Professor: Meghan Clayards
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Lab 2: VOT and Vowel Duration

Winda Hao, 260742006
Jiayao Zhang, 260767074
Joy Han, 260845974

0 Introduction

We investigated the effects of the voicing of stops on Voice Onset Time (VOT). The particular questions we explored include:

(1) How is vowel duration affected by the voicing of a vowel's following stop?
(2) How is vowel duration affected by the voicing of a vowel's preceding stop?
(3) Is the VOT of a CVC's word-initial consonant C_1 affected by itself?
(4) Is the VOT of a CVC's word-initial consonant C_1 affected by its word-final consonant C_2?
(5) Does the place of articulation of a stop C_1 affect its own VOT?

We hypothesized for (1) that if the following stop of a CVC word's vowel, C_2, is voiced, the vowel duration should be longer than if C_2 is voiceless. Likewise for (2), if the preceding plosive of a word's vowel, C_1, is voiced, the vowel duration should be longer than if C_1 is voiceless. For (3), we believed that the duration of C_1's VOT affects C_1, i.e. itself. For example, if C_1 is a voiceless, unaspirated stop, we thought it's VOT should be shorter than if it is a voiceless, aspirated stop. For (4), unlike C_1 which may affect its own VOT, we hypothesized C_2 would not affect C_1's VOT, due to their articulatory gap, separated by a vowel. Regarding (5), we thought that depending on stop C_1's place of articulation, the VOT increases from front to back places of articulation. In particular, velar stops should have the longest VOT and bilabial stops should have the shortest VOT.

1 Methods

To explore our research questions, we used four sound files consisting of thirty-two CVC words spoken by a female in standard American English, and ran five experiments with sounds to help us investigate our research questions. The main focus of these tasks required us to accurately measure the words' C_1 and C_2 VOT, as well as their vowel duration.

In our first task, we compared vowel durations in CVC words when the vowel followed a phonologically voiced versus voiceless stop. In our second task, we compared CVC word vowel durations when it preceded a phonologically voiced versus voiceless stop. The third task had us compare the effects of C_2 voicing on C_1's VOT, while in the fourth task we investigated the effect of C_1 voicing on its own VOT. For our fifth and final task, we categorized the mean VOT duration of different plosives depending on their place of articulation and whether they are voiced or not.

To measure the VOT of C_1, we began with checking whether prevoicing is present. If there is prevoicing, the word would have negative VOT. If the word does not have prevoicing, it would have a positive VOT, which could be short or long lag. The VOT is positive if voicing begins after the stop release of C_1, and if there is no periodicity of any waveforms present before C_1's release burst. We could tell where the release burst occurs, by looking at the spectrogram. If aspiration is present in a segment and has no clear formants, it is probably a voiceless plosive. To measure vowel duration, we identified them in the waveform if waveforms are consistent, large oscillations. In the spectrogram, vowels have patterns of high energy, repeating dark bands, and clear formants (particularly F_1). When these characteristics are no longer present, it marks the ending of a vowel.

