Kirkham, Sam (2011) The acoustics of coronal stops in British Asian English. *Proceedings of the XVII International Congress of Phonetic Sciences* 1102-1105.

THE ACOUSTICS OF CORONAL STOPS IN BRITISH ASIAN ENGLISH

Sam Kirkham

University of Sheffield
s.kirkham@sheffield.ac.uk

ABSTRACT

This study reports on an acoustic phonetic analysis of the realization of the coronal stop consonants /t/ and /d/ in British Asian English. These segments are often reported to be salient features of the variety, but have rarely been subjected to comprehensive acoustic analysis. The results demonstrate that, compared to ethnically White speakers, British Asian /t/ is characterized by shorter voice onset times, greater burst intensity, lower overall spectral energy, and a more compact burst spectrum. The acoustic measures suggest a louder and shorter burst with a more retracted place of articulation. Results for /d/ revealed no significant differences between ethnic groups.

Keywords: sociophonetics; stop consonants; ethnicity; language variation; British Asian English

1. INTRODUCTION

The aim of this study is to describe some of the acoustic correlates of the coronal stops /t/ and /d/ in British Asian English, a minority ethnic variety of British English commonly found in urban areas of the United Kingdom. British Asian communities are comprised of a number of different communities of South Asian origin, predominantly from Pakistan and India. According to the 2001 Census, British Asians constitute 50.3% of the UK's ethnically non-European population.

Previous research has investigated the possibility of a distinctive 'British Asian' accent amongst British-born children of Asian immigrant families [1, 7, 10]. One commonly documented feature in this research is the realization of the coronal stop consonants /t/ and /d/, which are often said to have a 'retracted' or 'postalveolar' articulation in British Asian English. Coronal stops in this variety have been the subject of a number of auditory phonetic analyses [7, 10], but little is known about their acoustic characteristics (but see [1]), or about how British Asian speakers differ from ethnically White speakers.

This paper thus asks the following questions: (1) Do White and Asian speakers of British English differ in the realization of coronal stop consonants? (2) On what acoustic dimensions do they differ? (3) What are the possible explanations for such differences?

2. METHODOLOGY

Data were collected from 8 native speakers of British English, 4 Asian and 4 White, with gender balanced across each group. All speakers were aged between 14 and 15 years old and were born and resident in Sheffield, a city in the north of England. All White speakers were monolingual speakers of English and all Asian speakers were to some extent bilingual in English and Panjabi. The families of the four Asian speakers all originate from the Mirpur region of Pakistan.

Participants were recorded in a quiet room at a local school using a Beyerdynamic Opus 55 MkII headset microphone recording to a laptop computer via a USB audio interface. All stimuli were monosyllabic CVC words and featured word-initial /t/ or /d/ preceding one of four vowels /i a ɒ u/. Words were presented in a carrier phrase, *say* ___ *again*, which the participants read aloud from a computer screen. Each speaker produced 3 repetitions of 16 target words alongside 73 filler words, resulting in 192 tokens of /t/ and 192 tokens of /d/ across the sample. Values were averaged over repetitions of a word prior to statistical analysis. The sound files were sampled at 22.05kHz and low-pass filtered at 11kHz prior to analysis. All acoustic analysis was carried out using the Emu speech database analysis system [3].

A mixed-design ANOVA was carried out for each measure, with voicing (/t/ or /d/) as the within-subjects factor and ethnicity and gender as between-subjects factors.

2.1. Voice onset time

For voiceless stops, voice onset time (VOT) was taken as the interval from burst release to the onset of periodic energy. 14.7% (N=27) of /t/ tokens were removed due to an unclear burst or clipped signal, 63% of which were produced by White female speakers.

For the two Asian males, 12.5% (N=6) of their /d/ tokens featured voicing throughout closure and release, resulting in no discernable burst transient. These tokens were included in the analysis of closure voicing, but were removed for the intensity and spectral analyses. A further 3.6% (N=7) of tokens were removed from other speakers due to a clipped signal or ambiguity over the location of burst onset. All other tokens of /d/ showed a degree of voicing through the closure, which often dampened and eventually ceased prior to release, as well as a degree of aspiration following the burst release. In order to avoid making analytic assumptions over which aspects of the stop were most relevant, burst duration and closure voicing were measured separately. All remaining tokens of /d/ were measured for voice onset time, comprising the duration from burst release to the onset of periodicity.

