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Pronunciation problems: Acoustic analysis of the English vowels produced by Sudanese learners of English

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The purpose of this study is to provide experimental evidence for certain linguistic causes of production errors of English spoken with Sudanese Arabic accent. The subjects of the study were expected to have problems with the production of English vowels in both individual words and real communication. Participants were ten Sudanese University learners of English who primarily speak Arabic. English vowel data are the materials of the native speakers of English. Based on acoustical analysis of the English vowel tokens spoken by both Sudanese and native speakers of (RP) English, the acoustical differences that would provide insights into the issue under concern were sought. The results indicated that most of the differences appeared in the area of central and back vowels of English. However, some of English tense – lax vowels showed no serious problems probably because there is correspondence between English and Arabic long /short vowels. Moreover, the production errors detected in this study followed different directions that suggest that the Sudanese learners of English had difficulty learning the English vowels. The main linguistic causes of these production errors were mother-tongue interference and lack of English knowledge.

Key words: Error, acoustic analysis, vowel properties, interference, intelligibility, vowel space, automatic classification, normalization, duration.

INTRODUCTION

Producing English vowels is one of the most challenging tasks for the Sudanese university EFL learners. Arguably, such learners have difficulties in distinguishing between English vowels like /ε/ and /∈⌉/ in words like *gale ~ girl* and /A⌉, Θ, ℘, □/ in words like *cart, cat, cut, cot*. According to Flege (1995) and Gilbert (1984) segmental errors like these frequently occur in ESL/EFL due to differences between L1 and L2.

Moreover, the way a language is taught has some effect on the learning of English. In Sudan context, where English is taught as a foreign language, pronunciation skills recently have a little space in the syllabus taught. Most EFL classes focus on teaching language aspects such as grammar, vocabulary, and morphology to help learners command the structure of English sentence. However, learning to produce correct pronunciation is not given much care in these syllabuses. For example, there are hardly any sufficient items included for the teaching of pronunciation in an appropriate way, but only few lessons that treat the organs of speech accompanied by poor exercises.

In these lessons, teachers ask the learner to pronounce

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ABBREVIATIONS: SPIN, Speech Perception in Noise; **MRT,** The Modified Rhyme Test; **PS,** Proto-Semitic; **MSA,** Modern Standard Arabic; **SA,** Sudanese Arabic; **XL,** Excel format; **LPC,** Linear Predictive Coding.

repeatedly a set of minimal pairs, etc. The learners react to such types of pronunciation tasks reluctantly and this is probably because the lessons are less effective (Ali, 2011). Moreover, linguistic differences often lead to pronunciation difficulties among the ESL/EFL learners. Many learners whose L1 lacks contrastive sounds of L2 tend to substitute L2 sounds for the nearest sound available in their L1 (Cruttenden, 2008). One more related example is the unfamiliarity of the Sudanese learners with a large number of vowel sounds that arguably present another factor that slows down English vowel learning.

In this study, an experimental analysis of the English vowel sounds which are produced by Sudanese EFL learners was done. The analysis covers important properties such as graphical presentations of the vowel space, classification matrix, and duration of English vowels produced by Sudanese speakers. The aim behind this is to map out the potential differences between native RP vowel token and that of the Sudanese speakers, and to locate how such differences can cause intelligibility problems.

Background: Participants vowel inventory

As a background, Arabic is the first language of the Sudanese learners which has a small inventory of vowel sounds. It maintains a classical triangular Proto-Semitic (PS) vocalism which is represented as /ι, υ, α /. In Classical Arabic (CA) and in Modern Standard Arabic (MSA), such vowels are geminated to give long vowels. However, many dialects in MSA have developed other vowels (Kaye, 1997; Munro, 1993). Moreover, Arabic short vowels are normally not represented in letters at all, but indicated by special marking (diacritics) that have an essential morphophonemic function in the root structure of the Arabic words. For example, Arabic verbal roots such as /drs/, /ktb/ and /hml/ are interspersed with diacritics; /darasa/ 'he studied', /kataba/ 'he wrote', /hamala/ 'he carried', respectively, a process that reveals a non-concatenative morphological system of a deep "underlying" phonological analysis (Kenstowics, 1994; Nwesri et al., 2006; Frisch, 1996). Thus, Arabic vowels show correspondence to only similar English vowels. Munro (1993) stated that Arabic classical PS vowels /ι, υ, α/ stand for lax/short vowels /I, Y, α /, whilst their geminated forms plus the newly developed vowels /ε, ο/ are realized as tense/long vowels /ι⌉, υ⌉, α⌉, ε⌉, □⌉/. The Sudanese Arabic vowel inventory has adopted the MSA inventory, but it contrasts /ε/ and /ε⌉/. The long vowels are shortened in word-final position, that is, the long vowel /α⌉/ is reduced here to /α/ (Raimy, 1997).

In comparison to the Arabic vowel inventory, the Received Pronunciation (RP) English vowel system is complex. It consists of twenty vowel phonemes: twelve monophthongs and eight diphthongs. The RP vowel system becomes more complicated with durational variation, especially due to a tense vs. lax opposition in the monophthongs. Among the most common phonemic features of R.P there is a wide spread loss of /υ↔/ and merger of /□⌉/ in words like *sure*, although other words may retain /Y↔/; examole, *poor*. There is no longer a distinction between /□↔/ for speakers with /□⌉/, example in words like *paw*, *port*, and *talk*, etc. Thus, some words such as *sure* are pronounced as /Σ□⌉/ *shoe*, but *poor* as /πυ↔/. In the majority of accents now the phoneme /υ⌉/ is commonly used in words like *suit*, and *enthusiasm*, etc. (Trudgill and Hananh, 2001). All in all, contrasts in the number and the nature of Arabic and English vowel sounds are expected to make the learning of English vowels difficult for Sudanese-Arabic speakers.

