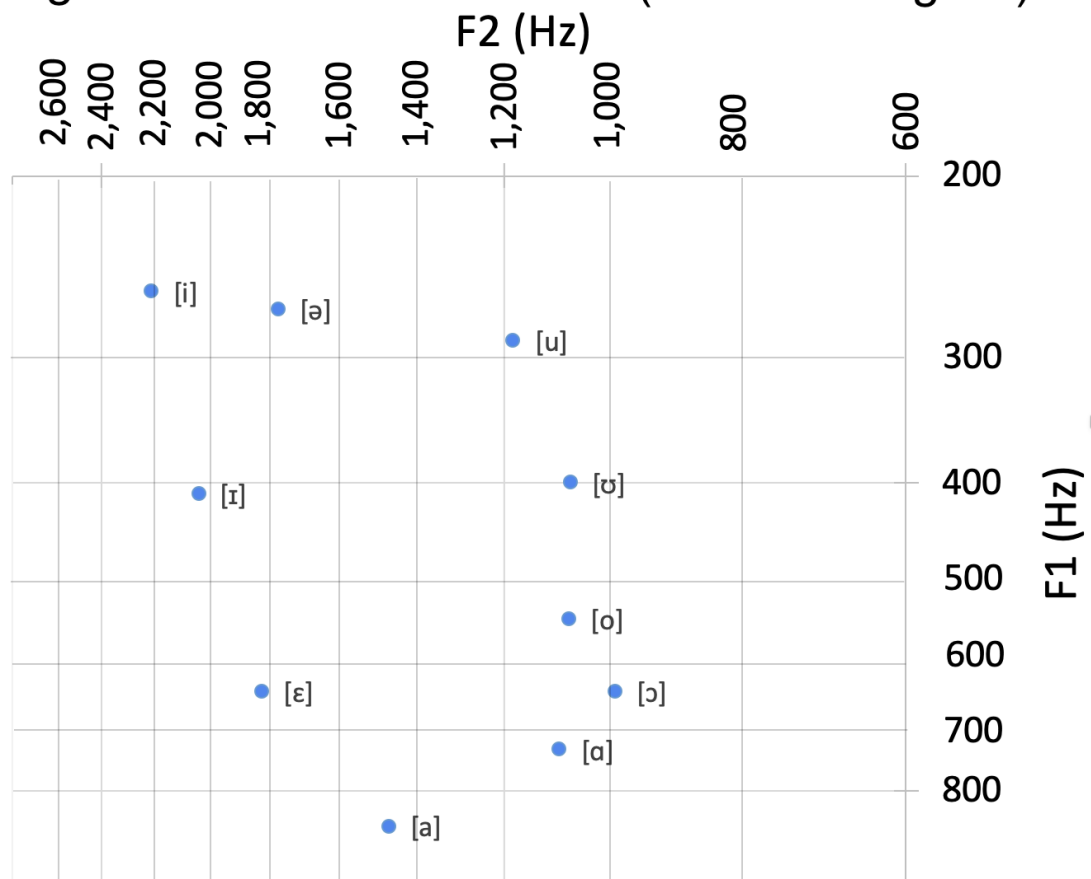
Fig. 1: Formants per Vowels of Wexford English

Fig. 2: F1-F2 Formant Chart (Wexford English)

4.1.2.   Diphthongs

The following table shows the words used to test for five diphthongs of Wexford English. The corresponding IPA symbols can be seen below the words.

TABLE B									
a	hayed	**b**	hoed	**c**	hide	**d**	Hoyd	**e**	how'd
	[eɪ] or [eː]		[oʊ] or [oː]		[aɪ]		[ɔɪ]		[aʊ]

The formant values and durations obtained from the recordings can be viewed at tables 5 and 6 at Appendix B. Below is a summary of the observations of table 6.

a. Significant differences in the F1 and F2 values, the word *hayed*'s vowel was determined to be a diphthong and was assigned the IPA symbols [eɪ].

b. The variations in all three formant bands was not considered significant enough to classify the utterance as a diphthong. Instead it was determined to be a long pure vowel with a duration of 182ms. For this reason, the symbol [oː] was assigned instead of [oʊ]. Figure 3 has the vowels plotted separately to demonstrate the similarity.

c. The vowel in the word *hide* was confirmed to be uttered as a diphthong. The formant values for the separate vowels showed significant differences in F1 and F2. See figure 3 for an illustration of the diphthong.

d. In the case of *Hoyd* the vowel was also confirmed as a diphthong. F1, F2, and F3 all showed large differences between the two vowel points.

e. Similar to above, *how'd* also had remarkable differences in all three formant bands and was confirmed to be a diphthong.

