GLOTTALS AND GRAMMAR: DEFINITE ARTICLE REDUCTION AND MORPHEME BOUNDARIES

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Abstract
Definite Article Reduction (DAR) involves vowel-less forms of the definite article, usually a 'glottal stop' [ʔ], and is found across large parts of northern England. The present acoustic analysis of DAR investigates the acoustic correlates of the glottal form of DAR in the context high vowel + /s/. However, the glottal stop is also the realisation of a word-final /t/ before a following consonantal onset. A second part of the experiment investigates whether there are production differences between the two kinds of glottal stop – one a realisation of the definite article preceded and followed by a morpheme boundary, and one a realisation of word-final /t/ followed by a morpheme boundary. The results show that speakers do distinguish the two sequences in production, but the effects are subtle and highly variable, both within and across speakers.

1. Introduction

Definite Article Reduction (DAR) is a phenomenon found in vernacular speech across large parts of the north of England which involves vowel-less forms of the definite article, usually a 'glottal stop' [ʔ], or less commonly, the voiceless obstruents [t] and [θ] (Jones 1952; Barry 1972; Jones 1999). DAR is first recorded in 1673 (Cawley 1959) and has a long tradition of orthographic representation in literature and the media, most commonly as <t'> (for [t] and [ʔ]) or <th'> (for [θ]). Zero forms are also reported to occur in East Yorkshire (Ellis 1889; Jones 1952).

Whilst the presence of a reduced article is noted across the north of England, the form that the article takes has been shown to vary. Some forms are very limited in their geographical distribution (e.g. the [θ] form), but others occur widely. More than one form is found at most localities, resulting in variation which is usually ascribed to segmental phonological context in the first instance. Wright (1905) contends that the fricative form occurs with vowels and the <t'> form (plosive and glottal realisations not distinguished) with consonants, a statement which is only partially true as discussed in more detail in Jones (2002), and illustrated in (2) and (3) in the data set below. A thorough analysis of the conditioning factors for phonological variation in DAR forms at a single locality is not possible using existing data sets (see Jones 1999):

(1)	[ɪ θ ʊun]	'in the oven' (Read, Lancashire; SED locality La09)
(2)	[ɪ t ʊvən]	'in the oven' (Cawood, Yorkshire; SED locality Y24)
(3)	[ɪ ʔ ʊvən]	'in the oven' (Tickhill, Yorkshire; SED locality Y33)

The origin of DAR is unknown, though it seems likely to have developed from the Middle English definite article <þe> via unrecorded historical processes of vowel loss and subsequent consonant assimilations and lenitions (Jones 2002).

Variation between the DAR forms and the standard English article 'the' is common in speech, and need not imply that DAR usage is being eroded. In a case study, Jones (2003) attributed DAR-the variation to a range of factors, including psycholinguistic ones, noting that the ‘the’ form seemed to occur in more careful or reported speech, with idioms, and around disfluencies, with blocks of ‘the’ forms apparently occurring for a time across a range of varied contexts once use of ‘the’ had been triggered. Rupp & Page-Verhoeff (2005) analysed DAR-the distributions in interview-style conversations and associated use of DAR with particular discourse or pragmatic contexts. Incidence of DAR forms as a percentage of all definite articles from four studies are set out in table 1 below. Rupp & Page-Verhoeff (2005) report a very low incidence of DAR forms (12%), similar to that seen in Tidholm’s (1979) interview data, much lower than that reported by Glauser (1984), who spent long periods resident with his subjects, and Jones (2003), who used his mother as a subject. DAR-the variation may be regulated by the factors identified by Rupp & Page-Verhoeff (2005). However, given the relatively low incidence of DAR reported in that study, it may be that these factors are interacting with others which govern accommodation of vernacular morphological features to the standard English speech of a less familiar (though known) interlocutor. Geographical factors may also play a role: Egton, the locality used for Tidholm (1979), lies at the northernmost boundary of the area exhibiting DAR. For a more complete overview of DAR, see Jones (1999, 2002) and Rupp & Page-Verhoeff (2005).

Study (date)	*% DAR forms*
Tidholm (1979)	6.7-39.7
Glauser (1984)	91.4-93.5
Jones (2003)	59
Rupp & Page-Verhoeff (2005)	12

Table 1: Incidence of DAR forms (%) in data from four studies.

In one sense, DAR is unique: only varieties of English spoken contiguously across northern England realise the article in this way. How native speakers produce and perceive these forms as adults and how they acquire them as children are topics of obvious relevance to an understanding of the varieties themselves, aside from questions on phonological patterning, historical origins, and sociolinguistic distribution. However, looking more widely afield, DAR is far from unique in two respects. If the diachronic scenario of [θ] > [t] > [ʔ] in Jones (2002) is accepted, DAR is a language-specific instance of a common cross-linguistic process in which plosive realisations alternate with [ʔ] synchronically or diachronically in some phonological contexts. Some examples from a wide range of geographically and genetically diverse languages showing similar alternations are presented in (4)-(8) below.

(4) Latin CATENA > Sardinian dialects [ʔaˈdena] (Wolf 1985);

(5) standard Slovene *roka* = Slovene dialects [roʔa] ‘hand, arm’ (Priestly 1976);

(6) Samoan /kele/ ‘black’ = Hawai’ian /ʔele/ (Kenstowicz 1994: 132-3);

(7) Australian languages: Gunjwingu /mak/ = Ngalakan /maʔ/ ‘good’ (Harvey 1991: 100);

(8) North Burmese /tat/ ‘attach’ = Standard Burmese /taʔ/, (Lass 1976: 155, citing Maran 1971: 29-30).

Clearly there is some link between plosives and [ʔ], and the diversity of sources suggests that this link is not due to language contact, but is grounded in phonological or phonetic principles of speech production and perception common to all humans. An analysis of the phonological or phonetic conditioning factors governing alternations of [t] and [ʔ] DAR forms, whether synchronic or diachronic, might reveal something of considerable cross-linguistic interest in terms of how and why a change of voiceless plosive like [t] > [ʔ] takes place.

