Formant Frequencies of British English Vowels Produced by Native Speakers of Cypriot Turkish

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ABSTRACT : In this paper, we discuss issues relating to phoneme (in particular, vowel) production in a subject's second language, focusing on the vowel systems of Standard Southern British English (SSBE) and Cypriot Turkish. We describe a study wherein first language Turkish speakers, who were experienced second language speakers of SSBE, were recorded attempting to produce SSBE vowels in words within a standard carrier phrase. The first and second formants of the vowels so produced were measured, and the results compared with measurements of SSBE and Turkish vowels produced by L1 speakers from previous studies, and discussed with reference to perceptual theories such as the perceptual magnet effect.

1 INTRODUCTION

The problems encountered by non-native speakers pronouncing or perceiving unfamiliar phonemes in a second language (L2) are well-known. Several previous studies have focused on such issues – including the common problem producing or perceiving the /r/-/l/ contrast in English by native speakers of Mandarin Chinese or Japanese [1]. The *perceptual magnet hypothesis* [2] proposes that non-native speakers tend to "attract" phonemes in their L2 to standard exemplar phonemes in their first language (L1). This is believed to be the case both for perception of other people's speech and their own production of sounds in their L2 [3].

The formants of vowel sounds can be particularly important both from the point of view of intelligibility (correct identification of the vowel) and perceived "naturalness" or "native quality" of speech. For the purposes of classification, it is generally believed that the two lowest frequency formants, F1 and F2, are the most important. However, different languages vary considerably in the set of phonetic vowels they use, and in the precise acoustic properties (including formants) of those vowels. For example, Castillian (European) Spanish has just 5 phonetic vowels {/a/, /e/, /i/, /o/, /u/ }, all of which are relatively close together in F1-F2 space (often referred to as the "vowel quadrilateral") [16]. This contrasts with the case of Standard Southern British English, which is normally considered to have 11 phonetic vowels (not including diphthongs), which are widely distributed across F1-F2 space. A good understanding of how the phoneme system of a particular L1 affects a non-native speaker's perception and pronunciation of English can have significant applications to the Teaching of English to Speakers of Other Languages (TESOL), for example, producing teaching aids to help learners of particular L1s speak better English [4], in speech therapy for L2 English language learners with various speech impairments, and in biometric speaker classification or identification – for example, trying to identify a speaker's L1 from the way they attempt to pronounce various English phonemes. Although many previous studies have looked at non-native listeners perception of various sounds in their L2, produced by both native and non-native speakers (e.g. [5] for Norwegian speakers), and some researchers have investigated L2 productions by speakers of some particular L1s - e.g. Latin American Spanish [4], German [4], Greek [6] and Persian (Farsi) [7] - there is still much work which can be done to extend these to a wider range of speakers' native languages. The only previously published work on the perception of English by native speakers of Turkish seems to be that of Ettlinger & Johnson [20], who investigated the different abilities of L1 speakers of English, French and Turkish to distinguish between different vowel sounds. However, this study did not make any quantitative measurements of quantities such as vowel formants of English vowels produced by L1 speakers of Turkish.

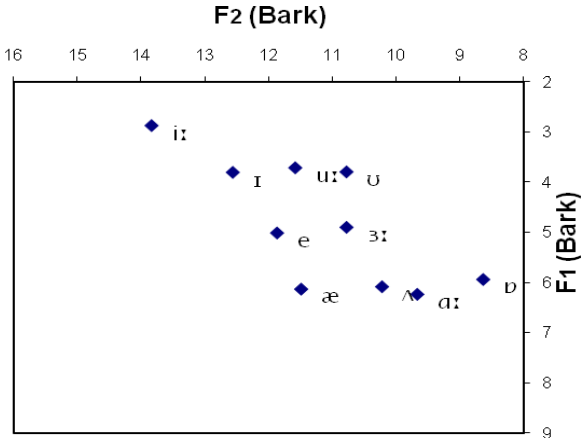
2 THE VOWEL SYSTEM OF SSBE (STANDARD SOUTHERN BRITISH ENGLISH)

It is commonly accepted that Standard Southern British English contains 11 monophthong vowels [9] { /iː/, /ɪ/ , /e/ , /æ/ , /ʌ/ , /ɑː/ , /ɒ/ , /ɔː/ , /ʊ/ , /uː/ , /ɜː/ }. Formant values for each of these have been measured by Wells [8] and more recently by Deterding [9, 10]. Summaries of the latter's findings are given in Table 1 and Figure 1 below.

Table 1: Mean Formant frequencies of the eleven phonetic monophthong vowels of SSBE, as produced by three L1 speakers [10].