Fig. 3: Diphthongs of Wexford English
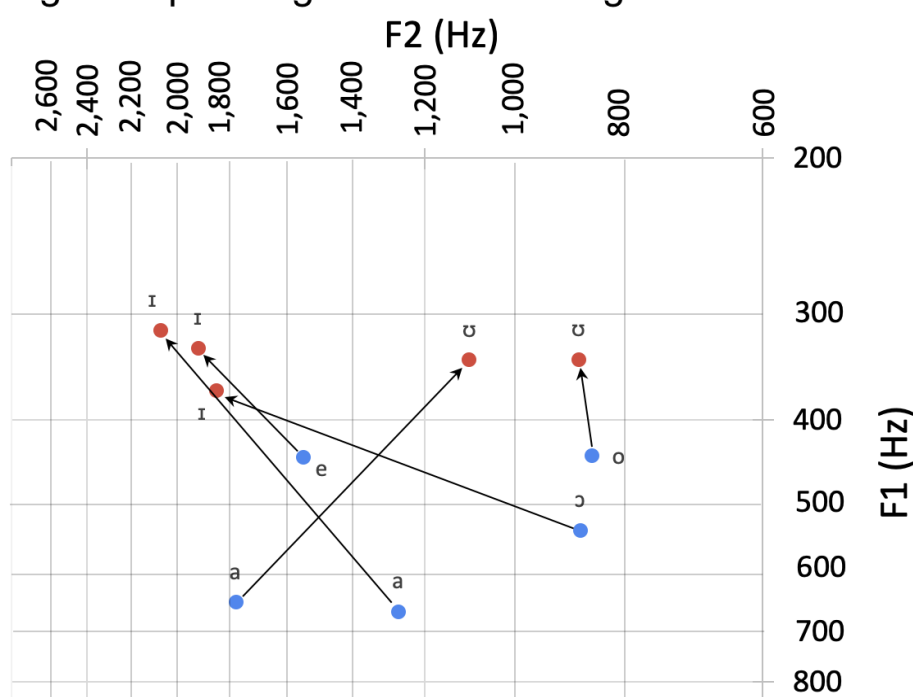
4.1.3.   Low (open) vowels

The low vowels of Wexford English that were analysed are [a] and [ɑ]. The open-mid back rounded vowel [ɔ] also appeared quite low as a pure vowel, this can be seen at figure 2, above. These vowels have high F1 values.

In the case of the [a] vowel, the six samples were averaged, the maximum and minimum was found, and the standard deviation was calculated. The standard deviation was found to be 30.4 Hz, 43.4 Hz, and 56.2 Hz for F1, F2, and F3, respectively. The deviations are not very significant. Please see table 3 for the complete results.

The open back unrounded vowel [ɑ] occurred roughly as is to be expected for standard Hiberno English. It had an average duration of 97ms; not long enough to be considered a long vowel utterance.

As mentioned, the open-mid back rounded vowel appeared quite low in the Wexford variety of English. One might consider using a diacritic to demonstrate this if one wishes to produce very precise in transcriptions.

4.1.4.   Durational differences (particularly among vowels of similar height)

A number of word pairs were analysed to compare their durations, measured in milliseconds using the *Praat* intervals of the vowels. The exact millisecond values were rounded somewhat so usable ratios could be produced, the ratios can be seen below (figure 4).

The pairs chosen compared vowels which have similar heights and attempts to determine the extent of the role vowel length plays in this vowel system. The word pairs and their corresponding heights and IPA symbols can be seen at below.

TABLE C						
	Word 1	**IPA**	**Height**	**Word 2**	**IPA**	**Height**
a	heed	[i]	close	hid	[ɪ]	near-close
b	hayed	[eɪ]	close-mid/near-close	head	[ɛ]	open-mid
c	aunt	[a]	open	ant	[a]	open
d	hawed	[ɔ]	open-mid	hod	[ɑ]	open
e	hoed	[o]	close	Hudd	[ʊ]	near-close
f	who'd	[u]	close	hood	[ʊ]	near-close

Figure 4 is a bar chart of the vowel lengths for the vowels in table C.