On the other hand, DAR is a language-specific instance of the way in which languages reconcile the potentially conflicting or disruptive phonetic gestures which occur when sequences of [ʔ] and other consonants are allowed, either word-internally or across word boundaries. The larynx is a multifunctional articulator, which generates and modifies sound for general speech production, lexical contrasts, post-lexical effects, and paralinguistic functions. The larynx produces voice for vowels and other sonorants, marks the voicing contrast in obstruents, and produces pitch changes for stress and intonation, as well as voice quality effects to mark emotion such as anger, boredom, or resignation. At the most basic level, speakers must produce [ʔ] forms in a way in which they can be recovered from the signal, and integrated with laryngeal modifications for e.g. surrounding consonants. How human beings are able to carry this out across a range of contexts is important to understand, and since many other languages have [ʔ] forms, either as lexically contrastive elements (e.g. Arabic) or as positional variants of other sounds (e.g. Southern British English), the results of any analysis of the phonetic effects of DAR have wider significance in determining the general principles underlying glottal coordination.

The glottal form of DAR is therefore of particular interest. Glottal stops, the form implied by the IPA symbol [ʔ], are relatively easy to identify within sonorant contexts as they interrupt vocal fold vibration before a period of silence, and a release which lacks any oral place cues. However, glottal stops are rare in contexts where voicing is continuous, with a distinct voice quality, creaky voice or laryngealisation, being much more common (Ladefoged and Maddieson 1996: 75). When there is no immediately adjacent sonorant context, the glottal form may have very different effects, perhaps modifying the degree of aspiration of a voiceless stop or airflow for a voiceless fricative. These effects may sound very different from creaky voice, and they may even involve a different kind of laryngeal modification as the [ʔ] form interacts with the laryngeal settings for other sounds, but the results could still be due to laryngeal modifications. The effects of the [ʔ] form may also spread widely from its morphonsyntactically determined position, and disrupt the voice quality of relatively distant vowels, or phrase-level patterns of stress and intonation. In the absence of more [ʔ]-like cues, it is not impossible that speaker-listeners use very subtle effects to judge where an article has occurred. The glottal forms have been linked with an increase in stop closure duration (as judged impressionistically) at some localities (e.g. Hirst 1906; Brilioth 1913; see also Ellis 1874, 1889 on ‘suspended’ forms). As the effects of DAR may be very subtle, particularly in certain contexts, zero forms cannot be identified with certainty until more detailed understanding of the acoustic correlates of DAR is provided, including experimental confirmation by perceptual tests involving native speakers.

Glottal realisations of stops in British English are of course not limited to DAR dialects and the definite article, and word-final realisations of voiceless plosives, particularly /t/, are commonly realised as [ʔ] in many contemporary varieties of English, including the DAR dialects. Consequently, for the DAR dialects, the broadly transcribed sequence /siːʔsaks/ could be a realisation of "seat sacks" or of "see t' [i.e. the] sacks". These sequences with morpheme boundaries indicated (#) are illustrated in (9) and (10) below. Slanted brackets are used in all the examples which follow to indicate a relatively broad, but not necessarily phonemic, transcription.

(9) DAR condition "see t'sacks" /siː # ʔ # saks/

(10) Glottal condition "seat sacks" /siːʔ # saks/

In the DAR condition in (9), the glottal form of the article is preceded by a morpheme boundary after the vowel of 'see' and followed by a morpheme boundary before the /s/ of 'sacks'. In the Glottal condition in (10), the glottal is a realisation of word-final /t/ in 'seat' so there is no morpheme boundary between the vowel and the glottal as in the DAR condition, but [ʔ] is followed by a morpheme boundary before the /s/ of 'sacks'.

Recent instrumental work has shown that grammatical boundaries may affect subtle aspects of speech production and the acoustic signal (Cho 2001; Bird 2004; Baker, Smith & Hawkins 2007). The question arises as to whether speakers of DAR dialects cue a difference in the grammatical status of the glottal, and if so, whether this difference can be directly related to the location of morpheme boundaries.

This study investigates the acoustic correlates of the [ʔ] form of DAR in a single phonological context using data collected from speakers in and around Barnsley (South Yorkshire). Data from the DAR condition are compared with comparable data from the non-DAR condition. In addition, data are analysed on the same sequence in which [ʔ] is a realisation of word-final /t/ rather than of the article (the Glottal condition). Using acoustic analysis of controlled data allows any consistent effects observed to be uniquely associated with the article, and can help to identify potential perceptual cues which might be utilised by native listeners.

2. Method

The subjects are two male (BM1 and BM2) and one female (BF1) native speakers of Barnsley English still resident in the area. All speakers were 50 or over at the time of recording. As the phonetic analysis of DAR was the object of study, the speakers were not selected with any particular sociolinguistic criteria in mind, but had to be native speakers of Barnsley English who exhibited DAR (and other characteristics of the local dialect) in informal speech. Learned sociolinguistic differences may of course have an effect on the detail of DAR realisations, and physiologically determined differences between speakers of different sexes and ages most certainly will. These remain to be investigated. One of the male subjects whose DAR forms are analysed here (BM1) differed from the others in having a more traditional northern realisation of the voicing contrast in terms of voicing not aspiration (Wells 1982). His voiceless plosives were unaspirated, and his voiced plosives were always prevoiced. More details on the voicing contrast in this sample of Barnsley English speakers can be found in Jones (2007). These differences may affect his realisation of DAR.

The present study uses controlled data to investigate the realisation of the [ʔ] form of DAR in a single context: post-vocalic position after the high front unrounded vowel /iː/ before the voiceless fricative /s/. This context was selected as being one in which the three minimally contrasting sentences reproduced in (11)-(13) below would all be well-formed (if unusual) sentences, and one in which effects on the duration of the fricative could be measured. Subjects read aloud a series of sentences, some of which contained the article in the required position. They were also required to read 'minimal pair' sentences lacking the article, and sentences containing a sequence of vowel + [ʔ] + /s/ in which the [ʔ] was a realisation of word-final /t/. The three sentences analysed for this study are presented in (11), (12) and (13) below.

