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Aspects of non-native pronunciation in a case of altered accent following stroke (foreign accent syndrome)

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Abstract

Foreign accent syndrome (FAS) refers to a disorder that involves foreign sounding speech, usually following stroke. This paper presents a case study of an English patient allegedly speaking with a Scottish English accent after right-hemisphere stroke. The results of detailed impressionistic and acoustic analyses are reported, based on a direct comparison of the patient's pre-stroke and post-stroke speech samples. The emphasis is on a comparison of the typical features of Scottish English and phonetic features actually found in the patient's post-stroke speech. The respective roles of prosodic and segmental features in the post-stroke speech sample are also discussed. Rather untypically, prosodic features seem to be affected to a much lesser extent than segmental phonetic features in the patient's post-stroke speech. They are, therefore, less likely to contribute to the perception of a foreign accent.

Keywords: Foreign accent syndrome, adult acquired disorders, prosody, speech production, phonetics, accents.

Introduction

This paper presents a case study of a stroke-patient with foreign accent syndrome (FAS). FAS is a disorder that involves the production of speech that sounds foreign to native speakers. It is characterized by an inability to make the normal phonetic

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and phonological contrasts of one's native accent (Whitaker, 1982; Blumstein *et al.*, 1987; Gurd *et al.*, 1988). The number of cases published to date is small. Whether this reflects the true rarity of FAS, or the fact that FAS has largely escaped the attention of the research community, is an open question.

Majority of studies provide an impressionistic analysis of speech but only a few of them go beyond this by performing acoustic measurements (e.g. Blumstein *et al.*, 1987; Gurd *et al.*, 1988; Ingram *et al.,* 1992; Kurowski *et al.*, 1996). The present paper reports the results of detailed impressionistic and acoustic analyses conducted on an English FAS patient presenting with an allegedly Scottish English acquired accent. A unique opportunity to study changes in speech production before and after the stroke was provided by having the patient's pre-stroke speech sample available on tape and comparing it to a post-stroke recording of the same text. Although there have been some studies that compared speech before and after stroke (Graff-Radford *et al.*, 1986; Ingram *et al.,* 1992; Kurowski *et al.*, 1996), the pre-stroke samples in these studies usually involved spontaneous speech, thus preventing recording and analysis of the identical text after stroke. Comparison of segmental properties, such as vowel quality and quantity, when the segments occur in different linguistic contexts, is likely to bring in confounding factors. For example, it is well-known that the realization of vowels is affected by a number of factors, including the presence/absence of stress, the number of syllables in the word, and the word's position within a phrase (e.g. Klatt, 1976; van Santen, 1992). The nature of our material made it possible to compare the pre-stroke and post-stroke speech directly, and therefore to control for the effects of contextual factors.

The emphasis of this paper is on a comparison between the typical features of Scottish English and phonetic features actually found in our patient's post-stroke speech. We consider how these may or may not contribute to the impression of a Scottish accent. We also consider the respective roles of prosodic and segmental features in the post-stroke speech sample, and discuss possible physiological explanations for how they differ from the patient's pre-stroke speech. Finally we discuss the results of our analysis in relation to the findings published in previous studies of FAS.

The first systematic report on FAS was published by Pick (1919). It describes a case of a Czech male who appeared to speak with a Polish accent following a stroke. A more extensive description of FAS was provided by Monrad-Krohn (1947) and involves the case of a Norwegian woman who acquired German-sounding accent. Later studies include a variety of other language combinations. For example, Gurd *et al.* (1988) illustrate a case of an English patient whose accent was described by lay-listeners as French. Ardila *et al.* (1988) documented the case of a Spanish man who spoke with an English accent after stroke. A number of other studies involved American English speakers. For example, Graff-Radford *et al.* (1986) described a patient whose accent was Nordic. The patient in Blumstein *et al.*'s study (1987) was perceived as having an eastern/western European accent, and the patient of Kurowski *et al.* (1996) as having a Scottish, Irish, or an eastern European accent. Some of this variability must accordingly be in 'the ear of the beholder'.

One of the most important, and at the same time puzzling aspects of FAS is that it seems to be phenomenologically different from other speech disorders, particularly from the segmental and prosodic impairments that typically accompany Broca's aphasia (e.g. Ryalls, 1981; Danly and Shapiro, 1982; Ingram *et al.*, 1992), and from pure disorders of prosody (e.g. Ross, 1981; Weintraub *et al.*, 1981). Why the speech of FAS patients is perceived as being 'foreign' rather than impaired has yet to be explained. It has been suggested that FAS speech has to be reasonably fluent, i.e. without the articulatory dysfluencies found in, for example, Broca's aphasia. It should also be comprehensible and possess phonetic realizations and processes that are linguistically possible, i.e. attested in at least some of the world's languages (Blumstein *et al.*, 1987). It has been suggested that slight agrammatisms may actually contribute to the impression of a foreign accent (Ardila *et al.*, 1988).

Three main issues arise with respect to FAS: (i) Do all the known FAS cases involve similar neurological damage? (ii) Does the speech of different FAS patients invariably involve the same set of phonetic features? (iii) If so, could these features be explained by a common underlying physiological, or articulatory mechanism? If this is the case, it is possible that FAS arises as an unusual form of compensation for, or adaptation to, a voice or speech problem rather than being a direct manifestation of the brain damage itself (Kurowski *et al.*, 1996).

With respect to lesion sites, all but one FAS case described thus far in the literature involved left-hemisphere damage. (The exception is a study by Miller and O'Sullivan (1997), whose patient presented with right-hemisphere damage.) However, within the left hemisphere there does not seem to be a single lesion site that is reliably associated with FAS. Kurowski *et al.* (1996) observed that most commonly the damage affected either prerolandic motor cortex (BA 4), frontal motor association cortex (BA 6 or 44), or striatum (i.e. lesions typically implicated in Broca's aphasia).

A rather confusing picture also arises when considering whether in FAS the same set of phonetic features is typically affected (possibly in different directions across patients—with consequently different accents resulting). Does it involve changes in vowel quality or quantity, place or manner of articulation in consonants, or in prosodic features? Monrad-Krohn (1947) suggested that the factor primarily responsible for the perceived 'foreignness' of his patient's speech was 'dysprosody' (the term Monrad-Krohn used for altered prosody). Abnormal prosody (i.e. abnormal with respect to the native language accent in question), particularly stress, intonation and rhythm, has been mentioned in most studies published thus far and, in fact, prosody seems to have become the aspect of speech most typically associated with FAS (Hawkes, 1997; but cf. Gurd *et al.*, 1988 *per contra*). With respect to intonation, rising pitch in phrase final position has been reportedly observed in contexts where a fall would be expected in the patient's original accent (Monrad-Krohn, 1947; Blumstein *et al.*, 1987). Rhythm may also be affected in various ways. Firstly, some (English) subjects showed a tendency towards syllable-timing. As Dauer (1983) pointed out, syllable-timing may manifest itself in a number of ways; this variety is reflected in FAS reports. Some have found a tendency towards more equal syllable durations (Blumstein *et al.*, 1987), some towards non-reduction of unstressed vowels (Whitaker, 1982; Blumstein *et al.*, 1987) and/or towards the occurrence of epenthetic vowels (Blumstein *et al.*, 1987; Ardila *et al.,* 1988; Ingram *et al.*, 1992). Secondly, an occasional misplacement of lexical stress (Monrad-Krohn, 1947; Moen, 1996), reduced intensity for stress (Blumstein *et al.*, 1987; Ingram *et al.*, 1992) and staccato speech rhythm (e.g. Ingram *et al.*, 1992) may contribute to the impression of syllable-timing. In a further analysis of Monrad-Krohn's case, Moen (1996) pointed out that the loss of the distinction between the two Norwegian pitch accents, while retaining stress-timed rhythm, could lead to prosodic patterns resembling those found in (West) Germanic languages. The resemblance may be strengthened by the close phonetic similarity between many consonants and vowels in Norwegian and German.

Prosody is by no means the only aspect of speech held responsible for FAS. A number of segmental features have also been discussed in the literature. Generally, vowels appear to be affected more often than consonants. In a number of cases, vowels became more tense after stroke—they shifted to a more peripheral position in the vowel space (Graff-Radford *et al.*, 1986; Blumstein *et al.*, 1987) and strengthened in terms of increased diphthongization (Graff-Radford *et al.*, 1986; Ardila *et al.*, 1988). Other studies report the opposite tendency—laxing of vowels, centralization and weakening in terms of monophthongization of diphthongs (Whitaker, 1982; Kurowski *et al.*, 1996). Vowel shortening (Pick, 1919; Ingram *et al.*, 1992) but also lengthening (Graff-Radford *et al.*, 1986) have been observed as well.