To provide some control for speech rate, a proportional measure was also derived in which VOT was calculated as a percentage of the duration from burst release to vowel offset. [5] find that the relationship between VOT and vowel length remains the same as speech rate slows down, making this a potentially useful measure for accounting for individual differences in rate.

2.2. Closure voicing

All tokens of /d/ were measured in terms of the percentage of periodic energy during the stop closure period. This ranged from 25.6% to 100% across the eight speakers. The onset of stop closure was segmented as the offset of F2 in the preceding vowel as visible on the spectrogram. Voicing during closure was measured based on visual evidence of periodicity on the waveform.

2.3. Relative burst intensity

Relative burst intensity was calculated to normalize inherent intensity differences amongst individual speakers. Relative intensity was measured by subtracting the peak intensity of the following vowel (dB) from the intensity of a 10ms Hamming window centered on burst onset (dB). A value of 0 indicates that burst and vowel intensity are the same. Negative values indicate a progressively softer burst.

2.4. Spectral moments

Spectral moments analysis has been widely used to classify place of articulation for stop consonants [2]. The first four moments – mean, standard deviation, skew, kurtosis – were derived from the stop burst using a 256-point Fast Fourier Transform, with 6dB pre-emphasis above 1000Hz and an 11.6ms Hamming window centered on burst onset. Tokens of /t/ were high-pass filtered at 70Hz in order to reduce the effects of the air blast from the plosive release [8]. Tokens of /d/ were filtered using a 200Hz high-pass filter to remove any effects of pre-voicing [4, 11].

Prior research suggests that the four spectral moments may have broad articulatory correlates relating to the length of the front oral cavity. A longer front oral cavity (suggesting a place of articulation further away from the lips) is often characterized by greater low frequency energy (lower mean; positive skew), a more compact burst spectrum (lower standard deviation), and a more peaked distribution (positive kurtosis) [3, 6].

3. RESULTS

3.1. Voice onset time

Table 1: Voice onset time [mean (SD, number of words)]. Values in milliseconds.

Speakers	/t/	/d/
Asian females	65.8 (18.2, 16)	15.2 (4.9, 16)
Asian males	52.3 (17.6, 16)	10.6 (3, 16)
White females	82.9 (9.7, 16)	18.4 (7.6, 16)
White males	89.1 (23.7, 16)	12.6 (4.3, 16)

Table 2: Proportional voice onset time (values represent VOT as a percentage of the duration from burst release to vowel offset) [mean, (SD, number of words)].

Speakers	/t/	/d/
Asian females	38.7 (7.7, 16)	10.6 (3, 16)
Asian males	27.7 (4.5, 16)	6.5 (1.8, 16)
White females	37.2 (7.5, 16)	9.9 (4.8, 16)
White males	38.6 (4.2, 16)	7.4 (3.6, 16)

Table 1 displays the results of the raw VOT analysis. The mixed-design ANOVA confirmed that Asian males had significantly shorter VOTs than White speakers for /t/ only [$F(1,60) = 4.85$, $p = .032$]. The differences for /d/ were not statistically significant.

When measured as proportions of the interval from burst release to vowel offset, the mean VOT differences were considerably reduced, with all groups except Asian males having near identical means for /t/ (see Table 2). This suggests that Asian females' shorter VOTs for /t/ in Table 1 may be an effect of a faster speech rate. As was the case with raw durations, Asian males had shorter proportional durations for /t/ [$F(1,60) = 10.56$, $p = .002$] but not for /d/.

3.2. Closure voicing

Table 3: Percentage of voicing throughout /d/ closure [mean (SD, number of words)].

Speakers	% voicing
Asian females	73.4 (15.6, 16)
Asian males	90.7 (7, 16)
White females	42.8 (7.5, 16)
White males	86 (12.2, 16)

A univariate ANOVA confirmed that Asian speakers had a greater proportion of voicing during the closure portion of /d/ [$F(1,60) = 59.8$, $p < .001$]. The difference between Asian and White males was not significant, however, with this effect being caused by the fact that Asian females had significantly more voicing during closure than White females [$F(1,60) = 21.52$, $p < .001$].