(11) non-DAR condition 'they see sacks after' /ðe siː saks aftə/

(12) DAR condition 'they see t' sacks after' /ðe siː ʔ saks aftə/

(13) Glottal condition 'they seat sacks after' /ðe siːʔ saks aftə/

Note that the northern character of the utterances is indicated by the monophthongal /e/ in 'they' (most often reduced to [ə] in the sound files) and the short /a/ in 'after'. Like Southern Standard British English (SSBE), the dialect is non-rhotic with final /ə/ in 'after'.

As described above, the major difference between the DAR and the Glottal conditions is in the location of a morpheme boundary between the glottal and the /s/ of 'sacks'. These sentences are transcribed again in (14) and (15) below, with # indicating the location of the relevant morpheme boundaries.

(14) DAR condition 'they see t'sacks after' /ðe siː # ʔ # saks aftə/

(15) Glottal condition 'they seat sacks after' /ðe siːʔ # saks aftə/

The elicitation of different contexts was separated in time within the elicitation task. All sentences were presented to the subjects in semi-random order in blocks by condition (non-DAR, glottal, or DAR, in that order) with similar filler sentences on a PowerPoint slideshow running on a Toshiba laptop computer. Subjects read the sentences aloud 5 times. Recordings were made in the field using a high quality Sennheiser microphone connected via a Demion preamplifier to a Creative Nomad portable hard-drive recorder. Files were recorded as WAV format at a sampling rate of 22,050 Hz, and transferred to a laptop computer for acoustic analysis using Praat.

The analysis measured various aspects of the sound files from wideband spectrograms and waveforms. The duration of the interval from the offset of aperiodicity for the /s/ of 'see' or 'seat' to the onset of aperiodicity for the /s/ of 'sacks', the /s/-/s/ interval, was measured visually from the waveform and spectrogram. The /s/-/s/ interval contained the vowel and the glottal, whether article or word-final /t/. The fundamental frequency (F0) of vocal fold vibration was measured over a 30 ms window placed at the vowel midpoint in 'see/seat', and similarly at the vowel onset in 'sacks'. The duration of the aperiodicity of /s/ in ‘sacks’ was measured, with absolute durations in milliseconds (ms) normalised against the duration of the vowel in ‘sacks’. In addition to these quantitative measures, qualitative assessment was also made of the waveform shape at vowel offset, and the temporal distribution of any observed characteristics.

In the case of the DAR and the Glottal contexts, two further measures were applied. The duration of the penultimate visually discernible glottal pulse of the vowel was measured and used to calculate an F0 value for that period (duration/1000=F0). The interval from the onset of the penultimate visually discernible glottal pulse to the onset of frication was also measured. The penultimate pulse of the vowel was used because the waveshape of the final glottal pulse was very variable and the onset and offset were often hard to determine. There were occasionally glottal pulses separated from the vowel by a period of voicelessness, and these were not considered when determining the penultimate pulse.

The results were highly variable across subjects, as discussed in detail in section 3 below, and have not been subjected to a statistical analysis.

3. Results

Two subjects BF1 and BM1 produced forms of ‘seat’ which could be considered broadly homophonous with ‘see t’’ but subject BM2 produced ‘seat’ with the diphthong [iə] in accordance with the traditional dialect realisation of words like ‘mean’. The [iə] realisation was considered by the author to be moribund or severely lexically restricted on the basis of informal observation of dialects in South Yorkshire. Subject BM2 did not noticeably produce any such forms spontaneously in conversation, though subject BM1 did in ‘tea’ (pronounced [tiə], with unaspirated /t/). As indicated by the author’s observations during prolonged residence of South Yorkshire, this may be a lexical effect rather than a stylistic one. The data from BM2 are included here on the assumption that vowel quality differences are unlikely to have a great effect on the realisation of [ʔ] and that vowel duration in the diphthong [iə] probably approximates the duration of [iː]. Future work will have to be sensitive to the possibility of residual [iə] forms in the search for ‘minimal triplets’ of non-DAR, DAR and Glottal conditions.

Average results of the quantitative measures for each subject in each condition are presented graphically below. Means and standard deviations are presented in the appendix. In all cases, n = 5.

All subjects agree in having a greater average duration of the /s/-/s/ interval in the DAR condition than in the non-DAR condition. This greater duration reflects the presence of glottalisation for the reduced article, included within the calculation of the /s/-/s/ interval. Results for the Glottal condition are varied, with subjects BF1 and BM2 having a further increase in duration of the /s/-/s/ interval, but subject BM1 showing a reduction in duration. Variability is also greater for all subjects in the Glottal condition than in the DAR condition.

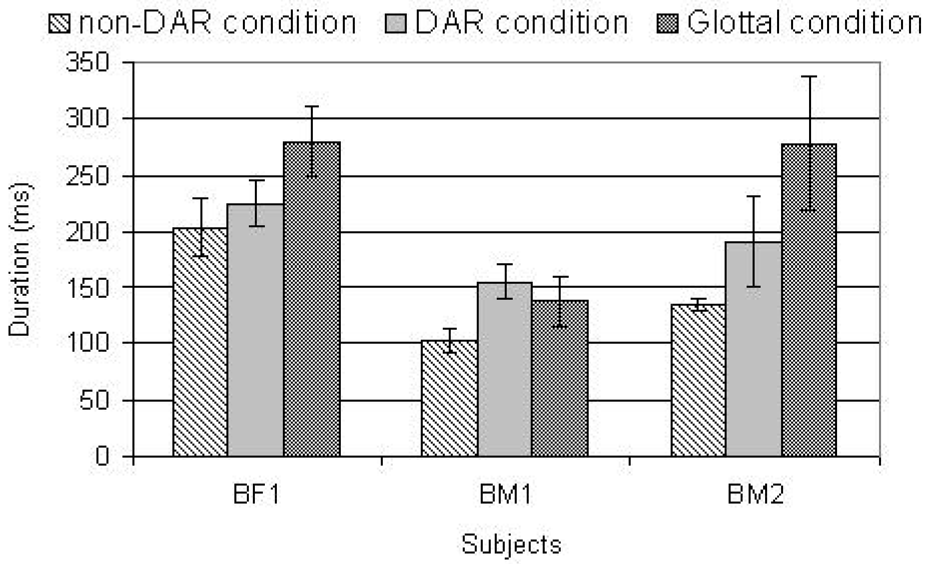

Figure 1: Average duration (ms) from /s/ *of 'see' or 'seat' to* /s/ *of 'sacks'. Error bars show ± 1 standard deviation.*

Figure 2 below shows that subjects BM1 and BF1 have a higher F0 at the midpoint of the 'see' vowel in the DAR context than in the non-DAR context. Subject BM2 has a very similar F0 in both contexts, with only a 1 Hz difference. Standard deviations indicate that variability in F0 is similar across conditions for BF1 and BM2, but greater for BM1. The F0 at vowel midpoint is lower in the Glottal condition (in 'seat') than in the DAR condition for BF1 and BM1, but higher than in the DAR condition for BM2. Standard deviations indicate that speaker variability across conditions is very similar in each individual case.