Fig. 4: Vowel Length Comparison for Wexford English
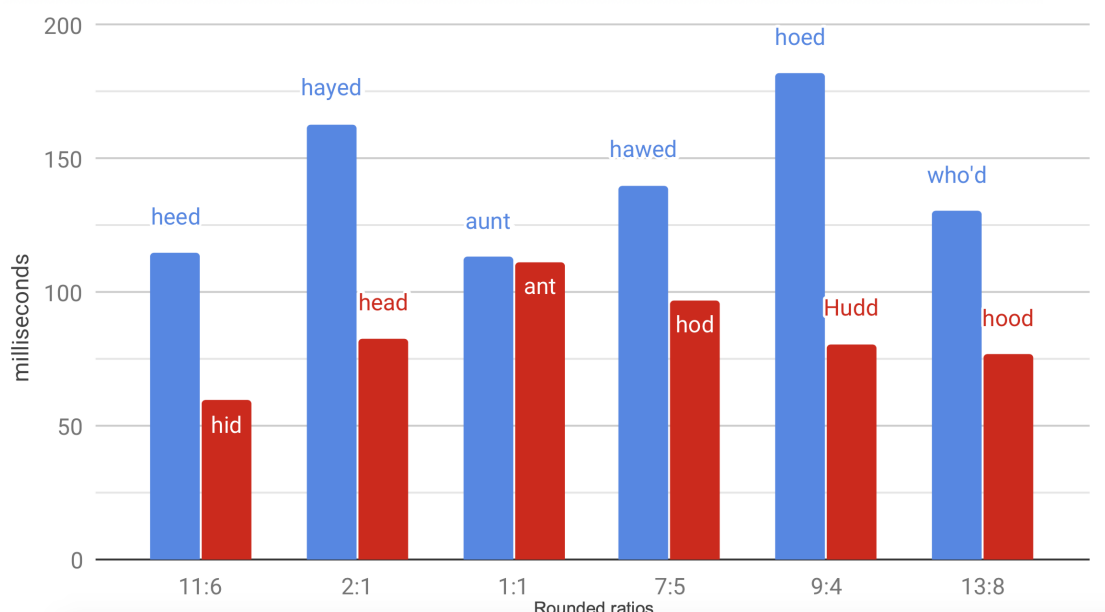
4.1.5.   Quality and duration in the vowel system

The vowel quality of Wexford English is for the most part in line with a standard variety of English. The front vowels appeared very close to their cardinal vowel counterparts, and back vowels were also within their expected quadrants. The back vowels do appear to be somewhat fronted (differences between frequencies of F1 and F2). The schwa vowel taken from the recordings was not clear enough to determine its exact formant values, nevertheless it was included in figures 2 and 3, above.

In relation to duration, it should be noted that all the provided words featured the vowel utterance in between two consonants. Vowel durations can vary greatly when they appear word-final. The vowel pairs compared showed significant durational differences, meaning vowel length plays an active role in this vowel system. However, the role that vowel length plays is not significant enough to overshadow that of vowel quality.

4.2.   Wexford English vowels in a rhotic environment
4.2.1.   Pure vowels in a rhotic environment

Vowels that occur in a rhotic context in Wexford English all bar one vowel showed formant value reductions in F3. The [i] vowel is the only vowel that did not conform to this trend, however the increase from the transition point to the point in full /ɹ/ is only 20 Hz so this may be an error in measurements. A number of the vowels in the rhotic context also showed an increase in F2, with a few exceptions. All F1 values stayed relatively steady. The following figure shows graphs of each vowel in a rhotic context.

Further to the results obtained on diphthongs above, [o] has also been included as a pure vowel. The diphthong [eɪ] appeared as the pure vowel [e] in the rhotic context based off spectrogram analysis, therefore it has also been included.

Key for graphs: *Leftmost points* - formant steady states early in vowel.
Middle points - formant values at midpoint in the transition to /ɹ/.
Rightmost points - final formant values in /ɹ/.

