ACQUISITION OF ENGLISH DENTAL FRICATIVES BY PAKISTANI LEARNERS

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Abstract

This paper is based on a study of the acquisition of dental fricatives by advanced Pakistani learners of English. The results are analyzed in light of predictions of the speech learning model (SLM: Flege 1995) using Optimality Theory (Prince & Smolensky 2004). In Pakistani English, dental fricatives [θ ð] are substituted with dental stops [t̪h d̪]. The current study aims to find out if Pakistani learners, after having acquired Pakistani English, can acquire British English dental fricatives at advanced level. Perception and production experiments were conducted with a group of 30 advanced Pakistani learners of English who, after acquiring Pakistani English (which substitutes dental fricatives with dental stops), were taught British English. The perception test was based on an identification task, a 3-alternative forced choice task and an AX discrimination task. In the production task, they were asked to produce the words ‘thieve’ and ‘these’ each three times along with some other distracters. The productions were evaluated by four native speakers of English on a Likert scale ranging from 5 to 1. The productions were also analyzed acoustically. The results show that the learners perceive English dental fricatives as labial fricatives [f v] but they can discriminate them from the L1 stops [t̪h d̪]. However, acoustic analysis of the productions indicates that the learners produce English dental fricatives as dental stops [t̪h d̪]. This asymmetry between perception and production poses a challenge for the speech learning model which predicts a correspondence between perception and production. The findings of the study point out that the speech learning model should account for the phonological behaviour of L2 learners and the phonology-phonetics interface which the model lacks.

1. Introduction

British traders of the East India Company introduced the English language in the Subcontinent (Pakistan and India) in 17th century CE (Baumgardner 1990). Later, English became the official language when the East India Company occupied the Subcontinent in 1857. In 1947, Pakistan got independence from English rulers but the English language remained the official language in the country. It is a dominant language of media, education and official correspondence in Pakistan (Haque 1993). After the native speakers left, there was no native speaker model for Pakistani learners of English to follow, but they had to learn English because of its national and international importance. Resultantly, a specific variety of English developed in Pakistan during last six decades which, like other post-colonial Englishes, claims the status of a dialect of English (Rahman 1990). Pakistani English (PE) has its own linguistic features some of which differ from the British English (for details see Baumgardner 1993, Mahboob & Ahmar 2004, Rahman 1991, etc.).

One of the prominent features of PE is that it does not have dental fricatives in its phonemic inventory and the dental fricatives [θ ð] of British English are produced as dental stops [t̪h d̪] (Rahman, 1991, Mahboob & Ahmar, 2004). The dental stops exist in most indigenous Pakistani languages. An interesting situation emerges for the students of English language and linguistics in Pakistan when they are taught phonology of English as a module. In the classroom, they are taught the phonology of British English. Thus, they are taught that the dental fricatives [θ ð] exist in English, and the place and manner of articulation of these
phonemes are also explained to them. They are also encouraged to speak British English (BE) with as much native-like accuracy as possible. But despite all this effort at academic level, practically what the students normally hear around them in the society is PE which substitutes English dental fricatives [θ ð] with dental stops [t̪ d̪]. The current study aims to test the perception and production of advanced Pakistani learners of English who, after having acquired PE, are taught BE. The research question is whether such students remain faithful to the already acquired PE and produce English [θ ð] as stops or whether they acquire BE, accurately producing these sounds as dental fricatives.

The remainder of this paper is divided into five sections. The next section provides a brief introduction of the basic ideas and predictions of the speech learning model (SLM: Flege 1995) relevant to the current study. The findings of the study will be analyzed in light of the predictions of the SLM. Section 2 provides details of the participants and experiment conducted for data collection. The data will be presented in section 3. Section 4 is based on a detailed analysis and discussion of the results. The analysis will be done using classical Optimality Theory (Prince & Smolensky 2004). Section 5 concludes this paper.

2. The speech learning model

Several models of second language acquisition have been presented to account for the acquisition of L2 sounds. The perceptual assimilation model commonly known as PAM (Best 1994, 1995), feature model known as FM (Brown 1998, 2000) and the speech learning model (Flege 1995) are some of the most well known models of second language acquisition. The findings of the current study will be analyzed in light of the predictions of the speech learning model so only the speech learning model will be discussed in detail. The reason for this is that the SLM is based on phonetic perception of L2 learners which is the main concern of this study. The SLM also predicts a correspondence between perception and production whereas other models (e.g. FM, PAM, etc.) primarily account for perception of L2 learners. Since the objective of the current experiment is to study a relationship between the perception and the production of L2 sounds, the speech learning model suits the study.

