Frication of /k/ and /p/ in Australian English: Inter - and Intra-Speaker Variation

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Abstract

Frication of stops occurs when a phonemic stop is produced with incomplete closure such that it is effectively reduced to a fricative. This is a typical connected speech process in dialects of British English, and has also been observed in Australian English. The present study examines patterns of frication of the voiceless stops /k/ and /p/ in Australian English produced by a group of male speakers from Melbourne. Acoustic analysis of spontaneous speech shows that frication of /k/ and /p/ occurs to a significant extent in Australian English, and that this behaviour also exhibits systematic speaker-specific variation.

1. Introduction

1.1. Frication of plosives

This investigation focuses on the realisation of voiceless stop consonants as fricatives in Australian English. This is a typical connected speech process in English (Gimson 1980; Shockey and Gibbon 1993; Shockey 2003), and is described by Gimson (1980:160) as 'where easy intelligibility rather than articulatory precision is the aim, the closure of plosives is often so weak that [a] ... fricative sound ... is produced'. The process is often referred to as *frication* or *reduction of closure* (cf. Shockey 2003). Shockey and Gibbon (1993) have also used the term *stopless stop* to describe a plosive for which closure is incomplete.

Fricated plosives tend to be observed in weak phonetic environments, especially intervocalic word-final position (Shockey and Gibbon 1993:1), while plosives in syllable-initial, word-initial and metrically stressed syllables are least likely to occur with incomplete closure (Shockey 1991:12; see also Honeybone 2001:230). Some examples from British English (RP), also typical of those found in the present study of Australian English, are *baker* realised as [beɪxə] and *pepper* as [p^{h}eɸə] (Gimson 1980:160).

1.2. Previous research

Research on frication of plosives in English has typically focused on /t/ and has most commonly concerned dialects of British English; for example, Middlesbrough English and Dublin English (Jones and Llamas 2003, also see references therein). Jones and Llamas note that intervocalic /k/ and /p/ often show pre-glottalisation or glottal reinforcement in Northern English dialects (2003:655), but do not mention fricated realisations of these particular stops.

Frication of /k/ has been documented for certain dialects of British English, most notably Liverpool English (Newbrook 1999, Honeybone 2001, Sangster 2002, Shockey 2003). For example, Newbrook (1999:97) reports that in spontaneous speech data produced by 68 speakers of Liverpool English, 8% of /k/ tokens were fricated. This includes realisations of /k/ as both the fricative [x] and affricate [kx], but Newbrook adds that the realisation was 'most usually fricative [x]' (1999:97). Allophonic variation in the production of /k/ has also been observed in spontaneous American English, with [x] included among its possible variants (Lavoie 2002:41).

While frication of /p/ has been noted as a connected speech process in English, it has not been the specific focus of phonetic research. This is probably because bilabials are less likely to be realised with incomplete closure (cf. Honeybone 2001:236).

In Australian English, frication of /t/ has been discussed in some studies (e.g. Horvath 1985 for Sydney; Tollfree 2001 for Melbourne and rural Victoria), but the realisation of /k/ as [x] and /p/ as [ɸ] has received little attention. Ingram (1989) does not refer to frication of voiceless stops in his outline of connected speech processes in Australian English, nor is there any evidence of it in the examples of phonetically transcribed connected speech throughout his report. His analysis focuses on allophones of /t/, for which frication is not listed as a variant (1989:31). It is possible that frication of stops is not mentioned in Ingram's analysis because his data comprises speech of adolescent speakers from Brisbane, for whom this process might not occur.

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1.3. Speaker-specific behaviour?