For consonants, selective 'strengthening'[1] has been found in some cases (e.g. Ingram *et al.*, 1992). This is in contrast with many dysarthrias in which slurring and weakening of consonantal gestures consistent with articulatory undershoot are found (Barlow *et al.*, 1998). Associated with consonantal strengthening, a reduced incidence of expected lenition processes has also been observed. For instance, failure of alveolar stops to weaken to flaps in intervocalic environments was found in American English (Blumstein *et al.*, 1987; Kurowski *et al.*, 1996). In FAS, undershoot of consonant targets seems to be rare though there are some reports. For example, in the case of an English patient speaking with a French accent, Gurd *et al.* (1988) found that the targets for /w/ often failed to be achieved, resulting in the effect of a labial approximant [ʋ], and /r/ was either weak, failing to reach the apical target, or was not realized at all. Gurd *et al.* suggest that both mistakes are common in foreigners speaking English. Voicing errors were occasionally reported, such as regressive voicing assimilation, devoicing of word-final plosives (Blumstein *et al.*, 1987; Gurd *et al.*, 1988; Ingram *et al.*, 1992) or unusually long pre-voicing in voiced stops, leading to the impression of a central vowel preceding the stop release and thus contributing to the syllable-timed quality of the patient's speech (Blumstein *et al.*, 1987; Kurowski *et al.*, 1996). Finally, changes in place of articulation (Ardila *et al.*, 1988) have also been observed.

The above summary indicates that the range of phonetic features in FAS is relatively wide, and it is certainly not the case that these features would be found in every FAS patient. In terms of perceptual impressions, the studies on FAS often mention the fact that when listeners are asked what accent they think is involved, the responses are far from consistent. Furthermore, the range of languages can be rather wide, as is apparent from the studies mentioned above. It has also been noted that the patient's speech often lacks some of the most typical features of the actual foreign accent in question (e.g. Blumstein *et al.*, 1987; Ardila *et al.*, 1988). Thus, Blumstein *et al.* (1987) suggest that FAS is characterized by a 'generic' foreign accent rather than by any particular foreign accent. They claim (p. 243) that listeners categorize the patient's speech 'on the basis of stereotypical features which are part of the universal properties found in natural language'.

The third issue concerns whether the phonetic manifestation of FAS could be explained by a common underlying physiological mechanism. Graff-Radford *et al.* (1986) and Ingram *et al.* (1992) suggested a 'tense speech posture', arising from increased muscle tone and/or altered long-term vocal tract postural setting during speech production. Blumstein *et al.* (1987), on the other hand, claim that both segmental and prosodic effects in their patient may be explained by a general prosodic disturbance—disturbance of speech timing. This is presumably also meant to reflect a problem at the level of actual articulation, not at some higher level, though this is not entirely clear. In any case, the evidence seems to argue against a single underlying physiological mechanism—not only does there not seem to be a common set of features associated with FAS, as the summary above illustrates, but conflicting errors have been found within the speech of the same speaker (Gurd *et al.*, 1988; Ingram *et al.*, 1992). An alternative to the explanations in terms of a disturbance of the articulatory mechanism was described by Moen (2000). In this explanation, FAS is regarded as a problem with the mechanism of higher-order *control* of speech motor behaviour, as a mild form or sub-type of apraxia of speech. As yet there is no consistent evidence which clearly supports any of the three explanations. A full explanation of FAS is still awaited.

Case report

The subject of the investigation was a right-handed female Southern British English speaker who prior to suffering a cerebrovascular accident (CVA) was working as a television producer and presenter. At the time of the CVA she was 43 years of age. A CT scan revealed a sub-arachnoid haemorrhage (with evidence of bleeding around the basal system and right Sylvian fissure) and a large terminal carotid aneurysm. After neurosurgery, in which the aneurysm was clipped, she suffered an extensive infarct in the territory of the right middle cerebral artery, following which she developed a left hemiplegia.

While still in the district hospital (three weeks post-onset), the patient was seen by a speech and language therapist, who reported mild dysarthria, the use of lengthy, convoluted sentences (half of which were apparently unintelligible) and some pragmatic difficulties. These included overly rapid speech and lack of self-monitoring. Some of the patient's responses were apparently in French. Formal assessment at this stage involved using the Mount Wilga High Level Language Assessment (unpublished), as the Shortened Minnesota Test for Differential Diagnosis of Aphasia (Shuell, 1965; Thompson and Enderby, 1979) appeared too easy. All parts of the test, except for absurdities, sentence construction and inferential paragraphs, proved unproblematic.

While recovering from her stroke, the patient developed an unusual feature in her speech—she seemed to her friends, relatives and the speech therapist to be speaking with a Scottish accent. She was very concerned about her accent and was keen to return to her original Southern British accent. She listened to tapes of her premorbid speech and tried to copy her 'old voice'. However, as reported by the therapist 5 months post-onset, her speech became slightly slurred and less fluent when she consciously attempted to change her Scottish accent. In contrast, she talked rapidly and fluently in conversation, albeit using a Scottish-sounding accent. At this stage of her recovery, the patient still presented with some subtle pragmatic difficulties, including poor maintenance of eye contact in conversation and poor topic maintenance in conversation. However, there were no other apparent difficulties with her expressive language skills. The patient was able to mark stress patterns, use rising and falling intonation patterns on a single vowel or on a word, and to imitate different intonation patterns to convey emotion. However, in spontaneous speech she often used rising intonation in statements, which was perceived by the therapist as conforming to a Scottish accent. Eight months post-onset, after a period of oral-motor exercises focusing on precision and rate of articulation, her slurring gradually became less frequent and the Scottish accent less stable.

Sixteen months post-onset the patient was seen by a neuropsychologist, who conducted a number of tests on memory, language and speech. The results were as follows:

(Wechsler memory scale—revised WMS-R, 1987)

- Working memory: digit span forward = 8 (above average)
  digit span backwards = 6 (normal)
- Memory: Paragraph recall—immediate = 12 (normal)
  delayed = 9 (normal)

(Coughlin and Warrington, 1978)

- Word finding: Naming to definition 30/30

(Gurd and Ward, 1989)

- Verbal fluency (word/minute):
  - animals = 20 (above average)
  - furniture = 24 (above average)
  - S-words = 23 (above average)
  - A-words = 21 (above average)
  - alternating between animals and furniture = 27 (above average)
  - alternating between S-words and A-words = 15 (normal)

(Boston Diagnostic Aphasia Examination, 1983)

- Oral agility—nonverbal 4/12 (impaired)
  —verbal 14/14 (normal)

Apart from nonverbal oral agility test, in which our patient was clearly impaired, the scores of the above tests are normal or above average. The reason why the patient failed the nonverbal oral agility test is beyond the scope of this paper. However, nonverbal oral dyspraxia has been cited as a cause of patients' difficulty in copying nonverbal activities (Miller, 1986).

Twenty months post-onset, another speech and language therapist reported that the features she hypothesized as possible contributors to the perceived 'Scottishness' of the patient's accent were still present, particularly, rhythm, stress, and non-English intonation manifesting itself by most statements ending with an upward inflection. Increased lip-rounding of some vowels and lengthening and raising of short high vowels /i/ and /ɪ/ were noted as well. These observations were based on free conversation, responses in controlled conversations, and listen-and-repeat exercises.

Judging from the speech therapists' reports, no formal assessment of right-hemisphere language processing was conducted. However, some of the aspects of the patient's speech and language production described in the therapists' observations are traditionally attributed to the right hemisphere, and so to some extent we can infer possible effects of right-hemisphere damage (Tompkins, 1995). In particular we mentioned several pragmatic difficulties. However, another aspect of processing usually associated with the right hemisphere, the use of affective prosody, appeared normal.

Material

The speech material that was analysed for the present paper consisted of matched samples of the patient's pre-stroke and post-stroke speech. The pre-stroke recording was a television news report (i.e. prepared speech), a passage of 125 words which she had recorded 4 years prior to the stroke. The post-stroke sample consisted of reading out the same television report. This enabled us to directly evaluate the extent and nature of the alteration of her accent. The original, pre-stroke recording was supplied to us on a VHS video cassette. The audio track was transferred to digital audiotape in order to facilitate downloading to computer disk for acoustic analysis, though the audio quality of the original recording was not especially high fidelity. The post-stroke recording of the television news report was made in an acoustically insulated booth in the Oxford University Phonetics Laboratory, 27 months after the patient's CVA. All speech samples were digitized with a sampling rate of 16 kHz, and 16 bit quantization.

