Kangcheng Li

Ling 104

Lab 2

Lab Report 2

1. Introduction

This lab aims to test various hypotheses regarding the properties of formant values of vowels in 'h-V-d' and 'bilabial-V-t' configuration. This lab specifically tests how place of articulation and voicing of the preceding and succeeding consonant can affect formant values for vowels in onset-vowel-coda formation. Additionally, this lab also compares formant value measurement with such measurements from previous work by Hillenbrand (1995) and describes the similarities and differences between these various formant values.

Since the formant value of vowels can be affected by the coarticulation with the preceding consonant, as well as by the voicing of the coda consonant which affects the duration of the vowel itself, we have formulated two hypotheses to tests these properties of formant values. Firstly, we propose hypothesis 1 that states the F2 of a vowel is lower when it follows a bilabial consonant than when it follows a glottal consonant, since we could have C-V coarticulation of the bilabial consonant which tends to lower vowel formants. We test this hypothesis on front vowels. Secondly, we propose hypothesis 2 that states the F2 of a vowel with a voiceless coda is different from that of a vowel with a voiced coda, since vowels with voiceless coda generally have shorter duration than vowels with voiced coda and thus could have formant values that are not fully developed. We test this hypothesis on back vowels.

2. Method

2.1. Subjects

In this lab, our speakers are five male native speakers of American English living in New York City. All speakers are monolingual English speakers in their 20's. All speakers confirmed before recording that they had no known history of impaired hearing or communication-related disorder.

2.2. Data

The data are shown in the table below. We have 8 English words that differ by their vowel, onset consonant, and coda consonant.

	h-V-d	bilabial-V-t
/i/	heed	beat
/ɛ/	head	bet
/u/	who'd	boot
/ɑ/	hod	pot

Table 1: All target tokens in the experiment

All tokens are produced in the same prosodic condition. They are embedded in a carrier sentence: "The first word is _____, and the second word is _____.", where the first blank is a filler word outside of our interest, and the second blank is our target word. (Lab handout)

2.3. Procedure

The carrier sentence appeared on the screen one at a time; each speaker read the sentence twice. Recordings took place in a sound-attenuating audiological booth, using a Shure SM10 head-mounted microphone. The sound was recorded with 44,100 Hz sampling rate. (Lab assignment handout)

All formant values are measured in the software Praat, using Praatscript and built-in formant tracking method that Praat provides. All values are then checked by hand to make sure they fit in reasonable bounds. Formant values checked by hand are taken from the darkest center section of the formant.

For task 1, the measurements are taken in the middle section of the vowel where the formant values are the most stable. For hypothesis 1 in task 2, in order to measure the influence from coarticulation, measurements are taken at roughly 20 milliseconds after the onset of the vowel. For hypothesis 2 in task 2, measurements are taken in the middle section of the vowel in order to test the effect of duration and syllable coda on the development of formant values.

3. Results

3.1 Task 1

In this task, we are interested in finding out the formant value for every token produced by the five speakers, grouped by their respective vowel. Measurements of vowels in all "h-V-d" words are made and their respective F1 and F2 values are measured.

Formant value for /i/			
Mean F1(Hz)	Mean F2(Hz)	Std dev F1	Std dev F2
248.837134	2567.38404	21.44727841	209.7369758

Table 1: Mean, Standard Deviation of F1, F2 for the vowel /i/

Formant value for /ɛ/			
Mean F1(Hz)	Mean F2(Hz)	Std dev F1	Std dev F2
585.164641	1905.38178	47.28097907	142.6277562

Table 2: Mean, Standard Deviation of F1, F2 for the vowel /ɛ/

Formant value for /u/			
Mean F1(Hz)	Mean F2(Hz)	Std dev F1	Std dev F2
282.399278	1011.67337	26.2720444	120.004871

Table 3. Mean, Standard Deviation of F1, F2 for the vowel /u/

Formant value for /ɑ/			
Mean F1(Hz)	Mean F2(Hz)	Std dev F1	Std dev F2
796.670686	1161.44349	57.6592586	66.4640751

Table 4: Mean, Standard Deviation of F1, F2 for the vowel /ɑ/

As we can see from the tables above. For /i/ we have measured F1 value 248.84Hz, F2 value 2567.38Hz. For /ɛ/, we have measured F1 value 585.16Hz, F2 value 1905.38Hz. For /u/, we have measured F1 value 282.39Hz, F2 value 1011.67Hz. For /ɑ/, we have measured F1 value 796.67Hz, F2 value 1161.44Hz. Using Praat, we can plot the vowel space of these four vowels using all measurements of 'h-V-d' words.