The speech learning model divides L2 sounds into 'new', 'similar' and 'identical' out of which the similar ones are considered most difficult to perceive for L2 learners (Flege 1995). The SLM develops different hypotheses about different learning scenarios. According to the model, learners perceive gradient phonetic details of L2 sounds. This implies that learners can perceive allophonic variance of L2 sounds. If L2 learners perceive a difference between an L2 and the closest L1 sound, they develop a separate phonetic representation for the L2 sound. The phonetic categories developed by bilinguals may be different from those of monolinguals, either for maintaining contrast between the L2 and the corresponding L1 sound, or if the categories of bilinguals are based on features different from those of the monolinguals of the L2. On the other hand, if L2 learners do not perceive a difference between L2 and the corresponding L1 sounds clearly, they equate the two sounds. Flege calls this a mechanism of equivalence classification (Flege ibid.). In case of equivalence classification, the establishment of a new phonetic category for the new L2 sounds is blocked. In this case, learners develop the same phonetic representation for the L2 and the closest L1 sound.

Defining, the concept of equivalence classification, Flege comments that equivalence classification between two sounds may be of two types: weak equivalence classification and strong equivalence classification. In case of weak equivalence classification, learners can perceive a little difference between an L2 and the closest L1 sound but they cannot perceive it clearly enough to develop a new phonetic representation for the L2 sound. Sometimes weak equivalence between two sounds leads to the development of a phonetic representation which
is a merger of the two sounds (Flege 1987). In case of a strong equivalence classification, establishment of a new phonetic category for L2 sounds is totally blocked. In that case, learners perceive the L2 sound as the closest L1 sound and have the same representation in perception and production of the two sounds.

As pointed out earlier, the speech learning model claims that learners perceive gradient phonetic details of L2 sounds. On the other hand, it also claims a correspondence between the perception and production of L2 sounds. This means that, according to the SLM, there is a symmetry between phonetic perception and phonological (lexical) production whereas it is well-known in the literature that sometimes phonetic and phonological factors play critically different roles in L2 acquisition. The interface of phonetics and phonology and its influence on the perception of L2 sounds is well-established in the field of second language acquisition. See Boersma & Hamann (2009) for a detailed discussion on phonetics-phonology interface. The current study is conducted with a view to determine how well the speech learning model can account for the perception and production of English dental fricatives by Pakistani learners.

3. The current study

A group of thirty Masters students of English were selected for this experiment. The participants spoke the same L1 and were studying in the same university in Pakistan. At the MA level the students have a lot of opportunity to speak and listen to English. In Pakistan, English is taught as a compulsory part of courses of studies from primary school regardless of the discipline of the student. Therefore, the participants of this study were taught PE up to Bachelor level. At the time of experiment, they were registered as regular students of the MA English programme in their second year.¹ In the Masters programme, although they still hear PE around them, they are taught the phonology of British English (BE) in class. According to their statements, they speak English for an average of 2 hours (standard deviation 1.20) and listen to it spoken by non-native Pakistani speakers for an average of 2.56 hours (standard deviation 1.65) daily. Their average age was 21.97 (standard deviation 2.63) years.

Before the main experiment, the students were asked to provide information about their academic and linguistic background through a questionnaire. The above information was elicited through the questionnaire. They were also requested to provide written permission for recording of their voice and using the data for research purposes anonymously. Permission to conduct the experiment within the campus was also obtained from the heads of the institutions where the participants were studying.

Afterwards, the learners were given a perception and production test. The perception test had three tasks: an identification task, a 3 alternative forced choice (hereafter 3AFC) discrimination task and an AX discrimination task. In the identification task, the participants were asked to identify and write, in Urdu² and English in the relevant columns of a given answer sheet, which consonants they heard between two low vowels in the stimuli. The stimuli of the test carried along with other distracters, [aθa] and [aða] produced by a female native speaker of English aged 27. This task had 3 repetitions providing 90 responses (30 participants * 3 repetitions). Before being used in the test, the stimuli were played to four native speakers of English who confirmed that the consonants were produced in correct

