

Insertion of Glottal Stops before Word-Final Voiceless Stops in English

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Introduction

A glottal stop is a vocal phenomenon found in various languages where airflow is obstructed in the glottis, creating a “creaky voice quality” (Pierrehumbert, 1995, p. 39). In American English, glottal stops are considered to be voiceless allophones, meaning that they can be used in place of phonemes, such as /p t k/, without changing the meaning of a word and do not require vocal fold approximation (Eddington & Channer, 2010). Little research has been conducted on the occurrence of glottal stops in American English; this study aims to collect more data on the phonetic contexts that facilitate the use of glottal stops, specifically in Northeast Ohio. Four previous studies were used to help compose a word and sentence list, compare methods, and evaluate data at the conclusion of the study.

Eddington and Channer (2010) analyzed the frequency of the use of glottal stops for word-final /t/ according to age, region, and phonetic context of the phone in American English. Recorded and transcribed data from a total of 40 participants ranging from 11 to 60 years of age were used. 19 of the 40 participants were considered to be Westerners from California, Idaho, New Mexico, Washington, Colorado, Oregon, and Montana, while 21 of the 40 participants were considered to be non-Westerners from Illinois, Louisiana, New York, Massachusetts, Michigan, New Jersey, Pennsylvania, and Wisconsin. The researchers searched through the transcribed data and located 1,101 productions of word-final /t/. The researchers found the 1,101 productions of word-final /t/ in the recordings and analyzed each one to determine whether a /t/, glottal stop, apical flap, or deletion was produced. Any productions that were questionable as to which allophone was used were analyzed using spectrographic analysis. The speakers’ age, gender, and geographical location, along with the phonetic context of each production, were documented. The results suggested that the use of glottal stops for word-final /t/ is favored by Westerners

between 11 and 29 years of age, and glottal stops are used most frequently when the /t/ is preceding a stressed syllable (Eddington & Channer, 2010). The small sample size, lack of Ohioans, and the absence of data regarding glottal stop use for the voiceless stops /p k/ supports further investigation.

A study conducted by Pierrehumbert (1995) aimed to discover the effects of phrase stress on glottal stops in the final position, along with the phonetic context that facilitates the use of glottal stops. A list of 30 phrases that included compound words thought to promote the use of glottal stops was compiled. Two participants were recorded speaking the 30 target phrases twice in different contexts. The recordings were then analyzed acoustically. The results indicated that phrase stress has no effect on the use of glottal stops in place of final voiceless stops; however, it is evident that glottal stops are used for /t/ more frequently when a sonorant consonant, such as /l/ or /w/, follows. The use of glottal stops in place of /p/ was found to only occur occasionally when preceding the nasal sonorant /m/ (Pierrehumbert, 1995). The extremely small sample size and the lack of research on glottal stop use for the velar voiceless stop /k/ supports further investigation.

A third study conducted by Eddington and Taylor (2009) researched the use of glottal stops specifically in the word-final prevocalic position. A total of 58 participants were used in this study. Of those participants, 42 were classified as Westerners from Utah, Arizona, Colorado, Washington, Arizona, Oregon, and Idaho. The remaining 16 participants were classified as non-Westerners from Mississippi, Texas, Louisiana, Virginia, Michigan, Iowa, Minnesota, Ohio, Illinois, Oklahoma, and New Jersey. 20 word pairs containing word-final /t/ preceding a vowel were put into sentences and recorded by a middle-aged white male with a Western U.S. accent. All of the productions of /t/ in the recordings were deleted and replaced by a 100 millisecond 440

Hertz pure tone so as to not influence the participants' productions. The participants were recorded while repeating back each sentence three times within a six second time frame. The recordings were initially analyzed by each researcher separately using impressionistic coding of each production of /t/. Any productions that were coded differently by the researchers were analyzed using spectrographic analysis to come to a conclusion. The results suggested that glottal stops are favored when /t/ precedes a front vowel such as /æ/ or /e/; however, considering there were only 8 test words with front vowels and 11 with back vowels, more research is warranted on this topic. The results also indicated that Western women between the ages of 19 and 39 years of age are more likely to use glottal stops than any other age, gender, or regional group (2009). Again, the small sample size, the lack of non-Western participants, and the absence of data on the use of glottal stops for the voiceless stops /p k/ justifies further research.

Lastly, Roberts (2006) investigated the phonetic contexts in which glottal stops and other allophones of /t/ most often replace word-medial and word-final /t/ in northwestern Vermont. The study consisted of 47 participants all from the same small town in northwestern Vermont ranging in age from 3 to 80 years. There were a total of 11 preschool students between 3 and 4 years of age, 7 kindergarten students 5 years of age, 6 fourth grade students 9 years of age, 6 high school students between 15 and 18 years of age, 14 parents between 20 and 40 years of age, and 3 older adults. All participants were recorded during multiple interview sessions. All recorded productions of word-medial and word-final /t/ were analyzed impressionistically as to which allophone of /t/ was used. The results suggested that glottal stops are inserted more frequently when word-final /t/ follows a vowel. The results also suggested that glottal stops occur more often when word-final /t/ precedes a pause. The author also examined which phonetic contexts did not facilitate the use of glottal stops for word-final /t/. The author found

that final /t/ preceding a vowel or liquid was the least favorable phonetic context for glottal stops to occur (2006). This finding contradicts Pierrehumbert's claim that glottal stops occur more frequently before sonorant consonants such as /l/ and /r/ (1995), and also contradicts Eddington and Taylor's find that glottal stops are inserted more often when final /t/ precedes a front vowel (2010). The inclusion of children 5 years and younger lowers the validity of this study because children's speech and language development is not yet complete at those ages. Also, the small sample size and the lack of data on the voiceless stops /p k/ supports further research.

The data found in these studies suggested specific phonetic contexts that facilitate and hinder the use of glottal stops for final voiceless stops. Using these specific phonetic contexts, a word and phrase list was created to further investigate the use of glottal stops in American English spoken by Northeast Ohioans.

Methods

The participants in this study consisted of 20 native English-speaking individuals between the ages of 18 and 23 years with no reported speech, language, or hearing problems except for one participant who consistently produced /s/ distortions which should not have affected his pronunciation of the sounds being studied. Of the 20 participants, 14 were women and 6 were men. 16 of the participants considered themselves to be Caucasian, while 4 considered themselves to be African American. All participants currently reside in Northeast Ohio; however, 2 participants were from Pennsylvania, 1 participant was from Illinois, 1 participant was from Maryland, 1 participant was from North Carolina, and 1 participant was born in Ohio, but had lived in Minnesota for longer than 6 months during her lifetime.