Analysis and results

Two kinds of analysis were performed. First, impressionistic observations were made independently by two groups of professional phoneticians. One group (consisting of three phoneticians) focused on differences between pre-stroke and post-stroke pronunciation, while the other group (two phoneticians), who had additional expertise in Scottish dialect pronunciation, were asked to identify aspects of the patient's post-stroke pronunciation which could be characteristic of Scottish English and which might lead listeners to judge her speech as sounding Scottish. This latter group was also asked to adjudicate as to whether the Scottish features of the patient's pronunciation were characteristic of a specific Scottish dialect or register, and whether it appeared consistent and convincing to Scottish listeners. These phoneticians were not supplied with recordings of pre-stroke speech. They assessed the post-stroke speech sample independently of each other. None of the five phoneticians had specific expertise in speech and language therapy. For the second part of the analysis, a number of acoustic measurements were made of properties of interest identified in the previous auditory analysis.

Impressionistic analysis

Informal overall impression of the accent

Based on their first impressions, the phoneticians regarded the patient's speech as like that of an educated Scottish person, rather than a broad dialect speaker from any particular region. One phonetician did not share the initial impression of his colleagues; he felt that the accent was not really Scottish, though it involved a number of features of a Scottish accent. For the other phoneticians, the impression of a Scottish accent diminished with closer auditory analysis.

As mentioned above, listeners often disagree about the kind of accent manifested by the same FAS patient (e.g. Kurowski *et al.*, 1996). Moreover, Ardila *et al.* (1988) claim that native speakers of the language in question do not recognize the FAS accent as being like their own. As none of the phoneticians used here are Scottish speakers themselves, an informal test involving four native Scottish speakers/listeners was therefore carried out. Three of them were phonetically naïve listeners, and one was a language and speech therapist. These listeners were asked to judge whether the speaker's accent could be Scottish. The therapist categorically rejected the speech sample as sounding 'Scottish'. However, the answer of the other three listeners was positive. One judged the speaker as having a Scottish accent, although not from any identifiable region of Scotland. Her speech reminded him of speech used by Scottish broadcasters and of one female broadcaster in particular. Another of the three listeners also had an impression of Scottish English, while to the third listener the speaker sounded either like a foreigner speaking English with some Scottish English features or like someone who used to live in Scotland.

Further perceptual testing was conducted with 43 undergraduate students reading for a degree in Speech Sciences at University College London to become speech and language therapists. The students (of mixed nationalities but with the majority being native speakers of English) were simply asked to guess the accent of the speaker on the recording, and they were not given any indication that the accent had been 'identified' as Scottish by other listeners before. All the 43 students agreed that the accent sounded Scottish to them. None of them suggested any other accent.

Detailed impressionistic phonetic analysis

Although the two groups of phoneticians worked independently, their judgements, based on a detailed impressionistic analysis, were largely consistent. There were rare points of disagreement, which will be pointed out below, but otherwise their impressions will not be further differentiated.

The post-stroke speech was judged as fluent, with no apparent abnormal features. The first concern in the impressionistic analysis was prosody, since most cases reported in the literature suggested that dysprosody was present as a main underlying factor contributing to the impression of a foreign accent. Moreover, as mentioned in the case report, a speech and language therapist assessing the patient's post-stroke speech also reported dysprosody (in spontaneous speech). The analysis revealed the following results. Regarding intonation, the phoneticians arrived at different conclusions. One claimed that the intonation in the patient's post-stroke speech sounded neither English nor typically Scottish. However, it was still felt that it resembled Scottish more than anything else, and, in particular, was reminiscent of intonation patterns used by Scottish broadcasters. The conclusion of the other phoneticians was that the post-stroke intonation was not Scottish at all, rather English, though not typically English; to one of them it sounded unnatural. In several places a noticeably higher pitch in post-stroke speech was observed. The disagreement among the phoneticians about the 'Scottishness' of the patient's intonation may not be that surprising given the following facts. The impressionistic analysis of intonation focused on phrase-final pitch movement, as Scottish English is commonly assumed to have rising pitch in statements (Glasgow) or relatively little pitch movement (Edinburgh), while standard English would have falling pitch in statements (Brown *et al.*, 1980). However, phrase-final pitch movement has, in fact, been found to be variable in Scottish accents (Chirrey, 1999), with low nucleus and final rise prevailing in West Scotland, and fall in East Scotland (J. Stuart-Smith, personal communication). The differences in the phoneticians' opinion may to some extent reflect this variability.

Rhythm sounded neither typically English nor Scottish but it was not possible to judge what caused the accent to sound rhythmically un-English.

In summary, although the patient's prosody did not sound like that of Southern British English, it did not sound clearly Scottish either. Thus the hypothesis that prosody was the major factor responsible for the impression of a Scottish accent in our speech sample seemed, on the face of things, unlikely. However, there seemed to be a number of segmental differences between the patient's pre-stroke and post-stroke speech, some of which seemed likely causes of the impression that her accent was Scottish.

In the list below, the main segmental characteristics which were different in the patient's pre-stroke and post-stroke speech are reported, with special regard to features typically occurring in Scottish English (as reported, for example, in Wells, 1982; Chirrey, 1999; Scobbie *et al.*, 1999 and Stuart-Smith, 1999).

(a) In a number of cases the Southern British English diphthongs /eɪ/ and /əʊ/ seemed to be produced with a more monophthongal pronunciation. This could be responsible for the impression of a Scottish accent (in Northern English and Scottish English, /eɪ/ and /əʊ/ are pronounced as /e/ and /o/). In the case of /əʊ/ this might partly be due to increased lip-rounding throughout the diphthong. In some cases, these two diphthongs appeared shortened only, with the first part of the diphthong involving closer articulation in the post-stroke speech than in the pre-stroke sample.

(b) In some cases the back vowel /ɔ/ sounded more closed and shorter in the post-stroke speech, thus perhaps contributing to the impression of a Scottish accent. The patient maintained the distinction between /ɒ/ and /ɔ/. However, a Scottish speaker would have only /ɔ/.

(c) Similarly, the patient retained the distinction between /ɑ/ and /æ/, although in Scottish English only /a/ would typically occur. In a few cases, however, /ɑ/ was shorter, more raised and somewhat fronter in her post-stroke speech.

(d) The distinction between /ʊ/ and /u/ was also preserved in the post-stroke sample although only one (fronted) high back vowel would be expected in Scottish English. Fronter pronunciation of both vowels might contribute to the overall 'Scottish impression'.

(e) The patient's post-stroke vowel /i/ sounded more fronted and /ʌ/ more raised than their pre-stroke counterparts. However, these would not necessarily make her speech sound Scottish.

(f) In some instances, where /r/ following a vowel would be expected in Scottish English but not in Southern British English, the impression of some degree of tongue-tip raising was discernible in the patient's post-stroke speech. However, the impression of an actually articulated [r] being present diminished after a closer auditory analysis.

(g) In the patient's post-stroke speech occasional dark [ɫ] was found where clear [l] occurred before. This commonly occurs in Scottish English though variation exists depending on geographical region (Wells, 1982). However, the realisation of /l/ was not systematic; the opposite trend, i.e. clear [l] occurring where dark [ɫ] was expected, was also found.

(h) Aspiration of syllable-initial plosives /p/, /t/, /k/ seemed rather reduced in all cases, although it was judged not to be sufficiently minimal to sound genuinely Scottish.
(i) Coronal consonants (e.g. /s/, /t/) appeared in some cases fronted, which is consistent with Scottish English (Stuart-Smith, 1999).

Two aspects of segmental production traditionally regarded as typical Scottish pronunciation were not observed at all in the patient's post-stroke speech. The first was the Scottish realisation of inter-vocalic /r/ as a tap. However, the patient's articulation of inter-vocalic /r/ did not sound as if she produced a typical standard English post-alveolar approximant [ɹ] either. In some cases the /r/ sounded retroflex. This, in fact, may have contributed to the accent sounding Scottish, since a retroflex approximant is also an attested realization of /r/ in Scottish English (Stuart-Smith, 1999).

The second case was the pronunciation of /w/ in words such as *what* or *which*, which could traditionally be expected in Scottish speakers as /ʍ/. The patient maintained her English /w/. It should be pointed out that both the pronunciation of /r/ and /w/ has recently been reported to vary widely across Scottish accents (e.g. Chirrey, 1999; Stuart-Smith, 1999), with /w/ being a possible realization (Lawson and Stuart-Smith 1999). The production of /r/ and /w/ in our patient's post-stroke speech may not be what many listeners would traditionally consider as Scottish, but it seems to be within the range of variation actually found among Scottish dialects, though it may be at the edge of the distribution.