¹ MA is a two-year degree in Pakistan.
² The participants were asked to write their answers in two languages, namely English and the national language Urdu because some of the sounds of English do not have proper letters in English script. For example, dental fricatives do not have specific letters in the English alphabet but the Urdu language does have relevant letters for these sounds. Writing answers in two languages provided the participants the required letters.
English pronunciation. It is important to point out an interesting fact that in Urdu, which is a national language of the participants and Saraiki, which is their mother tongue, the letters for dental fricative consonants [θ ð] exist but the sounds themselves do not exist. This is because Pakistani languages got their script from Arabic and the sounds [θ ð] do exist in Arabic. Therefore, the learners were aware of the existence of the letters for dental fricatives. Since they had been taught the phonology of British English, they also knew the IPA symbols for these English phonemes. Still, they were asked to point out if they felt that they were listening to a consonant in the stimuli for which they did not have proper letter available in Urdu3 and English. None of the participants pointed out such a difficulty. The purpose of using Urdu letters along with English ones is that the English alphabet system lacks proper letters for dental fricatives. Most of the participants preferred to write their answers in English letters (not in IPA symbols). Since English lacks letters for dental fricatives, those who wrote their answers correctly, wrote 'the' on listening to [θ] sound. Since Urdu has proper letters for dental fricatives, the participants were also asked to write their answers in Urdu. The responses in Urdu letters further confirmed whether the participants identified the target sounds correctly or not.

In the 3AFC task, they listened to sets of sounds including those listed below:

(1)  
[əða] [ava] [aga]  
[aθa] [asa] [aba]  
[aða] [ada] [aza]  
[aθa] [aga] [afa]

The learners were asked to choose by ticking one of the following on the given answer sheet after hearing each of the sets of the above sounds:

1. The consonant in the first syllable is the same as the consonant in the second syllable.  
2. The consonant in the first syllable is the same as the consonant in the third syllable.  
3. The consonant in the first syllable is different from the consonants in both the second and the third syllable.

Some other sets of sounds as distracters were also added to the above list. There was no repetition in this task so, in all, 30 responses were obtained in this task. The purpose of this task was to test whether the participants could differentiate English [θ] from [s] and [ʃ], and [ð] from [z] and [v]. Previous studies report substitution of English dental fricatives with either labial fricatives (Bell & Gibson 2008) or coronal fricatives (Hatten 2009, Lombardi 2003, Weinberger 1997). The third, apparently irrelevant stop given in the list of each of the sets of the stimuli in (1) above was included with the target sounds in the stimuli to make the task more difficult so that the participants would maintain their concentration and decide on the basis of careful listening. All the stimuli were prepared in the voice of the same native speaker of English.

The third task of the perception test was an AX discrimination task. All the instructions to the participants were given by the author in their L1 which is also the L1 of the author. The instructions were also written on the answer sheets in English. In this task, two sounds were played and the participants were asked to determine by ticking in the relevant column of the answer sheet if the consonants in the two sets of sounds were the same or different. The first set of sounds in the stimuli in this task was either [aθa] or [aða] spoken by

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3 The L1 of the learners also uses Urdu script with some modifications.
the same female native speaker of English followed by [əθ] or [əθa] spoken by a female monolingual native speaker of Saraiki which is the L1 of the participants of this study. The L1 sounds were recorded in the voice of a female native speaker who speaks the same dialect of Saraiki which the participants speak. \footnote[4]{According to Shackle (1976) there are six dialects of Saraiki. All participants of this study speak central dialect of Saraiki.} Before the Saraiki sounds were used in the test, two native speakers listened to them and confirmed that the sounds were produced with accurate pronunciation. The purpose of this task was to determine whether the participants could discriminate between English dental fricatives and Saraiki dental stops or if they confuse them. Recall that in PE the English dental fricatives [θ ð] are produced as dental stops. Aspirated and unaspirated dental stops exist in Urdu (Shackle 2007), the national language of the country and Saraiki (Shackle 1976), the L1 of the participants. The participants were instructed to neglect the differences in the tone, accent, pitch, etc. of the speakers and decide only on the basis of the consonants between two ‘a’s in the stimuli. This task had three repetitions. Some distracters were also included in the list of stimuli. The stimuli were presented in random order. A total of 90 responses (30 participants * 3 repetitions) were obtained from this task.