Participants were recorded in a sound attenuated booth, wearing a head mounted Shure SM10A microphone connected to a KayPentax CSL model 4500 digitization module.

Participants read a list of 24 different sentences (see Appendix A) created using the most and least facilitating phonetic contexts for glottal stops from previous studies as reviewed earlier. Each sentence contained a range of 4-6 words with an average of 5.04 words per sentence, along with a range of 5-7 syllables with an average of 6.25 syllables per sentence. In order to ensure that the order of sentences did not affect production of each sentence, 10 randomized lists labeled A-J were compiled. Participants read the lists in the order in which they were recorded; the lists were repeated after the first run.

Participants first read the instructions while the investigator read them aloud. Participants then read 3 test sentences in order to set the volume levels on the computer and to familiarize the participants with the task. Once the volume level was set, each participant was asked to read from one of the lists marked A-J. The participants were instructed to read the sentences in no special way, just the way they would normally say them. If a participant misread a sentence, he or she was asked to read the sentence again. After all data were collected, they were analyzed both impressionistically and by spectrographic analysis in Praat version 6.0.14. If a glottal stop was suspected impressionistically, it was analyzed spectrographically according to the voicing characteristics, wave shape characteristics, and duration. This was done in order to differentiate glottal stops from glottal fry and other productions of the target voiceless stops such as unreleased, released, ambisyllabic, resyllabified, or an apical flap. Analyses were performed by the author. Questionable segments were reviewed by the author and her advisor, and a consensus judgment was reached. Two sentences were left out of the analyses because participants read the sentences incorrectly. A total of 559 sentences were analyzed with 160 sentences containing /p/, 199 sentences containing /t/, and 200 sentences containing /k/. Next, criteria for labeling realizations are defined.

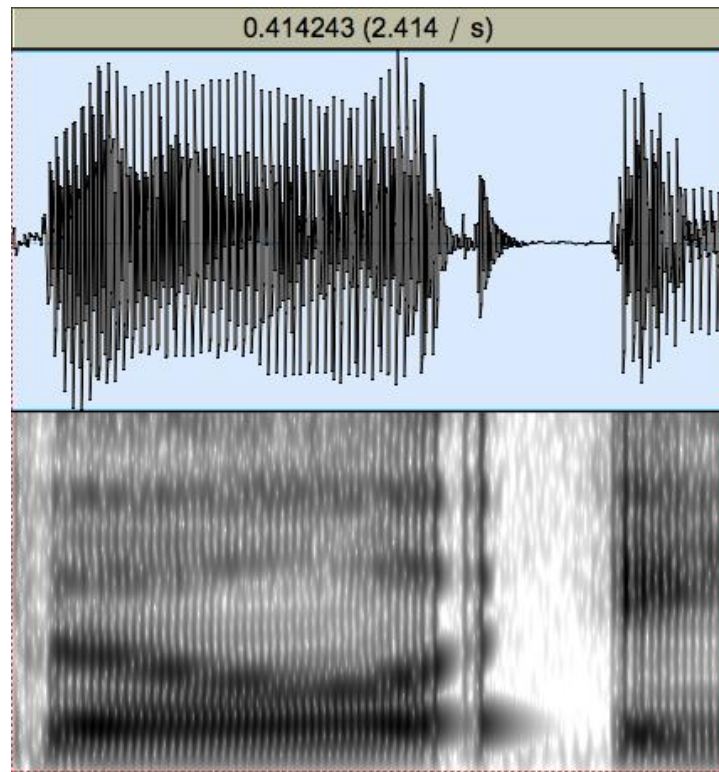


Image 1: Glottal stop realization in the phrase “built a.”

Glottal stops are typically considered to be voiceless; however, due to coarticulation factors with surrounding voiced phonemes, a glottal stop was considered to be produced in this study if alternating voiced and voiceless striations were present in a wavy pattern, indicating loss of stability. This pattern was only considered to be a glottal stop rather than glottal fry if the duration was less than or equal to 50 milliseconds and did not occur within other surrounding phonemes. An example of a glottal stop is shown in Image 1.

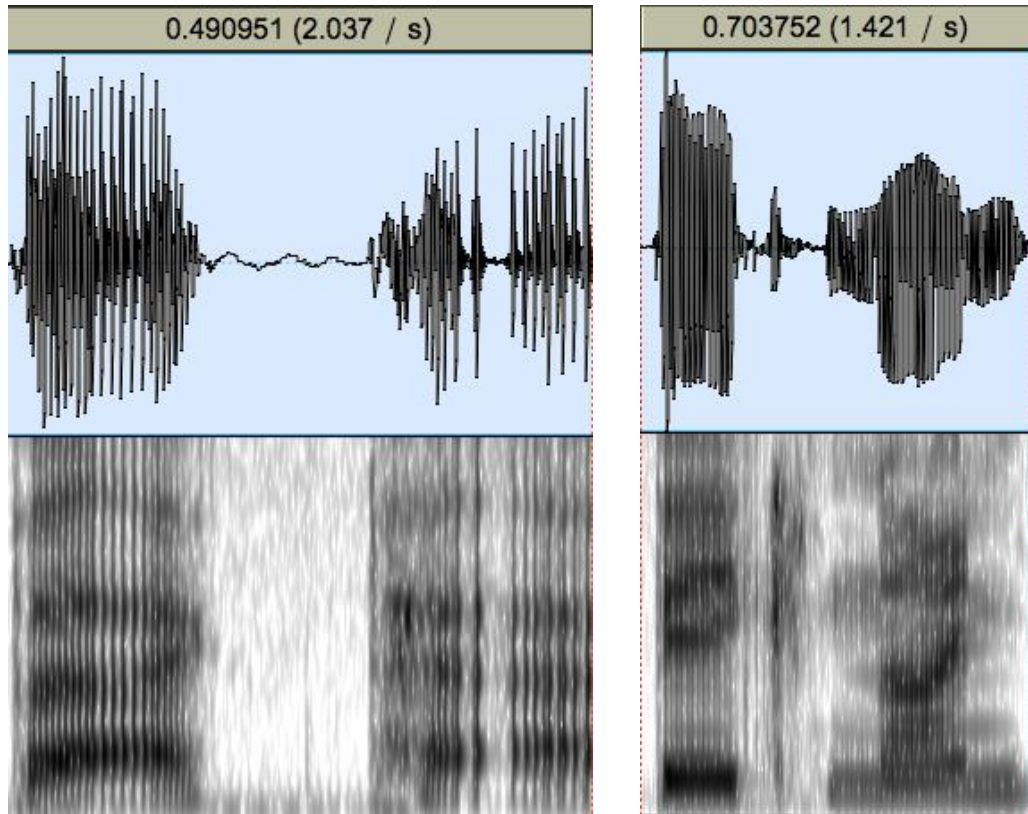


Image 2: An unreleased realization in the word “backpack” (left), and a released realization in the phrase “bake nine” (right).

