Acoustic cues to glottal stops in Polish-accented English

Akustyczne cechy wskazujące zwarcia krtaniowe w języku angielskim z polskim akcentem

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ABSTRACT

This paper examines the use of glottal stops in Polish-accented English in utterance-initial accented and unaccented positions. The major finding is that Polish native speakers use more glottal stops in English in unaccented than in accented syllables. Since this unexpected result questions the status of a glottal stop insertion as a fortition, potential acoustic cues to glottal stops in both contexts are investigated and phonological considerations are presented. Inspection of F0 effects and amplitude contours does not reveal any relation with glottal stop occurrence in accented and unaccented positions. This paper then follows the method employed by Przedlacka and Ashby [1] of linking glottalization with marked local minima in an auto-correlation function over the waveform to verify the results.

STRESZCZENIE

W artykule zbadane zostało użycie zwarć krtaniowych na początku wypowiedzi w pozycjach akcentowanych i nieakcentowanych w języku angielskim z polskim akcentem. Najważniejszym spostrzeżeniem jest to, że Polacy używają więcej zwarć krtaniowych w angielskim w nieakcentowanych niż w akcentowanych pozycjach. Ten niespodziewany wynik kwestionuje status zwarcia krtaniowego jako fortycji, zatem zbadane zostały potencjalne akustyczne cechy wskazujące zwarcia krtaniowe w obu kontekstach i przedstawione rozważania fonologiczne. Badanie nie wykazało powiązania efektów częstotliwości bazowej i konturów amplitudy z występowaniem zwarć krtaniowych w pozycjach akcentowanych i nieakcentowanych. W artykule wykorzystano więc metodę zastosowaną przez Przedlacką i Ashby'ego [1], polegającą na powiązaniu zwarć krtaniowych z zaznaczonymi lokalnymi minimami w funkcji autokorelacji fali dźwiękowej, aby zweryfikować wyniki.

1. Introduction

1.1. Glottal stops

A glottal stop is understood here as as a glottal adduction which results in a complete stop of glottal vibration (i.e. a glottal closure) or an irregular vibration at a low rate with a sudden drop in intensity (i.e. laryngealization or glottalization) after [2] who writes about the occurrence of glottal stops in American English. Glottal stops are not

always easy to identify on a spectrogram: it may not be clear whether a gap results from a pause or from a glottal stop, and irregular vibration, e.g. creaky voice, may be caused by extremely low pitch or very weak phonation. Not always is there a stop gap followed by a release (cf. Figure 1).

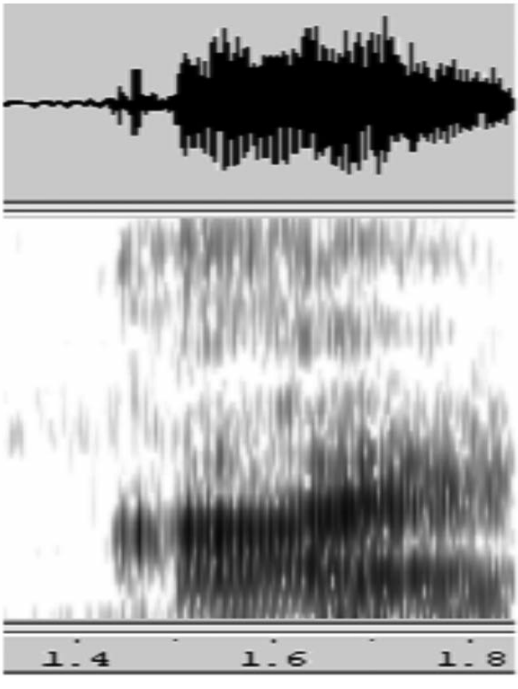

Figure 1: Waveform and spectrogram of 'eye' preceded by glottal stop (Polish female learner of English).

Very often a glottal stop is signaled by creaky or irregular voicing. Synthetic glottal stops are recognized on the basis of changes in F0 and amplitude [3]. Natural stimuli are more reliably associated with marked local minima in an autocorrelation function applied to the waveform, i.e. a local decline in regularity of vocal fold vibration, according to [1]. Umeda [2] uses the following criteria for glottal stop identification: a silence in the speech waves that is less than 100 ms long, or irregular vibration which occurs only in the first part of the vowel.