In the production test, the students were asked to read in natural, normal speed the words given in a list which contained, along with other English words, ‘these’ and ‘thieve’ each three times. Previous research shows that the front vowel is neutral in its effect on the production of L2 sounds (Syed 2011). Therefore, such words were selected for production in which the target sounds were followed by a tense front vowel. These words start with dental fricatives and are quite commonly used words with which the participants were already familiar. These words carry English dental fricatives on onset of the syllable which is quite a prominent position (Archibald 1998). Therefore, they provide suitable context for the study of English dental fricatives. Four native speakers of BE (aged 23, 32, 40, 42) were asked to evaluate the productions of English dental fricatives in the words ‘these’ and ‘thieve’ on a Likert scale ranging from 5 to 1. On the scale, 5 was ‘native-like’, 4 was ‘near native-like’, 3 ‘different from natives but understandable’, 2 ‘hardly understandable’ and 1 was ‘unintelligible’. The judges were asked to evaluate the productions only on the basis of the pronunciation of word-initial consonants in the words ‘these’ and ‘thieve’ without being influenced by the (in)accuracy of productions of the other phonemes in the target words. The scores awarded by the four judges were averaged. In the following analysis only averaged results will be presented. \footnote[5]{Only two words, namely ‘these’ and ‘thieve’ were selected as stimuli, one of which is a verb. The main reason for this is to control or equal the effect of the adjacent vowel on the production of consonants. If a different word starting with a voiceless dental fricative followed by another vowel e.g. [u] were selected as a stimulus, it would be difficult to determine whether the difference in production of voiced and voiceless dental fricatives is on account of learning or on account of the adjacent vowel. Therefore, ‘thieve’ was selected as a stimulus, which like ‘these’ starts with a dental fricative, is followed by the same front vowel like ‘these’ and also consists of one syllable. Therefore, the purpose of selecting phonologically similar words is to control the effect of different factors like familiarity, adjacent vowel, word size, etc.}

4. Presentation of the data

The data will be presented in the following two subsections. First, the results of the perception test are presented, followed by those of the production test. The results will be analyzed in Section 4.

\footnote[6]{θ-fronting is common in English native speakers living in and around Eastern London. The judges were tested for θ-fronting and it was confirmed that they produced the voiceless dental fricative as [θ], not as [f].}
4.1. Perception test results

In the identification test, accuracy of the participants was poorer on [θ] than on [ð]. They could not identify [θ] accurately even in a single trial out of 90 repetitions (30 participants * 3 repetitions) but they identified English [ð] accurately in 14 (15.56%) repetitions. English [θ] was identified as [s] 12 (13.33%) times and as [f] 78 (86.67%) times. English [ð] was identified as [z] 24 (26.67%) times and as [v] 51 (56.67%) times. Although the stimuli were presented in random order along with some other distracters, the respondents were consistent in their responses in the repetitions which confirms that their responses were based on their own careful perception and that they were not merely guessing.

The results of the other two tasks (3AFC & AX discrimination) are presented together in the following table. Table 1 shows the number of times a sound was discriminated from the closest sound accurately.

Table 1: Discrimination test result

<table>
<thead>
<tr>
<th>Sound pairs</th>
<th>3 AFC discrimination (N=30)</th>
<th>AX discrimination (N=90)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[aθa]</td>
<td>7</td>
<td>83</td>
</tr>
<tr>
<td>[afa]</td>
<td>14</td>
<td>79</td>
</tr>
<tr>
<td>[aθa]</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>[asa]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>[aða]</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>[ava]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>[aða]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>[aza]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L1 [aθa]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L2 [aθa]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L1 [aða]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L2 [aða]</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The above table shows that only 7 out of 30 students discriminated [θ] from [f] and 14 of them discriminated it from [s]. Similarly, 14 participants discriminated [ð] from [v] and 20 of them discriminated it from [z]. In this way, the performance of the participants was better on the discrimination of voiced dental fricative than the voiceless one. They assimilated both target sounds with the closer labio-dental fricatives in more trials than with the coronal fricatives.

The results of the AX discrimination task show that the participants discriminated the voiceless dental fricative from the corresponding L1 stop 83 times and the voiced dental fricative from the corresponding L1 stop 79 out of 90 times. The excellent performance of the participants in the AX discrimination task indicates that they can discriminate between English dental fricatives and the L1 dental stops.

4.2. Production test results

The participants’ productions of the target phonemes were evaluated by four native-speaker judges. Table 2 shows the averaged scores awarded by the judges.

Table 2: Production test results

<table>
<thead>
<tr>
<th>Stimuli</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>[θ]</td>
<td>2.00</td>
<td>4.33</td>
<td>3.24</td>
<td>.50</td>
</tr>
<tr>
<td>[ð]</td>
<td>2.00</td>
<td>4.67</td>
<td>3.51</td>
<td>.50</td>
</tr>
</tbody>
</table>

The results show that the participants performed better on the voiced [ð] than on voiceless [θ]. The variance in the means of the two scores is significant (Z= -2.81, p=.005). Overall, the participants could not obtain an average score of 4 which means they were not rated by the

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7 In one of the trials, the English voiced fricative was identified as an irrelevant consonant.