LITERATURE

Very little literature is available on the English vowel pronunciation problems that face the Sudanese university EFL learners. The learners are expected to make different types of English vowel production errors; example in words such as *bait, and, ask, let, fate, make, lace, poor, peat, put pot, putt, bit, fear, bet, stay,* etc. Bobda (2000) found that the English NURSE vowel /∈⌉/ is rendered in Sudan as /℘/, or /□/ where /□/ is represented orthographically in words like *work, worth, word*, etc., due to the influence of Arabic linguistic background. In L2 production of English vowels, similar errors were reported in several studies of Arabic speaking groups. For example, Arabic speakers of English face serious difficulties in distinguishing between English vowels such as /A/ /□⌉/, /↔Y/ as in *cot, caught*, and *boat* all of which are often pronounced as /□⌉/ or undergo substitutions (Brett, 2004). Altaha (1995) also reported that Arabic learners of English mistake the English front vowel /ε / as /I/ in words such as *set*, and *sit*. Actually, learning difficulties of English vowels is common among EFL learners whose native languages have a small number of vowels, example Arabic. According to Cruttenden (2001), these difficulties are predictable in the vowel space where the short and long vowels such as /I, ι⌉, Y, υ⌉, and, □, □⌉/ are close to each other.

Vowel duration is used contrastively in some languages as an acoustic cue to show vowel identity which often adds up to vowel perception and production problems among EFL learners. In English, vowel duration presents a major element of intelligibility that is used as an acoustic cue for length distinction (Fogerty and Humes, 2010; Jenkins, 2000). In L2 production of the English vowels an exaggeration of duration differences between short (lax) and long (tense) vowels was shown due to transfer of L1 for Arab learners. For example, Arabic tense-lax duration of the English /ι, I/, /εI, ε / and /υ, Y/ vowels are 1.6:1, 1.6:1, and 1.5:1, respectively. On the other hand, the English subjects showed duration ratios of only 1.2:1 in the same vowel tokens. Moreover, Arab groups manifested the same ordering of vowel duration differences for front vowels, but different ordering for back ones (Munro, 1993). One more point of duration effect was reported by Hillenbrand and Clark (2000) that due to duration shortening the vowel /Θ/ tends to be heard as /E/, and /A/ as /□/, whilst the lengthened /E/ tends to shift to /℘/, and /℘/ as /A, or □/. However, Hillenbrand and Clark observed slight alterations in the perception of /Y/, /υ⌉/, and /I/, /ι⌉/ due to duration effect.

It is possible to conclude that L2 learners of English need to be aware that the English short vowels are not as short as those of their L1 nor are the long vowels (Tsukada, 2009). Linguistic theories describe ESL/EFL learners' incorrect pronunciation resulting from neurological development that occurs in the human brain due to a process of normal maturation in the speech muscles at puberty. Speech organs after this period become more specialized for the production of only L1 sounds. The native language specific prototypes interfere with the L1 learner's perception of some L2 contrasts by acting as a perceptual magnet which pulls L2 vowels towards L1 prototypes. Thus, L2 vowel sounds which are located near an L1 vowel prototypes are discriminated less readily than vowels that are not located near L1 prototypes. It was assumed that the phonetic "prototype" for each sound category exists in memory and plays a unique role in speech perception and production (Iverson and Kuhl, 1995). However, incorrect conceptual representations of English sounds adopted by such learners are described to be responsible for speech production problems (Flege, 1976).

The lack of knowledge of the English vowels is also expected to contribute to English pronunciation problems of learners. Research results of some Sudanese secondary school learners of English recently showed that phonological awareness is urgently needed for intelligible speech. The results revealed that the subjects group exposed to pronunciation knowledge achieved better results than those who received no training (Fahal, 2004). Similar problems with the production of the English speech sounds widely spread among Arabic speaking learners of English. To sum up, previous literature shows that most English pronunciation errors are due to the following: (i) the intricate nature of the English vowels, (ii) unfamiliarity of ESL/ EFL speakers with large numbers of vowel sounds (iii) incorrect perceptual representations of English vowels and (vi) by-product of ineffective teaching.

Research questions

To conclude this introduction, we will now summarize the research questions which we will address in the present article.

1. Which English vowels are most difficult to pronounce?
2. What is the nature of the vowel production errors observed among the Sudanese learners of English?
3. What are the linguistic causes of such errors?

More specifically,

1. Do the inventory differences between the learners L1 and the target language present a major cause of these problems?
2. To what extent does lack of L2 phonological awareness add to the problem?

MATERIALS AND METHODS

Recordings were made on a laptop computer using Adobe Audition software. The subjects were seated in a quiet room with their lips a few centimeters away from a head-mounted close-talking microphone. They were asked to read a list of monosyllabic English words which included all the target English vowels. These words were embedded in sentence carriers (*say …again*). The sentence carriers were intended to help the subjects to speak at a constant rate. The list of items (including keywords) can be found in appendix 1. The subjects were encouraged to give the best possible production of such words. If the experimenter suspected that an error in the production was simply a reading error, rather than a genuine indication of the subject inability to pronounce a certain word, the subject was asked to repeat the word. The recorded material was then submitted for acoustic analysis using Praat software (Boersma and Weenink, 1996).

Speakers

Ten Sudanese native Arabic male and female speakers preparing for bachelor degree in English language teaching were recruited primarily from the student population at Gadarif University. In selecting the subjects (henceforth called learners/speakers) we focused on semi-final learners who had reached a considerable level of English and hence a better performance was expected. Practically, they use English only inside the classroom and in other academic activities such as debates, discussions, etc. Importantly, there are no well equipped language laboratories for the teaching of English phonetics, phonology or pronunciation at such universities. Teachers just teach students some theoretical work, instructing them on how to transcribe words phonetically.

