

## ACOUSTIC PROFILING OF GLOTTAL AND GLOTTALISED VARIANTS OF ENGLISH STOPS

G. J. Docherty and P. Foulkes

Department of Speech, University of Newcastle upon Tyne

### ABSTRACT

An investigation of the acoustic characteristics of glottal and glottalised variants of stops in Tyneside English has found that the patterns of phonetic realisation which can be observed cannot straightforwardly be matched to the segmental categories [ʔ] and [ʔp, ʔt, ʔk] which are most commonly presented in accounts of these variants based on auditory analysis. The implications of these findings for phonological accounts of this aspect of English are discussed

### INTRODUCTION

The consensus of work on glottal variants of voiceless stops in British English [1, 2, 3] is (i) that they have become progressively more widespread, (ii) that there are two types of glottal variant (glottaling, where the oral stop is 'replaced' by a glottal stop, and glottal reinforcement where the oral stop is doubly articulated with a glottal stop), and (iii) that there is social and geographical variation with regard to the frequency with which these variants occur, the environments in which they occur, and the extent to which stops other than /t/ are affected. Most previous work on this aspect of English has focused on describing and explaining the environments in which the variants are found, but the precise phonetic nature of these variants seems to have been taken somewhat for granted and receives scarcely a mention in the literature. The view which appears to prevail [4] is that the glottal stop produced in English glottal variants has the features of other stops, namely an onset phase, an occlusion phase with a duration similar to that found in other stops (marked acoustically by a silent gap), and a release phase. A slightly different account is presented in earlier work [5] referring to a 'distinct crack of the voice, a ceasing of the vowel sound before the consonant sets in'. In the case of glottally reinforced stops, in most accents the reinforcing gesture is timed so as to

slightly precede the oral gesture [2, 4]. However, this is not universally the case, and in at least one other accent (Tyneside English) it is timed so as to mask the release of the oral stop articulation [2].

In the context of a project which aims to track phonological variation and change in British English, an auditory and acoustic study of glottal variants in Tyneside English has been carried out. Our aim is to provide a descriptive phonetic account of these variables to test existing accounts and to provide a firm phonetic foundation for subsequent phonological and sociolinguistic analyses. This paper presents the method used to construct an acoustic profile of the glottal variants, together with the principal findings of the analysis performed to date.

### METHOD

Fieldwork in the Tyneside region of England has produced recordings of 32 speakers (2 social groups [WC/MC] \* 2 [male/female] \* 2 age groups \* 4 speakers in each group). Speakers were recorded firstly in a dyad conversational exchange for around 50 minutes followed by reading a word-list designed to include a number of cases of stops in positions rendering them liable to glottaling or glottalisation. Field recordings have been supplemented by a smaller number of studio recordings of subjects reading a word-list and engaged in a map-description task.

Data from the field recordings has been analysed auditorily, with particular attention being paid to /p, t, k/ in word-medial and word-final position, revealing, as expected, numerous tokens where /t/ is perceived as glottalised and where /p, t, k/ are perceived as being glottally reinforced, with the latter occurring more frequently than the former. Rather than considering the frequency with which the different variants were encountered or the factors which led to one variant rather than

another being produced, our focus here is on the phonetic nature of the glottal variants which we have observed. Acoustic analysis has been carried out so far of the data from the 4 young UWC male subjects, one of which will be used to exemplify the findings below.

With little guidance available in the literature, the acoustic analysis set out to track a range of spectrographic parameters which seem relevant for describing these variants, and which allow identification of their salient features.

### Supralaryngeal Articulation

Following [6], as an index of supralaryngeal articulation, F1 and F2 have been tracked into and out of the stops undergoing analysis. Presence of transitions entering or emerging from a 'stop' indicates the existence of an oral gesture. Absence of such transitions is a little ambiguous, since it could mean that no oral gesture has been formed, or that an oral gesture is present but its existence has been masked by a reinforcing glottal gesture. A further indicator of the presence of an oral occlusion is the existence of a stop release burst. This indicates that there has been a build-up of intra-oral pressure posterior to an articulatory occlusion, but it does not, on its own, determine whether the occlusion has been fully pulmonic or whether it has been glottally reinforced (i.e. it could potentially be some form of ejective stop [2]).