Voice quality in pre-stroke and post-stroke speech was compared. Somewhat higher pitch overall was found in the patient's post-stroke speech and creaky voice occurred much more frequently post-stroke.

Acoustic analysis

Procedure

The instrumental analysis involved acoustic measurements of a number of features identified in the auditory analysis as different in the patient's pre- and post-stroke speech. These were vowel quality and duration, and aspiration of syllable-initial plosives. Analyses of intonation, articulation rate variation, and pause duration and frequency were also carried out.

The analysis was conducted using Entropics Waves+ speech analysis software. In order to make measurements of the duration of vowels and aspiration as accurate as possible, a combination of impressionistic listening and reference to waveform displays and wideband spectrograms was used. Formant frequencies F1 and F2 were measured using 30 ms 18 pole BURG spectra. In monophthongs the formant frequencies were measured at the mid-point of the vowel. In diphthongs the formant frequencies were measured at 25% and 75% points of the total diphthong duration.

Results

Vowel quality

In both pre-stroke and post-stroke samples the frequencies of the first, second and third formants were measured for nine monophthongs (/i/, /ɪ/, /ɛ/, /æ/, /ɑ/, /ʌ/, /ɔ/,

/ɒ/, /ʊ/) and four diphthongs (/aɪ/, /ɔɪ/, /əʊ/, /ɪə/). The picture of the patient's vowel space is nearly complete for monophthongs; the only missing monophthong is /u/. This vowel occurred only once and only in the post-stroke speech sample (due to a misreading of the text). Since no comparison was possible with the pre-stroke version for this vowel, it was not included in the analysis.

In this analysis only vowels in stressed syllables were examined to avoid confounding effects of variable stress placement. Table 1 below shows the number of tokens measured per vowel.

The analysis focused on the first two formants since these are the principal indicators of vowel quality. Figure 1 shows the patient's vowel space for monophthongs in her pre-stroke speech (filled circles) and in her post-stroke speech (empty circles). For each vowel, the mean formant frequency for F1 is plotted against the mean frequency for F2 (in the case of /ɒ/ there was only one observation available). The lines show the perimeter of the vowel space; /ɪ/ and /ʌ/ are regarded here as being within the perimeter.

Table 1. *Number of tokens measured per vowel*

Vowel	Number of tokens
/i/	3
/ɪ/	4
/ɛ/	5
/æ/	4
/ɑ/	3
/ʌ/	7
/ɔ/	5
/ɒ/	1
/ʊ/	2
/aɪ/	4
/eɪ/	4
/əʊ/	7
/ɪə/	3

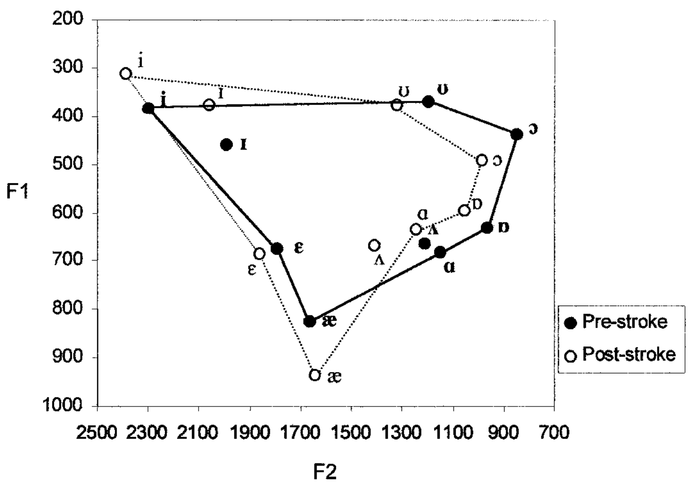

Figure 1. *The speaker's vowel space before and after stroke.*

Figure 1 shows that the average position of all vowels within the vowel space differs after the stroke versus before the stroke—reflecting somewhat different articulatory patterns underlying production of the vowels. However, articulatory patterns within the same speaker are known to vary to some extent (Labov, 1991, 1994), and thus the after-stroke production may be within the patient's pre-stroke range. It is therefore important to examine the consistency in the realization of tokens for each vowel, not only the extent of variation (as mentioned above, the points in figure 1 are based on mean values).

We found that with respect to F2 the tokens within each monophthong were highly consistent. However, with respect to F1 three out of nine vowels (/ɑ/, /ʌ/ and /ɔ/) involved a rather large degree of variation, reflecting an inconsistent post-stroke change across tokens. Note that all three vowels are back vowels.

The examination of F1 showed that there was no consistent shift across different vowels for this formant. The front close vowels /i/ and /ɪ/ and the one token of /ɒ/ had a lower F1 in post-stroke speech, indicating an articulation in which, most likely, the tongue was more raised in the mouth in comparison with pre-stroke speech. The opposite is, however, true of /æ/. Vowels /ʊ/ and /ɛ/ were probably produced with the same degree of opening after stroke as before, as F1 changed only slightly. Regarding F2 the data showed that all vowels (with the exception of /æ/) were produced in a fronter position after the stroke than before, as indicated by higher values for F2. Generally, the acoustic analysis of monophthongs confirmed the observations made in the impressionistic analysis.

A statistical analysis, involving a two-way analysis of variance, was conducted separately for F1 and F2. The factors were 'condition' (pre-stroke vs. post-stroke) and 'vowel'. It was predicted that 'condition' would be non-significant for F1, since the vowels did not shift in the same direction. This was confirmed; only 'vowel' was a significant factor.[2] On the other hand, the analysis of F2 showed a significant effect of both 'condition' [$F\,(1{,}58) = 6.2$, $p = 0.016$] and 'vowel' [$F\,(8{,}58) = 56.7$, $p < 0.001$]. Thus the tendency for F2 to increase in post-stroke speech was confirmed. The fact that the interaction 'condition' × 'vowel' was non-significant confirms that this tendency was consistent across different vowels.

In order to evaluate whether the changes in the patient's formant frequencies would be noticeable for the listener, the changes were compared for 'just noticeable differences' (Weber fractions) in formant frequencies. Weber fractions for formant frequencies have been determined in perceptual experiments (for a survey, see Rosner and Pickering, 1994). The relevant Weber fraction is defined as $(F - F_R)/F_R$, where F_R is the reference frequency, and F is the closest frequency to F_R which is perceptible. Previous studies have determined a Weber fraction of 0.03 for formant frequencies (Rosner and Pickering, 1994).

In our study, the differences between pre- and post-stroke formant frequencies, averaged across tokens, were calculated using the above formula. The pre-stroke value was the reference. Values which are greater than the reported value of 0.03 for the Weber fraction indicate changes in formant frequencies perceptible to the listener. The analysis was carried out separately for F1 and F2. However, in the case of F1 only those vowels were included in the calculation whose tokens behaved consistently. Table 2 presents the results.

The results in table 2 suggest that for all vowels (with the exception of /æ/) the increase in F2 would be perceptible to the listener. However, for the front vowels the effect seems weaker than for the back vowels. Regarding F1, the only vowels

Table 2. *Fractions for F1 and F2 (monophthongs)*

Vowel	F1	F2
/i/	0.183*	0.040*
/ɪ/	0.180*	0.032*
/ɛ/	0.012	0.038*
/æ/	0.134*	0.014
/ɑ/		0.079*
/ʌ/		0.161*
/ɔ/		0.166*
/ɒ/	0.057*	0.088*
/ʊ/	0.012	0.102*

* Perceptible differences between pre-stroke and post-stroke formant frequencies.

which did not show a perceptible change were /ʊ/ and /ɛ/. This is not surprising, as these vowels were noted earlier as changing only slightly after the patient's stroke.

Figure 2 shows formant frequencies for diphthongs. For each diphthong, both F1 and F2 were measured separately for the peak and 'offglide'; these are connected by arrows in the figure. Filled symbols again represent the pre-stroke condition, empty symbols the post-stroke condition. All symbols show mean values. Closer examination of the data showed a high degree of consistency across tokens within each diphthong and thus the mean values can be considered a good representation of the data.