Fig. 5: Vowels of Wexford English in a Rhotic Context
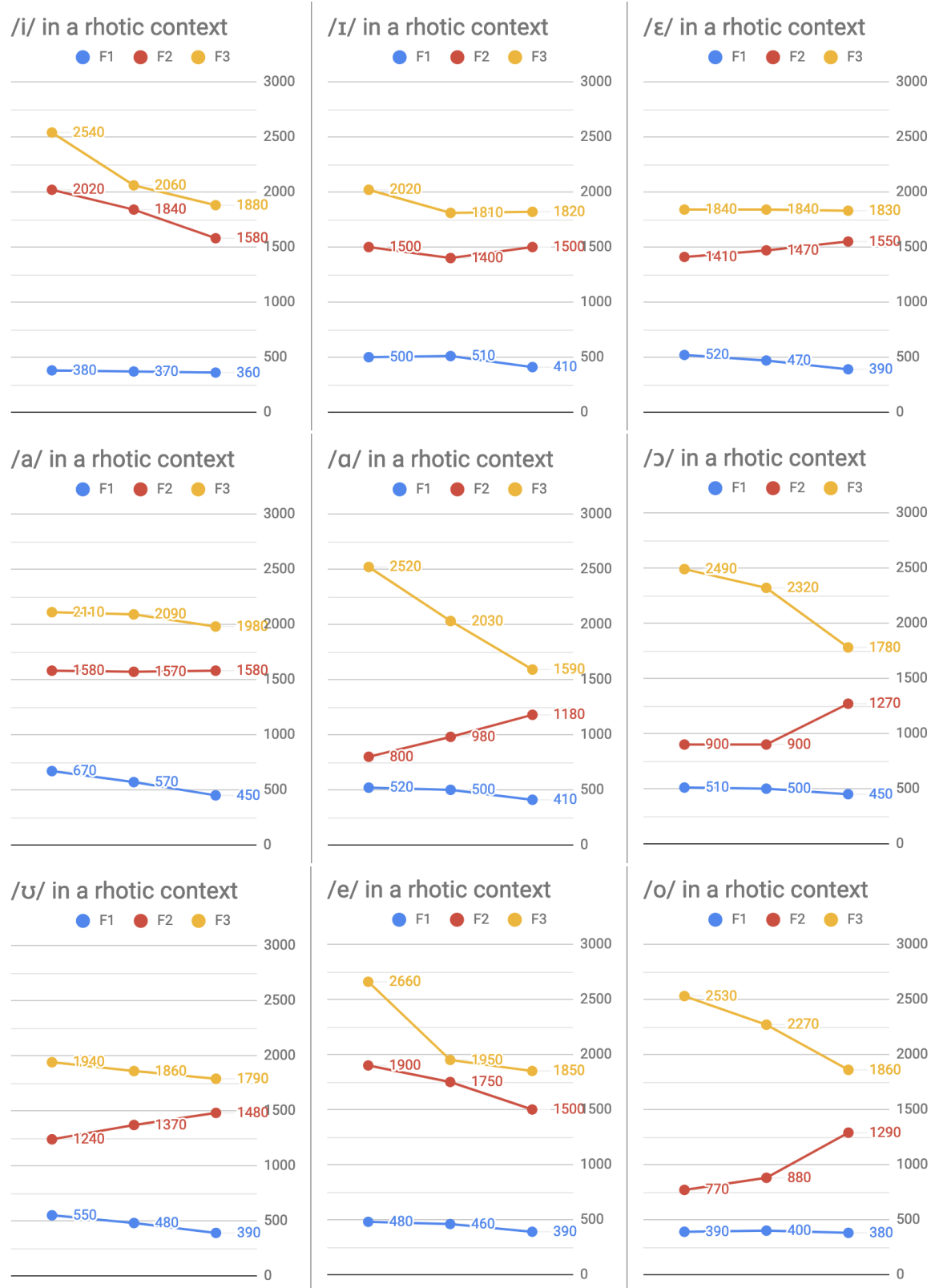
4.3. Comparison of Wexford English with the Standard Southern English Variety of British English

British English speakers, particularly those of the Standard Southern variety distinguish a number of vowels that Wexford English speakers do not. The words *hood* and *Hudd* are distinguished in SSE. These words correspond to the vowels [ʊ] and [ʌ], respectively. The [ʌ] vowel has a low position in the vowel quadrilateral in British English. There is also a greater distinction between the back vowels [ɔ] and [ɑ], with the [ɔ] vowel being much farther back than in Wexford English.

A number of the front vowels of SSE appear in similar positions to the results obtained for Wexford English. The vowels which differ the most are located in the open and back portions of the vowel quadrilateral.

The following figure (fig. 6) shows a vowel chart of the vowels of British English (Ladefoged, 2011). Figure 7 shows the spectrograms of eight vowels of British English.