An unreleased stop was considered to be realized when there was an audible stop with no visible or audible burst present. A released stop was considered to be realized when an audible stop was present along with a visible or audible burst accompanied by temporal disjunction between the burst and the following sound. An example of an unreleased stop and a released stop can be seen in Image 2.

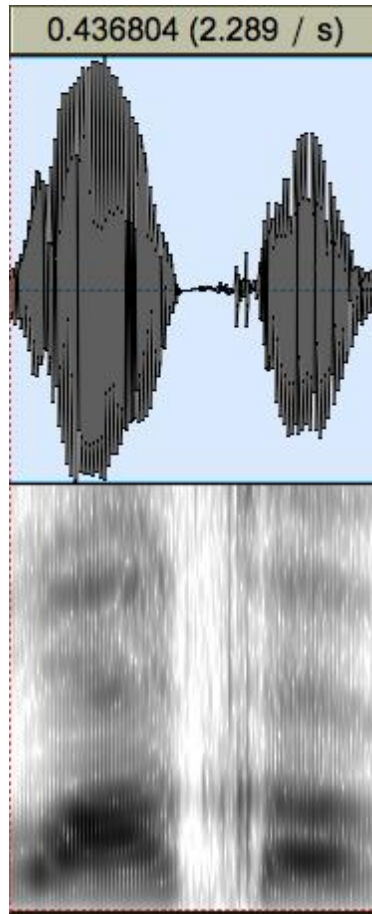


Image 3: Resyllabified realization in the phrase “walk over.”

If a word-final stop had a visible and audible burst that preceded a vowel with no temporal disjunction between the final stop and the beginning of the vowel, it was considered to be resyllabified. An example of a resyllabified realization can be seen in Image 3.

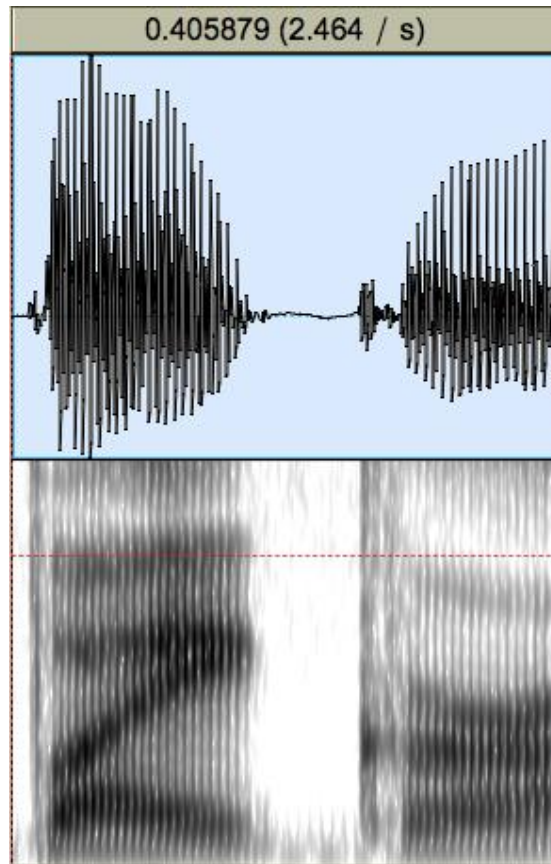


Image 4: Ambisyllabic realization in the phrase “bike garage.”

An ambisyllabic realization was considered if the final stop shared the same place of articulation with the following consonant and a sound combination was created between that final stop and the following consonant. An example of an ambisyllabic realization is shown in Image 4.

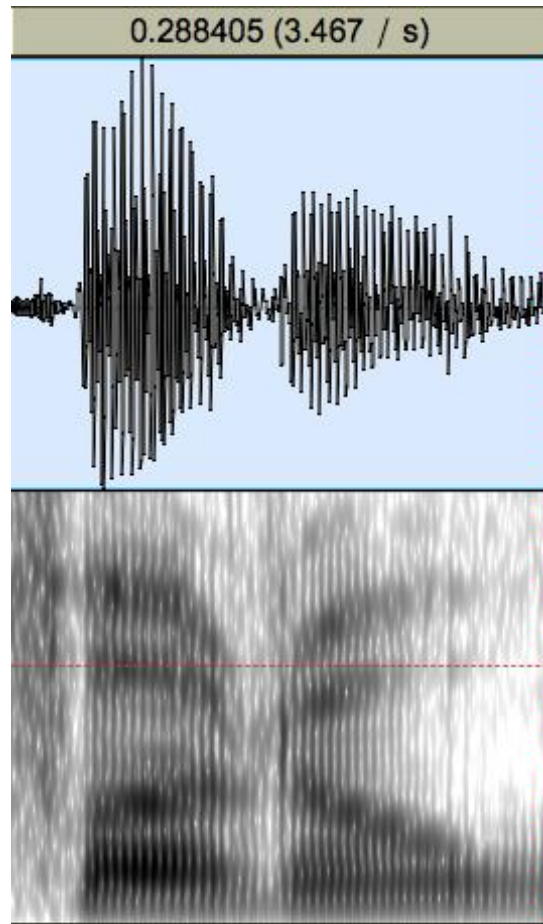


Image 5: An apical flap in the phrase “foot away.”

An apical flap was considered to be realized if an audible stop was seen with one visible or audible burst between the two words, and in one case, an apical trill was audible and visible. An example of an apical flap can be seen in Image 5.