Individual variation in the frication of plosives has not been investigated in detail in English, although Sangster (2002) comments on speaker-related variability in the duration of friction in Liverpool English /t/ and /d/. It has also been suggested that speakers vary in their strategies for producing consonants; for example, studies using EPG report variation between speakers in both the degree of closure and the degree of contact between the articulators in consonants production. Shockey and Gibbon (1993) observe variation in the degree of closure for 'stopless stops', while Tabain (2002:29) discusses speaker variability in the degree of articulator contact in production of voiceless fricatives. Individual differences have also been observed in reduction processes, for example, Nolan, in an investigation of three speakers' coarticulatory behaviour, found 'tendencies toward different strategies for reduction'(1985:N5)

Speaker-specific behaviour in the frication of stops is possible in English due to the fact that stop and fricative pairs such as /k/ - /x/ and /p/ - /ɸ/ are not contrastive. This means that there is potential for variation in speakers' production of /k/ and /p/ without trade-off for speakers and listeners. This has been confirmed for /k/ by Lavoie, who in a comparison of spontaneous American English and Spanish found both frication and approximation of /k/ (i.e. incomplete closure) in only 7% of cases in Spanish, for which /k/ and /x/ are contrastive, but in 21% of cases for English (2002:49).

Of further interest regarding the issue of speaker-specificity in consonant frication is the suggestion that lenition occurs as a natural class across a group of sounds. For example, a speaker who lenites the plosives /b/ and /d/ by realising them as fricatives or approximants is also likely to lenite the plosive /g/ in the same way (Jessen 2003:142; see also Rose 2002:180). The degree to which individual speakers are consistent in their patterns of frication across the natural class of voiceless stops in Australian English is a further source of potentially interesting variation in stop consonant production which requires investigation.

1.4. The current investigation

The present study examines patterns of frication of the voiceless stops /k/ and /p/ in Australian English, with particular reference to individual differences involved in this process. The following research questions are addressed:

1. How typical is the realisation of /k/ and /p/ as fricatives in Australian English spoken in Melbourne?
2. How do speakers vary in their production of /k/ and /p/ in Australian English?
3. Are individual speakers consistent in their patterns of frication across the natural class of voiceless stops?

2. Method

2.1. Twins' speech

The speech data examined here are drawn from a larger corpus collected by the first author as part of an investigation of individual variation in the speech patterns of male, Australian English speaking, identical and non-identical twin pairs from Melbourne (Loakes, forthcoming). This larger study is being undertaken from a forensic speaker identification perspective, and analyses between- and within-speaker differences in the speech of similar-sounding speakers; and, in the case of the identical twin pairs, among speakers whose vocal tract anatomies have the same physical dimensions (Decoster, Van Gysel, Vercammen and Debruyne 2001:50).

Acoustic studies of twins' speech are rare. However, those which have investigated the speech patterns of identical twins have shown that identical vocal tract anatomies do not necessarily give rise to identical articulatory behaviour (see especially Nolan and Oh 1996).

2.2. Participants

The participants in this study comprise 8 male speakers of Australian English from Melbourne (3 identical twin pairs and 1 non-identical twin pair), aged between 18 and 20. The speakers are all university students enrolled in different courses, though each speaker shared the same education as his twin until the end of high school (to 17 years of age). The speakers in this investigation are TbY & TfY, PF & CF and LG & RG (identical twin pairs), and RH & ZH (non-identical twin pair). These speakers were chosen from a wider corpus of nine twin pairs on the basis of auditory similarity. While not directly relevant to the current investigation, the analysis of speakers with similar-sounding voices was a requirement of the larger forensic phonetic investigation.

2.3. Recording and labelling

Each speaker took part in two Labovian-style interviews in which he discussed his interests and experiences with the first author. Approximately 8 minutes of spontaneous conversational speech from each interview (8 speakers x 2 sessions) is analysed in the present study. Before each interview, the speakers read a wordlist comprising focus items in /hVd/ context, as well as a number of foils. The read speech is not formally analysed in the current investigation, but is

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referred to in section 3.1. The two recording sessions with each speaker (henceforth referred to as S1 and S2) were separated by approximately 6 months and were undertaken to enable examination of non-contemporaneous variation.

The participants were recorded in the phonetics laboratory at the University of Melbourne. The recordings were made on 120 minute Sony Digital Audio Tapes using a Sony ECM-999 PR electret condenser stereo microphone set to 120°, using a studio quality rack mount Tascam DA-30 DAT recorder.