	Formants	
SSBE Vowel	F1 / Hz	F2 / Hz
iː	296	2241
ɪ	396	1839
e	532	1656
æ	667	1565
ʌ	661	1296
ɑː	680	1193
ɒ	643	1019
ɔː	480	857
ʊ	395	1408
uː	386	1587
ɜː	519	1408

Figure 1 : Data on SSBE vowels in Table 1 (from [10]) plotted as a "vowel quadrilateral", with formant frequencies converted to Bark scale [17, 18].



3 TURKISH AND ITS VOWEL SYSTEM

Turkish (Türkçe) is, if its various non-Anatolian dialects are included, L1 for over 70 million people [11], placing it amongst the 20 most widely spoken of the World's languages. It is the official and principal language of Turkey, one of the two official languages (along with Greek) of Cyprus and a "recognised language" of several other countries, notably some of the Central Asian and Causcasian states formerly part of the USSR, including Kazakhstan. In these states, there are believed to be around 197 000 L1 Turkish speakers, as opposed to L1 speakers of related languages, who form the majority in Central Asia. There are sizable groups of L1 Turkish speakers in Bulgaria (around 600 000), Cyprus (around 177 000 L1 speakers), Greece (around 128 000 L1 speakers), the Former Yugoslav Republic of Macedonia (around 71 000 L1 speakers) and Romania (around 28 000 L1 speakers) [11]. Turkish is one of the Turkic subgroup of the Altaic family of languages, and is closely related to Azheri (spoken in Azherbaijan and North-Western Iran), Kazakh, Tatar (spoken in several parts of Russia and the Ukraine), Turkmen and Uzbek [19]. It is generally accepted that Turkish contains 8 phonetic vowels { /i/, /ɯ/ written as ı, /y/ written as ü, /e/, /æ/ written as a, /ɒ/ written as o, /ɜː/ written as ö or œ, /u/} [12]. Like other members of the Altaic family of languages, and some others such as Hungarian (Magyar), Japanese and Korean, the individual vowels within a word must follow the principal of vowel harmony, in that front vowels are followed by front vowels (e.g. i by e), back vowels by back vowels (e.g. u by a), (2) unrounded vowels are followed by unrounded vowels (e.g. i by e), and (3) rounded vowels are followed by high rounded (e.g. o by u) or low unrounded vowels (e.g. o by a) [12].

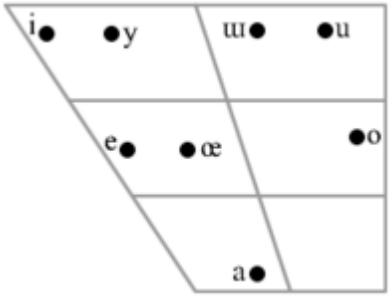
Table 2 : The eight phonetic vowels of Turkish, in IPA notation, with conventional Turkish orthography in brackets, in terms of their height, place and manner of articulation (adapted from [12]).

	Front		Back	
	Unrounded	Rounded	Unrounded	Rounded
High	/i/ (i)	y (ü)	/ɯ/ (ı)	/u/ (u)
Low	/e/ (e)	/ɜː/ (ö)	/æ/ (a)	/ɒ/ (o)

Acoustic analyses of these Turkish phonetic vowels, when produced by L1 Turkish speakers, were carried out by Bingöl & Karaca [21], and their results are summarized in Figure 2 below.

There are slightly more vowels in SSBE than in Turkish, and it was expected that Turkish speakers may fail to pronounce some of the SSBE vowels correctly [7]. In this paper, we describe a study where recordings were made of L1 Cypriot Turkish speakers attempting to produce British English vowels, within a controlled context. These recordings were analysed to measure the formants, in order to investigate the hypothesis that the speakers' productions of the English vowels would be influenced by the properties of the nearest equivalent Turkish vowel (when there was one such), and to study how well the speakers could produce vowel sounds which were not present in their L1.

Figure 2: The "vowel quadrilateral" for Turkish vowels (from [13]).



4 EXPERIMENTAL PROCEDURE

The study was performed by recording a number of adult L1 Turkish speakers, all originally from Cyprus, reading a number of English sentences aloud. Each sentence included a /bVd/ word, for example, “bad”, where V is a British English phonetic vowel, within a standard carrier phrase. The carrier phrase was used to control the phonetic environment for each vowel. The recordings were analysed to allow the measurement of the formants of each vowel. The project was carried out within the guidelines of our institution’s ethical policies for research involving human subjects.