3.3. Relative burst intensity

Table 4: Relative burst intensity [mean (SD, number of words)]. Values in decibels.

Speakers	/t/	/d/
Asian females	-0.7 (3.1, 16)	-6.6 (2.3, 16)
Asian males	-4.7 (4.1, 16)	-4.9 (3.1, 16)
White females	-16.7 (6.8, 16)	-5.5 (6.3, 16)
White males	-19.5 (6.5, 16)	-11.7 (3.8, 16)

Asian speakers had greater relative burst intensity for /t/ only [$F(1,60) = 128.3$, $p < .001$]. Interestingly, the means in Table 4 show that, within ethnic groups, Asian speakers have louder bursts for /t/ than for /d/, whilst White speakers have louder bursts for /d/ than for /t/. White females in particular show a marked difference, with a value of -16.7dB for /t/ and -5.5dB for /d/.

3.4. Spectral moments

The results of the spectral moments analysis are displayed in Table 5 (/t/) and Table 6 (/d/). Each analysis is discussed separately in the four sections that follow. Potential articulatory correlates of these measures are summarised in Section 2.4.

Table 5: Spectral moments values for /t/ [mean (SD)]. Mean frequency and standard deviation values in Hz.

Speaker	Mean	St. dev.	Skew	Kurtosis
Asian females	4783 (171)	3012 (46)	0.25 (0.83)	-0.98 (0.06)
Asian males	4592 (159)	3076 (70)	0.35 (0.07)	-0.98 (0.08)
White females	5351 (305)	3229 (114)	0.02 (0.15)	-1.19 (0.12)
White males	5088 (334)	3194 (87)	0.17 (0.14)	-1.15 (0.11)

Table 6: Spectral moments values for /d/ [mean (SD)]. Mean frequency and standard deviation values in Hz.

Speakers	Mean	St. dev.	Skew	Kurtosis
Asian females	4804 (162)	3034 (41)	0.29 (0.07)	-1.01 (0.07)
Asian males	4750 (179)	3137 (75)	0.32 (0.08)	-1.07 (0.09)
White females	5151 (271)	3145 (48)	0.17 (0.13)	-1.13 (0.08)
White males	4625 (213)	3073 (65)	0.4 (0.11)	-0.96 (0.08)

3.4.1. Mean frequency

Asian speakers had significantly lower mean frequency than White speakers for /t/ only [$F(1,60) = 26.82$, $p < .001$]. White females had higher mean frequencies than White males for both /t/ and /d/ [$F(1,60) = 10.69$, $p = .002$].

3.4.2. Standard deviation

Asian speakers had significantly lower standard deviation for /t/ only [$F(1,60) = 40.779$, $p < .001$]. There were no significant effects of gender.

3.4.3. Skew

Asian speakers had significantly higher skew for /t/ only [$F(1,60) = 34.348$, $p < .001$]. White males had higher skew than White females for both /t/ and /d/ [$F(1,60) = 10.26$, $p < .002$].

3.4.4. Kurtosis

Asian speakers had significantly higher kurtosis for /t/ only [$F(1,60) = 48.468$, $p < .001$]. White males had higher kurtosis than White females for /d/ only [$F(1,60) = 12.108$, $p = .001$].

4. DISCUSSION AND CONCLUSION

The results demonstrate that, compared to White speakers from the same region, British Asian speakers have shorter voice onset times, greater relative burst intensity, lower mean frequency, lower standard deviation, higher skew and higher kurtosis for the voiceless coronal stops. These results suggest that British Asian /t/ is characterized by a shorter and louder burst with a more retracted place of articulation.

None of the differences for /d/ were significant across ethnic groups, except for White females having less voicing during closure. This suggests that /t/ may be more perceptually salient than /d/ in British Asian speech, despite retroflex articulations of /d/ also being present in Panjabi. However, 12.5% (N=6) of the two Asian males' /d/ tokens were removed due to voicing through the burst, suggesting that other cues may be present in the signal for marking ethnic differences in /d/ realization. It also remains unknown how the results from these speakers generalize to spontaneous speech.