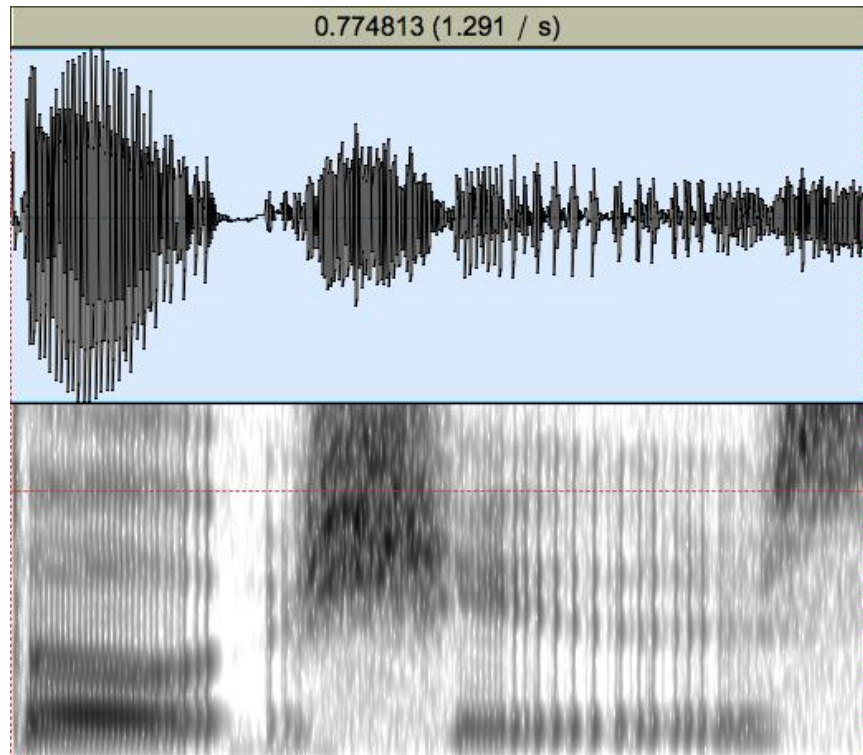


Image 6: Glottal Fry as seen in the phrase “boat shoes.”

There were 25 segments labeled as glottal fry. These segments could not be analyzed because there was no clear visual evidence for other realizations. An example of glottal fry is shown in Image 6.

Results

This study examined the occurrences of glottal stops inserted for word-final voiceless stops in different phonetic contexts in Northeast Ohio. Twenty speakers were recorded reading 24 sentences containing /p t k/ in word medial and final positions. The sentences included 559 occurrences of /p t k/. The number of occurrences is greater than the number of sentences because 20 participants read each sentence and multiple sentences included more than one occurrence of /p t k/ to be analyzed. Productions of each phoneme were evaluated auditorily and acoustically to determine their phonetic realization.

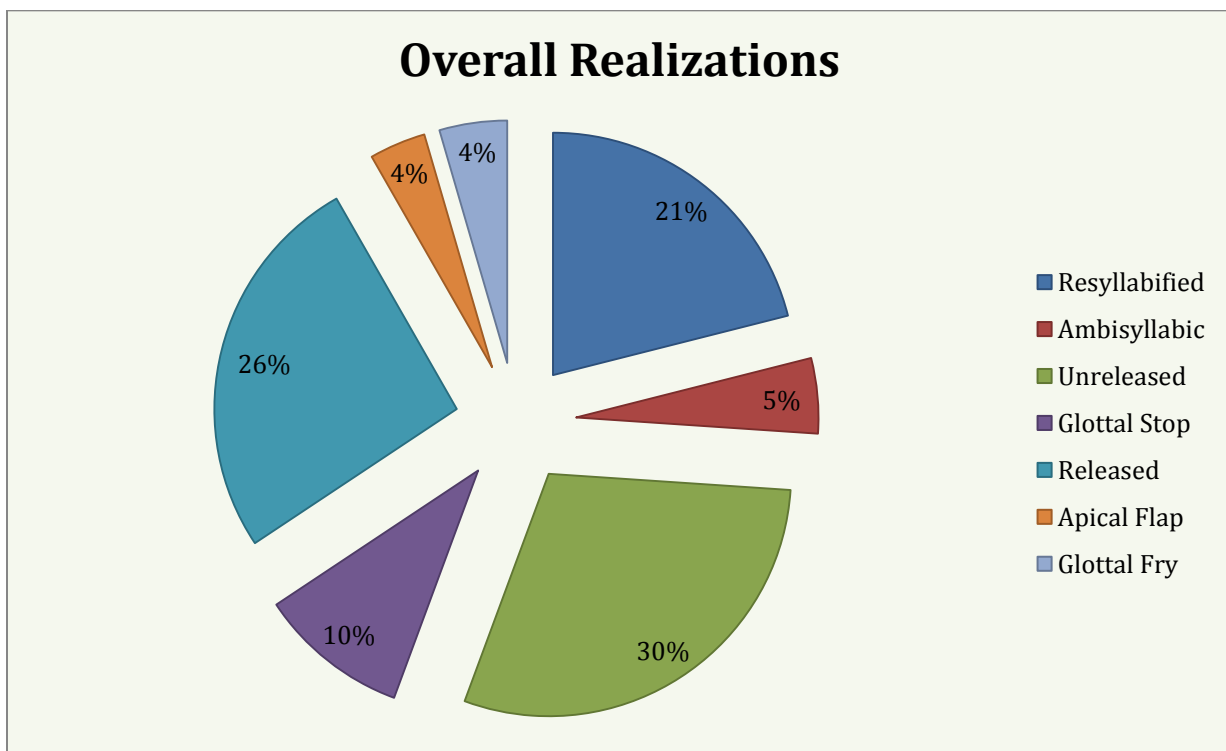


Figure 1: Overall realizations of word-final voiceless stops /p t k/ (n=559).

Overall, Figure 1 indicates that of the 559 opportunities to produce the final voiceless stops /p t k/, approximately 30% of the realizations were unreleased, 26% of the realizations

were released, 21% of the realizations were resyllabified, 10% were realized as glottal stops, 5% of the realizations were ambisyllabic, 4% were realized with glottal fry which was impossible to analyze, and 4% were realized as apical flaps. This demonstrates that all of the phonemes studied were realized in ways other than the expected released or unreleased phoneme.

Figure 2 illustrates the percent of realizations for /p/, Figure 3 illustrates the percent of realizations for /t/, and Figure 4 illustrates the percent of realizations for /k/. Figures 2, 3, and 4 highlight the fact that the final voiceless stop /t/ had the highest percentage of glottal stops at 25.1%, while /k/ had the second highest percentage of glottal stops at 3%, and /p/ had the lowest percentage of glottal stops at 1.25%. This indicates that glottal stops inserted for /t/ occurred more frequently than glottal stops inserted for /p k/.