4.1 Subjects

All subjects were L1 Turkish speaking Cypriots aged between 20 and 27 who had lived and studied in the U.K. for between 2 and 7 years, and were still so doing at the time of taking part in the study. Of these, 4 were female and 2 male. All had spent their formative years in Cyprus, but all were competent speakers of conversational English and were used to reading English text on a daily (or near daily) basis. All subjects were volunteers who had been informed of what the experiment involved, told that the recordings of their voices and their identities would not made public and that they had the right to withdraw from the study at any point.

4.2 Materials

Each subject was asked to read aloud a sequences of printed English sentences, each one containing a /bVd/ word within a standard carrier phrase, “Could you say the word /bVd/ please ?”, pausing briefly between successive sentences. Prior to the subject reading the sentences, each had been able to read the sentences silently whilst listening to a native SSBE speaker reading all the sentences aloud, in order to ensure the set did not contain any words with which the subject was completely unfamiliar. Examples of /bVd/ words where the vowel was an SSBE diphthong were also recorded, but the results are not presented here. Turkish vowel harmony (see section 3 above) should not cause any issues here, since all words being considered contain only one phonetic vowel.

4.3 Recording Procedure

Audio recordings of the subjects’ read utterances were made, and a electroglottograph (EGG) signal, to monitor the vibration of the subject’s vocal folds and facilitate pitch (fundamental frequency) calculation for further analysis, recorded simultaneously using a *Laryngograph* processor [14].

4.3 Analysis

The *Speech Filing System* (SFS) software suite [15] was used to analyse the recordings, including measuring the formants of each vowel. This system allows, amongst many other features, the display of both waveforms and spectrograms and the playback of sections of the recording to enable the easy identification of individual words and phonemes within an utterance. It was noted that some recordings were slightly affected by a “hum” due to air conditioning in the recording room. This has been taken into account in the subsequent analysis of the recordings.

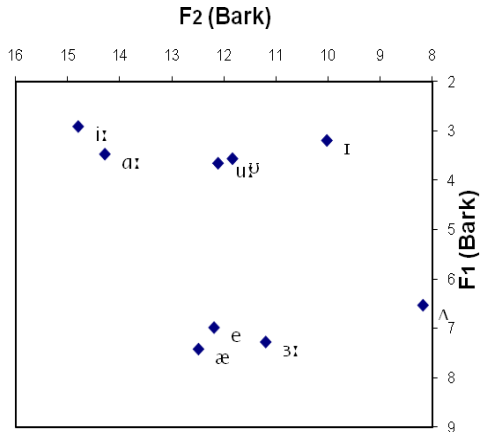
5 RESULTS AND DISCUSSION

The formants of the L1 Cypriot Turkish speakers’ attempts at producing SSBE monophthong vowels are given in tables 3 (for female subject) and 4 (for male subject) below. The values marked with * for /ʊ / were obtained from pronunciations of the word “good”, since there is no valid word /bʊ d/ in SSBE.

Table 3. Mean Formant frequencies of attempts at producing the eleven phonetic monophthong vowels of SSBE, by typical female L1 speaker of Cypriot Turkish.

		Formants	
SSBE word	SSBE vowel	F1 / Hz	F2 / Hz
bead	iː	300	2620
bid	ɪ	330	1260
bed	e	780	1740
bad	æ	840	1820
bud	ʌ	720	950
bard	ɑː	360	2410
bod	ɒ	330	800
bawd	ɔː	350	810
good	ʊ	370	1650
booed	uː	380	1720
bird	ɜː	820	1500

Figure 3: Data on attempts by Cypriot Turkish female speaker to produce SSBE vowels (from Table 3) plotted as a "vowel quadrilateral", with formant frequencies converted to Bark scale [17, 18].

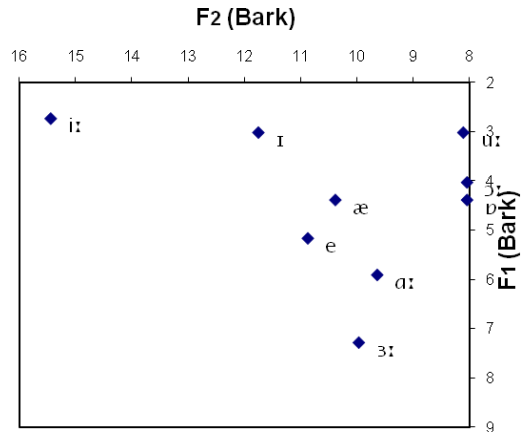


As can be seen from the tables and figures, there was considerable variation in the formants, and hence the level of success (in terms of F1 and F2 values), of the L1 Cypriot Turkish speakers attempting to produce approximations to SSBE vowels when there is a closely equivalent vowel in Turkish. Attempts by both male and female speakers at pronunciation of /i/ and /ɪ / tended to get confused (both words sounded like "beard"), as did /ɒ/ and /ɔː/ when pronounced by the male speaker.