Whilst the differences in /t/ realization are clear, why should it be the case that British Asian /t/ differs from White /t/? One hypothesis is based in the observation that British Asian English often features an articulation of /t/ that is auditorily similar to the phonologically retroflex coronals of Panjabi [7]. Therefore, retracted /t/ in British Asian speech may represent a process of cross-linguistic influence from the speakers' heritage language, which for many is Panjabi. [9] found that speakers of Hindi – a language that contrasts dental and retroflex stops, like Panjabi – classified English alveolars as retroflexes 91% of the time. This perceptual similarity could lead to a degree of overlap between the productions of Panjabi /t̪/ and English /t/, leading British Asian English /t/ to sound more retracted.

However, ethnographic fieldwork with the participants in the study suggests that the more actively bilingual Asian speakers do not necessarily possess more Asian-sounding features than the less bilingual or even monolingual Asian speakers. In fact, some of the more active Panjabi speakers often had articulations of /t/ that were auditorily closer to those of White monolinguals. [10] also find that reported bilingualism did not strongly predict a postalveolar articulation of /t/ in their sample of British Asians in Southall, London.

Another hypothesis is that differences in /t/ realization are due to the feature's socio-indexical characteristics for these speakers. All participants in the study attended the same high school and knew each other. The more retracted realization of /t/ may be well established in the British Asian children's repertoire due to the Panjabi and Asian English input from their parents. However, as social divisions begin to emerge and ethnic identity becomes more important in the children's peer networks, differences in /t/ realization also begin to emerge more sharply, with speakers' use of the retracted variant marking British Asian identity. This is supported by ethnographic observation of the participants in the high school environment, where peer groups had become more ethnically homogeneous at the time of data collection. More research into the socio-indexical properties of fine-grained phonetic variation in British Asian /t/ will no doubt further illuminate the patterns found in this analysis.

5. ACKNOWLEDGEMENTS

Thanks to Emma Moore, Claire Nance, Jane Stuart-Smith, Gareth Walker, and two anonymous reviewers for their comments. This research was supported by a Doctoral Award in Linguistics from the Arts & Humanities Research Council.

6. REFERENCES

[1] Alam, F. 2009. Community of practice does affect /t/ realization in adolescent Glasgow-Pakistanis. Poster presented at UKLVC7, Newcastle, UK.

[2] Forrest, K., Weismer, G., Milenkovic, P., Dougall, R.N. 1988. Statistical analysis of word-initial voiceless obstruents. *J. Acoust. Soc. Am.* 84, 115-123.

[3] Harrington, J. 2010. *The Phonetic Analysis of Speech Corpora*. Oxford: Wiley-Blackwell.

[4] Jongman, A., Blumstein, S.E., Lahiri, A. 1985. Acoustic properties for dental and alveolar stop consonants: a cross-language study. *J. Phonetics* 13: 235-251.

[5] Kessinger, R.H., Blumstein, S.E. 1998. Effects of speaking rate on voice-onset time and vowel production. *J. Phonetics* 26: 117-128.

[6] Laaksonen, J., Rieger, J., Harris, J., Seikkaly, H. 2010. A longitudinal acoustic study of the effects of the radial forearm free flap reconstruction on sibilants produced by tongue cancer patients. *Clinical Linguistics & Phonetics* 22: 253-264.

[7] Lambert, K., Alam, F., Stuart-Smith, J. 2007. Investigating British Asian accents: studies from Glasgow. *Proc. 16th ICPhS* Saarbrücken, 1509-1512.

[8] Milenkovic, P. 1986. Glottal inverse filtering by joint estimation of an AR system with a linear input model. *IEEE Trans. on Acoust., Speech and Sig. Proc.* 34, 28-42.

[9] Ohala, M. 1978. Conflicting expectations for the direction of sound change. *Indian Linguistics* 39: 25-28.

[10] Sharma, D., Sankaran, L. forthcoming. Cognitive and social factors in dialect shift: gradual change in British Asian speech. *Language Variation and Change*.

[11] Sundara, M. 2005. Acoustic-phonetics of coronal stops: a cross-language study of Canadian English and Canadian French. *J. Acoust. Soc. Am.* 118, 1026-1037.