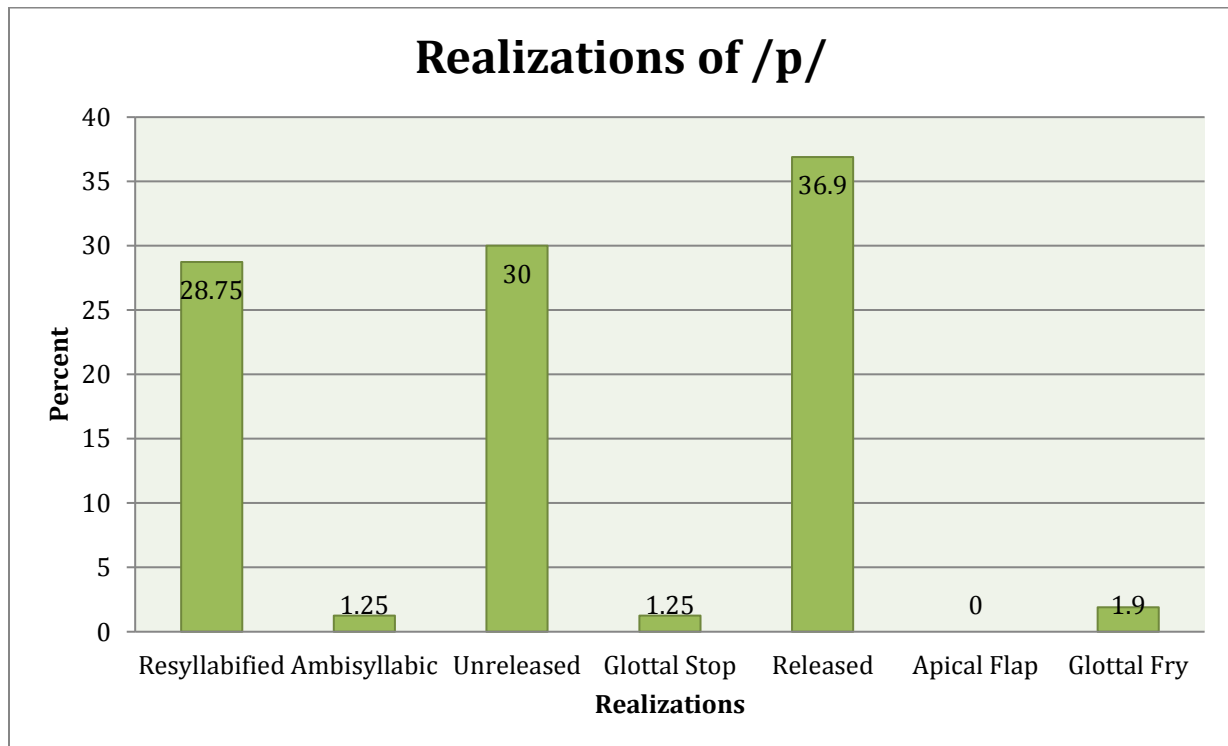


Figure 2: Percent of overall realizations for /p/ (n=160).

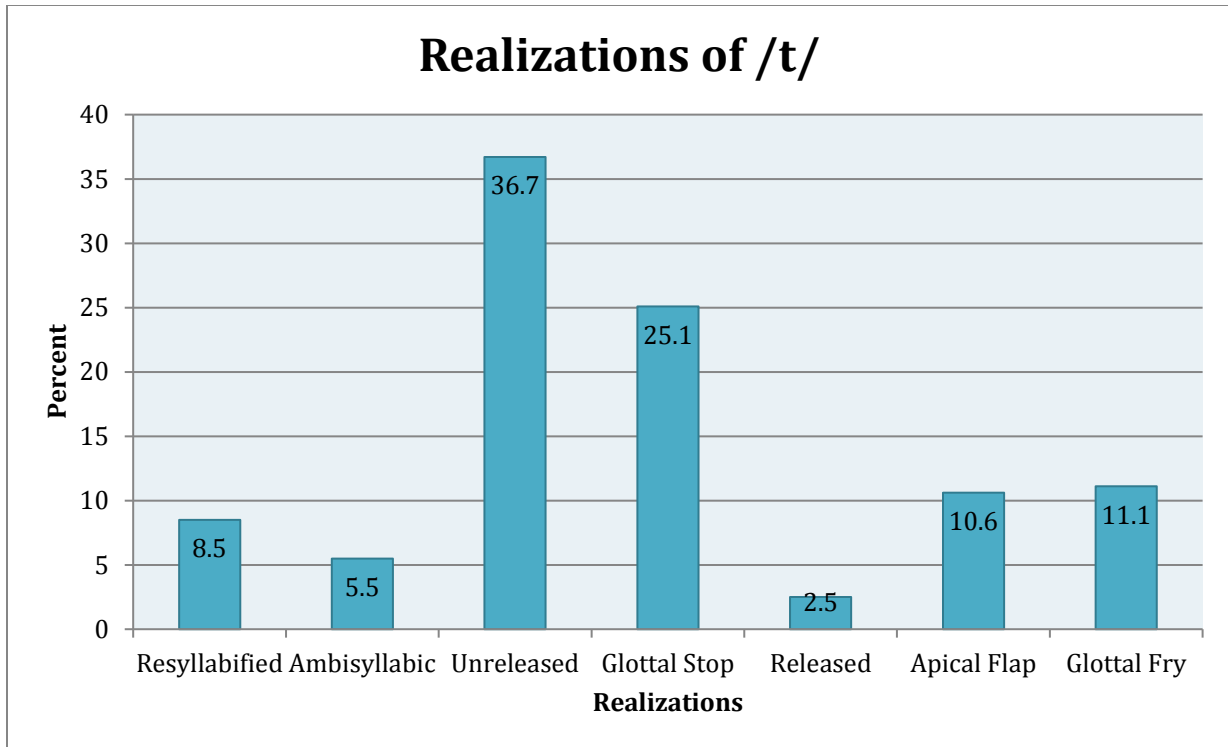


Figure 3: Percent of overall realizations for /t/ (n=199).