In general, the results confirmed the auditory impressions. All diphthongs examined, apart from /əʊ/, seem to be somewhat more fronted in the patient's post-stroke speech than in her pre-stroke speech (F2 increased in both peaks and offglides). However, ANOVA revealed that the shift was not statistically significant ($p > 0.05$). Her /eɪ/ and /ɪə/ were at the same time closer in the post-stroke version (F1 decreased in both peaks and offglides). The peak and offglide in the diphthong

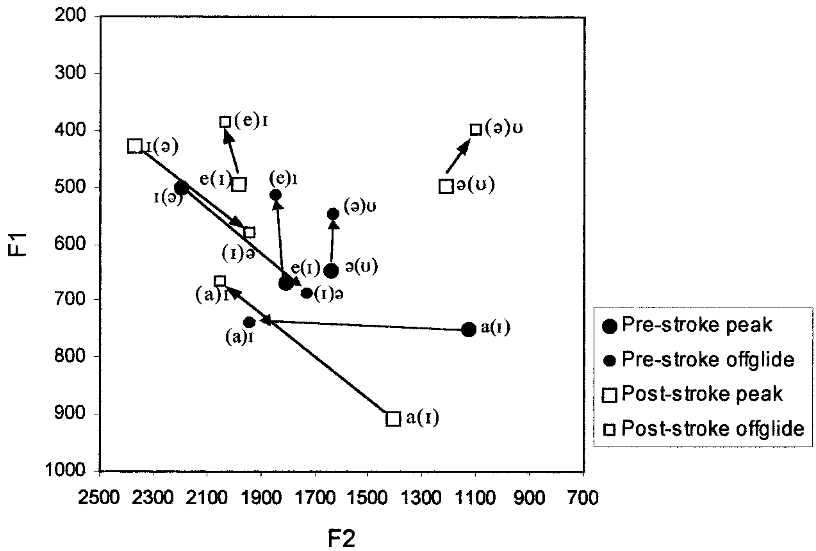

Figure 2. *Formant frequencies (F1 and F2) for diphthongs.*

/aɪ/ became more different in terms of degree of opening. In fact the peak of this diphthong became more open in post-stroke speech than in pre-stroke speech, thus drawing a parallel with monophthongs. The diphthong /əʊ/ seemed to be produced more raised and backer as a whole after the stroke, which is consistent with the auditory impression of greater backness, closeness and rounding. Overall, the examination of figure 2 suggests that the vowel space for diphthongs became more peripheral after the stroke. The ANOVA revealed that the shift in F1 was statistically significant for both the peak and offglide. In the case of F1 peak, 'condition' and 'vowel' were significant ([F (1,28) = 4.7, p = 0.039] and [F (3,28) = 30.4, p < 0.001] respectively) but also the interaction 'condition' × 'vowel' [F (3,28) = 8.3, p < 0.001], reflecting a different behaviour of the peak in /aɪ/ from the peaks in other diphthongs. Regarding F1 offglide, 'condition' [F (1,28) = 12.8, p = 0.001] and 'vowel' [F (3,28) = 13.3, p < 0.001] were significant. The decrease in F1 was consistent across the diphthongs.

The auditory analysis also suggested that the patient produced diphthongs /eɪ/ and /əʊ/ with a more monophthongal pronunciation post-stroke than pre-stroke, and that this might be in part the reason why these two diphthongs sounded more different between the two speech samples, compared to the others. However, data in figure 2 fail to support the auditory impression of monophthongization. The distance between the formants of peaks and offglides for these two diphthongs is comparable in the patient's pre-stroke and post-stroke speech.

The perceptibility of differences between pre-stroke and post-stroke formant frequencies was evaluated by comparison to the value of 0.03 for the Weber fraction, as for monophthongs. The evaluation was carried out both for peaks and offglides of diphthongs. The results are presented in table 3.

For all four diphthongs, the differences between pre-stroke and post-stroke formant frequencies are above the threshold for perceptibility. This applies to both the peak and the offglide. In the majority of cases, the fractions are considerably greater than the Weber fraction for formant frequencies, and, on average, they are greater than the values found for monophthongs. This indicates that formant frequencies in the patient's post-stroke speech have changed even more in diphthongs than in monophthongs.

It is obvious from table 1 that the number of tokens per vowel was uneven and rather small. Therefore, before any strong conclusions can be made about the change in the patient's production of vowels, more data would be needed.

Vowel duration

Vowel duration was measured in stressed and unstressed syllables of disyllabic words, and in (stressed) monosyllables. Vowel duration is expressed as a percentage of the

Table 3. *Fractions for F1 and F2 in peaks and offglides of (diphthongs)*

Vowel	F1 peak	F1 offglide	F2 peak	F2 offglide
/aɪ/	0.214*	0.097*	0.247*	0.057*
/eɪ/	0.259*	0.245*	0.097*	0.103*
/əʊ/	0.229*	0.268*	0.262*	0.327*
/ɪə/	0.145*	0.153*	0.078*	0.124*

* Perceptible differences between pre-stroke and post-stroke formant frequencies.

total word duration in order to compensate for possible differences in word duration between pre-stroke and post-stroke versions.

The results for disyllables are presented in figure 3a (stressed vowels, 17 tokens) and 3b (unstressed vowels, 15 tokens as two syllabic [ɫ] were excluded), and monosyllables in figure 4 (14 tokens). Pre-stroke vowel durations are plotted on the x-axis and post-stroke ones on the y-axis. Each data point represents a single pre-stroke token compared with the corresponding post-stroke token. Thus all vowels which are plotted below the diagonal have shorter durations in post-stroke speech than in pre-stroke speech. Paired tokens which differed in terms of the presence/absence of a following intonation phrase boundary were excluded from the analysis to avoid confounding effects of phrase-final lengthening.

Figures 3a and 3b show that in disyllabic words vowel durations tended to be shorter in post-stroke speech than in pre-stroke speech. This tendency is especially

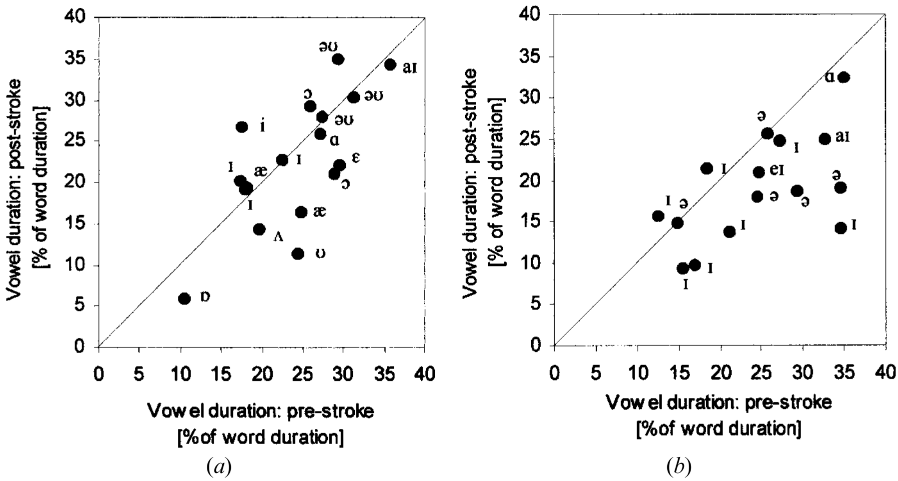

Figure 3. *(a) Duration of stressed vowels before and after stroke (disyllables). (b) Duration of unstressed vowels before and after stroke (disyllables).*

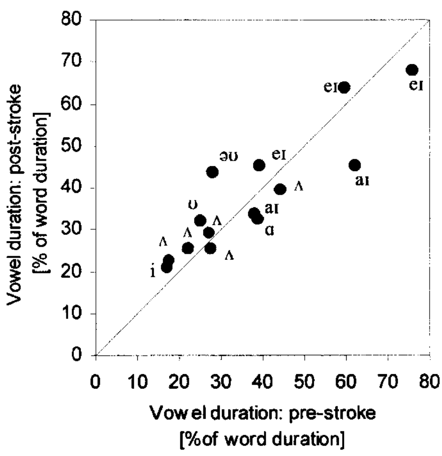

Figure 4. *Duration of stressed vowels before and after stroke (monosyllables).*

noticeable for vowels in unstressed positions. Vowels in stressed positions tended to be either shorter than, or of a similar duration to, those in the pre-stroke version. However, there was no consistent shortening of vowels in monosyllabic words. A statistical analysis (ANOVA) was carried out to test these observations. With regard to stressed vowels in disyllabic words, the tendency to shorten duration was in fact found, but the difference was too small to reach significance. On the other hand, shortening of unstressed vowels was highly significant [F (1,25) = 12.7, p = 0.002]. In monosyllabic words, the changes to vowel duration following stroke were not significant.

There are two possible explanations for the finding that vowels took up a smaller proportion of word durations in post-stroke speech than in pre-stroke speech. First, word durations may have simply shortened. It has been shown that in faster production, vowel duration is normally compressed proportionally more than consonant duration (Gay, 1981). Second, the word durations stayed the same but consonants lengthened. This would indicate some abnormal process taking place. In order to find out which of the two explanations holds for our data, word durations were examined.