8 Recall that the participants presented their answers by writing the consonant in English and Urdu.
native speaker judges as ‘native-like’ or ‘near native-like’ in their production of English dental fricatives. These results show the overall group average.

The following table illustrates in detail how many individuals were rated ‘as native-like,' ‘near native-like’ or in another category in their production of English dental fricatives.

**Table 3: Individual performance in the production test**

<table>
<thead>
<tr>
<th>Score</th>
<th>[θ]</th>
<th>[ð]</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>Unintelligible</td>
</tr>
<tr>
<td>2</td>
<td>8</td>
<td>2</td>
<td>Hardly understandable</td>
</tr>
<tr>
<td>3</td>
<td>19</td>
<td>24</td>
<td>Different from natives but understandable</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>4</td>
<td>Near native-like</td>
</tr>
<tr>
<td>5</td>
<td>0</td>
<td>0</td>
<td>Native-like</td>
</tr>
</tbody>
</table>

The above table shows that none of the participants were rated as ‘native-like’ in the native evaluation and only 3 participants for the voiceless and 4 for the voiced dental fricative were considered as ‘near native-like’. The above tests indicate that the participants were very poor in the perception and production of English dental fricatives. They confuse English dental fricatives mostly with labio-dental fricatives [f v] in perception. However, they can clearly differentiate between English dental fricatives and the corresponding L1 dental stops. Their average production is mostly far from even the ‘near native-like’ category.

For a clear understanding of the pronunciation of the learners, all recordings of the participants’ productions were acoustically analyzed using Praat (Boersma & Weenink 2012). The analysis shows that all dental fricatives were produced as stops by the participants. The following spectrogram and wave-form provide an example of the productions of the voiced dental fricative [ð] of one of the participants.

**Figure 1: Spectrogram of the word ‘these’**
In the wave-form, pre-voicing is quite clear before the burst. It is also visible in the shape of darkness at the bottom of the spectrogram pointed out by the arrow. During the burst phase, the vocal folds of the speaker stopped vibrating briefly and the burst was accompanied for a short time by a strong puff of air which is visible with the burst on the spectrogram but it may not be considered a fricative gesture because normally a continuant maintains frication for a considerable amount of time which is reflected in the shape of the concentration of acoustic energy normally on the upper half of the spectrogram depending upon the place of articulation. The final part of the spectrogram is a fricative [z] which clearly shows a concentration of acoustic energy on the upper half of the spectrogram for a considerable time period. There is no such acoustic correlate in the beginning of the word. This shows that the initial consonant of the word ‘these’ was produced as a stop with pre-voicing. In the L1 of the learners, voiced stops (including [d]) are produced with pre-voicing (Syed 2013). This means, the participants substituted voiced English dental fricatives with the voiced dental stops of their L1. For further confirmation of this, voice onset time for all productions of the target phonemes were measured which are given in the following table.

Table 4: Voice onset time

<table>
<thead>
<tr>
<th>Sound</th>
<th>N</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>[ð] produced as [d̪]</td>
<td>90</td>
<td>-173.67</td>
<td>-4.33</td>
<td>-111.2667</td>
<td>40.29</td>
</tr>
<tr>
<td>[θ] produced as [t̪h]</td>
<td>90</td>
<td>14.00</td>
<td>104.33</td>
<td>67.4333</td>
<td>18.63</td>
</tr>
</tbody>
</table>

The above table shows that the voiced dental fricative [ð] was produced as pre-voiced stop with negative VOT and the voiceless dental fricative [θ] was produced as voiceless aspirated dental stop [t̪h]. These results are analyzed in the following section.