Umeda [2] also lists places where a glottal stop is likely to occur: places where one grammatical or semantic unit ends and another starts, and if a member of a unit needs to stand out within the unit. In the first context both pauses and glottal stops may occur, in the second context a glottal stop is very likely to occur, but it might be substituted by a short pause. Both a pause and a glottal stop play the same role – they are boundary markers. The author also notes that it is usual for a glottal stop to accompany the beginning of vowel phonation after a silence. Umeda [2] hypothesizes on the basis of [4] concerning the influence of the pitch contour on the occurrence of glottal stops. Allen [4] claims that a vowel is more likely to be preceded by a glottal

stop if it occurs after a boundary and receives a rising or falling accent. According to the examination of the pitch contour in one speaker by Umeda [2] there is no consistent tendency. Out of ten occurrences of a rising pitch contour on the vowel, two vowels were accompanied by a glottal stop, out of two occurrences of a vowel with a falling contour – neither, out of eleven vowels with a flat pitch contour – three. Umeda [2] also presents conclusions about the occurrence of glottal stops in non-primarily stressed contexts, such as at the beginning of a function word, before an unstressed vowel or a vowel with secondary stress. In the list of short sentences a glottal stop does not usually appear before a function word, but it does appear in complicated material, where, like a pause, it seems to serve as a boundary marker and appears at the beginning of a function word. The percent occurrence of glottal stops in function words was relative to the total occurrences of function words not preceded by a grammatical break – the results for all speakers were below 20%. A function word preceded by an uncommon word, a long phrase preceding the function word, and the second and connecting three or more items seemed to be motivating factors for a glottal stop to occur. 63% of the total 230 function words without a grammatical break were not preceded by a glottal stop. 89% of the total 73 contexts where a grammatical break appeared were preceded by a glottal stop or a pause.

Summarizing the findings, Umeda [2] concludes that the speaker's habits are the best prediction factor for glottal stop occurrence. Analysis of recordings from five speakers showed that a glottal stop was used on the stressed vowel at the head of a content word from 25% to 80% of the cases. It was also found that the more difficult a passage is, the more glottal stops readers are likely to use. Glottal stops precede infrequent words twice as often as they precede frequent words. Certain phoneme sequences are more likely to be interrupted by a glottal stop: vowel-vowel sequences more than consonant-vowel sequences, and voiceless consonants more than their voiced counterparts. Pitch contour on the vowel does not show a consistent effect. Neither does the difference in tongue height between two vowels yield significant results. It is, however, not claimed that there is no aerodynamic influence of the vocal tract shape on glottal actions. It is speculated that higher-order factors override this effect (in Natural Phonological terms – phonology overrides physiology). An informal inquiry revealed that the reading which was the easiest and nicest to listen to was characterized by the use of glottal stops on content words and pauses instead of glottal stops in grammatical breaks.

In the study by Dilley et al. [5] it was shown that word-initial vowels are more likely to be preceded by a glottal stop when at the beginning of an intonational phrase and to a higher degree when the word is pitch-accented. The results also revealed considerable interspeaker differences in the distribution of glottal stops.

In Polish, like in English, a glottal stop is not a phoneme. It appears before a vowel, especially if emphasis is put on the word, in isolation, or after a pause [6], pp. 44–45. It is usually not inserted in the middle of a word, but it appears often between two vowels across a morpheme boundary *nieetyczny* /ɲɛʔɛtɨʦnɨ/ (unethical). It is, however, sometimes considered incorrect to insert a glottal stop between two vowels in loanwords *teatr* /teʔatr/(theater).