For the control group of native speakers we used the data published by Deterding (1997) which provides measurements of English vowels recorded by five male and five female BBC broadcasters. The data are found in a directory that contains ten files in XL format. Each file contains the measurements of the first 3 formants of the 11 monophthong vowels. Importantly, the words were not spoken in sentences but in isolation. Although duration ratios of Wells (1962) used in this study is old, there is a slight difference between them and recent duration data (Cox, 2006).

Procedure

Praat

For speech analysis, the Praat speech processing programme was used. Praat is an open-software tool which is used for speech signal edition and labeling, as well as for various acoustic (spectral, formant, and duration) analyses and manipulations (Biersma and Weenink, 1996). It has other advantages of being easily modified for specific research purposes; results can also be exported to XL-compatible spreadsheets.

Formants measurements

The aim of the experiment is to measure F1 and F2 because they present the most important acoustic properties which can be seen in spectrograms, where the vowel quality can accurately be determined and classified (Delattre et al., 1955). First we had an impression about where the formants were by looking at the spectrogram of the stimuli, particularly the target vowels. Formant tracks were automatically computed for the lowest three formants (F1, F2, F3) in the frequency range between 0 and 3200 Hz and superposed onto the spectrogram. Whenever there was a visual mismatch between the formant tracks and the spectrogram, the model order (number of formants required) and/or the frequency range of the LPC analysis was changed, until a satisfactory match was obtained. We set segmentation points in a text grid at the onset and offset of the target vowel, and noted the number of formants to be extracted (two or three) and frequency cutoff (in Hz) on a separate tier. Using a script the duration and the formant frequencies were extracted from the recordings off-line. The formant values were extracted at the temporal midpoint of the target vowel. The data were then further analysed with SPSS statistical software. As a first step, formant frequencies were converted from Hertz to Bark units[2]. In order to make acoustic distances between vowels in the formant space optimally correspond to auditory distances formant values were rescaled from hertz to Barks (using the conversion formula advocated by Traunmüller, 1990).

Vowel normalization

A z-normalization procedure was applied to the Bark-transformed F1 and F2 values of the Sudanese and native speakers of English. Vowel normalization is a statistical operation developed to compensate for speaker-specific differences in vocal-tract size, which in turn results in different formant resonances (Brett, 2004). Vowel normalization is crucial in order to compare the vowel realizations by different speakers in linguistically meaningful ways. Normally, comparison includes formants, durations and vowel classification. In the current study, normalization is used to preserve phonological distinctions among English vowels produced by British and Sudanese speakers. Normalization is used to achieve a significant improvement of acoustic output of F1 and F2 on the basis of z-transformed scores. The transformation involved subtracting the individual speaker's mean F1 (and mean F2) from the raw formant values of F1 (or F2), and subsequently dividing the difference by the speaker's standard deviation (of F1 and F2, respectively) (Wang and Van Heuven, 2006; Adank et al., 2004). After normalization, z-transformed values of F1 below 0 correspond to high (close) vowels, whilst values above 0 correspond to low (open) vowels. Similarly, positive z-values for F2 stand for front vowels, whilst negative z-values of F2 refer to back vowels (see: Appendix 2). In graphs of the results, F1 is plotted along the vertical axis (high F1 at the bottom, low at the top) and F2 along the horizontal axis (high F2 to the left, low F2 to the right). This configuration of the axes yields a representation which closely resembles a traditional articulatory vowel chart.

Duration measurement

The measurement of duration is a complicated task. This is because the delimitation of sound units in an acoustic sense requires dealing with segmentation of utterances in which different productive and auditory quality impressions of sounds can make the task of such impressions complex. Even when it can be done the duration rates provided might not correspond to linguistic judgments of length; example, in the short and long English vowels like *beat* and *bit*, etc. In making statements of vowels, absolute duration values should not be sought, since the duration of such vowels will vary considerably according to context and factors such as what utterance, how fast or slowly it is pronounced, and whether it is followed by a voiced or voiceless consonant, and so on. However, to get more valid data, we also implemented a z-normalization procedure on the duration of our Sudanese speakers' English vowels. Firstly, this was done because the speakers' a slow manner of speech may affect the accuracy of English vowels duration. Secondly, the English vowels duration are expected to be influenced by the Sudanese speakers L1 (Arabic) inventory where vowel durations in which tense and lax counterparts are contrasted through a quantity rather than a quality difference as in English (Algamdi, 1418/1998; Munro, 1993; Kopczynski and Meliani, 1993). This difference adds to the complexity the measurement of the duration of the English vowels produced by Sudanese Arabic-speaking subjects. Therefore, duration measurements were z-normalized by subtracting from each individual vowel token the speaker's mean vowel duration and dividing the result by the speaker's standard deviation. As a result the speaker's mean vowel duration changed to 0 and the new standard deviation changed into 1. Any z-duration shorter than the speaker's mean duration will have negative values, any duration longer than the mean will be positive.

RESULTS

The results of the English vowel space of Sudanese and British speakers.

Figures 1 and 2 present acoustic vowel charts of eleven English vowels produced by Sudanese and British speakers, respectively. As a correlate of vowel height F1 (in Barks) is plotted vertically against F2 (in Barks), which is plotted horizontally (from right to left) as a correlate of vowel backness. Each point in the graph represents the centroid (mean F1-F2 coordinates) in the acoustic vowel space, a one vowel type, measured at the temporal midpoint of the ten tokens produced by the Sudanese speakers (or by a variable number in the L1 control data). In the graphs long (tense) and short (lax) English vowels are indicated separately. The short vowels are the corner points of the polygon with the grey shading.