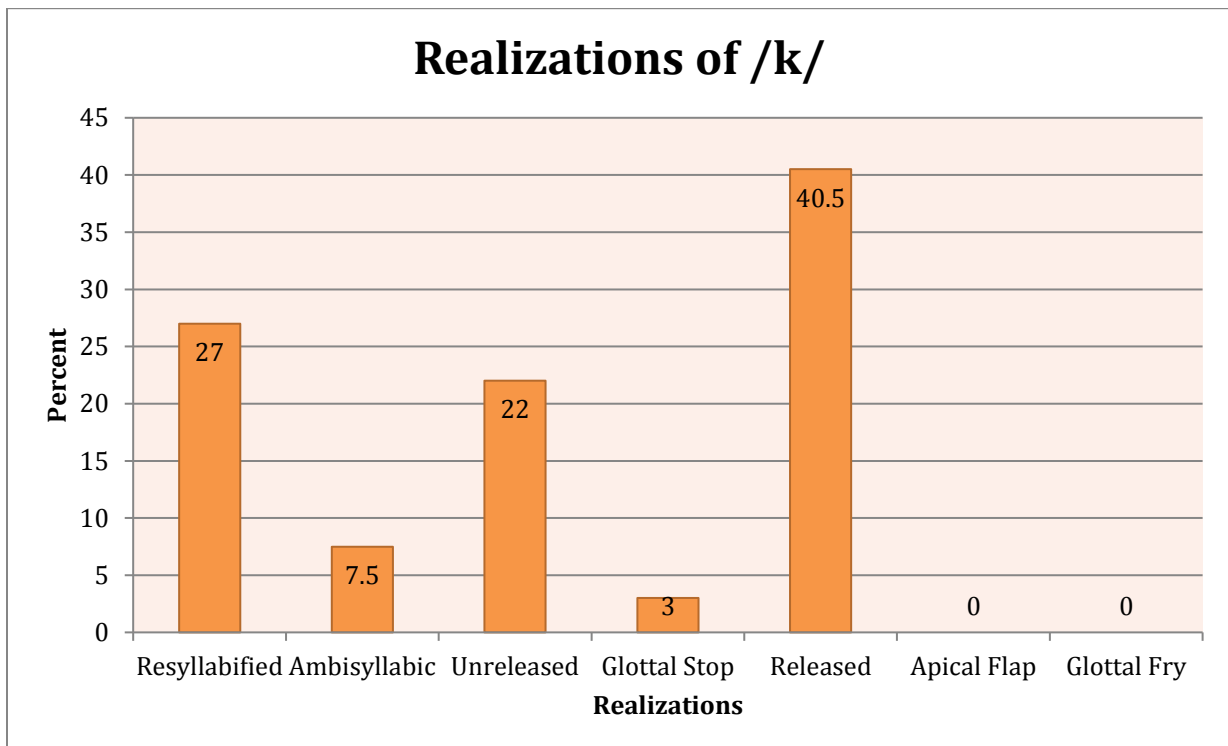


Figure 4: Percent of overall realizations for /k/ (n=200).

Considering the context of each phoneme, Figure 5 illustrates the most favorable context for the substitution of glottal stops for /t/, Figure 6 illustrates the most favorable context for the substitution of glottal stops for /k/, and Figure 7 illustrates the most favorable context for the substitution of glottal stops for /p/.

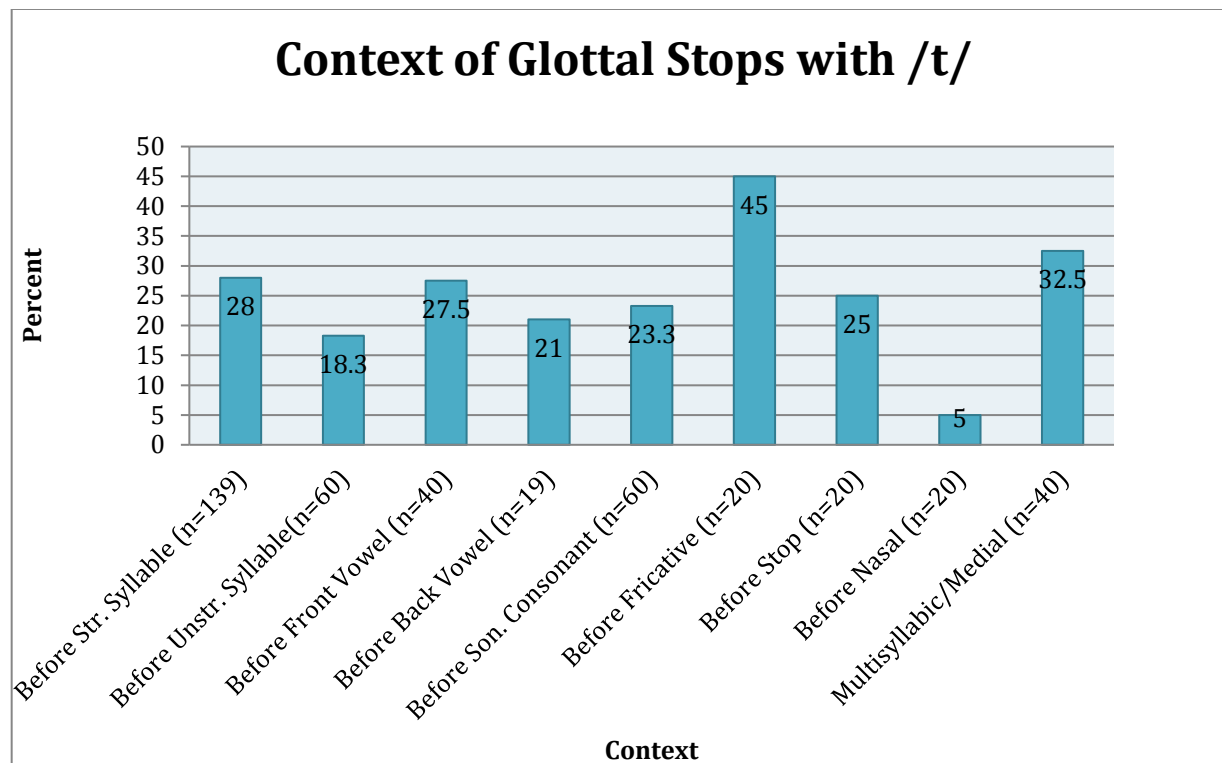


Figure 5: Glottal stop context for /t/ (50 out of 199 sentences).