### Laryngeal Articulation

In this respect, the aim of the analysis has been to track changes in laryngeal articulation from the voicing during the vowel preceding the target stop through the stop and into the following vowel or sonorant. In view of the observation [7] that laryngealisation often occurs as an intermediate stage between voicing and a glottal stop, particular attention has been paid to identifying intervals of irregular vocal fold vibration. Our definition of laryngealisation is therefore based on visual and acoustic criteria and is not capable of discriminating between the different types of vocal fold configuration which might lead to laryngealisation (cf [8].), which

represents one of the limitations of this study.

### Presence of 'Stop Gap'

Given the conventional wisdom that English glottal variants should be characterised acoustically by a stop 'gap' in the spectrographic trace, this is a further feature which forms part of our acoustic profile. Note that the interpretation of a stop 'gap' in a spectrographic trace is, on its own, not entirely transparent, since it could be produced by a glottal or oral occlusion or both, but it can be given a clearer interpretation in conjunction with information about any formant transitions into and out of the stop.

### RESULTS

The acoustic analysis confirms the auditory impression that some stops are produced without a supralaryngeal gesture whilst many others are produced with a supralaryngeal gesture, but it is not always transparent whether that gesture is a complete occlusion or not. It would only be possible to be sure about this if a stop release burst is present, but there are very few of these in the data. In addition, there is the possibility that these speakers are producing incomplete stop gestures (spirantised articulations of this sort are common in accents of English in exactly the same environments investigated in this data). This is clearly an area where a more detailed articulatory analysis, possibly with EPG, would be beneficial.

With regard to the laryngeal gestures, there are relatively few cases where the acoustic trace resembles a [canonical] glottal stop (as described by [4, 7, 8]). In most cases where /p, t, k/ are heard to be glottalised or in the relatively fewer cases of /t/ being perceived as glottaled, speakers produce a segment with laryngealised voice throughout.

With regard to the sequencing of laryngeal-supralaryngeal gestures, it seems that in general in Tyneside English there is a tendency for the laryngeal gesture to lag behind the supralaryngeal gesture, as revealed by the fact that transitions are often observed entering stops but not leaving them, and by the fact that laryngealisation has a tendency to spread into

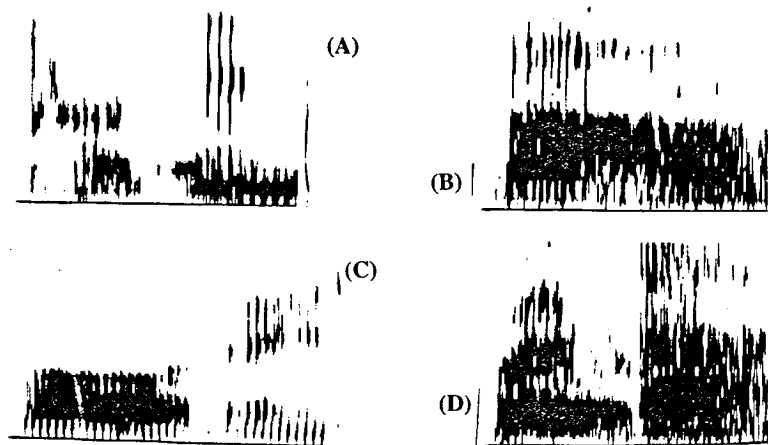


Figure 1 (A-D). Examples of the types of glottal variant observed (with 1kHz horizontal markers); (A) *put in*, (B) *battle*, (C) *bought it*, (D) *footer*. See text for further details.

following vowels, but is found less frequently on vowels preceding the stop. This corresponds to the observation made by previous auditory studies of Tyneside glottalisation which note that it is different from the patterns of pre-glottalisation found in other accents of English in that and it tends to mask the release burst of the stop as opposed to affecting the stop's onset (hence the difficulty in identifying whether a complete occlusion has been formed or not).

In general, the acoustic analysis described above reveals four types of glottal variant in Tyneside English, with (b) and (d) occurring most frequently; (a) a stop gap (although never entirely silent) with no indication of an oral gesture -- this is the variant which most closely matches descriptions of a canonical [ʔ] (Fig. 1A); (b) laryngealised voicing through the stop 'slot' with no indication of an oral gesture (Fig. 1B); (c) stop gap (although only rarely entirely silent) with clear indications of an oral articulation in the form of transitions into the stop, but note that the release burst and often the C-to-V transitions are masked by the glottal articulation (Fig. 1C); (d) laryngealised voicing through the stop phase together with clear indications of an oral

articulation but with the release burst and often the C-to-V transitions masked by the glottal articulation (Fig. 1D).