Fig. 6: F1-F2 Formant Chart (Std. Sth. Eng.)
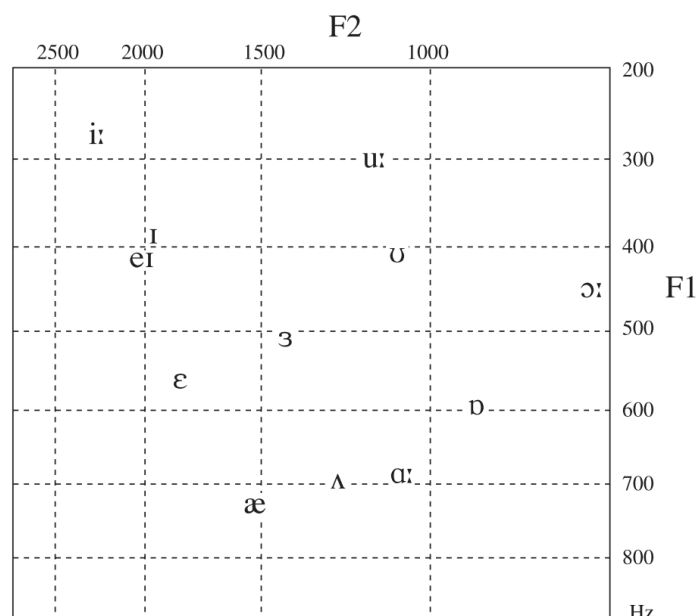
Fig. 7: Spectrograms of eight vowels of British English
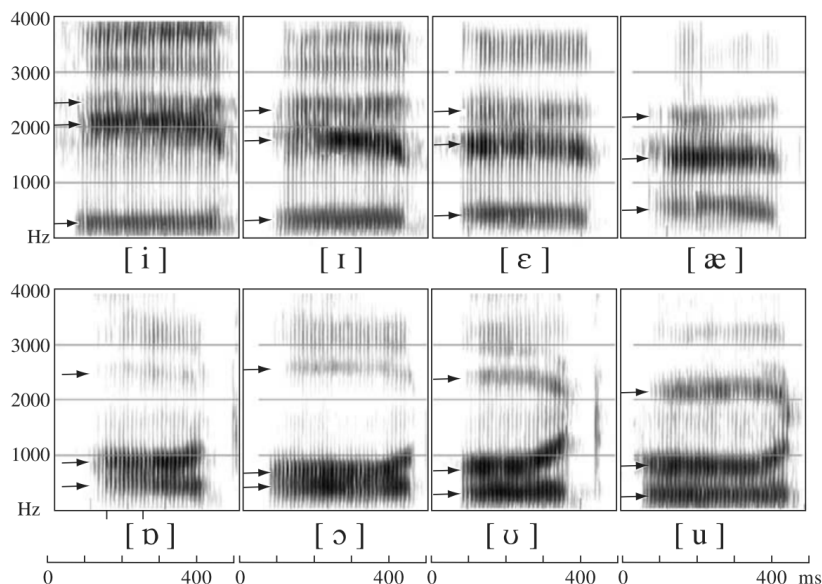
5.   Discussion & Conclusions

The study presented the above results in a usable and meaningful way. An acoustic and durational analysis was carried out which from which it was determined that vowel quality and duration play equally important roles in this vowel system. Generally, vowel height is determined by the frequency of F1, vowel backness is determined by difference between frequencies of F2 and F1. In rhotic contexts, the frequency of F3 decreases.

Vowels can be differentiated by vowel length especially in the case of pairs of vowels which have similar heights.

Some vowels which are differentiated in a British English variety are not distinct in the Wexford English variety. This is particularly apparent with the word pair *hood* and *Hudd,* the vowels [ʊ] and [ʌ] are not differentiated and instead are both articulated as [ʊ].

To continue the study, more Wexford English speaking participants are needed to get more accurate results. Word lists which feature word-final vowels could also be included to get a better overview of the vowel system of Wexford English.

6.   References

Wells, J. (1982): Accents of English. Cambridge: Cambridge University Press. Vols. 1 & 2.

Hickey, R. (2007): Irish English: History and Present Day Forms. Cambridge: Cambridge University Press.

Ferragne, E. & Pellegrino, F. (2010): Formant Frequencies of Vowels in 13 Accents of the British Isles. Journal of The International Phonetic Association. 40(01).

Ladefoged, P. & Johnson, K. (2011): A Course in Phonetics, Sixth Edition. Boston, MA: Wadsworth/Cengage Learning.

7. Appendices

7.1. Appendix A

The full provided word list.

Reading list to elicit vowel sounds - Wexford English, Male Speaker, 20s									
All words read in "Say _____ again" context.									
potential sound	#	V + d/t	#	V + ɹ + d/t	#	V + ɹ + d/t	#	V + ɹ + d/t	
[i]	1	heed	22	beard					
[ɪ]	2	hid	23	gird					
[eː] / [eɪ] ?	3	hayed	24	bared					
[ɛ]	4	head	25	heard					
[a]	5	had	26	hard					
[a]	6	Pam							
[a]	7	matter							
[a]	8	ant							
[a] ?	9	palm							
[a] ?	10	Mater							
[a] ?	11	aunt							
[ɑ]	12	hod	27	horticulture					
[ɔː]	13	hawed	28	lord	33	horse			
[oː] / [oʊ] ?	14	hoed	29	hoard	34	hoarse			
[ʌ] / [ʊ] ?	15	Hudd	30	Hurd	35	bird	#	sir	
[ʌ] / [ʊ] ?	16	hood							
[uː]	17	who'd	31	gourd*	36	Lourdes*			
[aɪ]	18	hide							
[ɔɪ]	19	Hoyd							
[aʊ]	20	how'd							
[ə]	21	petite	32	pertain					

* Informant may have mispronounced or misread word - may not reflect his phonemic inventory.

? Vowel quality to be checked in order to choose most appropriate transcription.