[2] Bark is a psycho-acoustical scale proposed by (Zwicker, 1961). It bears its name after Heinrich Barkhausen who performed the first subjective measurements of loudness. The scale ranges from 1 to 24 corresponding to the first 24 critical bands of hearing. The subsequent band edges are (in Hz) 20, 100, 200, 300, 400, 510, 630, 770, 920, 1080, 1270, 1480, 1720, 2000, 2320, 2700, 3150, 3700, 4400, 5300, 6400, 7700, 9500, 12000, 15500. According to Smith and Abel (1999) Bark units represent samplings of a continuous variation in the frequency response of the ear to a sinusoid or narrow band noise process.

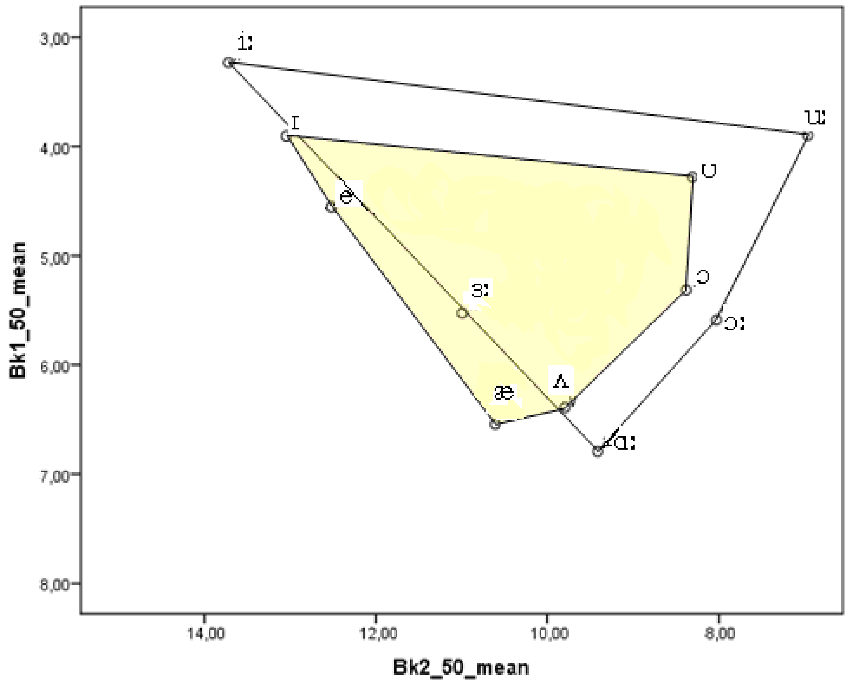

Figure 1. The mean vowel space of English vowel tokens produced by Sudanese speakers. Long vowels are linked by a line, but no color is added, whilst the short vowels are shown in yellow. F1 values are plotted vertically and F2 horizontally.

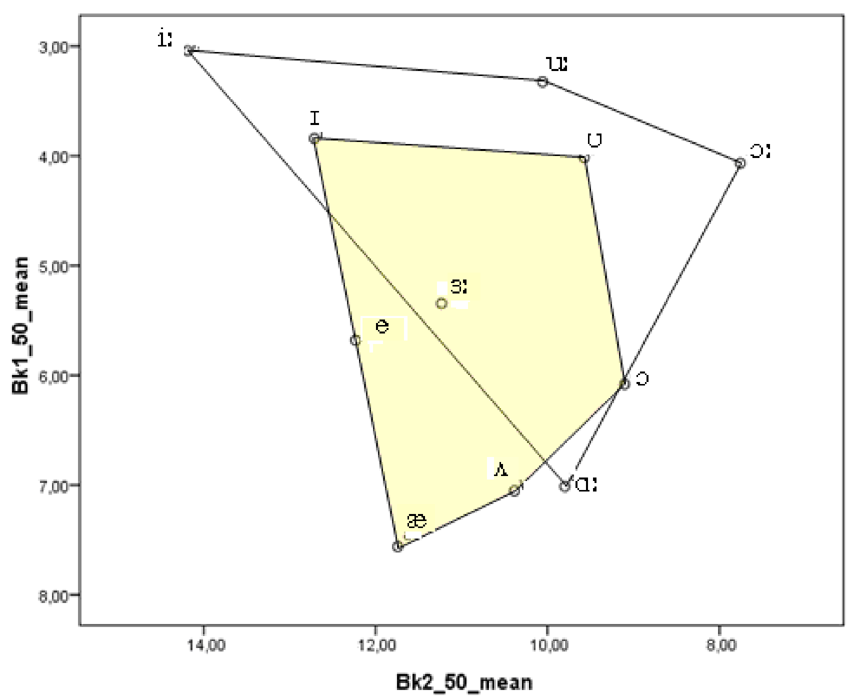

Figure 2. The mean of vowel space of English vowels tokens produced by British speakers. Long vowels are linked by a line, but no color is added, whilst the short vowels are shown in yellow. F1 rates are displayed vertically, and F2 rates are horizontally.

Figures 1 and 2 show the acoustic analysis of English vowels spoken by the Sudanese and British speakers. It is apparent from the results that the English vowel space of the Sudanese speakers differs from that of the natives. In the vowel area, the short and long English vowels of such speakers appear to be closely similar (though not identical) whilst their British equivalents are dissimilar, which reveals an important discovery. This implies that the Sudanese speakers follow the same track in producing the short and long English vowels which make their acoustic output of such vowels manifests a kind of correspondence. In terms of phonetics, the high front vowel /ι⌉/ is situated closer to the low front /I/. Similarly, the rounded back /□⌉/ and /□/ look closer to each other, but in the case of the native speakers, such pairs are totally separate, that is, /□⌉/ is located high back, whilst /□/ tends to be low back in the vowel area. Similarly, the English long vowel of the Sudanese speakers /υ⌉/ is produced further back than that of the British speakers. More interesting differences are that several Sudanese English vowels do not show a clear learning pattern; that is, do not look like those of the target language. As Figure 1 shows, /ε/ is less open and closer to /I/; that is, it is located almost near the contours of /I/.The short open /Θ/ fluctuates between /℘/ and /A⌉/, unlike that of the native speakers which normally sticks to the contour. These types of pronunciation problems occur due to different factors.

