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Original Paper

Testing English Speakers' Perception of Arabic Contrasts

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Abstract

This paper presents the results of an experiment conducted to investigate how adult native speakers of English perceive some Arabic contrasts within Brown's Phonological Interference Model (PIM) (1998, 2000), based on the theory of Feature Geometry. Three Arabic pairs of contrasts were chosen for the experiment: the contrast /b – d/ consisting of consonants present in both English and Arabic; the contrast /x – ɣ/ consisting of consonants that are non-native to English but are distinguished by the features [dorsal, voice, continuant] which are available in the English feature geometry; and finally the contrast /h – ħ/, of which only the former exists in English, whereas the latter is non-native to English and is distinguished by the feature [RTR], which is unavailable in the English feature geometry, thereby rendering /ħ/ completely alien to the English sound system. The experiment consisted of an AX Discrimination task where subjects heard two sounds and were asked to decide whether they were the same or different. Three groups participated in the experiment: an Arabic L1 control group, an English L1 group, and finally an Arabic L2 group. The results of the experiment confirm Brown's findings in a similar experiment with Japanese and Chinese speakers' perception of English.

Keywords

phonological interference, feature geometry, distinctive features, English, Arabic, discrimination

1. Introduction

Adult second language (L2) learners ultimately aspire to attain native-like proficiency in the target language. Through a variety of methods such as intensive formal instruction in the classroom (Lenneberg, 1967) and prolonged exposure to the target language (Flege, Mackay, & Meador, 1999; Munro, Flege, & Mackay, 1996; Senel, 2006), among others, adults do succeed eventually in achieving native-like proficiency with respect to the syntactic and morphological aspects of the target L2. However, they fail to fully acquire near native-like proficiency (let alone native-like proficiency) of the target L2 sound system (Best & Tyler, 2007). As a result, their L2 speech remains influenced by their first language (L1) phonology and is characterized as having a foreign accent (Altenberg, 2005; Bohn & Flege, 1992; Piske, MacKay, & Flege, 2001; Werker & Curtin, 2005; Zampini, 2008).

Infants and young children, in contrast, acquire their L1 without putting a conscious effort in the process (Kuhl, 2000). They do so by mere exposure to the language in a natural setting and with no formal instruction. Their phenomenal language learning ability is largely attributed to the interaction of the innate language faculty, known as Universal Grammar (UG), with input from the target language, which allows young children to set the parameters needed for the target language (Rice & Avery 1993; 1995; Brown & Matthews, 1993; 1997). Furthermore, by taking advantage of this relatively short-lived innate ability, young children are capable of acquiring native-like proficiency of multiple languages simultaneously other than their L1 so long they do so within the critical period. This ability, however, slowly but surely fades away as they mature into puberty (Scovel, 1988). The once adept language learner is eventually and inevitably rendered 'insensitive' to properties in the input of the target L2 (Matthews & Brown, 2004) and their perception of L2 phonemic contrasts is severely constrained by their L1 experience (Best & Tyler, 2007).

Several models of speech perception and production have been proposed in the field of Second Language Acquisition (SLA) research to account for adults' apparent failure to correctly perceive non-native L2 segments, for example, Altenberg (2005); Best et al. (1988); Best (1995); Eckman (1977, 1981); Flege (1987, 1995); Lado (1957); Major (1987, 1990, 1998, 2001); Polivanov (1931); Strange (1994, 1995); Strange and Shafer (2008) Trubetzkoy (1969), among others. However, it is beyond the scope of this paper to present a detailed review of these models. Thus, this paper will focus on the Phonological Interference Model (PIM) developed by Brown (1998, 2000) which is based on the theory of Feature Geometry (Brown, 1998; Matthews & Brown, 1998; Clements, 1985; Sagey, 1986). Specifically, this paper will seek to reaffirm the claims put forward by the model by conducting an experiment along the lines of Brown's (1998, 2000), the details of which will be explained later in the paper.