Our results suggest therefore, that, in Tyneside English, it is relatively rare for voiceless stops heard as glottalised or glottaled to be produced with a glottal stop as this has traditionally been defined. It is much more common for the perception of glottal articulation to be based on the presence of laryngealised voice quality, with this present throughout the target segment. The phonetic symbols [ʔ] and [pʔ, tʔ, kʔ] do not in most cases capture what we have observed. It has been reported before [9, 10] that laryngealised voice can correlate with the percept of a glottal or glottalised stop, but the present results suggest that, in at least one variety of English, 'glottal' variants may not involve the formation of full glottal stop at all, or at least only rarely.

The second principal finding of this study is that in glottally reinforced stops in Tyneside English, the laryngeal gesture tends to lag behind the oral gesture. This is a very subtle difference between Tyneside English and that found in other regions of the UK, but it has a very significant auditory effect, namely the masking of any stop release which is formed (thus confirming [2]).

## DISCUSSION

Any attempt to provide an account of the systematic phonetic characteristics of glottal variants of /p, t, k/ in Tyneside English will have to account for at least the following: (a) speakers have precise control over the timing of laryngeal and supralaryngeal articulations in cases of glottal reinforcement; (b) in the environments considered to date, there is a degree of flexibility about the glottal articulation which takes place, but it is only rarely a 'full' glottal stop, the more normal case being some form of increased glottal tension or constriction leading to laryngealised voice, and (c) in these environments, /t/ is sometimes produced with an oral gesture and sometimes without.

Whilst space does not permit a full exploration of these issues, it is likely that (a) - (c) above represent a challenge to the view held by many phonologists, and expressed in [11], that 'phonological representations should be mapped directly into speech output without passing through a buffer level of allophonic representation'. A feature representation has insufficient resolution to capture the temporal control exercised during the production of glottalised stops, and a direct mapping from feature specification (such as [+constricted glottis]) to speech output is not compatible with the variability observed in the glottal characteristics of the stops investigated in the present study. Furthermore, any account of glottaling and glottalisation as a form of lenition process must account for the fact that glottaling applies predominantly to /t/ and not to /p, k/, and that the linguistic and sociolinguistic distribution of glottaled and glottalised variants is not uniform [3].

It is possible that the present observations are part of the wide variety of fine-grained yet systematic language- and accent-specific characteristics of speech production which just cannot be governed by a phonological representation (as these are typically presented), and yet which are undoubtedly part of the grammar in the broadest sense of the term -- i.e. what it is that native speakers do, in order to be native speakers. Detailed phonetic studies such as that in which we are

engaged in serve to highlight the need for greater research into these aspects of speech production and a theory of phonetic implementation which does not have the built-in limitations of a feature geometry or distinctive feature matrix.

## ACKNOWLEDGEMENT

Research supported by the UK Economic and Social Research Council (Grant no. R000 234892 "Phonological variation and change in contemporary spoken British English").

## REFERENCES

- [1] Roach, P.J. 1973. Glottalization of English /p/, /t/, /k/ and /tʃ/ - a re-examination. *Journal of the International Phonetics Association*, 3: 10-21.
- [2] Wells, J.C. 1982. *Accents of English* (3 vols). Cambridge: Cambridge University Press.
- [3] Milroy, J., Milroy, L. and Hartley S. 1994. Local and supralocal change in British English: the case of glottalisation. *English World-Wide*, 15,1: 1-32.
- [4] Gimson, A.C. (1980) *An Introduction to the Pronunciation of English*. London: Edward Arnold.
- [5] Christopherson, P. (1952) The glottal stop in English. *English Studies*, 33, 156-163.
- [6] Manuel, S. & Vatikiotis-Bateson, E. (1988) Oral and glottal gestures and acoustics of underlying /t/ in English. Poster presented at the joint meeting of the Acoustical Society of America and the Acoustical Society of Japan, Hawaii.
- [7] Catford, J.C. (1977) *Fundamental Problems in Phonetics*. Edinburgh: Edinburgh University Press.
- [8] Henton, C., Ladefoged, P., & Maddieson, I. (1992) Stops in the world's languages. *Phonetica*, 49,65-101.
- [9] Grice, M., & Barry, W. (1991) Problems of transcription and labelling in the specification of segmental and prosodic structure. *Proceedings of the XIIIth ICPhS, Aix-en-Provence*, Vol 5: 66-69
- [10] Kohler, K. (1994) Glottal stops and glottalisation in German. *Phonetica*, 51:38-51.
- [11] Clements, G.N. (1992) Phonological primes: features or gestures? *Phonetica*, 49:181-193.