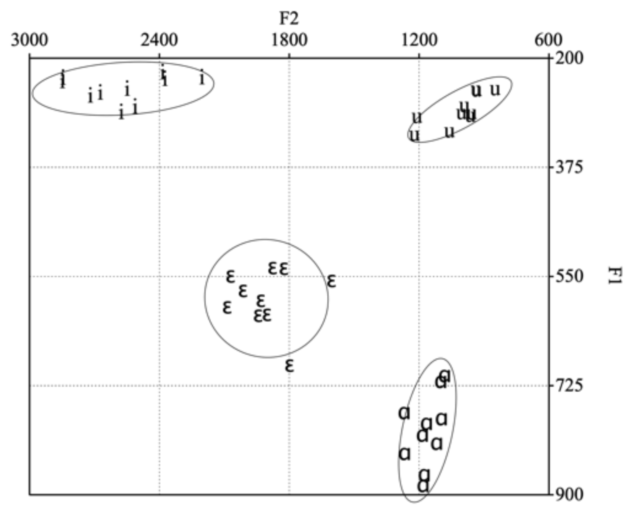

Chart 1: Vowel space of four vowels in 'h-V-d' word

3.2 Task 2

3.2.1 Hypothesis 1

In hypothesis 1, we argue that the labial closure could lower formants, and because of C-V coarticulation, we would have lower formant values for the vowels near a labial consonant than vowels near a glottal consonant. We test this hypothesis by measuring the F2 values for front vowels near a labial consonant and F2 values near a glottal consonant. We have the following results.

Mean bilabial(Hz)	Stdev labial	Mean glottal(Hz)	Stdev glottal	P(T<=t) one-tail
2353.61093	151.3468882	2602.16034	161.914219	0.00115344

Table 6: Mean of F2 values for /i/ after bilabial and glottal consonants

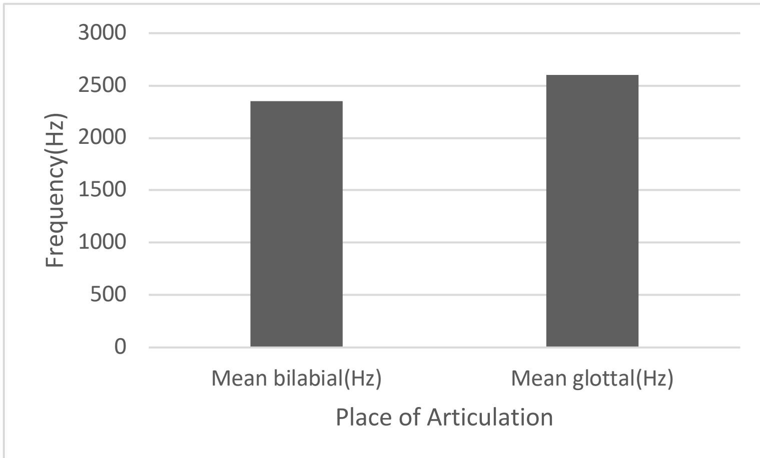

Chart 2: Mean of F2 values for /i/ after bilabial and glottal consonants

As we can see, the mean F2 value for /i/ after bilabial consonants is 2353Hz and for vowels after glottal consonants is 2602Hz. We can see that labial closure has indeed lowered our F2 formants. The subsequent t-test also indicates that this difference is significant with the one-tail t-test result being way less than our threshold of 0.05. We reject the null hypothesis.