The analysis showed that although on average the word duration did shorten (the pre-stroke mean word duration was 372 ms, SD 87 ms; post-stroke 318 ms, SD 70 ms), the change was not statistically significant, though very close to significance; [F (1,17) = 4.0, p = 0.054]. The finding of a proportional reduction in vowel duration in the context of faster rate predicts that consonant duration proportionally lengthened. The next step in the analysis confirmed this.

In this analysis, the time spent on articulation of consonants within each disyllabic word was compared across pre-stroke versus post-stroke conditions. Articulation time of all consonants within a word ('consonant duration') was calculated by deducting the time spent on articulation of both vowels from the total duration of the word. Figure 5 shows the results.

There is a clear tendency for consonants to take a larger proportion of the word duration in post-stroke speech than in pre-stroke speech. This effect was statistically significant [F (1,32) = 5.1, p = 0.031].

The results on proportional durations described above do not necessarily indicate anything abnormal. However, given that the perceptual impressions of the patient's

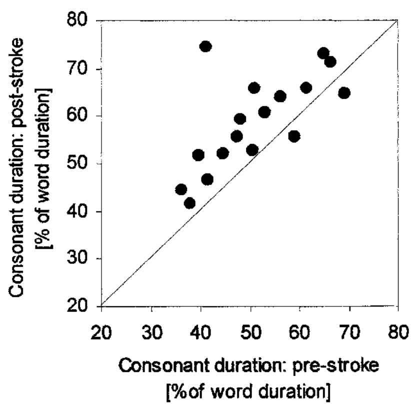

Figure 5. *Time spent on articulation of consonants in disyllables.*

post-stroke speech suggested some kind of change in speech rhythm, we also checked whether consonant durations lengthened in absolute terms. This would imply abnormal production. We found that overall, the absolute duration of consonants did indeed increase (the pre-stroke mean time spent in articulation of consonants in the word was 190 ms, SD 59 ms; post-stroke 233 ms, SD 78 ms), but the tendency just missed statistical significance [F (1,32) = 3.3, $p = 0.08$].

In summary, the proportional ratio between unstressed vowels and consonants within disyllabic words changed in the patient's post-stroke production; while vowels shortened relative to word duration, consonants lengthened. This change partly reflects a normal process at faster production rate, but in our case it also to some extent reflects abnormal production of consonants. Their articulation took a longer time in absolute terms in spite of the words being produced at a faster overall rate.

Aspiration

Duration of aspiration was measured for plosives in stressed syllable-initial position and expressed as a percentage of word duration. The results are shown in figure 6. There were eight tokens for /k/, five for /p/ and one for /t/.

Aspiration proved to be consistently shorter in the patient's post-stroke plosives than in her pre-stroke ones; the mean durations of aspiration were 14% of the word duration and 23% respectively. The largest difference was found in the word 'pub's', where the ratio was 10% to 35%. Only in one case was the ratio reversed (the word 'called'). However, the difference here was less than 5%. The statistical analysis, using one-way ANOVA, showed that the difference between the pre-stroke and post-stroke duration of aspiration was statistically highly significant; [F (1,26) = 9.53, $p = 0.005$].

Devoicing of sonorants after voiceless plosives in British English can be considered a parallel process to aspiration. In the only case of /l/ occurring after a plosive (the word 'closure'), the /l/ did not sound devoiced in post-stroke speech, while it did in the pre-stroke version. However, no acoustic evidence was found for this impression. The duration of aspiration for /k/ (which consisted of the devoiced portion of /l/) was measured for this word in both pre-stroke and post-stroke speech.

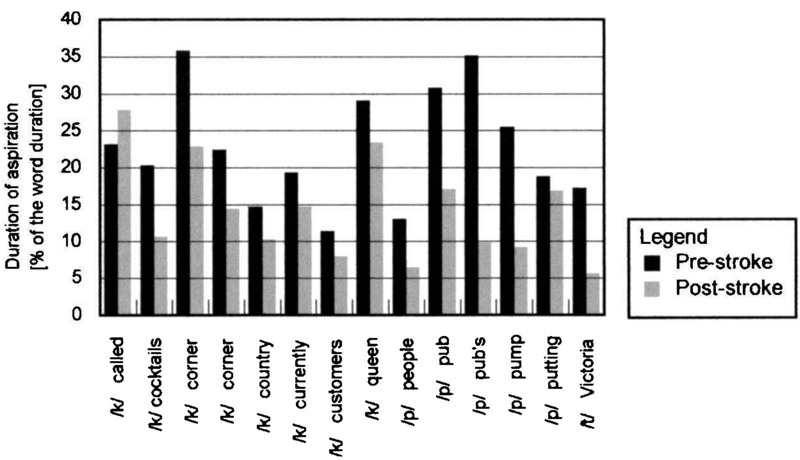

Figure 6. *Duration of aspiration in plosives /p/, /t/ and /k/.*

Aspiration duration in post-stroke /kl/ (44 ms) was found to be nearly half of that for pre-stroke (73 ms). This may contribute to the auditory impression of preservation of voicing in this token of post-stroke /l/. However, more evidence would be needed to make any stronger claims.

Intonation

In the impressionistic analysis, conflicting opinions emerged among participating phoneticians as to the degree of 'Scottishness' of the patient's intonation. However, the upward pitch movement in phrase-final positions, typical in some Scottish accents, was not observed (though apparently it occurred in her spontaneous speech; see case report). The focus of the acoustic analysis was on the f0 of pitch accents (i.e. local pitch prominences) and other turning points such as the ends of falls within intonation phrases and at phrase boundaries. Observation of f0 tracks suggested that the higher pitch of post-stroke speech noted in the impressionistic analysis occurred only locally and does not apply to the whole speech sample. The mean f0 of pitch accents was 209 Hz before stroke (SD 55 Hz) and 203 Hz after stroke (SD 59 Hz). The analysis of variance based on all turning points (186 in total) showed that the pre- versus post-stroke differences in f0 values failed to reach significance.

Articulation rate and pausing

Articulation rate variation, pause frequency and pause duration were also analysed. Following the procedures of Dankovičová (1997), articulation rate variation was measured across phonological words (a phonological word is defined as a string of syllables containing a single stress and respecting lexical word boundaries). This analysis of articulation rate is more informative than the frequently employed, but over-simple, overall measure (derived by dividing the total number of syllables in the sample by the total speech sample duration, excluding pauses). The main advantage of examining articulation rate variation across phonological words is that it can reveal patterns of acceleration and deceleration within units such as the intonation phrase (Dankovičová, 1997). Phonological word boundaries were identified auditorily. Only exceptionally were the boundaries placed differently in pre-stroke and post-stroke samples. (The phonological words which did differ in this way were excluded from the analysis.) The results showed no clear overall tendency towards higher or lower articulation rate in post-stroke speech (confirmed by non-significant results from the analysis of variance). The mean articulation rates, calculated across individual phonological words, were nearly identical in pre-stroke and post-stroke speech (5.79 syll/s, SD 2.11 syll/s as opposed to the pre-stroke 5.71 syll/s, SD 2.04 syll/s; the total number of observation was 55).

Both pause frequency and duration were within the normal-speech range in the patient's post-stroke performance, although they were less frequent and slightly longer on average than in the pre-stroke speech (8 pauses of the mean duration of 450 ms, and 13 pauses of the mean duration of 350 ms respectively).

Summary and discussion

This case of 'foreign accent syndrome' involved a patient who before her stroke spoke with a Southern British English accent, while after her stroke she appeared to speak with a Scottish accent. The case is unusual in at least two respects. Firstly, it involves *right* hemisphere damage. As mentioned previously, this can be regarded as exceptional in foreign accent syndrome, as all but one reported case involved left hemisphere damage. It was also noted earlier in the paper that there does not seem to be a common site within the left hemisphere that is affected in all (or even the majority of) FAS cases, thus giving a negative answer to the first main question regarding FAS, i.e. whether all FAS cases involve similar neurological damage. By investigating a patient with right hemisphere damage, our study makes the diversity in the location of the neurological damage even wider.

The second unusual aspect of our case was that it was primarily the segmental phonetic features that changed in the patient's speech rather than the prosodic features (although one can hypothesize that some of the segmental features affected prosody indirectly, particularly rhythm, as will be discussed further below). According to the classical neurological perspective on speech disorders, right hemisphere damage would be expected to result mainly in prosodic impairment, especially of non-linguistic, i.e. affective, prosody (e.g. Ross and Mesulam, 1979; Emmorey, 1987), though there is also some evidence of right hemisphere involvement in processing linguistic prosody (e.g. Weintraub *et al.*, 1981). Our demonstration of segmental impairment, and relatively unimpaired prosody speaks to the fundamental over-simplicity of the association between right-hemisphere functions and processing of prosody (on this issue, see also Mayer *et al.*, 1999).