5. Analysis and Discussion

The results presented in the previous section show that Pakistani learners perceive English dental fricatives either as labio-dental fricatives or coronal fricatives. They perceived dental fricatives as labio-dental fricatives in more trials than as coronal fricatives. This shows that most of the learners perceived the stimuli on the basis of acoustic cues. It has been pointed out in previous studies (Simon 2009) that L2 learners whose L1s do not have English dental fricatives perceive these consonants as labial on the basis of acoustic cues because the labial [f v] are acoustically very similar to [θ ð] (Wester, Gilbers & Lowie 2007) and if they perceive these sounds as [s z] this is on account of phonological reasons (Simon 2009) because both pairs of sounds are attached to the same place node i.e. CORONAL (Clements & Hume 1995). This means that most of the participants perceived the stimuli on the basis of acoustic phonetic cues. Better performance of the learners in the discrimination rather than the identification test is understandable since in a discrimination test learners simply determine on the basis of acoustic cues the difference between two sounds and respond with ‘yes/no’ type answers, but for identification of those sounds they have to retrieve from their L2 phonemic inventory the sound matching the stimuli which is only possible if the learners have clearly established a separate phonetic category for the sounds in their L2 phonemic inventory. Therefore, a better performance by L2 learners in discrimination rather than identification tests is always predictable (Archibald 2005).

In this way, most of the participants neglected the feature [coronal] and perceived English dental fricatives as labials on account of acoustic similarity. Some of them, who perceived the stimuli as coronal fricatives [s z], only neglected the feature [distributed] and
and Urdu (the national language of Pakistan) both have two letters for voiceless dental stops, [strident] since the English dental fricatives [θ δ] are [+distributed, -strident] whereas [s z] are [-distributed, +strident].

An interesting factor in the results is that most of the participants differentiated English dental fricatives from the L1 dental stops accurately (see table 1). However, in production, they substituted these English phonemes with dental stops. Since the stimuli were nonce words, the students perceived them purely on the basis of phonetic cues. The stimuli for the production test, however, were meaningful words of English, so the participants produced them on the basis of their lexical (phonological) understanding. This interface of phonetics and phonology indicates that although the learners can perceive the difference between fricatives and stops phonetically, they produce English dental fricatives as stops because under the influence of their already acquired Pakistani English they have developed a specific phonemic inventory of their own which is dominant in their production. This already acquired representation of English dental fricatives as stops only activates in a lexical or phonological environment.

The speech learning model does not seem to account for the above situation successfully. The study shows asymmetric results in perception and production, whereas the model predicts a symmetry between perception and production. Therefore, the results of the study do not accord with the SLM predictions since, i) the SLM assumes that in learners’ L2 phonemic inventory representation of sounds is based on only acoustic phonetic cues whereas the above results show that the Pakistani learners perceived L2 sounds on phonetic grounds but produced them on lexical and phonological grounds; ii) the SLM predicts a correspondence between perception and production, however the results show an asymmetry between the perception and production of the participants. According to the SLM, L2 learners perceive gradient phonetic details of L2 sounds and develop a phonetic category for the sound on the basis of their perception. Their production corresponds with the phonetic category developed by them in their L2 phonemic inventory. In other words, according to the SLM, phonological production is based on phonetic perception. However, the results of this study show a different picture. This phonetics-phonology interface points out that a revision in the speech learning model is required to incorporate the role of phonology in L2 perception.

The substitution of dental fricatives with dental stops is because of universal markedness hierarchy since stops are the most unmarked of the consonants (Simon 2009). There are examples of substitutions of English dental fricatives with stops (Lombardi 2003, Yildiz 2006), but the current substitution is triggered more under the influence of PE than the universal markedness of coronal stops. This is because the learners produced the English voiceless dental fricative [θ] as the voiceless aspirated stop [hθ], not as the unaspirated stop [h]. We already know that Pakistani speakers substitute English [θ] with their L1 [hθ] (Mahboob & Ahmar 2004, Rahman 1991). If it were a substitution purely on the basis of markedness only, the participants would have substituted [θ] with unaspirated [h] which also exists in the L1 of the learners. But the mean VOT for the first consonant in the word ‘thieve’ produced as stop by the participants is 67.43 ms (see table 4). This is a VOT value for aspirated stops not for unaspirated ones. This confirms that the substitution of the dental fricative with the dental stop is done under the influence of PE, not because of universal markedness.

An interesting question arises: why do Pakistani learners substitute English [θ] with the L1 [hθ] but not with [h] which also exists in the L1 phonemic inventory and is more unmarked than aspirated [hθ], since [hθ] along with primary articulation also involves a secondary articulation. The answer is that it is because of the influence of English orthography which does not have a separate letter for the voiceless dental fricative. The L1 and Urdu (the national language of Pakistan) both have two letters for voiceless dental stops, [strident] since the English dental fricatives [θ δ] are [+distributed, -strident] whereas [s z] are [-distributed, +strident].
one corresponding to dental stop and another 'h' which represents the aspirated dental fricative in their L1. Since in English the letters 'th' are used to represent the voiceless dental fricative, therefore, there is a strong probability that the participants substituted the fricative with the stop under the influence of orthography. The influence of orthography on production is already attested in literature (Bassette 2009, Erdener & Burnham 2005, Escudero & Wanrooij 2010, Nicol & Barker 2010, Hayes-Harb et. al 2010, LaCharite & Paradis, 2005, etc.). Another probability is that the learners perceive the existence of frication in the input i.e. [θ]; however, since they cannot produce the dental fricative, they substitute it with a stop but to compensate for the loss of frication they add aspiration. This is because of the fact that acoustically, friction and aspiration are similar. However, this is a mere hypothesis which needs confirmation.