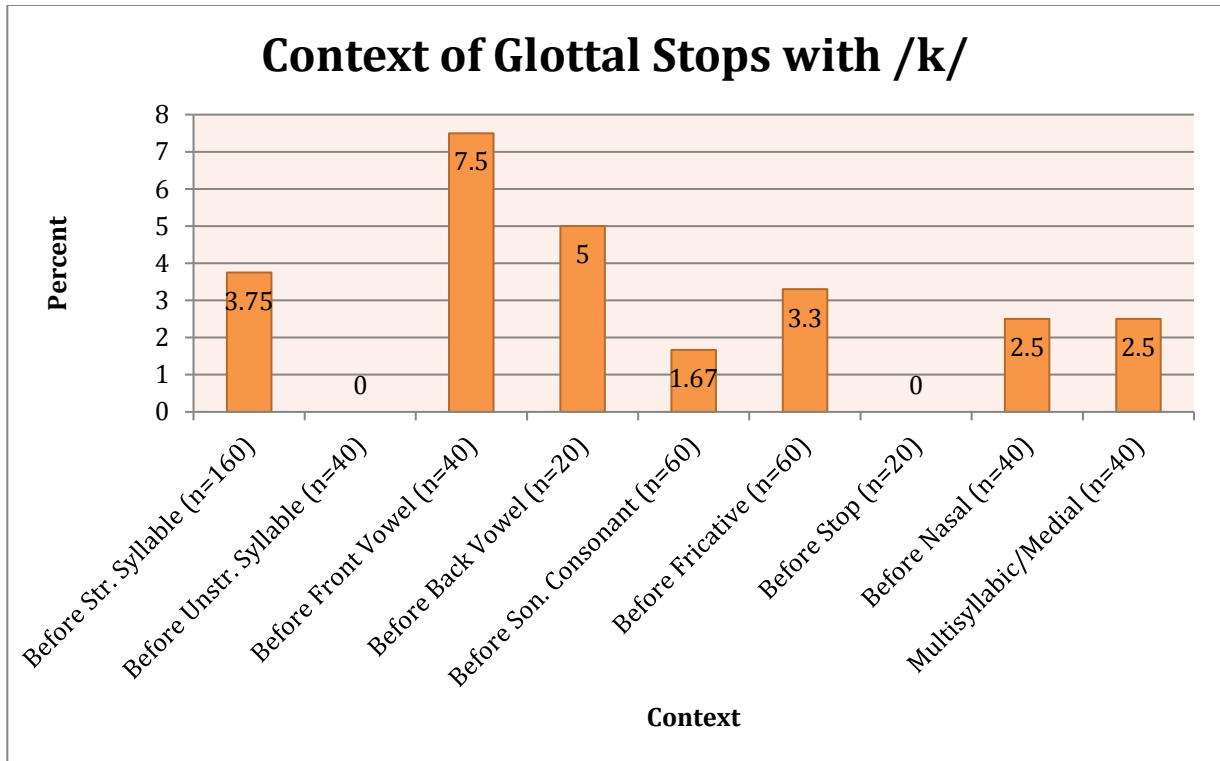


Figure 6: Glottal stop context for /k/ (6 out of 200 sentences).

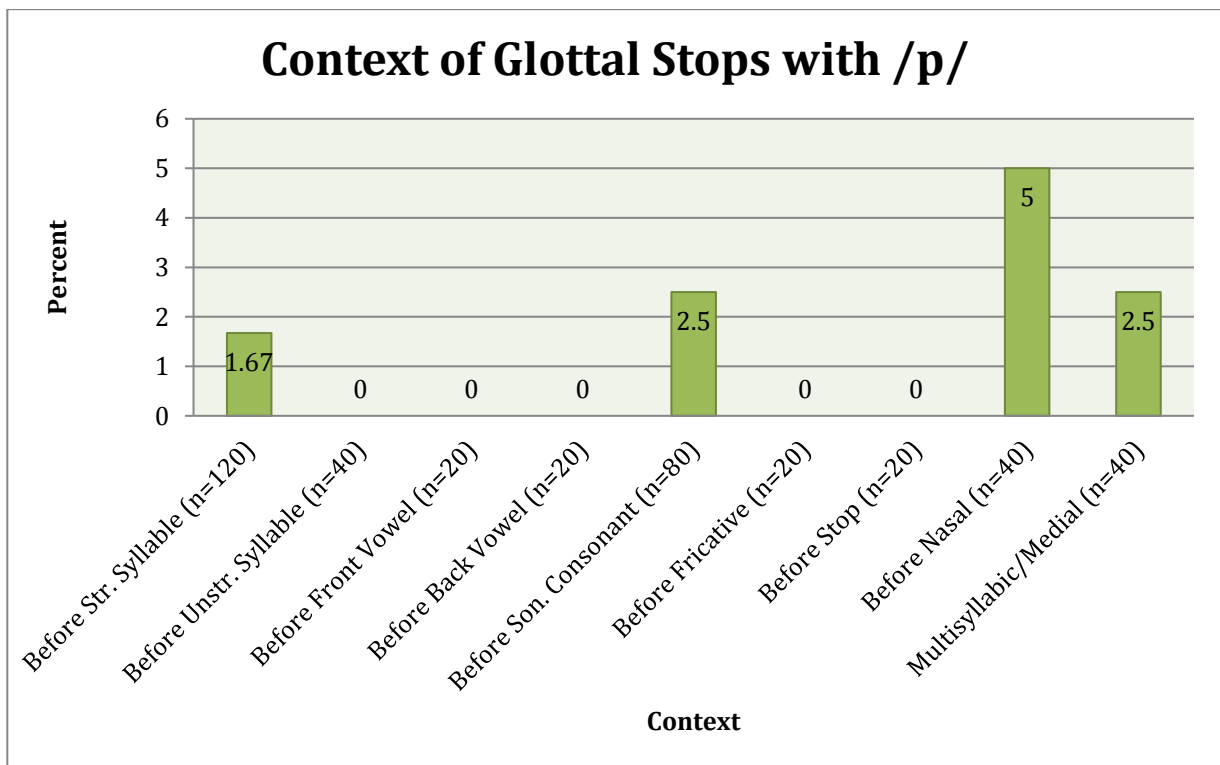


Figure 7: Glottal stop context for /p/ (2 out of 160 sentences).

The results showed that 28% of the 139 sentences containing final /t/ preceding a stressed syllable were realized as glottal stops, while 18.3% of the 60 sentences containing final /t/ preceding an unstressed syllable in the next word were realized as glottal stops. For 27.5% of the 40 sentences with final /t/ preceding a front vowel glottal stops were inserted, while 21% of the 19 sentences with final /t/ preceding a back vowel were realized as glottal stops. Of the 60 sentences with /t/ preceding a sonorant consonant, 23.3% were realized as glottal stops, while 45% of the 20 sentences with /t/ preceding an obstruent fricative were realized as glottal stops. Lastly, 25% of the 20 sentences with /t/ preceding an initial stop were realized as glottal stops, 5% of the 20 sentences with /t/ preceding a nasal were realized as glottal stops, and 32.5% of the 40 sentences with syllable-initial /t/ in a multisyllabic word or in medial position were realized as glottal stops. The data indicate that the most favorable contexts for insertion of glottal stops for /t/ are before a stressed syllable and preceding a fricative.