The phoneticians involved in the analysis initially shared the impression of a Scottish accent and further agreed that this impression was due to segmental characteristics rather than prosodic features. However, after a closer auditory analysis they did not find any strong evidence for important typical features of Scottish English in the patient's post-stroke speech. Yet three native Scottish speakers reported that her post-stroke accent did sound Scottish to them. As far as we know, all listeners who did have the impression of a 'foreign' accent in our patient mentioned a Scottish accent; no other accents were suggested, unlike in other cases reported in the literature (see Introduction).

With respect to segmental phonetic features, the picture is not straightforward. There are a number of features which could possibly be responsible for the impression of a Scottish accent; in the case of others, the relation is not clear. Our approach was to compare our patient to a typical (ideally invariant) Scottish-English speaker, which is the usual practice in the phonetic/phonological analysis of accents. However, as we now know, accents tolerate relatively large degrees of variation. The interpretation of the findings must, therefore, take this fact into account.

One of the main features expected was the quality of some monophthongs and diphthongs. However, rarely were there any vowel realizations that occur in Scottish English, and even where there were similarities (/ɔ/, /əʊ/ and /eɪ/), these were not systematic. However, it should be noted that the realization of diphthongs /əʊ/ and /eɪ/ is particularly salient for the distinction between Scottish English and Southern British English. Thus even a few realizations of these two diphthongs close enough to Scottish English may be sufficient to make a significant contribution to the perception of a Scottish accent (see the discussion of the concept of 'salience' in Trudgill, 1986).

Realization of /l/ was not systematic either. The fact that in a few cases dark [ɫ] occurred where English speakers use clear [l] might contribute to the impression of a Scottish accent. The impression of a post-vocalic /r/, a typical feature of Scottish

English, arose only rarely and, furthermore, no evidence was found for rhoticity as such in the acoustic analysis. Slight diphthongization of a neighbouring vowel was found in some cases, which is consistent with the increasing tendency for post-vocalic /r/ to be vocalized in Scottish accents (Stuart-Smith, 1999). In a few instances, creaky voiced vowels were found where /r/ might be expected in a Scottish accent. Whether creaky voice in these positions contributes to the perception of /r/ is uncertain. Reduced duration of aspiration in syllable-initial plosives and fronting of coronal consonants might also be factors contributing to the speech sounding Scottish.

The unusual advantage of having a recording of pre-stroke speech available provided an opportunity to make a direct phonetic acoustic comparison between the patient's speech before and after stroke, using the same text. The acoustic analysis generally confirmed the results of the auditory analysis. Changes both in vowel quality and quantity were found. The vowels were on the whole fronted and some were also closer in the post-stroke speech than in the pre-stroke speech (/i/, /ɪ/, /ɒ/), while others became more open (/æ/, /ɔ/). Overall, front vowels became more peripheral and back vowels more centralized. Especially in the case of /ʊ/, /ɑ/ and /eɪ/, fronting and raising might result in the impression of 'Scottishness'. This impression may also be enhanced by the fact that lowering /ɔ/ and raising /ɒ/ makes these two vowels come closer together in the vowel space: Scottish English does not phonologically distinguish these two vowels; it has /ɔ/ only.

Clear evidence was found for vowel shortening in disyllabic words, both in stressed and, especially, in unstressed syllables. Scottish English does not generally have a vowel length contrast, except in certain specific environments—certain vowels are longer before a pause, voiced fricative or /r/, while in other environments they are shorter (Aitken's Law; Wells, 1982; Scobbie *et al.*, 1999). The limited material available did not allow us to assess the occurrence of phonetic lengthening; there were more phonetic contexts where shortening would be expected in Scottish English. Thus shortening of vowels in the patient's post-stroke speech, detected already in the auditory analysis, might also be an important contributing factor to the impression of a Scottish accent. Moreover, shortening of vowels might influence the perception of vowel quality. We also hypothesized that the patient's diphthongs might be shortened, leading to the impression of monophthongization. However, the acoustic analysis of duration did not confirm this. The acoustic analysis of vowel quality did not suggest monophthongization either.

The acoustic analysis showed that not only had the vowels a tendency to be shorter in the patient's post-stroke disyllabic words, but that the whole timing relationship between vowels and consonants was affected. There was a clear tendency for consonants to be longer in the post-stroke speech than in pre-stroke speech. This peculiar tendency may well affect the perceived rhythm of speech and explain why rhythm sounded neither typically English nor Scottish in the impressionistic analysis.

The second main issue arising in connection with FAS and mentioned in the Introduction is whether the speech of different FAS patients always involves disturbance of the same set of phonetic features. Some similarities between different FAS cases were mentioned, particularly the fact that prosody invariably tended to be affected. However, our study shows that even this point of agreement does not hold—it was the segmental features that were mainly affected in our patient, who had relatively unimpaired prosody in the speech sample analysed here. Regarding segmental features, our survey of the literature illustrated a number of contradictory findings. This new case of FAS contributes further to the phonetic diversity of FAS. Although, for example, both centralisation and peripheralization of vowels were attested in previous FAS cases, no study has, to our knowledge, reported a mixed pattern of centralization (back vowels) and peripheralization (front vowels) in the same patient. A separate analysis of diphthongs (not normally performed in FAS studies) demonstrated general peripheralization of both the peak and the offglide.

Post-stroke vowel shortening has been reported before, but changes in the timing relationship between vowels and consonants within words is a novel finding. Previous studies reported either diphthongization or monophthongization. However, we found evidence for neither in our acoustic analysis. The impression of monophthongization in the initial perceptual analysis was subsequently revealed to be a likely consequence of diphthong shortening. This finding demonstrates the value of acoustic analysis in addition to impressionistic perceptual analysis. Finally, shortening of aspiration in plosives has not been mentioned for previous FAS cases.

A number of phonetic changes reported in other FAS cases were not attested for our patient, for example, voicing errors, changes in the manner of articulation of consonants, shifts in stress placement and changes in syllable structure due to epenthetic vowels or lack of vowel reduction. We can conjecture that for an English speaker/listener these changes would be more dramatic than the changes we observed, and were these changes to have occurred in our case, it is conceivable that the accent would be perceived as more distant from English English, i.e. foreign rather than dialectal within the United Kingdom.

The third main issue was that of a common underlying physiological mechanism to FAS. It is not clear whether the changes in our patient's post-stroke speech can be attributed to some motor (articulatory) impairment. Our data do not support straightforwardly either of the two physiological explanations suggested in the literature, i.e. tense speech posture or speech timing (prosodic) disturbance. We can speculate that both the tendency towards raising vowels, and the tendency towards making vowels shorter and consonants longer is due to insufficient jaw opening (F. Nolan, personal communication). However, the fact that in our patient's post-stroke monosyllabic words, the timing relationship between vowels and consonants was not affected, fails to support such an explanation. A larger data set would be needed to test whether the lowering of vowel /æ/, which would also be contra-indicated by such a speculation, is genuine, or only found unreliably in a small number of tokens. Finally, changes such as increased lip-rounding in some cases of /əʊ/ would be difficult to explain in terms of motor impairment.

It is not obvious how the tendency for front vowels to 'expand' into a more peripheral position, and for back vowels to centralise could be explained by a common underlying physiological mechanism. However, a rather striking parallel between our findings on lengthening of consonants and peripheralization of front vowels seems to emerge with findings for Italian (Payne, 2000). In Italian /i/ and /a/, when adjacent to geminate consonants (at least /dː/ and /lː/), become more peripheral than in other contexts. Payne explains this in terms of fortition, defined more generally, as more energetic articulation. This explanation might also be applied to changes such as increased lip-rounding, which we found in some cases of /əʊ/. It should be noted that Payne's analysis was restricted to the two front vowels only, and thus we do not have a comparison for back vowels, which in our case centralized. However, centralization would not be consistent with fortition. Overall, it is difficult to see how fortition could be explained in terms of motor impairment.

We could speculate that the process of fortition may reflect our speaker's efforts to return to her original pronunciation.