7.2. Appendix B

Full tables of measurements

TABLE1	**Durations and formant values obtained from the three chosen recordings**																						
NO.	SYMBOL	WORD	LIST2	ms	F1	F2	F3	LIST3	ms	F1	F2	F3	LIST4	ms	F1	F2	F3	AVERAGE	ms	F1	F2	F3
1	[i]	heed		128	248	2367	2970		109	255	2260	2762		107	266	1976	2305		115	256	2201	2679
2	[ɪ]	hid		62	399	2066	2515		59	378	2020	2647		58	439	1994	2403		59	405	2027	2522
3	[ɛ]	head		104	628	1937	2602		74	668	1794	2488		70	630	1741	2367		83	642	1824	2486
4	[a]	had		98	820	1475	2355		82	794	1434	2432		76	843	1534	2407		85	819	1481	2398
5	[a]	Pam		103	919	1462	2349		97	899	1394	2464		94	903	1437	2335		98	907	1431	2383
6	[a]	matter		90	843	1384	2424		85	841	1468	2290		94	895	1532	2325		90	860	1461	2346
7	[a]	ant		125	821	1586	2417		102	862	1603	2514		107	850	1517	2443		111	844	1569	2458
8	[a] ?	palm		148	882	1455	2315		146	897	1418	2390		140	889	1531	2335		145	889	1468	2347
9	[a] ?	Mater		90	864	1513	2389		94	868	1425	2374		94	877	1485	2404		93	870	1474	2389
10	[a] ?	aunt		119	852	1507	2421		110	891	1498	2561		111	813	1407	2516		113	852	1471	2499
11	[ɑ]	hod		100	739	1133	2427		93	741	1086	2258		98	696	1065	2396		97	725	1095	2360
12	[ɔː]	hawed		115	626	979	2463		155	636	990	2388		150	645	1008	2466		140	636	992	2439
13	[ʌ] / [ʊ] ?	Hudd		94	406	1021	2378		61	416	1152	2345		87	379	1070	2373		81	400	1081	2365
14	[ʌ] / [ʊ] ?	hood		87	392	1057	2383		72	419	1086	2292		71	395	1034	2359		77	402	1059	2345
15	[uː]	who'd		130	277	1105	2327		127	298	1234	2271		134	301	1216	2336		130	292	1185	2311
16	[ə]	petite		43	231	1706	2516		21	articulation too short - disregarded					49	304	1831	2517		46	267	1768	2516

TABLE2						
Average formant values (rounded) and durations						
		ms	F1	F2		F3
1	[i]	115	260	2200		2680
2	[ɪ]	59	410	2030		2520
3	[ɛ]	83	640	1820		2490
4	[a]	85	820	1480		2400
5	[a]	98	910	1430		2380
6	[a]	90	860	1460		2350
7	[a]	111	840	1570		2460
8	[a]	145	890	1470		2350
9	[a]	93	870	1470		2390
10	[a]	113	850	1470		2500
11	[ɑ]	97	730	1090		2360
12	[ɔ:]	140	640	990		2440
13	[ʊ]	81	400	1080		2370
14	[ʊ]	77	400	1060		2340
15	[u:]	130	290	1180		2310
16	[ə]	46	270	1770		2520
		F values rounded to nearest 10				

TABLE3					
Determination of quality of vowels 4-10 - [a]					
4	had	820	1480	2400	
5	Pam	910	1430	2380	
6	matter	860	1460	2350	
7	ant	840	1570	2460	
8	palm	890	1470	2350	
9	Mater	870	1470	2390	
10	aunt	850	1470	2500	
	AVG	863	1479	2404	
	MAX	910	1570	2500	
	MIN	820	1430	2350	
	DIFF	90	140	150	
	STDEV	30.4	43.4	56.2	
	COMMENT	deviation of F1 & F2 both <50 Hz			
		slightly more deviation for F3			

TABLE4						
Vowel Quality Comparisons						
13	Hudd			400	1080	2370
14	hood			400	1060	2340
	AVG			400	1070	2355
	DIFF			0	20	30
	COMMENT	same vowel, ʊ				
5	Pam	98		910	1430	2380
8	palm	145		890	1470	2350
	AVG	122		900	1450	2365
	DIFF	-47		20	-40	30
	COMMENT	Difference less than 50Hz, same vowel				
		~3:2 duration ratio				
6	matter	90		860	1460	2350
9	Mater	93		870	1470	2390
	AVG	92		865	1465	2370
	DIFF	-3		-10	-10	-40
	COMMENT	Difference less than 50Hz, same vowel				
		Same durations				
7	ant	111		840	1570	2460
10	aunt	113		850	1470	2500
	AVG	112		845	1520	2480
	DIFF	-2		-10	100	-40
	COMMENT	F2 difference of 100Hz, potentially significant or measuring discrepancy				