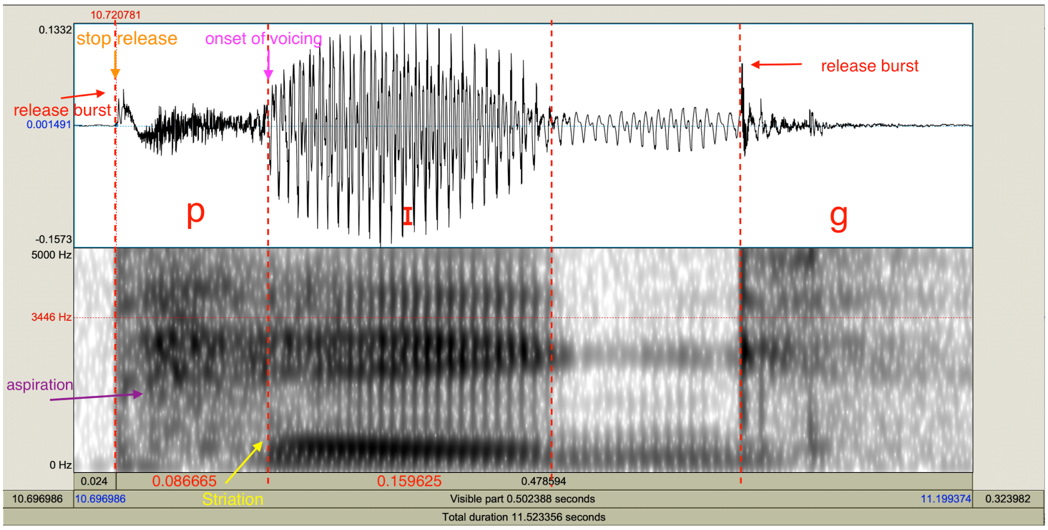

Figure 1

Figure 1 shows an example of our analysis for VOT and vowel duration. This particular utterance is the word 'pig'. We labelled the specific segments we were interested in investigating, like VOT, stop release, and voicing onset.

2 Results

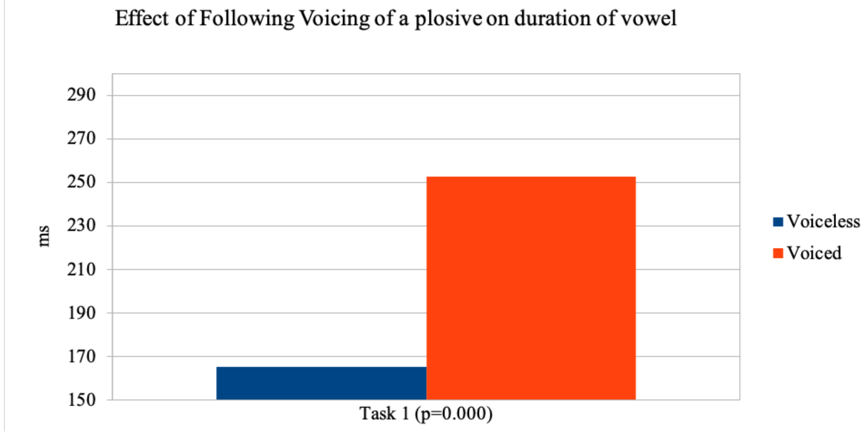

Figure 2

Figure 2 for Task 1 shows that the difference in vowel duration before voiced versus voiceless stops is statistically significant at the 0.01 level (p=0.000 < 0.001). In particular, the mean vowel duration before voiced stops are longer than vowels before voiceless stops.

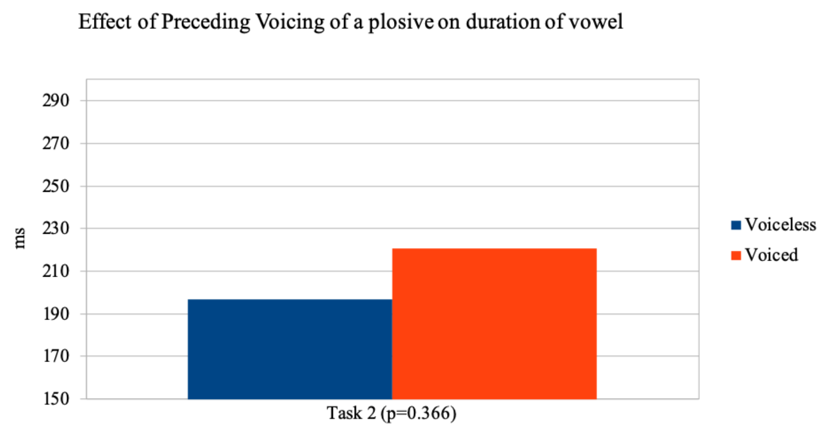

Figure 3

Figure 3 for Task 2 shows that the mean duration of vowels occurring after voiced stops versus the mean duration of vowels occurring after voiceless stops is not statistically different at a significance level of 0.05 (p-value = 0.366 > 0.05).