Conclusion

Post-stroke, the patient's speech changed in a number of ways. In some features her speech has indeed the characteristics of Scottish English speech. The realization of segments was not consistent but it seems possible that our patient's post-stroke variation in production of vowels and consonants overlaps with attested variation found in Scottish speakers. Like other English speakers, she has had extensive exposure to Scottish accents on television, etc. However, we cannot determine whether this experience is relevant to her current pronunciation. Overall, we do not feel that the evidence is sufficiently strong to conclude that foreign accent syndrome is merely an epiphenomenon in the sense suggested by Ardila *et al.* (1988). The differences compared to the patient's pre-stroke speech are not a disparate collection of random changes—a subset of features of the patient's post-stroke speech are quite specific characteristics of Scottish English.

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Notes

1. The terms 'strengthening' and 'weakening' are perhaps somewhat vague phonetic terms but they are commonly employed, particularly in phonology, but also in the literature on Foreign Accent Syndrome. They are used in relation to consonants as a cover term for processes such as fortition for 'strengthening', and lenition and articulatory undershoot for 'weakening'.
2. This simply reflects the known fact that different vowels differ in F1.

References

Ardila, A., Rosselli, M. and Ardila, O., 1988, Foreign accent: An aphasic epiphenomenon? *Aphasiology*, **2**, 493–499.

Barlow, S. M., Iacono, R. P., Paseman, L. A., Biswas, A. and D'Antonio, L., 1998, The effects of posteroventral pallidotomy on force and speech aerodynamics in Parkinson's Disease. In M. P. Cannito, K. M. Yorkston and D. R. Beukelman (Eds) *Neuromotor speech disorders* (Baltimore: Paul H. Brookes), pp. 117–156.

Blumstein, S. E., Alexander, M. P., Ryalls, J. H., Katz, W. and Dworetzky, B., 1987, On the nature of the FAS: a case study. *Brain and Language*, **31**, 215–244.

Brown, G., Currie, K. L. and Kenworthy, J., 1980, *Questions of intonation* (London: Croom Helm).

Chirrey, D., 1999, Edinburgh: Descriptive material. In P. Foulkes and G. J. Docherty (Eds) *Urban voices* (London: Arnold), pp. 223–229.

Coughlan, A. K. and Warrington, E. K., 1978, Word comprehension and word retrieval in patients with localised cerebral lesions. *Brain*, **101**, 163–185.

Dankovičová, J., 1997, The domain of articulation rate variation in Czech. *Journal of Phonetics*, **25**, 287–312.

Danly, M. and Shapiro, B., 1982, Speech prosody in Broca's aphasia. *Brain and Language*, **16**, 171–190.

Dauer, R. M., 1983, Stress-timing and syllable-timing reanalysed. *Journal of Phonetics*, **11**, 51–69.

Emmorey, K. D., 1987, The neurological substrates for prosodic aspects of speech. *Brain and Language*, **30**, 305–320.

Gay, T., 1981, Mechanisms in the control of speech rate. *Phonetica*, **38**, 148–158.

Goodglass, H., 1983, *The assessment of aphasia and related disorders/The Boston diagnostic aphasia examination* (Philadelphia: Lea & Febiger).

Graff-Radford, N. R., Cooper, W. E., Colsher, P. L. and Damasio, A. R., 1986, An unlearned foreign 'accent' in a patient with aphasia. *Brain and Language*, **28**, 86–94.

Gurd, J. M., Bessell, N. J., Bladon, R. A. W. and Bamford, J. M., 1988, A case of FAS, with follow–up clinical, neuropsychological and phonetic descriptions. *Neuropsychologia*, **26**, 237–251.

Gurd, J. M. and Ward, C. D., 1989, Retrieval from semantic and letter-initial categories in patients with Parkinson's Disease. *Neuropsychologia*, **27**, 743–746.

Hawkes, N., 1997, Scots stroke victim awoke with South African accent. *The Guardian*, 13 October.

Ingram, J. C. L., McCormack, P. F. and Kennedy, M., 1992, Phonetic analysis of a case of FAS. *Journal of Phonetics*, **20**, 457–474.

Klatt, D. H., 1976, Linguistic uses of segmental duration in English: acoustic and perceptual evidence. *Journal of the Acoustical Society of America*, **59**, 503–516.

Kurowski, K. M., Blumstein, S. E. and Alexander, M., 1996, The FAS: a reconsideration. *Brain and Language*, **54**, 1–25.

Labov, W., 1991, The three dialects of English. In P. Eckert (Ed.) *New Ways of Analyzing Sound Change* (New York: Academic Press), pp. 1–44.

Labov, W., 1994, *Principles of linguistic change* (Oxford: Blackwell).

Lawson, E. and Stuart-Smith, J., 1999, A sociophonetic investigation of the 'Scottish' consonants (/x/ and /ʍ/) in the speech of Glaswegian children. In *Proceedings of the 14th International Congress of Phonetic Sciences,* 1–7 August 1999, San Francisco, pp. 2541–2544.

Mayer, J., Dogil, G., Wildgruber, D., Riecker, A., Ackermann, H. and Grodd, W., 1999, Prosody in speech production: An fMRI study. In *Proceedings of the 14th International Congress of Phonetic Sciences,* 1–7 August 1999, San Francisco, pp. 635–638.

Miller, N., 1986, *Dyspraxia and its management* (London: Croom Helm).

Miller, N. and O'Sullivan, H., 1997, What makes foreign accent syndrome foreign? *ICPLA, International Clinical Phonetics and Linguistics Association, 6th Annual Conference,* Nijmegen, 13–15 October, poster presentation.

Moen, I., 1996, Monrad-Krohn's FAS case. In C. Code, C.-W. Wallesh, Y. Joanette and A. Roch Lecours (Eds) *Classic cases in Neuropsychology* (London: Psychology Press, L. Erlbaum), pp. 159–171.

Moen, I., 2000, Foreign accent syndrome: A review of contemporary explanations. *Aphasiology*, **14**, 5–15.

Monrad-Krohn, H. G., 1947, Dysprosody or altered 'melody' of language. *Brain*, **70**, 405–415.

Mount Wilga High Level Language Assessment (unpublished).

Payne, E., 2000, Consonant gemination in Italian: phonetic evidence for a fortition continuum (University of Cambridge, unpublished PhD thesis).

Pick, A., 1919, Über Änderungen des Sprach-characters als Begleiterscheinung aphasischer Störungen. *Zeitschrift für die gesamte Neurologie und Psychiatrie*, **54**, 230–241.

Rosner, B. S. and Pickering, J. B., 1994, *Vowel Perception and Production* (Oxford: Oxford University Press).

Ross, E. D., 1981, The aprosodias. Functional anatomic organization of the affective components of language in the right hemisphere. *Archives of Neurology*, **38**, 561–569.

Ross, E. D. and Mesulam, M.-M., 1979, Dominant language functions of the right hemisphere—prosody and emotional gesturing. *Archives of Neurology,* **36**, 144–148.

Ryalls, J. and Reinvang, I., 1985, Some further notes on Monrad-Krohn's case study of FAS. *Folia Phoniatrica*, **37**, 160–162.

Ryalls, J. H., 1981, Motor aphasia: Acoustic correlates of phonetic disintegration in vowels. *Neuropsychologia*, **19**, 365–374.

Schuell, H., 1965, *Differential diagnosis of aphasia with the Minnesota test* (Minneapolis: University of Minnesota Press).

Scobbie, J., Hewlett, N. and Turk, A., 1999, Standard English in Edinburgh and Glasgow: the Scottish vowel length rule revealed. In P. Foulkes and G. J. Docherty (Eds) *Urban voices* (London: Arnold), pp. 230–245.

Stuart-Smith, J., 1999, Glasgow: accent and voice quality. In P. Foulkes and G. J. Docherty (Eds) *Urban voices* (London: Arnold), pp. 203–222.

Thompson, J. and Enderby, P., 1979, Is all your Schuell really necessary? *British Journal of Disorders of Communication,* **14**, 195–201.

Tompkins, C. A., 1995, *Right hemisphere communication disorders: theory and management* (San Diego, CA: Singular Publishing).

Trudgill, P., 1986, *Dialects in contact* (Oxford: Blackwell).

van Santen, J. P. H., 1992, Contextual effect on vowel duration. *Speech Communication,* **11**, 513–546.

Wechsler, D., 1987, *Wechsler memory scale—revised WMS-R* (San Antonio, TX: The Psychological Corporation).

Weintraub, S., Mesulam, M. and Kramer, L., 1981, Disturbances in prosody. A right–hemisphere contribution to language. *Archives of Neurology*, **38**, 742–744.

Wells, J. C., 1982, *Accents of English* (Cambridge: Cambridge University Press).

Whitaker, H. A., 1982, Levels of impairment in disorders of speech. In R. N. Malatesha and L. C. Hartlage (Eds) *Neuropsychology and Cognition* vol. 1 (The Hague: Nijhoff), pp. 168–207.