Consonant and vowel segments were labelled manually with The EMU Speech Database System, version 1.5.1 (cf. Cassidy and Harrington 2001), according to visual inspection of the waveform and wideband spectrogram. Praat (version 2.4.07) was used to create figures for the present report, because this program allows use of the IPA symbols.

All consonants were labelled in *EMU* according to both their phonemic and phonetic quality. A tally of the total number of phonemic /k/ and /p/ segments, as well as the number of these which were fricated variants, was made using the function *emu.query* in *R* version 1.4.1. Fricated tokens were identified acoustically using:

1. The acoustic waveform, in which fricative noise was present for fricated tokens; and
2. The wideband spectrogram, where fricated tokens exhibited no evidence of a closure period. Instead, a degree of turbulent airflow in the high energy spectral regions was observed for these tokens, as well as the absence of a burst and presence of formant activity throughout the segment.

In some cases (i.e. in the environment of close-front vowels), realisations of [ç] as opposed to [x] were observed. Since manner of articulation is the primary focus of the investigation, these palatal fricative variants were allocated to the same category as the velar fricatives. In these cases place of articulation is incidental, due to the presence of coarticulation with the neighbouring vowel.

Statistical analysis of the data was undertaken with Excel (XP), using the binomial distribution function.

2.4. Acoustic appearance of fricated plosives

An example of /k/ realised as [x] by speaker TbY in the utterance "…normally they're in bla**CK** and white and I don't remember them…" is shown in the spectrogram in Figure 1. The [x] token has no period of closure, rather it exhibits fricative energy from approximately 1600 Hz through to 8000 Hz which extends throughout the consonant. In addition, formants are present, indicating that the vocal tract is not completely obstructed by the articulators as would be the case for a plosive. In addition to these cues to frication, a degree of voicing can be seen throughout the consonant.

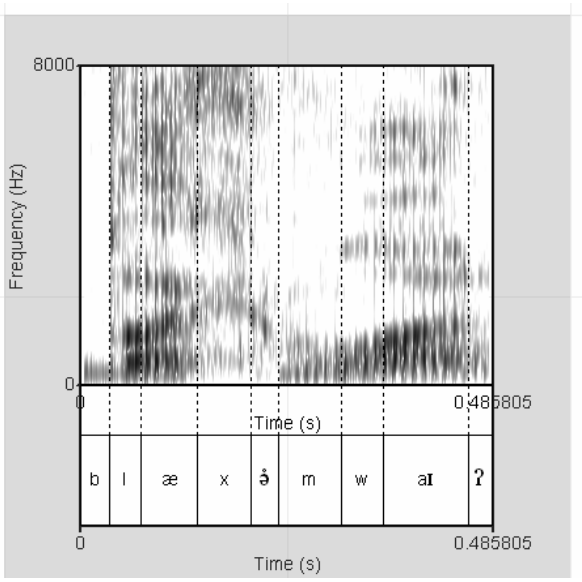

Figure 1: Spectrogram showing [x] in the phrase "bla**CK** and white" produced by speaker TbY.

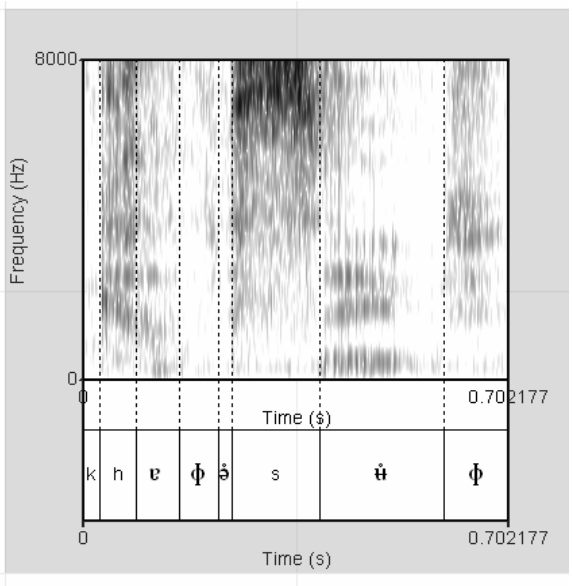

Figure 2: Spectrogram showing two examples of [ɸ] in "cu**P**-a-sou**P**" produced by speaker TbY.