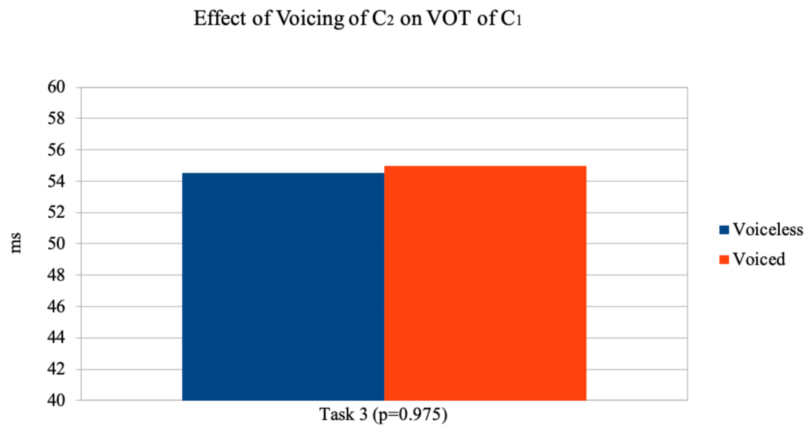

Figure 4

Figure 4 for Task 3 shows that at the 0.05 significance level, there is no statistically significant difference in the mean VOT of C_1, when C_2 is a phonetically voiced versus voiceless stop ($p=0.975 > 0.05$).

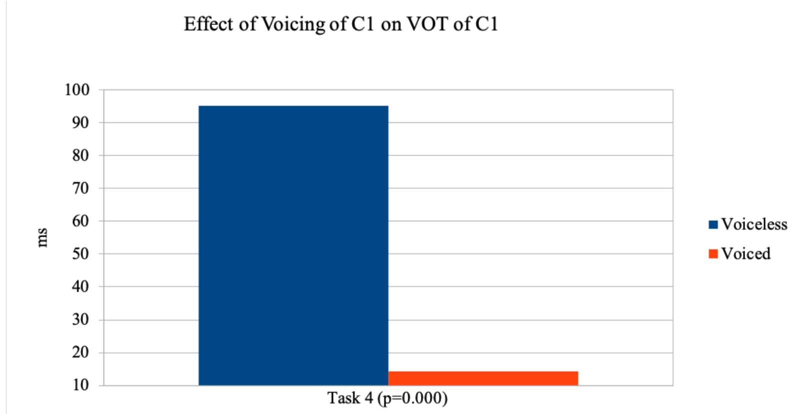

Figure 5

Figure 5 for Task 4 shows that there is a statistically significant difference in the mean duration of C_1's VOT, depending on whether it is a phonetically voiced versus voiceless stop. This significance is present at the 0.001 level (p-value = 0.000 < 0.001). Voiceless C_1 plosives have a longer VOT duration than the voiced C_1 plosives.

	Voicing	
Place	**voiceless**	**voiced**
Bilabial	**86.3**	**11.2**
Alveolar	**110.75**	**17.5**
Velar	**108.5**	**23.5**

Figure 6

Figure 6 shows the mean duration of VOT found in our thirty-two CVC words, organized by place of articulation and if it was voiced or voiceless. Our findings show that when corresponding to the same places of articulation, voiceless stops are always longer than voiced stops. Additionally, bilabial stops have the shortest VOT, consistent for both voiced and voiceless categories. Lastly, voiceless stops produced at the alveolar and velar regions have similar VOT, but if stops are voiced, the longest ones are produced at the velar region.

3 Discussion

For the first research question, the results accurately supported our hypothesis. If a CVC word's vowel is followed by a voiced stop, the vowel duration would be longer than if it is followed by a voiceless stop. The vocal folds vibrate when we pronounce vowels, and the vibration can help or constrain the articulate of following consonants. When the vowel precedes a voiced consonant, it takes less energy to pronounce consonant therefore the duration of vowel can be longer. However, when producing a voiceless stop after a vowel, the vocal folds would reduce their tension and become more open from modal voiced position, the transformation requires energy and time. Vowel duration is shorter when it is followed by a voiceless stop than a voiced stop.