In summary, the participants of this study perceived English dental fricatives mostly as labial fricatives but produced them as stops. Now the results are analyzed using classical Optimality Theory (Prince & Smolensky 2004). The L2 phonemic inventory of Pakistani learners does not have dental fricatives. We shall reflect this using a constraint *[θ δ]. This is an extension of the constraint *C (Tesar & Smolensky, 1996). *C resists the existence of a specific phoneme in a particular language e.g. *[p] in Arabic, etc. The substitution of dental fricatives with labio-dental fricatives is ascribed to a constraint ACOUSTIC CORRESPONDENCE (Wester, Gilbert & Lowie, 2007) which demands that the output should be acoustically the same as the input. The faithfulness constraint CORRESPONDENCE is active in the L2 grammar of the learners in different forms. CORRESPONDENCE demands that output is identical to the input. Explaining the CORRESPONDENCE constraint Wester, Gilbert & Lowie (2007: 485) comment:

[f] is the most similar segment to [θ] from an acoustic viewpoint: [f] and [θ] are acoustically (and thus perceptually) surprisingly similar and are hard to differentiate in a non-semantic context. This implies that when [θ] is ruled out by a MARKEDNESS constraint, maximal acoustic CORRESPONDENCE will demand [f] to be used as the realisation of [θ].

The substitution of dental fricatives with other consonants in the current context is a result of interaction between the markedness constraint *C and the faithfulness constraint CORRESPONDENCE. The following rankings reflect the perception of most of the participants.

(5) *[θ δ], CORRESPONDENCE [continuant], ACOUSTIC CORRESPONDENCE >> CORRESPONDENCE [COR], CORRESPONDENCE [strident]

<table>
<thead>
<tr>
<th>/θ δ/</th>
<th>*[θ δ]</th>
<th>CORRESPONDENCE [continuant]</th>
<th>ACOUSTIC CORRESPONDENCE</th>
<th>CORRESPONDENCE [COR], [strident]</th>
</tr>
</thead>
<tbody>
<tr>
<td>[θ δ]</td>
<td>*!</td>
<td>CORRESPONDENCE</td>
<td>ACOUSTIC CORRESPONDENCE</td>
<td>CORRESPONDENCE [COR], [strident]</td>
</tr>
<tr>
<td>[s z]</td>
<td></td>
<td></td>
<td>*!</td>
<td>*</td>
</tr>
</tbody>
</table>

9 That is why in some phonological theories, like Element Theory (Backley 2011, Harris 1994), frication and aspiration are represented with the same element i.e. H.

10 For those few participants who perceived English dental fricatives as coronal fricatives the CORRESPONDENCE [COR] will be ranked higher than ACOUSTIC CORRESPONDENCE and the overall ranking will be *[θ δ], CORRESPONDENCE [continuant], CORRESPONDENCE [COR] >> ACOUSTIC CORRESPONDENCE, CORRESPONDENCE [strident]

11 Due to space problem the constraint CORRESPONDENCE [strident] is not written separately. This is a low ranked constraint in the grammar of the learners which does not play any significant role in the current context.
The most faithful candidates [θ ɹ] lose for violating *[θ ɹ]. The learners also preserve the feature [+continuant] losing the place feature [COR] in that they perceive dental fricatives as labio-dental continuant. This shows that the constraint CORRESPONDENCE [COR] is low ranked in the perception ranking. The candidates [t ɹ] violate CORRESPONDENCE [continuant] and the velar [x ɣ] lose because they are not acoustically similar to the input so they violate the constraint ACOUSTIC CORRESPONDENCE. Therefore, [f v] emerge as the most optimal candidates.