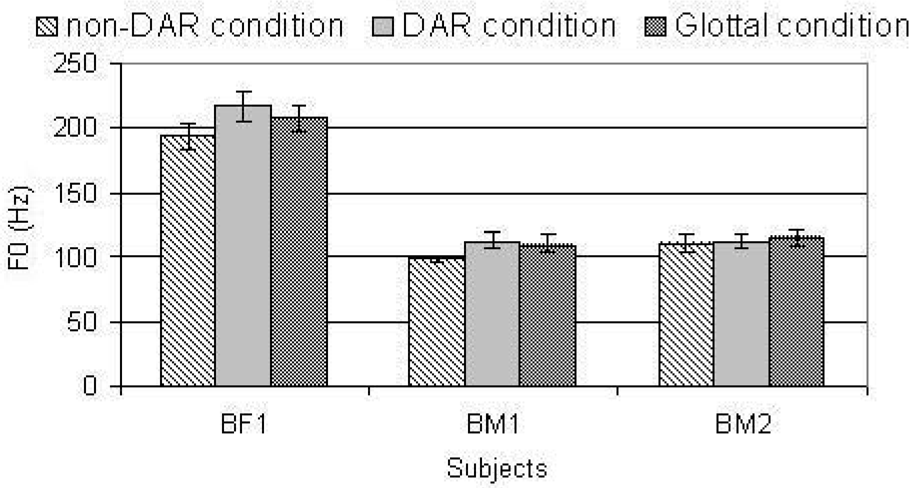

Figure 2: Average F0 (Hz) at the midpoint of the vowel in 'see' or 'seat'. Error bars show ± 1 standard deviation.

The average F0 at the vowel onset in 'sacks' is lower in the DAR condition than in the non-DAR condition for BF1, around the same for BM1, and higher for BM2, see figure 3 below. Variability patterns also differ, with greater standard deviations seen for BF1 and BM1 in the DAR condition, but a greater standard deviation in the non-DAR condition for BM2. Average F0 is generally higher in the Glottal than in the DAR condition. Similar standard deviations are seen for the male subjects, whereas BF1 has considerably reduced variability in the Glottal condition.

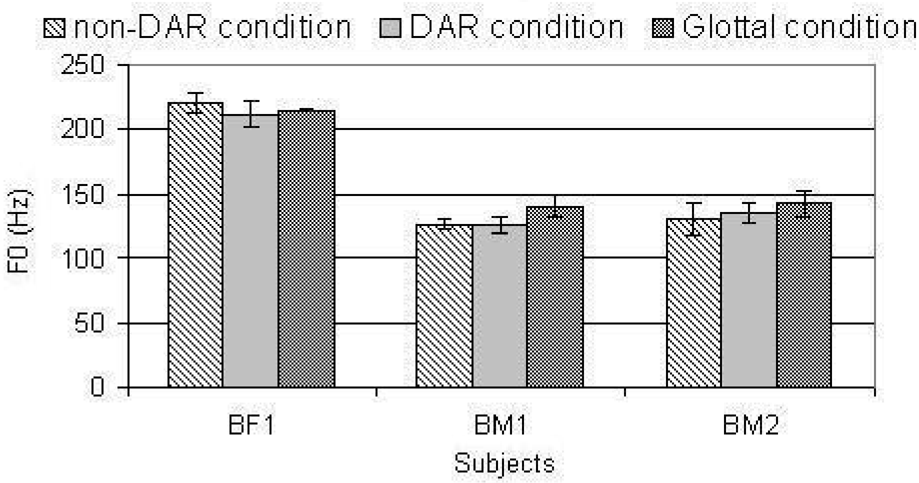

Figure 3: Average F0 (Hz) at the vowel onset of 'sacks. Error bars show ± 1 standard deviation.

The average duration of the fricative is shorter on average for all subjects in the DAR than in the non-DAR context. The duration of /s/ is longer in the Glottal condition than in the DAR condition for both BF1 and BM2, with near identical standard deviations, indicating similar variability. Subject BM1 has a shorter average duration of /s/ in the Glottal condition than in the DAR condition, but the duration is more variable, as shown in figure 4 below:

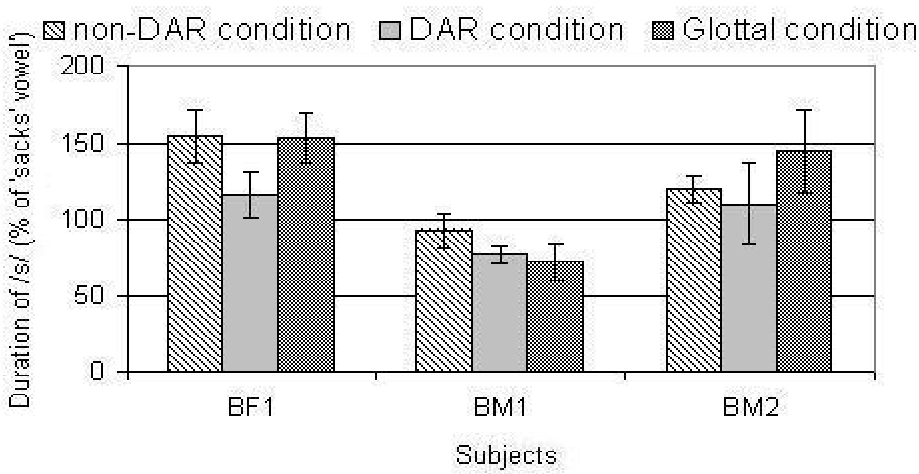

Figure 4: Normalised duration of /s/ in 'sacks' as a % of the vowel in 'sacks'. Error bars show ± 1 standard deviation.