For the final voiceless stop /k/, there were no results that suggested a most favorable context for glottal stop substitution; however, 7.5% of the 40 sentences with final /k/ preceding a front vowel were realized as glottal stops, and 5% of the 20 sentences preceding a back vowel were realized as glottal stops. Of the 60 sentences with final /k/ preceding a sonorant consonant, 1.67% were realized as glottal stops, while 3.3% of the 60 sentences with final /k/ preceding a fricative were realized as glottal stops. Moreover, 3.75% of the 160 sentences with final /k/ preceding a stressed syllable were realized as glottal stops, 2.5% of the 40 sentences with final /k/ preceding a nasal were realized as glottal stops, and 2.5% of the 40 sentences with /k/ syllable initial in a multisyllabic word or in medial position were realized as glottal stops. Of the remaining contexts (final /k/ preceding an unstressed syllable and final /k/ preceding a stop), 0% of the /k/s were realized as glottal stops.

Finally, for the final voiceless stop /p/, there were also no results that suggested a most favorable context for glottal stop substitution. The contexts where /p/ was realized as a glottal stop were final /p/ preceding a nasal at 5% of the 40 sentences produced, final /p/ preceding a sonorant consonant at 2.5% of the 80 sentences produced, syllable initial /p/ in a multisyllabic word or in medial position at 2.5% of the 40 sentences produced, and final /p/ preceding a stressed syllable at 1.67% of the 120 sentences produced. The remaining contexts exhibited 0% glottal stops.

Discussion & Conclusion

In this study, it was found that for Northeast Ohio speakers, glottal stops were substituted for the word-final voiceless stops /p t k/ within certain phonetic contexts; however, the majority of the productions of /p t k/ were realized as unreleased or released stops. This was not a surprising find, but it was unexpected for unreleased stops to be more common than released stops in this study, as we thought released stops would be the overall preferred production.

Glottal stops occurred most often for the voiceless stop /t/ as compared to /p k/. The most facilitative contexts were /t/ preceding an obstruent, when /t/ was in a medial position, and when /t/ preceded a stressed syllable. More research is warranted to determine why glottal stops occurred more often for /t/ than the other voiceless stops /p k/, and why these phonetic contexts were more facilitative than the other contexts.

Interestingly, a pattern of glottal fry production was found for a number of speakers, affecting 22 sentences including final /t/ and 3 sentences including final /p/. These words were not included in the analysis of glottal stops. It was also observed that women tended to use glottal fry more often than men (9/14 women, 1/6 men), and because there were more women than men who participated in this study, more data were compromised than was expected. Use of

glottal fry may be an increasing speech characteristic among the younger population, which could be related in part to society becoming more casual over time. More research in this area is warranted in order to decide the main factors for the possible finding of glottal fry use.

Many of the sentences were consistently produced with the same realizations across speakers, which was very interesting to observe. For example, the medial /p/ in “chipmunk” in the sentence “A chipmunk ate my carrots” was realized as an unreleased /p/ for 19 of the 20 participants. The same goes for glottal stops being consistently realized for /t/ in the same 3 sentences across participants. The sentences include “Get in the car everyone,” “Do you own any boat shoes,” and “I like to eat lemon drops.” As the results suggested, the best context for glottal stops for /t/ are preceding a fricative and when in word-medial position, so it is not surprising that “Do you own any boat shoes,” was affected.

A study conducted by Eddington and Channer (2010) found that the best phonetic context for glottal stops to occur for word-final /t/ was when the phone preceded a stressed syllable. Our findings contradict the results of Eddington and Channer’s (2010) study; our results indicated that word-final /t/ preceding a fricative was the best context to find glottal stops. However, final /t/ followed by a stressed syllable was the third best context for glottal stops and was much more facilitative than /t/ preceding an unstressed syllable. The same scenario occurred when comparing our results with those from a study conducted by Eddington and Taylor (2009) where they found that final /t/ preceding a front vowel was the best phonetic context to facilitate glottal stops. Although our study found /t/ preceding a fricative to be the overall best context for glottal stops to occur, we also found final /t/ preceding a front vowel to be more facilitative of glottal stops than /t/ preceding a back vowel, which is consistent with the findings from Eddington and Taylor (2009).

A study conducted by Pierrehumbert (1995) found that final /t/ preceding a sonorant consonant such as /l/ or /w/ was the most facilitative phonetic context for glottal stops. However, the results from this study indicated that final /t/ preceding a fricative was the most facilitative context for glottal stops. More research on whether word-final /t/ preceding a fricative or a sonorant is a better context for glottal stops is warranted because of this contradiction. Although the results from this study contradicted Pierrehumbert's results for glottal stop insertion for word-final /t/, the results from this study for word-final /p/ are consistent with Pierrehumbert's findings. Both our study and Pierrehumbert's study (1995) revealed that word-final /p/ preceding a nasal was the most facilitative context for glottal stops to occur, even though glottal stops did not occur very often for /p/ in both studies.

The last study used to compare data was conducted by Roberts (2006) who found that the least facilitative phonetic contexts for glottal stops in reference to word-final /t/ were preceding any vowel or liquid. Our results contradict the findings of Robert's (2006) study. Our results suggested that word-final /t/ preceding a nasal or an unstressed syllable were the two least facilitative contexts for glottal stop insertion.

Further research is needed to determine the most facilitative phonetic context for glottal stop insertion for the word-final voiceless stops /p t k/, especially because there is very little research that included /p k/.

This study has many limitations. The first limitation is the small sample size, as 20 participants are not enough to truly determine any generalizations to the entire population of Northeast Ohio. Second, more women participated in this study than men. An even number of men and women would help us understand gender differences in glottal stop usage. Third, the number of sentences containing /p t k/ were unequal across phonemes, making it difficult to

compare glottal stop insertion between phonemes. Also, this study initially did not take into consideration that phonetic contexts, such as syllable stress, overlapped with other phonetic contexts. This made it difficult to analyze and compare data; however, in order to try to moderate the effects of this problem, the percentage of the number of sentences that included glottal stops was taken for each context.

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