Mean bilabial(Hz)	Stdev labial	Mean glottal(Hz)	Stdev glottal	P(T<=t) one-tail
1774.92524	132.8202866	1901.47605	139.436865	0.02613945

Table 7: Mean of F2 values for /ɛ/ after bilabial and glottal consonants

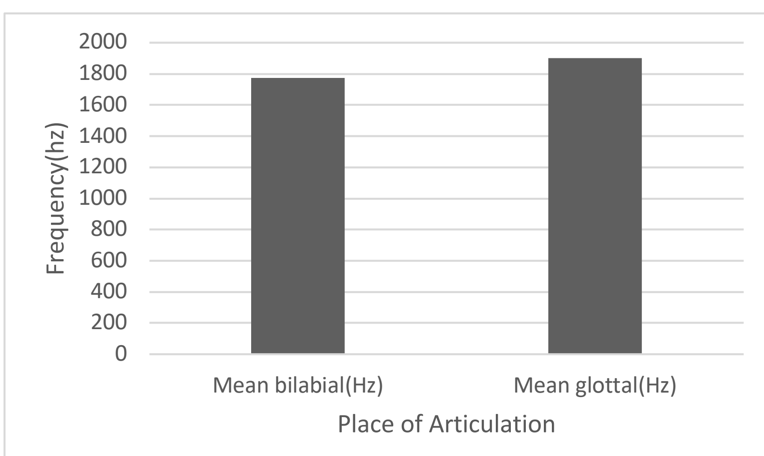

Chart 3: Mean of F2 values for /ɛ/ after bilabial and glottal consonants

As we can see for the case of /ɛ/, the mean F2 value after bilabial consonants is 1774Hz and for vowels after glottal consonants is 1901Hz. We can see that labial closure has also indeed lowered our F2 formants in this case. The subsequent t-test also indicates that this difference is significant with the one-tail t-test result being less than our threshold of 0.05. We reject the null hypothesis.

Mean bilabial(Hz)	Stdev labial	Mean glottal(Hz)	Stdev glottal	P(T<=t) one-tail
2064.26808	327.615757	2251.81819	388.365134	0.05351326

Table 8: Mean of F2 values for high vowels /i/ and /ɛ/ after bilabial and glottal consonants

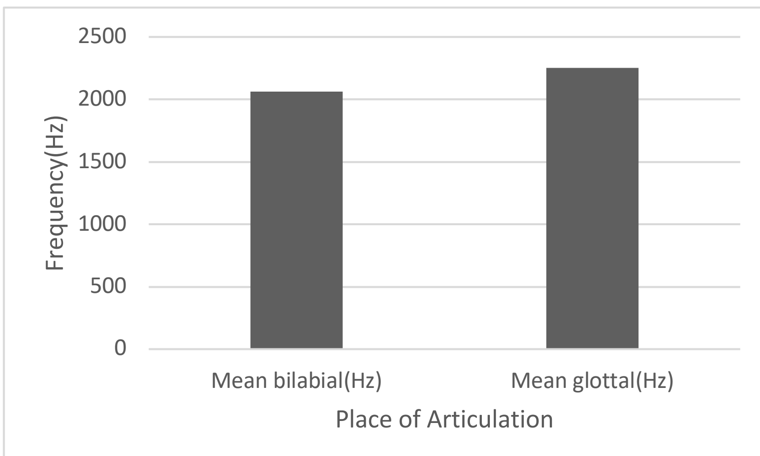

Chart 4: Mean of F2 values for high vowels /i/ and /ɛ/ after bilabial and glottal consonants

For the combined case, the mean F2 value after bilabial consonants is 2064Hz and for vowels after glottal consonants is 2251Hz. We can see that labial closure has also indeed lowered our F2 formants since the mean value for vowels after bilabial consonants is still lower than that of glottal consonants. However, the t-test indicates that this difference is not significant enough with the one-tail t-test result being just above our threshold of 0.05. We failed to reject the null hypothesis.

3.2.2 Hypothesis 2

In hypothesis 2, we argue that since for vowels with short durations, their formant values are often not fully realized, and that English vowels are shorter before a voiceless coda than before a voiced coda, the formant values of the same vowel would be different when it is placed before a voiceless coda versus a voiced coda. We test this hypothesis by measuring the low vowels /u/ and /ɑ/ with the formant values measured towards the middle of the vowel. We have the following results.