TABLE5	**Diphthong formant values and durations**					initial vowel				second vowel		
NO.												
LIST2	SYMBOL	WORD	ms			F1	F2	F3		F1'	F2'	F3'
17	[eː] / [eɪ] ?	hayed	180			455	1723	2165		323	2053	2260
18	[oː] / [oʊ] ?	hoed	190			434	854	2408		327	955	2274
19	[aɪ]	hide	158			717	1187	2430		294	2138	2389
20	[ɔɪ]	Hoyd	195			486	832	2536		374	1745	2335
21	[aʊ]	how'd	157			624	1798	2350		362	1118	2333
LIST3	SYMBOL	WORD	ms			F1	F2	F3		F1'	F2'	F3'
17	[eː] / [eɪ] ?	hayed	168			453	1216	2222		334	2123	2362
18	[oː] / [oʊ] ?	hoed	175			481	912	2379		353	832	2420
19	[aɪ]	hide	154			628	1314	2509		335	2143	2483
20	[ɔɪ]	Hoyd	231			559	904	2481		360	1923	2362
21	[aʊ]	how'd	166			668	1708	2362		332	1091	2269
LIST4	SYMBOL	WORD	ms			F1	F2	F3		F1'	F2'	F3'
17	[eː] / [eɪ] ?	hayed	141			414	1671	2229		334	1557	2262
18	[oː] / [oʊ] ?	hoed	181			401	786	2417		340	839	2307
19	[aɪ]	hide	148			643	1302	2464		316	1913	2344
20	[ɔɪ]	Hoyd	210			561	884	2504		378	1843	2370
21	[aʊ]	how'd	160			648	1801	2549		330	1076	2332
AVERAGE	SYMBOL	WORD	ms			F1	F2	F3		F1'	F2'	F3'
17	[eː] / [eɪ] ?	hayed	163			441	1537	2205		330	1911	2295
18	[oː] / [oʊ] ?	hoed	182			439	851	2401		340	876	2333
19	[aɪ]	hide	153			663	1268	2468		315	2065	2405
20	[ɔɪ]	Hoyd	212			535	873	2507		370	1837	2356
21	[aʊ]	how'd	161			647	1769	2420		341	1095	2311

	TABLE6	Determination of words 17-21 as pure vowels or diphthongs					
NO.	F1 - F1'	F2 - F2'	F3 - F3'			Diphthong?	Assigned symbol
17	111	-374	-89	significant differences in F1,F2		TRUE	[eɪ]
18	98	-25	68	no significant differences		FALSE	[oː]
19	348	-797	62	significant differences in F1,F2		TRUE	[aɪ]
20	165	-964	152	significant differences in F1,F2,F3		TRUE	[ɔɪ]
21	305	674	109	significant differences in F1,F2,F3		TRUE	[aʊ]
				sig diff = ±100 Hz			

TABLE7					early in vowel			mid-point in transition to /ɹ/			final values for /ɹ/		
NO.			LIST2	ms	F1	F2	F3	F1	F2	F3	F1	F2	F3
22	[i]	beard		185	370	2167	2963	383	1870	2213	368	1593	1964
23	[ɪ]	gird		188	500	1498	2005	496	1432	1837	407	1500	1817
24	[ɛ]	heard		137	574	1375	1933	485	1457	1870	392	1542	1874
25	[a]	hard		153	680	1548	2084	558	1495	2083	440	1549	1986
26	[ɑ]	horticulture		142	520	764	2464	479	949	2072	407	1179	1561
27	[ɔː]	lord		178	505	860	2483	492	878	2328	455	1218	1765
28	[ʌ] / [ʊ] ?	Hurd		171	585	1206	2022	502	1370	1878	389	1471	1836
29	[eː] / [eɪ] ?	bared		218	483	1893	2710	450	1732	2032	401	1492	1861
30	[oː] / [oʊ] ?	hoard		180	396	825	2487	395	855	2312	384	1271	1934

			LIST3	ms	F1	F2	F3	F1	F2	F3	F1	F2	F3
22	[i]	beard		175	390	2121	2593	367	1710	1983	365	1626	1850
23	[ɪ]	gird		190	490	1554	2121	513	1431	1860	420	1558	1872
24	[ɛ]	heard		134	519	1435	1782	484	1490	1855	396	1553	1775
25	[a]	hard		158	659	1608	2123	590	1614	2128	469	1626	2058
26	[ɑ]	horticulture		144	509	742	2748	511	957	1985	413	1200	1603
27	[ɔː]	lord		181	508	940	2560	503	868	2323	421	1275	1830
28	[ʌ] / [ʊ] ?	Hurd		180	498	1217	1954	441	1415	1888	394	1504	1800
29	[eː] / [eɪ] ?	bared		---	mispronunciation, articulation disregarded								
30	[oː] / [oʊ] ?	hoard		203	394	737	2650	406	895	2246	385	1277	1857