Considering now the measures applied only to the DAR and Glottal conditions, the duration from penultimate waveform pulse to the onset of /s/ in ‘sacks’ is similar for BF1 in both conditions, as shown in figure 5 below, whereas BM1 has a longer duration in the DAR condition, and BM2 has a shorter duration in the DAR condition. For all three subjects, the variability is greater in the DAR condition.

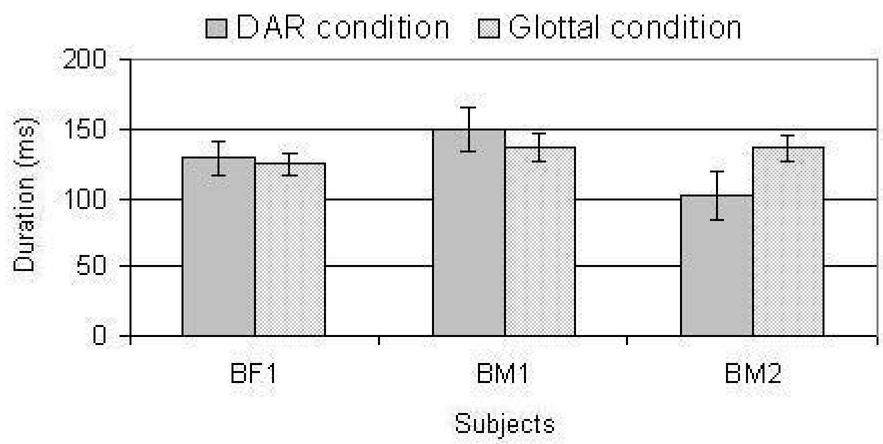

Figure 5: Average duration (ms) from the onset of the penultimate waveform pulse in the vowel in ‘see’ or ‘seat’ to /s/ *of ‘sacks. Error bars show ± 1 standard deviation.*

Average F0 of the penultimate waveform pulse in the vowel is higher in the DAR condition (indicating a shorter pulse period) than in the Glottal condition for subjects BF1 and BM1. Subject BM2 has a higher F0 in the Glottal condition. For all subjects, the variability is greater in the DAR condition, as shown in figure 6 below:

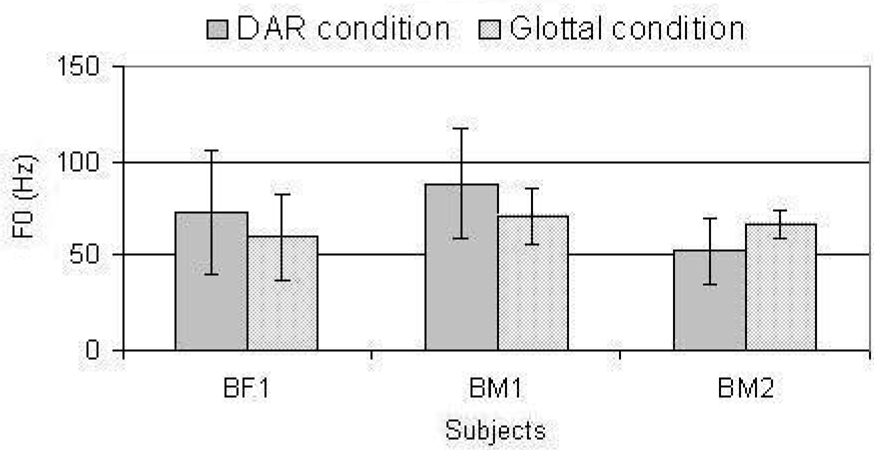

Figure 6: Average F0 (Hz) of the penultimate waveform pulse of ‘see’ or ‘seat’. Error bars show ± 1 standard deviation.

In qualitative terms, the vowel offset in the DAR context shows clear signs of creaky voice – the waveform shape is less regular from pulse to pulse, and the duration of each pulse is longer. The spectrograms in Figure 7 illustrate the difference at vowel offset in ‘see’ for the non-DAR (left-hand panels) and DAR conditions (right-hand panels) for subject BM2.