Examples of fricated /p/ are shown in the spectrogram in Figure 2 which contains two [ɸ] tokens, as produced by speaker TbY in the utterance "I came home and I had cu**P**-a-sou**P**…". The cues to frication evident in Figure 1 are present for the two examples in Figure 2, but there is also some variation between the [ɸ] tokens here. The first [ɸ] (intervocalic word-final in *cup*) appears to be more weakly articulated than the second [ɸ] (phrase-final in *soup*); this observation is based on the concentration of energy in the high spectral regions which is more evident in the second [ɸ].

3. Results and Discussion

3.1. Phonetic context of frication

The fricated tokens observed in the data typically occurred in weak environments, primarily intervocalically but also adjacent to other voiceless fricatives where assimilation had taken place. In addition, the majority of tokens showed a degree of voicing (though they are not typically completely voiced), which indicates less articulatory effort than is required for a voiceless segment (cf. Gimson 1980:153). The fricated tokens analysed in this investigation were all observed in the spontaneous speech, whereas there was no frication at all in the read speech produced by the same speakers. While not the focus of the present analysis, the opportunity for frication of /k/ and /p/ was present in the foil tokens *strike, six, choke, trip* and *nuclear*. For /p/ only [p^h] and [$p^=$] were produced in *trip*, and for /k/ only [k] (*six, nuclear*), [k^h] (*strike, nuclear*) and [$k^=$] (*strike*) were produced. Given the phonetic quality of the [x] and [ɸ] tokens in the spontaneous speech, and the environments in which they occurred, the frication is clearly a process of lenition.

3.2. Typicality of the frication of /k/ and /p/ in spontaneous speech in Australian English

The total number of observations of each consonant produced by the eight speakers in all recording sessions combined is given in the first column of Table 1. This includes all /k/ and /p/ tokens produced, not only those in potentially fricatable environments. The second column gives the frequency of fricated occurrences of /k/ and /p/, and in the third column this is expressed as a percentage of the total number of tokens. This information is also presented graphically in Figure 3.

Consonant	Total	Fricated	%
/k/	900	155	17.22
/p/	619	72	11.6

Table 1: Frequency of observations of /k/ and /p/

Overall, more /k/ than /p/ tokens were produced (900 compared with 619), and /k/ was fricated more often (17.2% compared with 11.6%). The more frequent occurrence of /k/ segments is not surprising. Gimson has shown that in English (RP), /k/ occurs more frequently than /p/, with distribution levels of 3.09% and 1.79% respectively, compared with all other phonetic segments (Gimson 1980:217-218). Binomial probability ($p = 0.05$) demonstrates that frication occurred to a significant degree ($p \leq 0.001$) at both places of articulation for the group of eight speakers.

In summary, almost 1 in 6 tokens of /k/ are realised as [x] and almost 1 in 9 tokens of /p/ are realised as [ɸ].

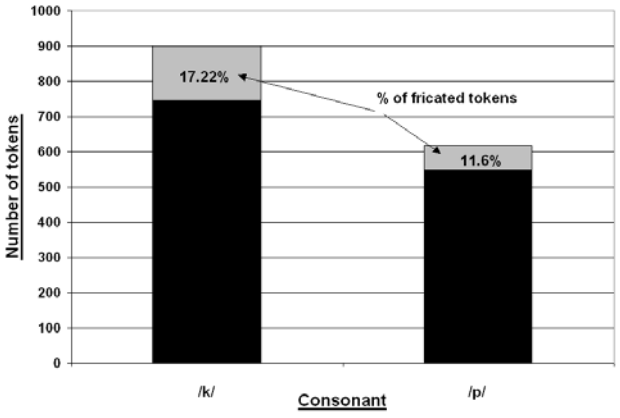

Figure 3: *Number of occurrences of /k/ and /p/ showing the proportion of tokens fricated.*

While frication has been observed at both the velar and bilabial places of articulation, it is more common for velars. This accords with Honeybone's (2001) comment that bilabials are less likely to be articulated with incomplete closure (see 1.2). It is important to note that, given the absence of voiceless stop frication in Ingram's discussion of connected speech processes in Brisbane English (1989), the findings presented above might be specific to Melbourne English, and cannot necessarily be generalised to Australian English as a whole.