DISCUSSION

The statistical analysis of acoustic output reveals that the dispersion of the English vowels spoken by the Sudanese speakers and their British counterparts uses different distinction categories. One of the most interesting findings is that the English tense-lax vowels pairs /υ⌉ ~Y, □⌉ ~ □/ are very closely positioned in the vowel space. This pattern of error reveals a clear effect of the speakers' L1 vowel system; that is, the English tense/lax vowels were pronounced with the subjects' L1 productive strategy (Mitleb, 1981). On the other hand, the English tense vowel /ι⌉/ shows no serious production problems probably because it is similar to the Arabic /ι⌉/ (see Munro, 1993). The misclassification of /ε/ as /I/ (Figure1) indicates no distinct learning of such vowels. It probably occur due to the fact that the English /ε / has no equivalent in Arabic, so Arab students always substitute it for /I/ or /℘/ (Kopczynski, and Meliani, 1993). However, this claim sounds less plausible, since previous studies have shown that Sudanese Arabic has /ε/ (Dickins, 2007).[3] Therefore, most probably this type of error refers to spelling/graphical differences between English and Arabic, where the Sudanese-Arabic speakers pronounce English /ε/ in the way it is spelt as a transfer of the Arabic spelling system which maintains a direct letter-sound relation. This means each vowel or consonant of Arabic has one sound that corresponds to its spelling, but there are no mute letters. Therefore, the English vowel /ε/ in words such as *enter*, *envelope*, *wet* and *let* are often mispronounced as /I/ by the Sudanese speakers which forms the major cause of confusion in this context.

The fluctuation of the English front low short vowel /Θ/ which is graphically shown in a mid position between /↔/ and /℘/ refers to the lack of such types of vowels in the learners' L 1 vowel inventory (Brett, 2004). Actually, the Sudanese Arabic - accented English /Θ/ was situated in a central position; however, the English /Θ/ has to be kept fully front by Arab speakers to avoid confusion with /℘/ (Cruttenden, 2001). Moreover, the lack of vowel contrasts between Arabic and English adds up to the problem. Arabic and English show similar simple syllable nuclei in that both show phonetically short and long vowel patterns. But because Arabic has fewer contrasts, the range of allophonic variation of each vowel phoneme is greater than that of English; example, Arabic /α/ has allophones within the area bounded by /E/, /Θ/, /A/, and /℘/. Thus, English contrasts such as *bet-bat, cat-cot, cot-cut, cot-caught* trigger difficulty (Lehn and Slager, 1983).

All in all, error patterns such as these are often accounted for on the basis of formant movements that can largely be categorized in terms of the speakers' L1 phonemic inventory as previous researchers have shown (Scholes and Robert, 1968; Liberman et al. 1957). That is, the Sudanese speakers' data tend to show different movement trends in comparison to those of the native speakers which indicate that Sudanese speakers fail to achieve correct movements.

Results and discussion of duration

Figure 3 presents mean duration of English vowel token of Sudanese university students and native speakers of English. Duration rates are arranged in descending order from left to right. Durations are measured in milliseconds. In the figure, the native speakers' vowel durations appea-red longer than their Sudanese counterparts because they were spoken in isolation.

Z-normalization was used to get more insightful vowel duration rates (see Normalization above). The computation

[3] Sudanese Arabic also developed monophthongs. These include /ε/ derived historically from the diphthong /ay/ as in /ℵαφν/ 'an eye', which coalesced in dialects such as Cairene and Central Sudanese (Hamid, 1984). Those spoken in much of the Levant, to be realized as / ε□/ or / □□/. In Sanani and a number of Peninsula dialects, the diphthongs are maintained in all phonological contexts. Moreover, among some Cairene speakers the monophthongs are shortened in closed syllables to give short /ε/ or /□/, hence, they are not considered to be separate vowels (Watson, 2002)