Mean voiceless(Hz)	Stdev v-less	Mean voiced(Hz)	Stdev voiced	P(T<=t) two-tail
1196.64049	160.921792	1023.8685	142.033537	0.02029116

Table 9: Mean of F2 values for /u/ before voiceless and voiced coda obstruent

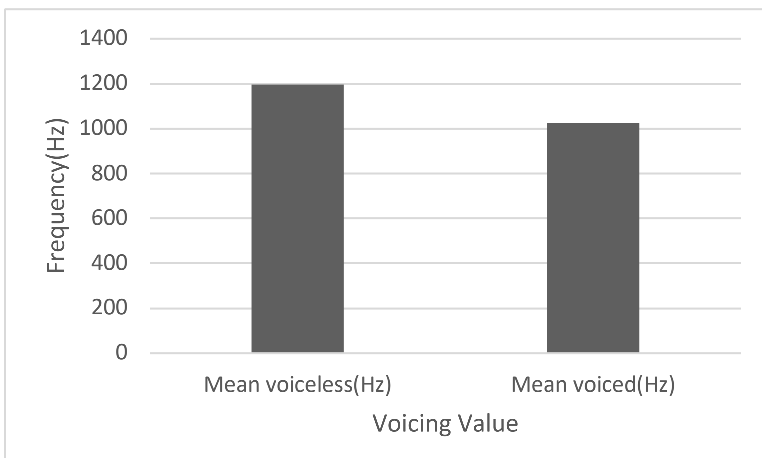

Chart 5: Mean of F2 values for /u/ before voiceless and voiced coda obstruent

As we can see from the table and chart above, the mean F2 value for /u/ before voiceless obstruent coda is 1196Hz and for /u/ before voiced obstruent coda is 1023Hz. We can see that voicing of the coda obstruent has indeed made a difference in our F2 formants since the mean value for vowels before voiceless coda is higher than that of voiced coda. The t-test also indicates that this difference is significant enough with the two-tail t-test result being less than our threshold of 0.05. We reject the null hypothesis.

Mean voiceless(Hz)	Stdev v-less	Mean voiced(Hz)	Stdev voiced	P(T<=t) two-tail
1210.89993	84.8376135	1153.43916	66.1584911	0.10847181

Table 10: Mean of F2 values for /ɑ/ before voiceless and voiced coda obstruent

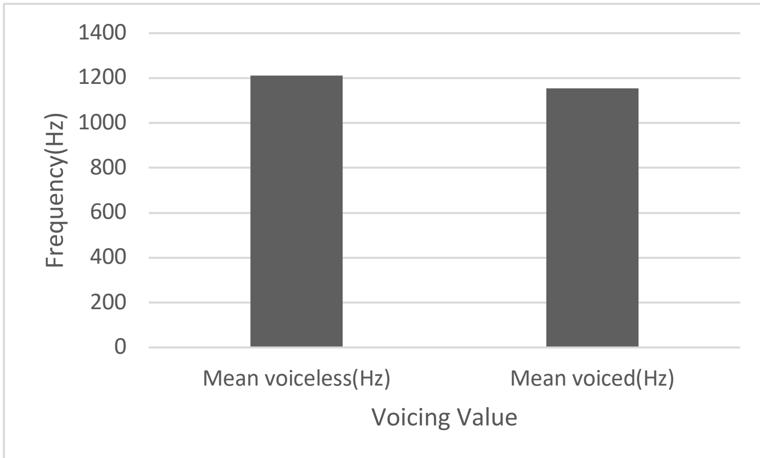

Chart 6: Mean of F2 values for /ɑ/ before voiceless and voiced coda obstruent

From the table and chart above, we can see that the mean F2 value for /ɑ/ before voiceless obstruent coda is 1210Hz and for /ɑ/ before voiced obstruent coda is 1153Hz. We can see that voicing of the coda obstruent has also made a difference in our F2 formants since the mean value for vowels before voiceless coda is higher than that of voiced coda. However, the t-test indicates that this difference is not significant enough with the two-tail t-test result being higher than our threshold of 0.05. We failed to reject the null hypothesis.

4. Discussion

4.1 Task 1

At this stage, we can compare the mean of F1 and F2 of our four vowels with those of the same vowels produced by male speakers presented in Hillenbrand et al. (1995), values presented as follows.