3.3. Individual variation in the production of /k/ and /p/ in Australian English

In the previous section, results were given for the overall rate of frication of /k/ and /p/ for the group of eight speakers. However an examination of the results for separate speakers shows that there is considerable individual variation present in the data.

3.3.1. Speaker-specific results: frication of /k/

The number of /k/ tokens observed in each recording session varies between 30 and 95. The percentage of /k/ tokens fricated by each speaker in the separate recording sessions is shown in Figure 4. Results for a given speaker's two recording sessions are presented adjacent to each other, and results for twin pairs are side by side.

Figure 4 shows that individual speakers exhibit a range of different behaviour, but the level of frication for each speaker is relatively consistent across recording sessions. The only exception is CF, for whom no /k/ tokens were fricated in S1, but 11% of tokens were fricated in S2. It can also be seen that TbY and ZH realise /k/ as [x] more frequently than the other participants. However, there is more variation across the recording sessions where TbY's speech samples are concerned; 26% in S1 and 35% in S2 for TbY, compared with 35% and 32% for ZH. Apart from CF's

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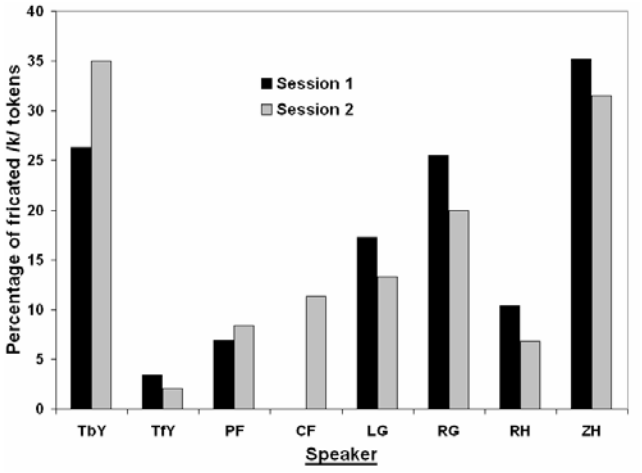

Figure 4: Percentage of the total number of /k/ tokens realised as [x] for individual speakers' separate recording sessions

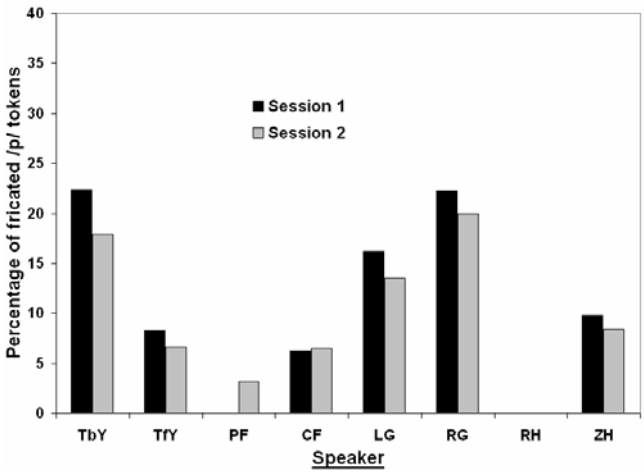

Figure 5: Percentage of the total number of /p/ tokens realised as [ϕ] for individual speakers' separate recording sessions

lack of [x] realisations in S1, the speaker fricating /k/ least often was TfY with 3% for S1 and 2% for S2.

Within twin-pairs, behaviours are quite different, especially for identical twins TbY and TfY. Taking into account both recording sessions, TbY realises /k/ as [x] in over 28% of cases, while TfY realises /k/ as [x] in less than 3% of cases. There is also a marked difference between the non-identical twins ZH and RH. ZH realises /k/ as [x] in over 33% of cases, while for RH the proportion is just under 9%. The performances of LG and RG are relatively similar, although RG fricated /k/ more often than LG (by approximately 7% in both recording sessions). The results for PF and CF do not appear as systematic as for the other twin pairs.