2. Phonological Interference and Feature Geometry

According to the theory of Feature Geometry, phonetic features that distinguish phonemes from each other are not simply packages of information about phonemes with no order or internal structure. These distinctive features are systematically arranged in a 'hierarchy of constituents' (Clements, 1985; Sagey, 1986). Thus, each phoneme in a language is uniquely represented by features arranged in a hierarchical structure (viz., feature geometry) that distinguishes it from other phonemes in that language. Redundant or predictable information is not included in such representations as they will be provided by a "system of implementation" (Avery & Rice, 1989). Brown argues that the "assimilation" of non-native segments into a phonological category already present in the L1 can be accounted for by the organization and/or presence/absence of distinctive features in the L1/L2 feature geometry. Thus, the

L1 feature geometry in effect acts as a mediator between the "incoming acoustic stimuli" of a speech stream and the auditory processing system, thereby sorting the stimuli into perceptual categories. Consequently, sounds which can be classified within the features present in the L1 would be able to pass through this geometry, whereas sounds which are alien to the L1 would be deflected away from it (Brown, 1998, 2000).

To illustrate with an example, Brown (2000) explains that the lateral approximant /l/ and the central approximant /r/, which are contrastive in English, are represented by the hierarchical structures (a) and (b), respectively, in Figure 1 below:

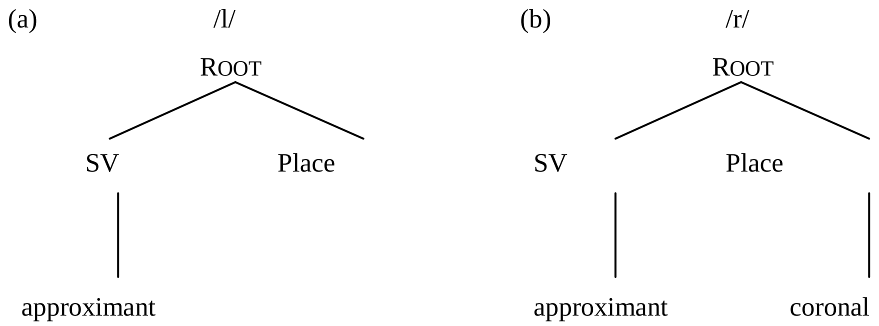

Figure 1. Segmental Representations for Phonemes that Are Contrastive in a Language (English /l/ vs. /r/) (Brown, 2000, p. 11)

By contrast, these two contrastive English phonemes are not contrastive in Japanese. They are allophonic variations of the same phoneme, namely /r/. As a result, /l/ and /r/ in Japanese are represented by only one underlying hierarchical structure, as shown in Figure 2 below:

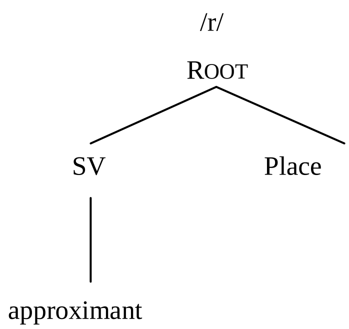

Figure 2. Segmental Representations of Japanese /r/ (Brown, 2000, p. 12)

The fact that /l/ and /r/ in Japanese are allophones of the same phoneme (i.e., /r/) essentially means that any Japanese word containing the sound /r/ can be replaced by /l/ without changing the meaning of the word. This is not the case in English, where substituting an English word containing /r/ with /l/ results in a different meaning, e.g., "rip" vs. "lip". The structural representations of /l/ and /r/ given in Figures 1 and 2 above predict that Japanese speakers perceive these two sounds as instances of the same sound, whereas English speakers perceive them as two distinct sounds.

These predictions are supported by a number of experiments conducted by Brown (1998, 2000) in which she examined the perception of the English /l – r/ contrast by native speakers of Japanese and Chinese, where /l/ and /r/ are not contrastive in both Japanese and Chinese. The feature necessary to distinguish these two sounds is [coronal], which is present in the English feature geometry, but absent in the Japanese feature geometry. Thus, Japanese speakers are predicted to have difficulty perceiving these two sounds as distinct. In Chinese, however, although /l/ and /r/ are not contrastive, the feature [coronal] is present in the feature geometry of Chinese as it is necessary to distinguish other segments in the Chinese phonemic inventory. Thus, in spite of the fact that /l/ and /r/ are not contrastive in Chinese, Chinese speakers are predicted to accurately perceive the /l – r/ contrast. Brown's experiments consisted of an "AX Discrimination" task and a "forced choice picture selection" task (for more details, see Brown, 1998, 2000). These predictions are supported by the results of her experiments. That is, the Japanese speakers were unable to accurately distinguish the two sounds, whereas the Chinese speakers were able to distinguish the two sounds. However, Brown also discovered that low-level and high-level learners demonstrate different responses in perception of novel L2 sounds. In short, high-level learners can be taught or trained through formal instruction to discriminate and distinguish sounds in the L2 category which, through time, a new feature geometry for the L2 will be established within the learners' mental grammar.