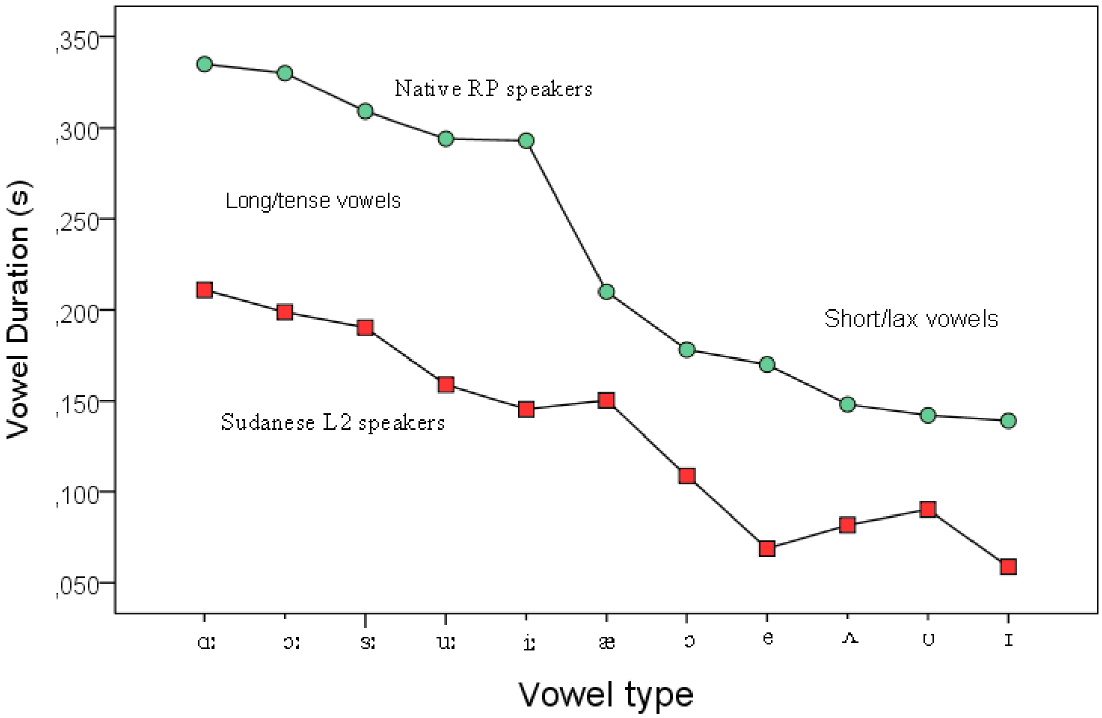

Figure 3. Mean duration (s) of English vowels produced by Sudanese (square markers) and native (circles) speakers of English, broken down by vowel type.

of the correlation revealed a strong positive relation between Sudanese speakers' mean vowel dura-tions and those of the native speakers (r = .943, p < .01).This statistical fact implies that the English vowel durations of Sudanese speakers correspond relatively well to English vowel duration norms (Jacewicz et al., 2006; Catford, 2001). In other words, the tense/long English vowel durations of our subjects correspond to the longest durations whilst the lax/short ones correspond to shortest durations norms.

Correspondence took place probably due to the assumption that Arabic tense-lax vowel categories re-semble those of English in terms of quality and duration; however, resemblance is not identical since each of the two languages possesses distinctive acoustic features. In the previous studies, Sudanese speakers showed English vowel duration ordering similar to that of the native speakers, in particular, long/short tokens; however, they show a narrow distinction from one another. It is likely because such learners incorrectly interpret English tense/lax vowels in terms of Arabic-like temporal pro-perties (Mitleb, 1984). Actually, in terms of acoustic cues, the Arabic long/short vowel distinction can best be described as a tense-lax contrast that bases on quantity[4] (Hassan, 2003; Alghamdi, 1418/1998, Flege and Port, 1981; Koeczynski and Mellani, 1993).

On the other hand, in English, the distinction between the tense-lax vowel pairs is primarily a qualitative diffe-rence perceived by the native speakers (Carrs, 1999; Catford, 2001; Cunningham-Anderson, 2003). Thus, cross-linguistic differences as such lead to difficulty potential among ESL/EFL learners. The results also imply that the Sudanese speakers are aware of the long/short vowel contrast but they have difficulty in implementing exact acoustic norms of the English vowel. Moreover, the poor performance on this area could be attributed to the speakers' relatively small exposure to English vowel sounds.

Automatic classification of L1 and L2 vowels

Although we have no perception data at this moment, we may attempt to make an educated guess of how native English listeners would identify the Sudanese L2 English vowels (or how Sudanese L2 listeners would identify the

[4] Vowel quantity is defined as that phonological distinction of a vowel relative to one or more other vowels of similar timbre in the language. Contrasts in vowel quantity are often acoustically realized by the duration of vowels where a long vowel quantity has a duration that extends twice as of a short vowel quantity. The greater amount of time associated with a long vowel quantity also allows the possibility for a more extreme articulation than a corresponding short vowel quantity. Consequently, the vowel spectrum, in particular the first and second formant frequencies, and perceived timbre may also be affected by vowel quantity (Takayuki, et al. 1999).

Table 1. RP vowels classification results: 76.4% of selected original grouped cases correctly classified. LDA trained and tested on RP vowels.

	Responses											
v_num	ι⎤	I	ε	Θ	℘	A⎤	□	□⎤	Y	υ⎤	∈⎤	**Total**
ι⎤	97.4	2.6										100.0
I	1.8	91.2	1.8							2.7	2.7	100.0
ε		10.5	66.2	7.5	.8			.8			14.3	100.0
Θ			9.5	82.5	6.3						1.6	100.0
℘			.9	1.7	71.6	18.1	1.7		.9		5.2	100.0
A⎤				1.1	17.8	66.7	14.4					100.0
□					1.0	16.7	67.6	10.8	3.9			100.0
□⎤							2.0	91.8	6.1			100.0
Y		5.3						14.0	59.6	19.3	1.8	100.0
υ⎤		6.3						5.1	25.3	63.3		100.0
∈⎤		3.8	13.8	1.3	10.0				1.3	1.3	68.8	100.0

Table 2. RP vowels classification results: 42.2%of unselected original grouped cases correctly classified. LDA trained in RP data but tested on L2 vowels: tells you how English listeners would classify the L2 vowels

v_num	Vowel identity predicted from RP production data (42.2%)											
	ι⎤	I	ε	Θ	℘	A⎤	□	□⎤	Y	υ⎤	∈⎤	**Total**
ι⎤	90.9	9.1										100.0
I	42.9	42.9		7.1				7.1				100.0
ε		54.5	45.5									100.0
Θ		8.3		50.0	33.3	8.3						100.0
℘					72.7	18.2					9.1	100.0
A⎤				9.1	63.6	27.3						100.0
□						9.1	45.5		36.4		9.1	100.0
□⎤						9.1	81.8	.0			9.1	100.0
Y		7.1					14.3	7.1	64.3	7.1		100.0
υ⎤								90.0	10.0	.0		100.0
∈⎤			50.0	8.3	16.7		8.3				16.7	100.0