	Vowels			
	/i/	/ɛ/	/u/	/ɑ/
F1(Hz)	342	580	378	768

F2(Hz)	2322	1799	997	1333

Table 5: Formant value for the vowel /i/ /ɛ/ /u/ /ɑ/ in Hillenbrand (1995)

We can observe that for /i/, our measured F1 is lower and F2 is higher than that of Hillenbrand. This means that our speakers produce /i/ higher and more front than Hillenbrand's speaker. For /ɛ/, our F1 is similar to Hillenbrand's measurement but our F2 is slightly higher than Hillenbrand's measurement, which could indicate our /ɛ/ is more front than measurement make by Hillenbrand. For /u/, our F1 is slightly higher than Hillenbrand's and our F2 is similar to Hillenbrand's measurement, which indicates our speaker produce /u/ in a slightly lower position. For /ɑ/, our F1 is similar to Hillenbrand's and our F2 is higher than Hillenbrand's, which means /ɑ/ is produced more front in our measurement than in Hillenbrand's measurement.

4.2 Task 2 – Hypothesis testing

4.2.1 Hypothesis 1

For hypothesis 1, the difference between the F2 value of vowels after bilabial onset and after glottal onset is significant when the vowels are compared with itself. In other words, the F2 value of vowels in 'beat' is significantly lower than that of vowels in 'heed', and the F2 value of vowels in 'bet' is also significantly lower than that of vowel in 'head'. However, our result shows the combined set of 'beat' and 'bet' does not have its F2 value of vowels significantly lower than the vowel F2 value of the combine set of 'heed' and 'head'. We have very narrowly failed to reject the null hypothesis. This, however, could be attributed to the difference of the formant value in /i/ and /ɛ/ since their F2 values are roughly 250Hz apart, which gives us a set of formant values that is more spread out within each group. This is the reason which caused our t-test result to show an insignificant difference between the two groups as it minimizes the significance of the difference in formant values between the two groups.

4.2.2 Hypothesis 2

For hypothesis 2, we have rejected the null hypothesis in the case of the vowel /u/ and conclude there is a significant difference between F2 values of vowels with a voiceless coda and vowels with a voiced coda. However, we have failed to reject the null hypothesis in the case of the vowel /ɑ/. In this sense, we have conflicting evidence in that we observe a greater difference between the F2 values of the high back vowel than the low back vowel. This suggests that for hypothesis 2 in its entirety, we are not able to conclude that formant values of the same vowel are different depending on the voicing of the consonant coda.

4.2.3 Generalizations

In general, the measurements we obtained from this lab have shown promising results for what we predicted in the hypothesis, especially with hypothesis 1 and the vowel /u/ in hypothesis 2 with fairly strong evidence supporting our hypothesis. This indicates that there are some merits to the hypotheses we formulated in this lab in terms of factors influencing formant values.

There are a few modifications that can be done to this lab. First of all, in order to test the validity of hypothesis 2, we can have more tokens for other back vowels with variable height, for example, /o/, /ʌ/ or /ɔ/, and test whether vowel height can affect the significance of the difference between formant values with voiceless and voiced consonant coda. Additionally, 'h-V-d' and 'bilabial-V-t' do not form minimal pairs. In this case, we could instead have some other sets of English words with 'h-V-t' and 'bilabial-V-d' such as 'hot', 'hoot', 'bed', 'bead' so that we can have perfect minimal pair to compare with.

5. Appendix

5.1 Measurement for Task 1

Word	Vowel	F1	F2	F3
m2-heed	i	231.909789	2843.53581	3227.2447
m2-heed2	i	237.459876	2847.05187	3220.61449
m3-heed	i	231.053204	2202.63262	2766.32426
m3-heed2	i	249.703849	2547.66778	3251.7042
m4-heed	i	233.648948	2373.68227	3121.36206
m4-heed2	i	223.060173	2383.98861	3287.90275
m5-heed	i	287.046295	2574.98159	2996.51778
m5-heed2	i	278.320288	2510.6664	2845.32914
m6-heed	i	255.684426	2671.43825	3132.7708
m6-heed2	i	260.484488	2718.19523	3334.77814