The significance in which Brown ties segmental phonology to L2 speech perception is of immense relevance to L2 acquisition. It explains why learners of a particular L1 are adept or not adept in discriminating certain sounds in the L2. It predicts, too, which sounds will present the least problems to the learner and which sounds the learner will encounter the most difficulties in learning. Knowledge of this kind is believed to be greatly appreciated by L2 teachers and learners alike.

Brown's PIM model and findings are also of significance to the present study as it is a partial replica of her experiments. It is, to the best of my knowledge, one of the first studies on Arabic within this particular theoretical framework. The main purpose is to further test the claims and predictions put forward by the model by applying them to another language, namely Arabic, thereby reaffirming or otherwise Brown's model of L2 speech perception. This is discussed in the following section.

3. The Experiment

As mentioned earlier, the present study aims to further assess the claims and predictions of Brown's model of phonological interference. To that end and inspired by Brown's own experiments (1998, 2000), a partially similar experiment was conducted. The experiment was designed to study two related issues. Firstly, whether the feature geometry of English speakers facilitates/constrains their perception of non-native Arabic contrasts, and secondly, whether the English L1 feature geometry can be modified over time through L2 formal instruction thereby allowing native English speakers to accurately perceive non-native Arabic contrasts.

3.1 The Arabic Contrasts under Investigation

Three pairs of Arabic contrasts were selected to test Brown's model of phonological interference. These contrasts along with the feature that distinguishes each contrast are given in (1) below.

(1) (a) /b – d/ [coronal]

(b) /x – ɣ/ [dorsal, voice, continuant]

(c) /h – ħ/ [RTR (retracted tongue root)]

These pairs were chosen because of the nature of the English feature geometry. First, the pair /b – d/ consists of phonemes that exist in the phonemic inventory of both Arabic and English. Thus, this pair was used as a control contrast or foil to insure that subjects' poor performance on the task was not attributed to difficulty of the task itself. If the task itself was difficult, then we would observe poor performance equally across the board in all groups with native and non-native contrasts as well.

Second, the pair /x – ɣ/ consists of Arabic phonemes which are not present in the English phonemic inventory, however, the features necessary to distinguish these sounds are available in the feature geometry of English as they are needed to distinguish other English phonemes, i.e., [dorsal, voice, continuant] (Alotibi & Meftah, 2013; Davenport & Hannahs, 2010).

Third, the pair /h – ħ/ consists of Arabic phonemes of which only the former exists in English (i.e., /h/), whereas the latter (i.e., /ħ/) is not present the English sound system. Moreover, the feature [RTR], which is necessary to distinguish between /h/ and /ħ/ (Esling, 1999; McCarthy, 1994; Rose, 1996), is also unavailable in the English feature geometry. As a result, /ħ/ is completely alien to the English speaker, unlike /x – ɣ/ which although do not exist in the English sound system are distinguished by features available in the English feature geometry. Table 1 below gives a summary of the status of each Arabic contrast in English.

Table 1. Status of Arabic Contrasts in English

Arabic Contrast	Segment Exists in English	Distinguishing Feature(s)	Feature Present in English
/b/	Yes	[coronal]	Yes
/d/	Yes		
/x/	No	[dorsal, voice, continuant]	Yes
/ɣ/	No		
/h/	Yes	[RTR]	No
/ħ/	No		

3.2 Tasks and Materials

The experiment consisted of an AX Discrimination task designed to test the native English subjects' ability to acoustically perceive each of the three pairs of Arabic contrasts listed above (i.e., a total of three tasks). For each contrast, subjects hear a pair of sounds separated by a brief interval and are asked to indicate as quickly and as accurately as possible whether each pair of sounds contained two different sounds (e.g., /ba/ – /da/) or two instances of the same sound (e.g., /ba/ – /ba/) by pressing the corresponding button on the keyboard. Subjects' reaction times were measured and the percentage of accuracy was calculated.