L1 English vowels). In order to do so, we will use Linear Discriminant Analysis (LDA). LDA (Klecka, 1980; Strange et al., 2004) is an automatic classification technique that can be trained to optimally classify the vowel tokens in our study in terms of the English vowel categories. In the training stage of the analysis we feed the algorithm exemplars of L1 tokens of English, in terms of F1 (Bark and subsequently z-transformed) and vowel duration (z-transformed). As the results will point out, the algorithm, once trained on the native English vowel data, achieved a good classification of the native English vowel tokens (76% correct identification; chance would be 9% correct, that is, 1 in 11). We then used the same algorithm (optimized for L1 English vowel categories) to classify the Sudanese L2 English vowel tokens. In this way, the LDA functions as a model of a typical native L1 listener on the assumption that L1 listeners know where the vowel tokens in his language are typically located and how far individual vowel tokens may stray away from their prototypes (icentroids in the F1-by-F2 by duration) space. We have also repeated the process, and trained the model with Sudanese L2 English tokens; we then examined how well it identified the vowels spoken by Sudanese learners and by native speakers of English.

Tables 1, 2, 3 and 4 show the results of the LDA in the shape of confusion matrices. In the rows of the matrices we list the vowel types as intended by the speakers, whilst in the columns we display the vowel types identified by the LDA as the most likely category. As a result, the main diagonal in the matrix contains the

Table 3. The classification results of Sudanese accented English vowels: 48.7% of unselected original grouped cases correctly classified. LDA trained on L2 vowels but tested on L1 vowels.

	Responses											
v_num	ι⌉	I	ε	Θ	℘	A⌉	□	□⌉	Y	υ⌉	∈⌉	**Total**
ι⌉	95.6	4.4										100.0
I	1.8	61.9	35.4								.9	100.0
ε		.8	25.6	11.3						.8	60.9	100.0
Θ			.8	79.4	4.0	5.6					10.3	100.0
℘				3.4	46.6	40.5	3.4	.9	1.7		3.4	100.0
A⌉					15.6	54.4	4.4	25.6				100.0
□					3.9	7.8	10.8	63.7	3.9	9.8		100.0
□⌉								3.1	3.1	93.9		100.0
Y		1.8	3.5						70.2	24.6		100.0
υ⌉	2.5	5.1	2.5						72.2	17.7		100.0
∈⌉		1.3	13.8	3.8	3.8		3.8		3.8		70.0	100.0

Table 4. The classification results of Sudanese accented English vowels: 54.7% of selected original grouped cases correctly classified. LDA trained and tested on L2 vowels.

	Responses											
v_num	ι⌉	I	ε	Θ	℘	A⌉	□	□⌉	Y	υ⌉	∈⌉	**Total**
ι⌉	90.9	9.1										100.0
I	57.1	28.6		7.1						7.1		100.0
ε		45.5	45.5								9.1	100.0
Θ		8.3		50.0	25.0	16.7						100.0
℘				9.1	36.4	36.4		9.1			9.1	100.0
A⌉				9.1	18.2	72.7						100.0
□						9.1	9.1	45.5	36.4			100.0
□⌉							9.1	81.8			9.1	100.0
Y			7.1				28.6		57.1	7.1		100.0
υ⌉									10.0	90.0		100.0
∈⌉			16.7	16.7	8.3			8.3			50.0	100.0

correct identification, while confusions are found in the off-diagonal cells. We will first examine Table 1, which contains the results of the LDA when trained and tested on L1 English vowels.

Table 1 shows that correct classification of vowel type ranges between 60 (for /Y/) and 97% (for /ι⌉/) with an average of 76%. The strongest confusion is found between /υ⌉/ and /Y/: the tense vowel is misclassified as its lax counterpart in 25% and the lax member is confused with the tense member in 19%.

Even though the classification is imperfect (as would be the classification by human listeners) we may now classify the Sudanese L2 tokens by applying the native classification schema. The results are presented in Table 2.

The performance of the rate of confusion was low (42.2%) compared to previous one (76%). Similar types of errors were repeated where /υ⌉/ was almost substituted for /□⌉/ and less often for /Y/, and /□⌉/ for /□/. Other frequent errors were the misclassifications of /I / as /ι⌉/, /ε/ as /I/, /Θ/ as /℘/, /A⌉/or /∈⌉/ and finally /∈⌉/ was misidentified as /ε/, and less often as /℘/and /□/.

The last analysis is an LDA trained on L2 data and used to classify native English vowels.

Most of the English vowels produced by the Sudanese speakers were misclassified, with a mean correct of 55% and lot of confusions. For example, /I/ was misclassified as /ι⌉/ (57% confusion), /□/ as /□⌉ and Y/, /Y/ as /□/, and

/℘/ as /A⎤,or □⎤/ and /ε/ was misclassified as /I/ (46%). The results also showed that /∈⎤/ was almost mispronounced as /ε, I, Θ, □⎤/; however, there were no serious errors made in the classification of /ι⎤/. There are other slight mispronunciations of English vowels made by the subjects which do not reflect a clear error pattern (Table 2).

In Table 4, we submitted the rate of confusion was even worse (48.7%) when the same English vowel tokens were identified automatically in native listeners' terms. For instance, /□/ and /□⎤/ were almost mis-classified as /Y/ or /υ⎤/, whilst tense-lax pair /υ⎤ ~ Y/ was interchangeably misclassified. Automatic identification also shows that the tense vowel /I/ is often replaced by /ε/ or visa versa. Furthermore, the English vowel tokens /ε/, /℘/, /∈⎤/ and /Θ/and /A⎤/ were interchangeably substituted for one another; however, the English vowel pair /I ~ι⎤/ was rarely confused.