Word	Vowel	F1	F2	F3
m2-head	ε	572.231218	2013.58089	2998.86258
m2-head2	ε	588.200957	1930.94581	2904.15172
m3-head	ε	598.682514	2086.43891	2603.5575
m3-head2	ε	548.934723	2071.1265	2859.1372
m4-head	ε	536.707872	1824.7819	2492.22871
m4-head2	ε	535.838823	1876.92829	2586.63411
m5-head	ε	556.281411	1604.86798	2791.92375
m5-head2	ε	692.262933	1798.69136	2698.92666
m6-head	ε	611.961432	1943.67579	2832.28932
m6-head2	ε	610.544524	1902.78034	2776.00596

Word	Vowel	F1	F2	F3
m2-whod	u	291.817226	962.587186	2542.11047
m2-whod2	u	287.271535	1003.08272	2517.6146
m3-whod	u	287.525979	956.317235	2399.82187
m3-whod2	u	275.677413	989.403156	2641.67014
m4-whod	u	251.199821	933.08544	2309.013
m4-whod2	u	316.491187	1058.48608	2371.12885
m5-whod	u	249.563855	936.707555	2741.08776
m5-whod2	u	248.892194	847.419056	2588.04755
m6-whod	u	321.980478	1220.3416	2569.14652

m6-whod2	u	293.573095	1209.30365	2595.36527

Word	Vowel	F1	F2	F3
m2-hod	ɑ	767.996838	1266.53944	2720.29329
m2-hod2	ɑ	833.740992	1263.82306	2729.29389
m3-hod	ɑ	785.56243	1162.96541	2883.88239
m3-hod2	ɑ	804.386701	1181.68288	2945.40062
m4-hod	ɑ	718.250883	1097.32923	2656.07038
m4-hod2	ɑ	708.678236	1079.79218	2750.83843
m5-hod	ɑ	777.846691	1094.19717	2580.39094
m5-hod2	ɑ	817.493389	1115.91098	2724.46246
m6-hod	ɑ	867.542126	1173.24618	2127.82491
m6-hod2	ɑ	885.208576	1178.94839	2046.2645

5.2 Measurement for Task 2

5.2.1 Hypothesis 1

Word	F2(Hz)	Word	F2(Hz)
m2-beat	2267.25789	m2-heed	2824.60105
m2-beat2	2460.74789	m2-heed2	2833.5811
m3-beat	2516.30506	m3-heed	2656.46064
m3-beat2	2466.08057	m3-heed2	2525.0122
m4-beat	2286.808	m4-heed	2366.5625
m4-beat2	2188.6204	m4-heed2	2364.18715
m5-beat	2073.3795	m5-heed	2553.95408
m5-beat2	2305.37741	m5-heed2	2581.1029
m6-beat	2468.04276	m6-heed	2695.84205
m6-beat2	2503.48978	m6-heed2	2620.29971
m2-bet	1828.9984	m2-head	1976.69442
m2-bet2	1819.5032	m2-head2	1938.33281
m3-bet	1893.04446	m3-head	2096.23338
m3-bet2	1852.46223	m3-head2	2088.20468
m4-bet	1727.9967	m4-head	1832.39812
m4-bet2	1692.06291	m4-head2	1881.56253
m5-bet	1505.45303	m5-head	1616.8744
m5-bet2	1631.22055	m5-head2	1808.71201
m6-bet	1881.29645	m6-head	1891.61083

m6-bet2	1917.21446	m6-head2	1884.13728

5.2.2 Hypothesis 2

Word	F2(Hz)	Word	F2(Hz)
m2-boot	1132.60599	m2-pot	1332.99902
m2-boot2	1140.37164	m2-pot2	1355.75429
m3-boot	1189.41522	m3-pot	1212.96712
m3-boot2	1175.28431	m3-pot2	1187.06219
m4-boot	1196.55643	m4-pot	1091.40305
m4-boot2	1136.85759	m4-pot2	1153.46463
m5-boot	1002.20708	m5-pot	1138.38677
m5-boot2	1049.41519	m5-pot2	1152.36915
m6-boot	1545.1875	m6-pot	1248.60027
m6-boot2	1398.50395	m6-pot2	1235.99284
m2-whod	963.306976	m2-hod	1266.89532
m2-whod2	982.871828	m2-hod2	1263.63918
m3-whod	949.783573	m3-hod	1164.87257
m3-whod2	996.291275	m3-hod2	1162.47311
m4-whod	934.992852	m4-hod	1098.55549
m4-whod2	1031.74636	m4-hod2	1080.31808
m5-whod	892.305099	m5-hod	1097.25211
m5-whod2	922.163069	m5-hod2	1103.31462
m6-whod	1297.67831	m6-hod	1155.14539
m6-whod2	1267.54564	m6-hod2	1141.92571