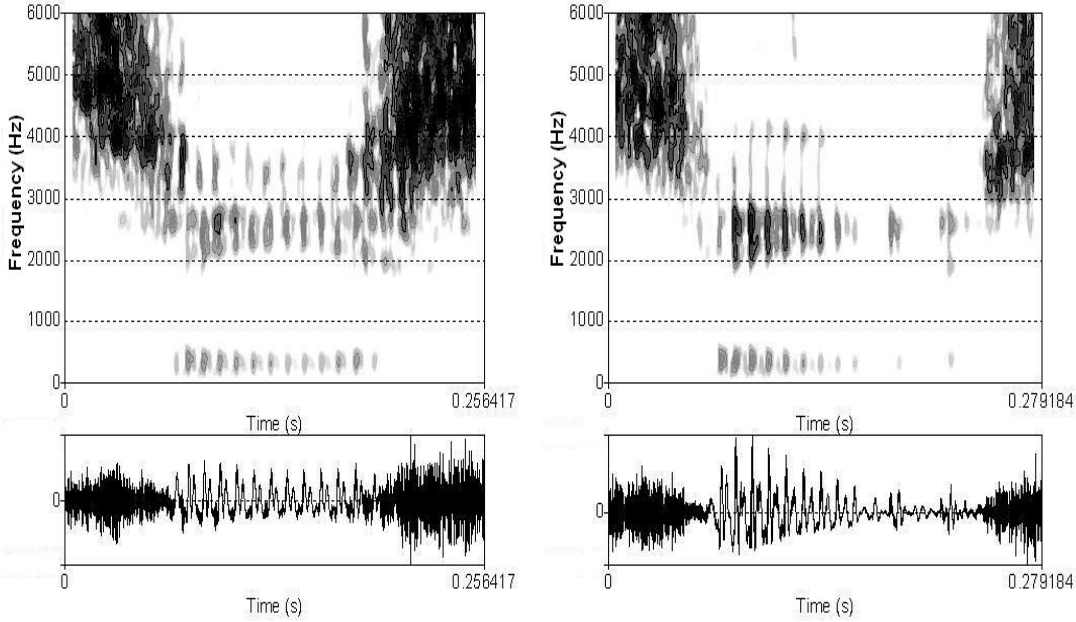

Figure 7: Spectrograms (top panels) and waveforms (bottom panels) for the non-DAR condition (left-hand panels) and DAR condition (right-hand panels) showing the vowel offset of ‘see’ before /s/ *of ‘sacks’ for subject BM2. The non-DAR condition has continuous voicing up to the* /s/ *of ‘sacks’ with regular periodic pulses and an increase in high frequency energy due to vocal fold abduction just before the* /s/*. The DAR condition has intermittent voicing at the vowel offset, with sporadically occurring irregularly shaped pulses, indicative of creaky voice.*

Figure 7 shows wideband spectrograms (top panels) and waveforms (bottom panels) for one token each of the non-DAR and DAR conditions produced by subject BM2. These tokens were chosen at random, and illustrate the general characteristics of vowel offset in each condition for all subjects. In the non-DAR condition (left-hand panels), the voicing for the vowel is continuous with little change right up to the onset of frication for /s/ of ‘sacks’. In the waveform, the pulses are all of similar shape and regularly spaced (quasi-periodic). The last three pulses before frication onset show the addition of high frequency components due to the increasing vocal fold abduction for the following /s/, and this is also reflected in the presence of more energy at higher frequencies in the spectrogram. The vowel offset is marked by continuing voicing with some breathiness, therefore. In the DAR condition (right-hand panels), the spectrogram and waveform show disruption to periodic voicing at vowel offset, with a reduction in amplitude and irregularly shaped pulses which occur sporadically. This pattern is indicative of increasing laryngeal tension for creaky voice.

Quality differences between the DAR and Glottal conditions in the vowel offset are variable across subjects. Subject BM1 shows no obvious differences to the naked eye – patterns of voice offset for both conditions appear to overlap qualitatively. His data are not shown here, though quantitative differences were found (see above).

Waveforms for subject BM2 for the vowel offsets in the DAR and Glottal conditions do show more obvious differences, and are shown in figure 8 below.

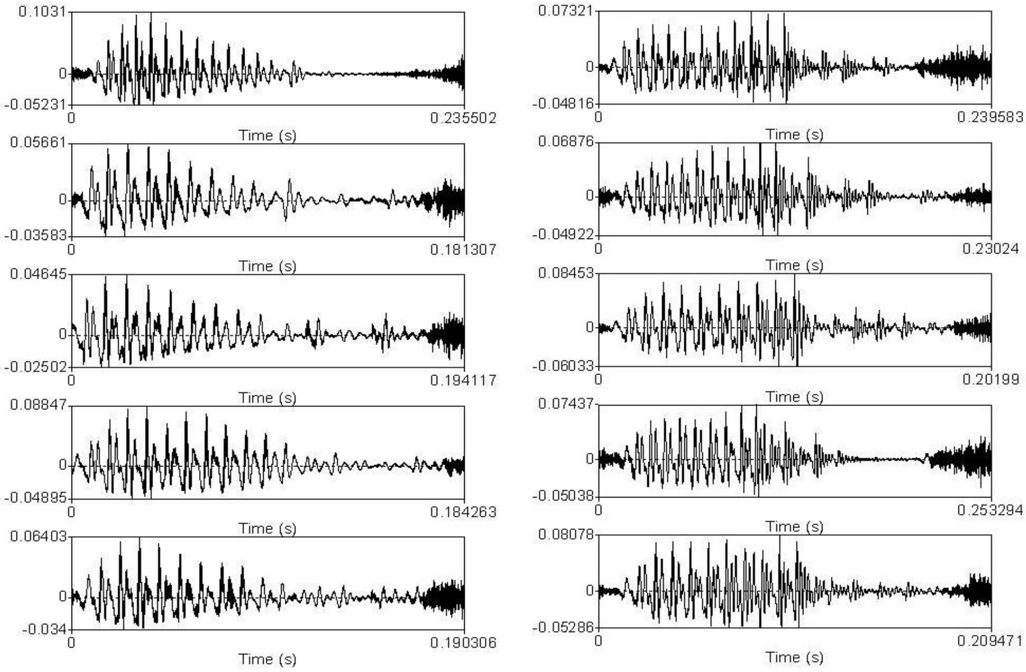

Figure 8: Waveforms for the vowel-[ʔ] *sequence in the DAR condition (left-hand panels) and the Glottal condition (right-hand panels) for subject BM2. The DAR condition shows a more gradual decline in amplitude across the vowel with different pulse patterns at vowel offset (less regularly shaped and more sporadic) compared with the Glottal condition.*

The left-hand panels of figure 8 show waveforms of all tokens for the vowel offset in the DAR condition and the right-hand panels show the vowel offset in the Glottal condition, in both cases before the onset of frication for /s/ of ‘sacks’ for BM2. The DAR forms have a gradual reduction in amplitude of the vowel with one or more irregularly shaped pulses occurring sporadically between the vowel and /s/. The Glottal forms have a more sudden reduction in amplitude, with a change in shape which precedes the amplitude reduction by 3 or 4 pulses. The higher amplitude preceding the glottal articulation could be due to the more open vowel quality at the offset of the /iə/ diphthong, but is also seen in the Glottal condition for BF1 (figure 9 below). The portion with reduced amplitude continues to show periodic pulses up to the onset of /s/ in most cases, though these are markedly different in shape from those at vowel onset.

Subject BF1 also has a distinctive pattern of laryngealisation for each condition, although here the visual patterns are not completely categorical (Figure 9 below).