Binomial probability ($p = 0.05$) showed that four speakers fricated /k/ to a significant degree across both recording sessions: TbY (S1 $p \leq 0.001$, S2 $p \leq 0.001$), LG (S1 $p \leq 0.001$, S2 $p \leq 0.01$), RG (S1 $p \leq 0.001$, S2 $p \leq 0.01$) and ZH (S1 $p \leq 0.001$, S2 $p \leq 0.001$). Two speakers fricated /k/ to a significant degree in only one recording session: CF (S2 $p \leq 0.05$) and RH (S1 $p \leq 0.01$).

3.3.2. Speaker-specific results: frication of /p/

The graph in Figure 5 represents the same information as Figure 4, but for /p/. Again the patterns of frication are relatively consistent across a given speaker's two sessions, but differences between speakers are clearly evident.

As was the case for /k/, TbY and RG produced the largest proportions of fricated /p/ tokens in their respective two recording sessions. By contrast RH produced no fricated /p/ tokens at all in either S1 or S2. PF had no fricated tokens in S1, and 3% in S2; which is the result of only one [ϕ] token out of 32 observations of /p/ in S2.

Differing articulatory behaviours within twin pairs are also evident for the frication of /p/, though this is less marked than for /k/. TbY and TfY differ the most, followed by non-identical twins RH and ZH, as was also the case for /k/. LG and RG are again the pair exhibiting the most similar behaviour to each other, but again, RG has a greater number of fricated /p/ tokens than LG in both recording sessions. Low levels of frication are exhibited by PF and CF. As mentioned previously, PF produced only one [ϕ] token; similarly CF produced only one fricated token in S1, and two in S2.

Binomial probability ($p = 0.05$) shows that only three of the speakers fricate /p/ to a significant level, across both recording sessions. These were TbY (S1 $p \leq 0.001$, S2 $p \leq 0.01$), LG (S1 $p \leq 0.001$, S2 $p \leq 0.05$) and RG (S1 $p \leq 0.001$, S2 $p \leq 0.01$). While there appears to be relatively similar levels of frication across the recording sessions for both TfY and ZH, the levels of frication of /p/ for these two speakers are not statistically significant.

3.4. Speaker-specificity of frication across the class of voiceless plosives

The data from the present study offers some confirmation of Jessen's (2003) suggestion that lenition occurs across a class of sounds for individual speakers (see 1.3). Table 2 shows the ranking of each speaker from 1 (most frication) to 8 (least frication) for each of /k/ and /p/, using the proportions from Figures 4 and 5.

Each speaker's ranking for the degree of frication for /k/ is close to his ranking for /p/. That is, the speakers
who fricate /k/ the most also fricate /p/ the most; the shading in Table 2 shows this by categorising the speakers into two distinct groups. For a given speaker, a

Speaker	Rank /k/	Rank /p/
ZH	1	4
TbY	2	2
RG	3	1
LG	4	3
CF	5	6
RH	6	8
PF	7	7
TfY	8	5

Table 2: Ranking of speakers by level of frication

decrease in the frication for one consonant is accompanied by a decrease in frication for the other,indicating a relative consistency in the speakers' fricating behaviour for /k/ and /p/ within the class of the voiceless stops.

4. Conclusion

The analysis of the production of /k/ and /p/ in the spontaneous speech of eight speakers shows that frication of both consonants occurs to a significant extent in Australian English spoken in Melbourne. Considerable speaker-specific differences were observed in the frequency with which they fricated the consonants, and this variation tended to be systematic within the class of /k/ and /p/ for the individual speakers. Whether these patterns are also consistent for /t/ is a question for future research. The individual variation observed in this study reaffirms the assertion of Westbury, Hashi and Lindstrom (1998) that a detailed consideration of individual differences is of great importance in studies of speech processes.

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