1.2. Hypothesis

It is hypothesized that glottal stops precede word-initial diphthongs, because they precede word-initial vowels in Polish [6, 7]. It is claimed that the more emphasis a given word receives, the more likely it is to receive a glottal stop. In Natural Phonology glottal stop insertion is traditionally viewed as a fortition. Therefore it is hypothesized, according to the 'rich get richer' principle, that initial diphthongs in stressed positions are more likely to be preceded by a glottal stop than initial diphthongs in unstressed positions. Following the findings of Umeda [2] that the more difficult a passage is and the more infrequent a word is, the more likely it is that a glottal stop will be inserted, it is hypothesized that Polish learners of English use glottal stops extensively, as L2, which they do not use on daily basis, is likely to be both difficult and full of words which they use infrequently.

2. Experimental methodology

Recordings of 17 native speakers of Polish (9 males and 8 females) speaking English were analyzed. The age of the subjects ranged from 19 to 25, with the mean age of 22 years. All the subjects spoke English at an advanced level. They had passed the Cambridge First Certificate Examination and at the time of the recording were preparing for the Cambridge Certificate in Advanced English. None of the subjects had ever received pronunciation training or had been to an English speaking country for more than a month.

English word-initial diphthongs were tested in actual words in sentences, in whose construction prosodic criteria were taken into account and the occurrence of the words containing the diphthongs under examination was controlled for stress position in a sentence, and the sentences were controlled for rhythmic units and length. Polish vowel plus glide sequences similar to the ones present in English diphthongs were tested for comparison in similar conditions.

In order to control for rate of speech, initial practice sessions and randomization of test materials within the three blocks, each containing the set of 61 English sentences, was used. Initial trial sessions were conducted to ensure that the talkers do not increase the rate of speech once they get familiar with the type of the task. The sentences were randomized within the blocks to counterbalance the order across the three blocks read by one subject and to counterbalance the order across subjects.

The recording scenario involved diphthongs embedded in 61 sentences, each read three times by each subject. The subjects were instructed to read the sentences at a normal speed and with a falling intonation. The subjects controlled the tempo of recordings themselves and they were allowed to repeat a sentence when they wished to do so. The sentences were displayed on the computer screen in random order. The recordings were made with a 22050 Hz sampling frequency and a 16-bit resolution in a quiet office environment.

The data were hand-annotated with Praat [8], using the SAMPA [9] phonetic alphabets for Polish and English, with an orthographic tier, and then with a tier containing segments of interest and their contexts. These were annotated with broad and narrow transcriptions and the canonical British English transcription was also

noted for each word potentially containing a glottal stop of interest. The corpus is stored in XML format, with TASX specifications [10]. The re-usable format allows for further applications of the corpus. The corpus has been recorded, annotated and stored following EAGLES recommendations [11] and [12].

3. Results

Glottal stops have been hypothesized to precede word-initial diphthongs, because they precede initial vowels in Polish [6, 11]. In Polish-English contrastive phonetics teaching it is customary to claim that, even if glottalization is not as strong as in German, Polish initial vowels are always preceded by a glottal stop, whereas in English glottal stops occur in syllable codas reinforcing or replacing a stop or an affricate. Furthermore, it is expected that according to the 'rich get richer' principle, initial diphthongs are more likely to be preceded by a glottal stop when they are in an accented position than otherwise. The results of the present experiment are, however, more complex. Polish learners of English use glottal stops to precede diphthongs in unaccented positions more often than in accented positions. There were 115 diphthongs examined in the accented position and 65 diphthongs in an unaccented position, so the sample is considered to be representative. In an accented position 61% of the diphthongs are preceded by a glottal stop, whereas in an unaccented position 77% of the diphthongs are preceded by a glottal stop. The z value of –2,20 is significant at the 5% level, suggesting that the difference is significant.

To check whether this unexpected result might have acoustic grounding, it was investigated whether the presence of a glottal stop is related to dips in pitch contour or amplitude contour (cf. [3, 13 and 14]). F0 for the glottal stops was not found to be different from F0 for vowels (t = 1.3 at the 5% level). Also F0 for the vowels which are preceded by glottal stops is not different from F0 of the vowels not preceded by glottal stops (t = 0,373). The amplitude of the vowels preceded by glottal stops is not significantly different from the amplitude of the vowels not preceded by glottal stops (t = 1,526 at the 5% level).