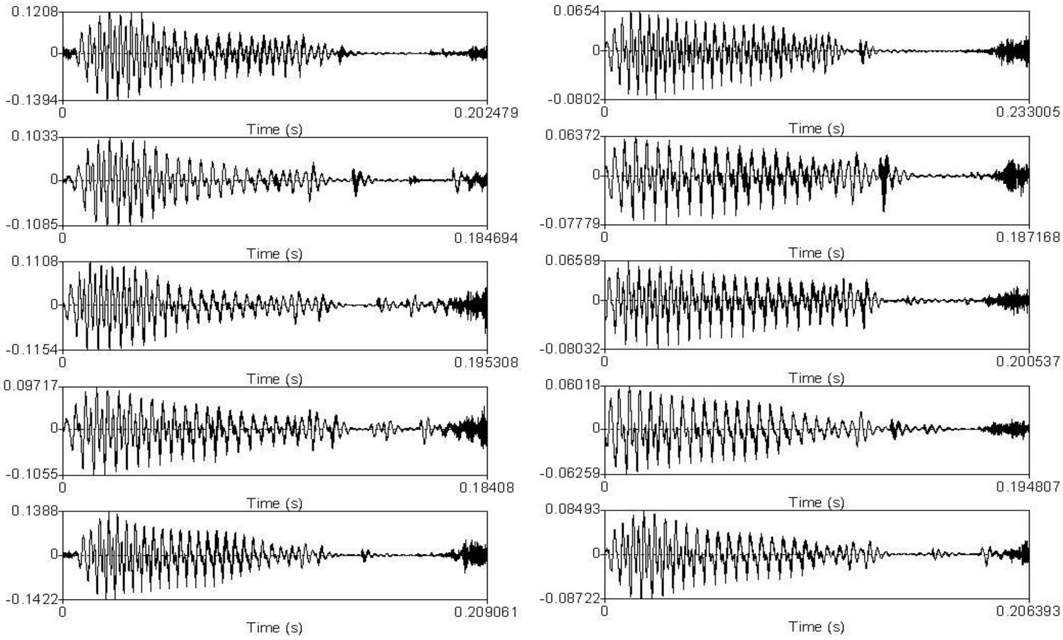

Figure 9: Waveforms for the vowel-[ʔ] *sequence in the DAR condition (left-hand panels) and the Glottal condition (right-hand panels) for subject BF1. Some differences are apparent in terms of vowel amplitude and occasional pulses immediately preceding the frication onset of 'sacks' in the DAR condition which are absent from all but one token in the Glottal condition.*

Similar to the data from BM2 shown in figure 8 above, BF1 has a different pattern of reduction in amplitude during the vowel in most tokens in the DAR condition compared with the Glottal condition. Although less categorically different than the data for BM2 in Figure 8 above, BF1 has glottal pulsing immediately prior to the onset of frication for /s/ in 'sacks' in the middle three panels in the DAR condition, a pattern which is absent from all but one panel in the Glottal condition (bottom panel). Differences in the shape of the pulses are hard to identify. An anonymous reviewer suggests that the more categorical pattern for BM2 could be attributed to the difference in preceding vowel quality. This is certainly a distinct possibility given anatomical linkages between the tongue and the larynx, though in an initial analysis of this sort, it might be expected that the temporal coordination of vowel quality and laryngeal articulations were relatively independent of one another.

4. Discussion

The analysis presented here has considered the acoustic correlates of the glottal form of the reduced definite article in a single segmental context for three speakers of Barnsley English, in contrast with a control condition (no article) and a condition where glottalisation is a realisation of word-final /t/. In general terms, the vowel offset of 'see' is characterised by irregular pulses associated with creaky voice in the DAR condition, as opposed to indications of breathy voice in the non-DAR condition, and the /s/-/s/ interval is longer in the DAR case. These patterns are what would be expected given the broad transcription of the article as [ʔ] and its presence as an additional (segment-sized?) element in the sequence.

However, the effects of DAR are not just seen at the vowel offset. The F0 at the midpoint of the vowel in ‘see’ is also higher on average in the DAR context than in the non-DAR context, though variation between subjects is evident. Furthermore, there are differences in the normalised duration of /s/ in ‘sacks’, even though the /s/ belongs to a different word following the article after a morpheme boundary. Durational differences are surprising. The differences in voice quality and F0 between the non-DAR and DAR conditions can be attributed to the laryngeal modifications needed for the article, but the durational differences not only occur away from the source, and are separated from it by a morpheme boundary, so they cannot be equated directly with the coarticulatory effects of laryngeal articulation.

The analysis also considers possible differences between the cohesion of the glottal and surrounding segments in the DAR condition and the Glottal condition, where [ʔ] is a realisation of word-final /t/. Differences are expected, as the DAR condition has an additional morpheme boundary compared with the Glottal condition, between the vowel and [ʔ]. Recent work on a range of languages (Korean, Cho 2001; Lheidli, Bird 2004; British English, Baker et al. 2007) shows that grammatical boundaries can have an effect on gestural timing and acoustic effects. It was hypothesised that DAR speakers could differentiate in production between the DAR and the Glottal conditions.

Differences between the DAR and the Glottal conditions in the /s/-/s/ interval are apparent, as well as in F0 at the vowel onset of ‘sacks’ and differences in the normalised duration of /s/. Further measures on duration and F0 of the glottalisation in the DAR and Glottal conditions (penultimate pulse to /s/ onset, F0 of penultimate pulse) also show differences. In general, variability between tokens for each subject (indicated by standard deviation) is also higher in the DAR than in the Glottal condition. Qualitative differences in the patterns seen at vowel offset are also evident for two subjects (figures 8 and 9 above). In both cases, the relationship between the glottalisation and the vowel seems closer in the Glottal than in the DAR condition. This observation suggests that the morphological boundary present between the vowel and the glottal realisation of the article in the DAR condition does have an effect on the interrelationship between vowel and glottalisation.

Durational effects have been noted before in connection with the glottal form of the article (Hirst 1906, Brilioth 1913), particularly as regards the possibility of lengthened stop closures. The data here suggest for two of the three subjects that the duration of frication for /s/ is shorter in the DAR context than in other contexts. Supposed increases in the duration of stop closure in the DAR condition may relate simply to an extended period of silence rather than to a lengthened period of articulatory constriction *per se*.