As the results of the study show, the learners have different rankings for the perception and production of English dental fricatives [θ ɹ]. They perceive [θ ɹ] as fricatives but produce them as stops, which means that CORRESPONDENCE [COR] is inviolable in their production grammar. The constraint rankings for production of voiceless and voiced phonemes are also different from each other since the learners add aspiration to the voiceless stop but no such thing occurs with voiced dental fricative [ɹ]. As hypothesized earlier, the learners perceive frication in [θ] in the input and compensate for it by adding aspiration to the output. If this hypothesis holds, it means that the constraint CORRESPONDENCE FRICATION sits higher in the grammar of the learners. It strengthens the SLM point of view that L2 learners perceive sounds on account of their phonetic properties. The following ranking reflects the substitution of voiceless fricative with voiceless aspirated stop.

(6) *[θ], CORRESPONDENCE [COR], CORRESPONDENCE [distributed], CORRESPONDENCE FRICATION >> CORRESPONDENCE [continuant], CORRESPONDENCE [strident]

<table>
<thead>
<tr>
<th>/θ/</th>
<th>*[θ]</th>
<th>CORRESPONDENCE [COR, distributed]</th>
<th>CORRESPONDENCE FRICATION</th>
<th>CORRESPONDENCE [continuant, strident]</th>
</tr>
</thead>
<tbody>
<tr>
<td>[θ]</td>
<td><img src="6" alt="" /></td>
<td><img src="6" alt="" /></td>
<td><img src="6" alt="" /></td>
<td><img src="6" alt="" /></td>
</tr>
<tr>
<td>[s]</td>
<td><img src="6" alt="" /></td>
<td><img src="6" alt="" /></td>
<td><img src="6" alt="" /></td>
<td><img src="6" alt="" /></td>
</tr>
<tr>
<td>[f]</td>
<td><img src="6" alt="" /></td>
<td><img src="6" alt="" /></td>
<td><img src="6" alt="" /></td>
<td><img src="6" alt="" /></td>
</tr>
<tr>
<td>[ɹ]</td>
<td><img src="6" alt="" /></td>
<td><img src="6" alt="" /></td>
<td><img src="6" alt="" /></td>
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</table>

The above tableau shows that the most faithful candidate is defeated for violating a highly ranked constraint *[θ] whereas [s] and [f] lose because the former violates CORRESPONDENCE [distributed] and the latter violates CORRESPONDENCE [COR]. Candidate 4 i.e. [ɹ] loses because it does not obey the constraint CORRESPONDENCE FRICATION which is also highly ranked. The input [θ] has frication whereas [ɹ] lacks it. Therefore, the laurels go to [ɹ] which emerges as the most optimal candidate. However, we have to differentiate between frication and the feature [+continuant]. The former is a phonetic phenomenon and the latter is a phonological feature. The learners lose a phonological feature but compensate for it by producing an output which is phonetically similar to the input. The following ranking reflects the substitution of [ɹ] with [ɹ].
(7) *[ð], CORRESPOND [COR, distributed] >> CORRESPOND [continuant, strident]

<table>
<thead>
<tr>
<th>/ð/</th>
<th>*δ</th>
<th>CORRESPONDENCE [COR, distributed]</th>
<th>CORRESPONDENCE [continuant, strident]</th>
</tr>
</thead>
<tbody>
<tr>
<td>[ð]</td>
<td>*!</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>[z]</td>
<td>*!</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>[v]</td>
<td>*!</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>[d]</td>
<td></td>
<td>*</td>
<td></td>
</tr>
</tbody>
</table>

The place feature CORONAL and its dependent [distributed] sit higher than CORRESPONDENCE [continuant] so the dental stop [d] emerges as the most optimal candidate because [z] is defeated on account of a fatal violation of CORRESPONDENCE [distributed] and [v] loses for violating CORRESPONDENCE [COR]. The successful candidate only violates CORRESPONDENCE [continuant] which is lower ranked in the production grammar of the learners.

6. Conclusion

This study reported on an experiment with a group of advanced Pakistani learners of English. Perception and production test results show that Pakistani learners perceive English dental fricatives as labial fricatives on account of acoustic cues but produce them as stops under the influence of Pakistani English. This shows that the learners have two parallel constraint rankings for perception and production, one of which is based on the phonetic nature of the target sounds and the other is based on phonological features. The findings of the study pose a challenge to the speech learning model, which claims a correspondence between the perception and production of L2 learners. It points out a gap in the SLM, that it is only a phonetics-based model, whereas the current study demonstrates that both phonetic and phonological factors interact in the grammar of L2 learners. This suggests a revision in the model by incorporating phonological factors besides phonetic factors into it.

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