The method employed by Przedlacka and Ashby [1] of linking glottalization with marked local minima in the autocorrelation function was also used. Initially, it was hypothesized that autocorrelation might help explain the unexpected result of glottal stops occurring more frequently before unaccented syllables, if it was related differently for accented and unaccented vowels. The difference, however, is not statistically significant (t = 0,123 at the 5% level). Autocorrelation of the vowels not preceded by glottal stops is on average lower than autocorrelation of the vowels preceded by glottal stops, but the difference is also not statistically significant (t = 1,633 at the 5% level). Crucially though, vowel autocorrelation is significantly higher than glottal stop autocorrelation (t = 16.786 at the 5% level).

4. Discussion

In [3, 13, 14] the role of pitch contour and amplitude contour in glottal stop identification was emphasized. In the present study inspection of F0 effects and examination

of the relationship of F0 values with the occurrence of glottal stops did not provide an acoustic phonetic basis for the explanation of the phenomenon. Dips in the pitch contour did not turn out to be significantly different in accented vs. unaccented syllables. Amplitude was indeed higher in vowels than in glottal stops, but it was not significantly different for vowels preceded by a glottal stop and the ones that were not preceded by a glottal stop.

Autocorrelation over the waveform reflects regularity in vocal fold vibration and, as expected, is higher for vowels than for consonants, in this case glottal stops. Autocorrelation had been, nevertheless, expected to be lower for vowels not preceded by glottal stops than for the ones preceded by them, as the glottal stops preceding vowels could make the vowels noise-free. This expectation was not confirmed.

The fact that Polish learners of English inserted more glottal stops before diphthongs in unaccented positions than before accented positions is also unexpected. This finding opposes the findings of Dilley et al. [5] and questions the status of a glottal stop as a fortifying sound – cf. glottal stop reinforcement. As a consequence of being associated with fortition, the glottal stop has been assumed within the Natural Phonological reasoning to be more likely to occur in accented positions in accordance to the principle "rich get richer." There are certainly at least two possible ways of reasoning, which could lead to the explanation of the phenomenon of glottal stop insertion in unaccented positions. Either a glottal stop insertion does not always have a fortition function, or sometimes "poorer can get richer."

Other issues worth considering are the following. Since glottal stops add additional intensity to the following element, perhaps they are employed to make up for the loss of energy in a following vocalic element in an unaccented position. Perhaps a preference for a consonant-vowel sequence is ranked higher than the prosodic division into strong and weak positions. This hypothesis, however, would only explain why there appear so many glottal stops, but it would not be able to account for the statistically significant difference between the employment of glottal stop insertion in accented and unaccented positions. Polish is less likely than English to reduce vowels and delete syllables. Maybe Polish learners of English, in an effort not to delete a diphthong in an unaccented position, insert a glottal stop to strengthen such a weak position and preserve the syllable. Glottal stop insertion would be a way of fortifying an onset.

Glottal stops may also perform a function of word boundary markers. Weak initial positions may need such a word boundary marker more than accented positions.

Finally, the findings of [2] might turn out to be helpful. The more difficult a passage and the more infrequent a word is, the more likely it is that a glottal stop will be inserted. The results provided by [2] were based on native speech. If it is taken into account that Polish learners of English, when reading English sentences, are very likely to come across words which they infrequently use, words which are judged to be difficult or even unknown to them, it seems reasonable that they use glottal stops extensively.

5. Conclusions

The study has revealed that in Polish English glottal stop insertion in word-initial positions might occur even more frequently than in Polish. Moreover, in Polish and in

the English of Polish learners glottal stop insertion occurs more frequently in unaccented than in accented positions. This phenomenon might be motivated by a preference for a CV sequence or by the need to strengthen an utterance-initial position. The most likely explanation is, however, that the process of glottal stop insertion by Polish learners of English is a reaction to difficult and unknown words. More detailed research is needed on the relationship of the acoustic realization of a glottal stop and the environment of occurrence in terms of prosodic position in Polish.

Acknowledgement

I would like to thank Wiktor Jassem, Katarzyna Dziubalska-Kołaczyk and Dafydd Gibbon for their helpful comments.

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