Table 4. Mean Formant frequencies of attempts at producing the eleven phonetic monophthong vowels of SSBE, by typical male L1 speaker of Cypriot Turkish.

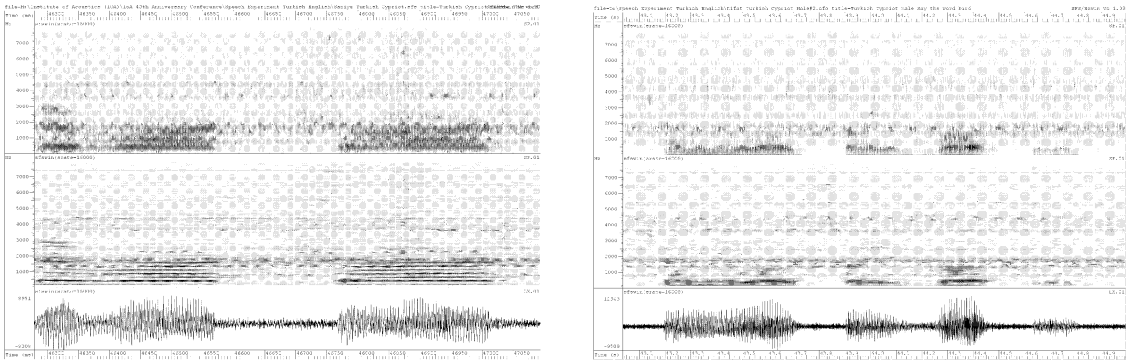
		Formants	
SSBE word	SSBE vowel	F1 / Hz	F2 / Hz
bead	iː	280	2920
bid	ɪ	310	1630
bed	e	550	1430
bad	æ	460	1330
bud	ʌ	490	900
bard	ɑː	640	1190
bod	ɒ	460	930
bawd	ɔː	420	930
good	ʊ	350	890
booed	uː	310	940
bird	ɜː	820	1250

Figure 4: Data on attempts by Turkish Cypriot male speaker to produce SSBE vowels (from Table 4) plotted as a "vowel quadrilateral", with formant frequencies converted to Bark scale [17, 18].



The Turkish Cypriot female speaker (Figure 3) has an English vowel space which is less tightly-clustered than that for SSBE speakers (Figure 1), and some of her productions of English vowels do seem to be very close to the nearest Turkish equivalent (Figure 2). The male speaker's vowel space for production of English vowels is more tightly clustered and, albeit distorted, is perhaps a better approximation to the approximate "trapezium" of SSBE vowel space. In both cases, / ɪ /, / ʌ / and /ɑː / (which have no direct Turkish equivalents) have been displaced significantly from their "correct" SSBE positions. Both produce /ɜː/ as a low vowel (as in Turkish) and the male speaker produces /æ / as back vowel . Both produced /ɜː/ as a lower vowel than expected. However, it is clear that further investigation and analysis is required, particularly from the point of view of understanding inter-subject variation.

Example sets of SFS outputs, showing speech signal waveform, wideband and narrowband spectrograms are shown in Figure 5 ((a) for a female Turkish Cypriot speaker and (b) for a male Turkish Cypriot speaker.



(a) (b)

Figure 5: SFS output, showing wideband spectrogram, narrowband spectrogram and speech signal waveform for an L1 Turkish Cypriot female speaker (a) and male speaker (b) uttering “The word bird”.

6 CONCLUSIONS AND FUTURE WORK

We have recorded attempts at producing SSBE vowel sounds by experienced L2 speakers of English whose L1 is Cypriot Turkish, and measured the first two formants of the resulting phonemes. There was considerable variation in the “quality” of the SSBE vowels produced by different participants. As expected, the participants generally produced “good” examples of SSBE vowels when there was a Turkish vowel which was close in F1-F2 space to the required SSBE one. However, their productions of SSBE vowels for which there was no close equivalent in Turkish were considerably poorer, but the results had formants which were often rather close to those for some other Turkish vowel. As a consequence, the subjects frequently confused certain SSBE vowels. These findings are consistent with the perceptual magnet hypothesis [2]. However, further investigation and analysis are needed – particularly to understand the inter-speaker variations. These could be due to a number of factors, including how (and by whom) each speaker was taught to speak English, and how much they currently converse with L1 speakers of SSBE.

It is planned to extend this study to investigate productions of a wider range of SSBE phonemes, and possibly perception of such phonemes, by L1 Turkish (both Cypriot and Anatolian) speakers, and also to diversify this study to other L2 speakers of English, such as Punjabi, whose L1 has received relatively little attention in this context.

7 ACKNOWLEDGEMENTS

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