In conclusion, the classification matrices show that the perception of such vowels proved to be more problematic for Sudanese speakers. However, results of the native speakers revealed better performance as Table 1 shows. These results allow us to predict that the Sudanese speakers do not follow certain learning patterns probably because these types of vowels are lacking in Arabic language. The data also allow us to predict that Sudanese listeners /speakers were more intelligible to each other than to the native speakers, and vice versa, which reflects an inter-language effect in which speech participants benefit from their national backgrounds[6].

Conclusion

The articulation of the /ε/, /℘/, /∈⎤, /□/,/A⎤/, /υ⎤/, /□⎤/, /I/ and /Θ/ proved to be difficult as the subjects show a poor performance. However, there are few errors made in the pronunciation of the tense vowel /ι⎤/. This is probably because the Sudanese speakers have similar equivalents for such vowels.

In contrast to the native speakers of English, the Sudanese speakers' vowels are mostly distinguished with lower formant values. The speakers need to enhance their vowel inventory to produce less foreign-accented English vowels.

The English vowel durations of the Sudanese learners show a correspondence to the duration norms of the native speakers. However, some vowel durations are slightly lengthened, probably due to the circumstance that the learners tend to produce English vowels with their L1 productive strategies.

Both speakers benefit from their national backgrounds (inter-language) which appeared in English vowel perception and production levels. In other words, each of the Sudanese and British speakers manifests a greater level of intelligibility they are exposed to subjects with the same nationality and vice versa

Differences between L1 and L2 present part of the causes of the production problems of English by Sudanese university learners of English. The lack of L2 phonemic knowledge also forms a second factor which adds to the problems.

The results represent important experimental evidence of the learning problems of English vowels experienced by Sudanese EFL learners.

[6] In this context, interlanguage describes the possibility that, in interactions, listeners can explicitly categorize unfamiliar speakers due to regional dialects/ linguistic backgrounds, (Wang and Van Heuven, 2006:).Thus, for English native listeners, the native speakers of English are most intelligible. Similarly, the non-native listeners find the non-native with the same linguistic background more intelligible than the natives- matched inter-language speech intelligibility benefit. On the other hand, the type of degraded level of intelligibility that occurs between native and non-native speech participants is referred to as -mismatched inter-language speech intelligibility benefit (Bent and Bradlow, 2003).

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Appendix 1. Vowel list: /hVd/ meaningful words in fixed carrier (say …..again); 19 different full vowels and diphthongs read by Sudanese learners of English.

No.	Vowel	Key words
1	air	(chair pair)
2	pet	(met, let)
3	pat	(rat, fat)
4	pot	(lot, got)
5	nut	(hut, cut)
6	pit	(hill, tin)
7	peat	(feet, meet)
8	fool	(cool, school)
9	full	(bull, good)
10	mile	(file, Nile)
11	peer	(dear, fear)
12	poor	(sure, tour)
13	late	(shade, rate)
14	out	(shout, loud)
15	boy	(toy, foil)
16	bird	(girl, curt)
17	bard	(hard, card)
18	board	(lord, short)
19	boat	(coat, goat)

Appendix 2. English vowel durations of eleven Sudanese university learners of English.

Speaker no.	1	2	3	4	5	6	7	8	9	10	11
vowel	dur	dur.	dur.	dur.	dur	dur.	dur.	dur.	dur.	dur.	dur.
A⎤	.252	.207	.174	.133	.293	.160	.356	.215	.130	232	.170
Θ	.258	.148	.149	.098	.204	.137	.190	.189	.099	069	.113
↔Y	.415	.200	.241	.245	.247	.280	.366	.256	.272	161	.190
αI	.207	.141	.197	.174	.261	.188	.353	.165	.158	177	.164
ε	.000	.042	.059	.038	.112	.078	.103	.066	.053	089	.059
ε↔	.278	.433	.269	.166	.279	.247	.318	.217	.246	.000	.211
εI	.237	.145	.181	.114	.221	.179	.302	.163	.181	241	.180
I	.092	.042	.061	.058	.067	.058	.068	.051	.032	061	.047
ι⎤	.191	.148	.160	.093	.158	.113	.180	.000	.092	217	.086
I↔	.248	.280	.241	.142	.256	.212	.277	.202	.144	201	.139
□	.156	.110	.058	.047	.113	.000	.312	.065	.068	128	.082
□⎤	.264	.188	.186	.147	.265	.158	.318	.191	.128	178	.163
ow	.262	.137	.170	.145	.125	.232	.346	.133	.118	266	.113
□I	.363	.226	.244	.241	.450	.181	.666	.227	.261	210	.202
Y	.137	.056	.082	.092	.088	.092	.092	.075	.072	103	.078
υ⎤	.000	.084	.154	.115	.187	.134	.337	.000	.125	186	.114
Y↔	234	.129	.163	.165	.203	.203	.197	.164	.238	000	.226
∈	.077	.091	.081	.068	.074	.091	.094	.000	.077	099	.066
∈⎤	.252	.244	.159	.140	.265	.179	.313	.123	.000	046	000

Appendix 3. English vowel durations: mean absolute duration expressed in seconds. Abstracted from: Wells (1962) website 2/1/2001 Wells, Formants of Pure Vowels: relative amplitude.

No.	**Vowel**	**Mean absolute duration**
1	I	.139
2	Y	.142
3	℘	.148
4	ε	.170
5	□	.178
6	Θ	.210
7	I⌉	.293
8	υ⌉	.294
9	∈⌉	.309
10	□⌉	.330
11	A⌉	.335
Average of all vowels		.232