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Ling 104

Lab 2

Research Proposal

1. Introduction

This study will focus on speech rate and coarticulation in consonant-vowel sequence, as well as properties of vowel formants and how coarticulation influence formation of formants. Specifically, this lab aims to test how speech rate affects the degree of coarticulation of consonant-vowel sequence, and how vowel's formant can be affected by the place of articulation of the preceding consonant. In particular, this lab will test words with velar onset and compare their vowel's formant value with that of words with glottal onset produced in different speech rates.

We have formulated two hypotheses to test these properties of formant values, speech rate, and coarticulation. Firstly, we propose hypothesis 1 that argues the velar place of articulation causes F2 of the following vowel to be higher than glottal place of articulation, since we could have C-V coarticulation with the velar consonant which tends to rise vowel's F2 value. Secondly, we propose another hypothesis 2 that argues higher speech rate could intensify the coarticulation and create more visible F2 difference between the words with velar onset and words with glottal onset, since phonemes are produced closer together in faster pace. We will test both of these hypotheses on a range of vowels of various frontness and height.

2. Method

2.1. Subjects

The speakers that will be consulted in this lab will be 6 monolingual native speaker of American English from Los Angeles, California. All consultants will be male college students in their early 20's. All speakers will confirm before recording that they have no known history of impaired hearing or communication-related disorder.

2.2. Data

The data are shown in the table below. This lab will have 10 English words that differ by their vowel and onset consonant.

	velar-V-C	h-V-C
/i/	geek	heat
/ɛ/	get	head
/u/	goose	who'd
/ʌ/	gut	hut
/ɑ/	got	hot

Table 1: All target tokens in the experiment

To obtain data with slower speech rate, all tokens will be produced in the same prosodic condition. They are embedded in a carrier sentence: "The first word is _____, and the second word is _____.", where the first blank is a filler word outside of our interest, and the second blank is our target word. (Lab assignment handout)

To obtain data with faster speech rate, all tokens will be presented in a script that will be provided to the speaker. The script will contain a story and a scenario that features daily conversation between friends with tokens of interest embedded in the story.

2.3. Procedure

For data with slower speech rate, the carrier sentence will appear on the screen one at a time; each speaker will read the sentence twice. For data with faster speech rate, a script will be provided to the speaker to imitate case of rapid speech and the conversation section will be conducted in pairs with another speaker in the study. Recordings will take place in a sound-attenuating audiological booth, using a Shure SM10 head-mounted microphone. The sound is going to be recorded with 44,100 Hz sampling rate. (Lab assignment handout)

All formant values will be measured in the software Praat, using Praatscript and built-in formant tracking method that Praat provides. All values are then checked by hand to make sure they fit in reasonable bounds. Formant values checked by hand will be taken from the darkest center section of the formant.

For hypothesis 1, in order to measure the influence from coarticulation, formant measurements will be taken at roughly 20 milliseconds after the onset of the vowel. Similarly, for hypothesis 2, formant measurements will also be taken at roughly 20 milliseconds after the onset of the vowel to test coarticulation.

3. Prediction

For hypothesis 1, I would predict that we can observe a significant difference between the formant values of vowels following velar consonant compared to formant value of vowels following glottal consonant. In other words, F2 values of vowel following velar consonant are significantly higher than the F2 value of vowels with glottal onset. This is because /k/ and /g/ have high F2 locus, and they can create the velar pinch where there is an upward slope of F2 value in the preceding and following vowel.

For hypothesis 2, I would also predict that there is a significant difference between the formants in faster paced speech compared to in slower paced speech. In this case, faster paced speech could increase the level of C-V coarticulation because it shrinks the vowel space. This could cause the vowel formant to be even more influenced by the preceding vowel, and we should see a more definitive difference between F2 value of vowels with velar and glottal onset. Additionally, in order for the hypothesis to be true, I would expect that F2 value of vowels following velar consonant produced in higher speech rate to be also significantly higher than that of vowels produced in slower speech rate.