TABLE7, CONTINUED											
			LIST4	ms	F1	F2	F3	F1	F2	F3	F1	F2	F3
22	[i]	beard		232	372	1782	2057	362	1936	1990	360	1532	1816
23	[ɪ]	gird		211	518	1433	1920	510	1327	1727	403	1440	1760
24	[ɛ]	heard		148	478	1414	1812	445	1455	1797	393	1560	1836
25	[a]	hard		159	676	1570	2110	550	1600	2055	440	1565	1888
26	[ɑ]	horticulture		108	527	900	2356	500	1020	2020	405	1155	1612
27	[ɔ:]	lord		186	522	895	2435	510	947	2305	465	1305	1758
28	[ʌ] / [ʊ] ?	Hurd		152	575	1295	1836	485	1320	1817	387	1475	1728
29	[e:] / [eɪ] ?	bared		249	475	1906	2602	463	1775	1861	387	1505	1840
30	[o:] / [oʊ] ?	hoard		180	390	755	2450	395	885	2255	385	1315	1778

				early in vowel			mid-point in transition to /ɹ/			final values for /ɹ/		
			AVERAGE	ms	F1	F2	F3	F1	F2	F3	F1	F2	F3
22	[i]	beard		197	380	2020	2540	370	1840	2060	360	1580	1880
23	[ɪ]	gird		196	500	1500	2020	510	1400	1810	410	1500	1820
24	[ɛ]	heard		140	520	1410	1840	470	1470	1840	390	1550	1830
25	[a]	hard		157	670	1580	2110	570	1570	2090	450	1580	1980
26	[ɑ]	horticulture		131	520	800	2520	500	980	2030	410	1180	1590
27	[ɔ:]	lord		182	510	900	2490	500	900	2320	450	1270	1780
28	[ʊ]	Hurd		168	550	1240	1940	480	1370	1860	390	1480	1790
	below appear as pure vowels in rhotic context												
29	[e:]	bared		234	480	1900	2660	460	1750	1950	390	1500	1850
30	[o:]	hoard		188	390	770	2530	400	880	2270	380	1290	1860

7.3.   Appendix C

Praat script used

```
writeInfoLine: "Extracting formants..."

thisSound$ = selected$("Sound")
thisTextGrid$ = selected$("TextGrid")

#Extract number of points in the formants tier
select TextGrid 'thisTextGrid$'
#tier3 is formants tier
numberOfPoints = Get number of points: 3
appendInfoLine: "No. of points: ", numberOfPoints

# Create the Formant Object
select Sound 'thisSound$'
To Formant (burg)... 0 5 5000 0.025 50

# Create the output file and write the first line.
outputPath$ = "/Users/*user*/Desktop/formants_out.csv"
writeFileLine: "'outputPath$'", "point,time,duration,symbol,F1,F2,F3,point2,diphthong,F1',F2',F3'"

for thisPoint from 1 to numberOfPoints

        select TextGrid 'thisTextGrid$'
        timePoint = Get time of point: 3, thisPoint
        thisInterval = Get interval at time: 2, timePoint
        thisIntervalLabel = Get label of interval: 2, thisInterval
        thisLabel$ = Get label of point: 3, thisPoint
        appendInfo: thisLabel$

        vowelStart = Get start point: 2, thisInterval
        vowelEnd = Get end point: 2, thisInterval
        duration = vowelEnd - vowelStart

        if thisPoint <> numberOfPoints
                timePoint2 = Get time of point: 3, thisPoint + 1
                thisLabel2$ = Get label of point: 3, thisPoint + 1
        endif

        diphthong = 0 ;boolean false

        if timePoint > vowelStart and timePoint2 < vowelEnd
                select Formant 'thisSound$'
                f01 = Get value at time... 1 timePoint2 Hertz Linear
                f02 = Get value at time... 2 timePoint2 Hertz Linear
                f03 = Get value at time... 3 timePoint2 Hertz Linear

                diphthong = 1 ;boolean true
                appendInfo: thisLabel2$
        endif

        appendInfo: newline$

        # Extract formant measurements
        select Formant 'thisSound$'
        f1 = Get value at time... 1 timePoint Hertz Linear
        f2 = Get value at time... 2 timePoint Hertz Linear
        f3 = Get value at time... 3 timePoint Hertz Linear

        appendFile: "'outputPath$'",
                ...thisPoint, ",",
```

```
                    ...timePoint, ",",
                    ...duration, ",",
                    ...thisLabel$, ",",
                    ...f1, ",",
                    ...f2, ",",
                    ...f3, ","

        if diphthong = 1
                thisPoint = thisPoint+1
                appendFile: "'outputPath$'",
                        ...thisPoint, ",",
                        ...thisLabel2$, ",",
                        ...f01, ",",
                        ...f02, ",",
                        ...f03
        endif

        appendFile: "'outputPath$'", newline$
        diphthong = 0
 endfor
```