In broad terms the results from the DAR and Glottal conditions support the results of Cho (2001), Bird (2004) and Baker et al. (2007), and show that language-specific implementation patterns can reflect grammatical boundaries. Whether the effects can be attributed solely to gestural cohesion and timing is less clear (see also Cho 2001). It appears that speakers can control quite subtle aspects of laryngeal activity, but the effects may be due to active enhancement of differences rather than automatic differences due to timing (cf. Kingston and Diehl 1994). These overall results are not always easy to ascribe to the presence of a morpheme boundary between the vowel and [ʔ] in the DAR condition. The qualitative patterns, the duration of penultimate pulse to /s/ onset, and occasionally greater variability in the DAR condition, do fit with what might be expected (see Cho 2001). However, differences are also seen in all conditions in the 'sacks', even though a morpheme boundary intervenes between glottalisation and /s/. As all conditions have a morpheme boundary in this position, no difference between them might be expected. Clearly, the different status of the glottalisation in the DAR context can be cued in ways which do not respect a straightforward analysis of phonetic effects across morphological boundaries.

The level of individual variability means that the origins and purpose of these differences come into question. The variability of patterns observed across subjects means that listeners may have problems in attributing any particular correlates with one condition or the other, and so there may be no intended perceptual purpose on the part of the speaker in making the grammatical distinction. Of course, these differences may be useful for speaker identification, or in identifying the grammatical context against the background of sufficient speaker knowledge, or the patterns of variation may be more stable across finer social groupings, as an anonymous reviewer suggests, but the utility of the patterns observed here in determining a community norm at a higher level seems doubtful. The apparent lack of any community norm (albeit in a limited sample) not only suggests the possibility that these effects are not intended to robustly encode morphological boundaries for listeners, but also that they may not be directly acquired from the speech community. It may be that these patterns emerge within the production habits of an individual when morphological boundaries become apparent during acquisition.

Further work is clearly required to address these issues. A more sophisticated approach, perhaps using other instrumental techniques such as electrolaryngographic data, may reveal greater differences between the DAR and Glottal conditions. Rhythmic aspects of the signal, and longer-domain effects on intonational patterns should also be examined. This study has used controlled data to be certain that the effects seen are due to the presence of the article, and not uncontrolled effects due to a range of other possible factors. The data analysed were not 'real' speech, but speech produced under optimal conditions. How these effects translate into spontaneous conversational data is an obvious point of interest. The [ʔ] realisation of /t/ in the Glottal condition is domain-final, and reduction of the glottalisation is likely in spontaneous connected and casual speech. It may be that the additional morpheme boundary before the article in the DAR condition makes it domain-initial and protects it from this kind of domain-final reduction. Investigating the extent of socioindexical marking of the type identified by the anonymous reviewer will also be of obvious interest to some, but will require the kind of controlled and detailed large-scale acoustic analysis not normally applied in sociolinguistic investigations. Such an investigation will also require reference to cross-linguistic controls, particularly as regards possible universal physiological tendencies due to sex and age differences.

The results of this pilot study show that the effects of DAR may be subtle and present across the duration of an entire short utterance. Speakers can distinguish between the glottal article and the glottal allophone of word-final /t/. It is not clear whether this distinction arises automatically and lawfully due to the effect of morpheme boundaries on articulatory coordination, or whether speakers implement a specific and more conscious enhancement of one condition relative to the other. In the case of enhancement, the effects could be greater than or different from those which might be expected due to a change in coordination.

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The author gratefully acknowledges the support of a post-doctoral research fellowship from the British Academy in conducting this research, and the comments and suggestions of an anonymous reviewer. Any errors remain my own.

Appendix – Means and standard deviations

	non-DAR condition (SD)	DAR condition (SD)	Glottal condition (SD)
BF1	204 (25)	225 (20)	280 (31)
BM1	103 (11)	155 (16)	137 (22)
BM2	134 (5)	191 (40)	278 (59)

Table 2: Average duration of the /s/-/s/ interval from the offset in 'see' to the /s/ onset in 'sacks' in non-DAR, DAR and Glottal conditions (standard deviations in parentheses).

	non-DAR condition (SD)	DAR condition (SD)	Glottal condition (SD)
BF1	194 (10)	217 (12)	208 (10)
BM1	98 (3)	113 (6)	110 (7)
BM2	111 (7)	112 (6)	115 (7)

Table 3: Average F0 (Hz) at the midpoint of the vowel in 'see' in non-DAR and DAR conditions and 'seat' in the Glottal condition (standard deviations in parentheses).

	non-DAR condition (SD)	DAR condition (SD)	Glottal condition (SD)
BF1	221 (8)	212 (10)	215 (1)
BM1	127 (4)	126 (7)	141 (8)
BM2	131 (13)	136 (8)	143 (10)

Table 4: Average F0 (Hz) at the onset of the vowel in 'sacks' in non-DAR, DAR and Glottal conditions (standard deviations in parentheses).

	non-DAR condition (SD)	DAR condition (SD)	Glottal condition (SD)
BF1	154 (17)	116 (15)	153 (16)
BM1	92 (12)	76 (6)	71 (12)
BM2	120 (9)	110 (27)	144 (27)

Table 5: Average normalised duration of /s/ as a % of the duration of the vowel in 'sacks' in non-DAR, DAR and Glottal conditions (standard deviations in parentheses).

	DAR condition (SD)	Glottal condition (SD)
BF1	129 (12)	125 (8)
BM1	150 (16)	137 (10)
BM2	102 (18)	136 (10)

Table 6: Average duration (ms) from the onset of the penultimate waveform pulse in the vowel 'see' to the onset of /s/ in 'sacks' in the DAR and Glottal conditions (standard deviations in parentheses).

	DAR condition (SD)	Glottal condition (SD)
BF1	73 (33)	60 (23)
BM1	88 (29)	71 (15)
BM2	52 (17)	67 (8)

Table 7: Average F0 (Hz) of the penultimate waveform pulse in the vowel in 'see' or 'seat' in the DAR and Glottal conditions (standard deviations in parentheses).