For the second question, we thought that the longer the C_1's VOT, the longer the vowel duration. Surprisingly, the data shown in **Figure 3** suggests that there was no significant relationship between vowel length and its preceding consonants. This may be so, since both voiced and voiceless stops end with a release, so it does not affect following vowels.

For the third question, our guess was supported by the results shown in **Figure 4**, indicating to us that there is no relationship between the duration of C_1's VOT and C_2. C_1 and C_2 are separated by a vowel sound, and this prevents them from affecting one another's production.

For the fourth question, our hypothesis was supported by the results shown in **Figure 5**. We found that the duration of C_1's VOT is affected by C_1. Voiceless C_1 stops have a longer VOT duration than the voiced C_1 stops. It might depend on whether C_1 is aspirated or not, which would have an impact on the start of voicing. For example, if a vowel follows an aspirated consonant, the voicing of the vowel would start later and have a longer VOT than if the vowel follows an unaspirated one.

For the last question, our hypothesis was supported by our data. **Figure 6** shows bilabial stops have a shorter VOT compared to alveolar and velar stops, and voiceless alveolars and voiceless velars have similar VOT durations. These results may be due to changes in air pressure of the oral cavity after a stop's release. The bilabial stops are articulated in the frontest part of the oral cavity, whereas alveolar and velar stops are articulated in more central areas. When we pronounce velar and alveolar stops, the oral cavity has less volume than when a bilabial stop is produced. If we assume there is a similar amount of pulmonic airflow involved in the production of all stops, then stops requiring a smaller oral cavity should have greater air pressure. This may explain why velar stops have the longest VOTs. Compared to alveolar and bilabial plosives, velar plosives have the largest difference in air pressure within the oral cavity and the outside world, so it would take longer for air pressure to equalize. This also accounts for why bilabial stops have the shortest VOT; they have the largest oral cavity and lower air pressure, so it is shorter for the air pressure within the cavity and the outside world to equalize. Since the articulatory positions for alveolar and velar stops are similar, the difference in their oral cavity pressure is small. This may be why their VOT durations are similar, as supported by our findings in **Figure 6**. Note, due to our limited amount of data, our results may not be consistent enough to be generalized. As we discussed for Task 4, voiceless stops were found to have a longer VOT than the voiced stops.

For initial stops, i.e. C_1, we speculate that native French speakers would perceive different VOTs compared to English speakers. They may also not be able to distinguish some of the stops English speakers can. Unlike in English, which have contrastively used long-lag stops, there exists no aspirated stops in French. For example, French speakers may perceive [p^h] as [p] and perceive [p] as [b]. This entails that French speakers would perceive the C_1 VOTs in initial English stops to be much shorter, or even a negative VOT.

4 Appendix

Effect of Following Voicing of a plosive on duration of vowel	
Voiceless	**Voiced**
204	299
189	321
196	320
130	181
212	266
101	203
98	190
82	159
208	339
232	309
222	315
148	224
237	314
138	218
147	204
95	180

Figure 7

Effect of Preceding Voicing of a plosive on duration of vowel	
Voiceless	**Voiced**
204	208
189	232
196	222
130	148
212	237
101	138
98	147
82	95
299	339
321	309
320	315
181	224
266	314
203	218
190	204
159	180

Figure 8

Effect of Voicing of C_2 on VOT of C_1	
Voiceless	**Voiced**
93	104
111	83
125	92
63	105
111	114
73	70
109	109
74	87
6	6
15	9
27	20
12	14
15	17
14	14
14	24
10	12

Figure 9

Effect of Voicing of C_1 on VOT of C_1	
Voiceless	**Voiced**
93	6
111	15
125	27
63	12
111	15
73	14
109	14
74	10
104	6
83	9
92	20
105	14
114	17
70	14
109	24
87	12

Figure 10