The stimuli consisted of minimal pairs of single CV-syllables that differed only in their onset consonants, e.g., /ba/ vs. /da/. The vowel used in all the stimuli was the vowel /a/. All stimuli were naturally produced by an adult male native speaker of Arabic (age 35). For the stimuli to be as natural as possible, minimal pairs containing the relevant sounds (e.g., haram "pyramid"/ ħaram "campus") were uttered in a short sentence, recorded digitally, and then transferred to a computer using SoundEdit 16 software. The sounds under investigation were then clipped (e.g., /ha/, /ħa/, etc.) and presented in experimental sessions using PsyScope 1.2.2 PPC software.

Each of the experimental contrasts consisted of four test items (AA, AB, BA, BB), as shown in Table 2 below. Each experimental task consisted of 40 stimuli (or trials) presented in random order (i.e., 10 trials for each item).

Table 2. AX Discrimination Tasks

	Task 1 /b – d/	Task 2 /x – ɣ/	Task 3 /h – ħ/
Item 1	/ba – ba/	/xa – xa/	/ha – ha/
Item 2	/ba – da/	/xa – ɣa/	/ha – ħa/
Item 3	/da – ba/	/ɣa – xa/	/ħa – ha/
Item 4	/da – da/	/ɣa – ɣa/	/ħa – ħa/

Finally, the correct response for each test item is shown in the Table 3 below.

Table 3. Correct Responses for the AX Discrimination Tasks

/b – d/ Task	Correct Response	/x – ɣ/ Task	Correct Response	/h – ħ/ Task	Correct Response
Item 1: /ba – ba/	same	Item 1: /xa – xa/	same	Item 1: /ha – ha/	same
Item 2: /ba – da/	different	Item 2: /xa – ɣa/	different	Item 2: /ha – ħa/	different
Item 3: /da – ba/	different	Item 3: /ɣa – xa/	different	Item 3: /ħa – ha/	different
Item 4: /da – da/	same	Item 4: /ɣa – ɣa/	same	Item 4: /ħa – ħa/	same

3.3 Subjects and Procedure

A total of 19 adults with no reports of hearing problems participated in the experiment. The subjects were divided into two experimental groups and a control group as follows:

(1) Ten native speakers of English who had no prior knowledge of Arabic served as the English group (henceforth, "English L1" group).

(2) Four native speakers of English who had been studying Arabic for at least a year served as the L2 group (henceforth, "Arabic L2" group).

(3) Five native speakers of Arabic served as the control group (henceforth "Arabic L1" group).

All 19 subjects participated in the experiment and each subject was tested individually in a quiet computer lab with the experimenter present. All of the three tasks were completed in one session with a five minute break between each task. The /b – d/ task was administered first, followed by the /x – ɣ/ task, followed by the /h – ħ/ task.

3.4 Summary of Predictions

On the basis of Brown's Phonological Interference model and the theory of Feature Geometry, the following predictions are made. First, since /b/ and /d/ are sounds that exist in the sound inventory of both English and Arabic and are distinguished by the feature [coronal] which is also available in the feature geometry of both languages, subjects in all three groups are expected to perceive and distinguish these sounds with very high accuracy.

Second, although the sounds in the Arabic contrast /x – ɣ/ do not exist in English, they are, however, distinguished by the features [dorsal, voice, continuant] which are available in the English feature geometry as they are needed to distinguish between other sounds in the English phonemic inventory. As a result, this particular non-native contrast is predicted to be perceived by the English speakers (both English L1 group and the Arabic L2 group) as accurately as the Arabic L1 group. The English speakers, however, are expected to require greater processing time.

Third, as for the third Arabic contrast /h – ħ/, where only the former segment exists in English, the feature [RTR], which is necessary to distinguish between the two sounds, is absent in the English feature geometry. Therefore, the English L1 group, on the one hand, are predicted to be unable to accurately perceive and distinguish them and would generally require greater processing. The Arabic L2 group, on the other hand, are predicted to be more accurate and require less processing time than the English L1 group, but to be less accurate and require more processing time than the Arabic L1 group.

4. Results and Discussion

For each group, the subjects' performance scores from the three experimental tasks (i.e., /b – d/, /x – ɣ/, and /h – ħ/) were tabulated and pooled for statistical analysis. The groups' performance accuracy results are presented in section 4.1 below followed by the groups' reaction time results in section 4.2.

4.1 Performance Accuracy

The graph in Figure 3 below shows the mean performance scores of the three groups on each of the three experimental tasks. To begin with, as predicted, the subjects in all three groups were able to perceive with very high accuracy the /b – d/ contrast, which is native to both Arabic and English and is distinguished by the feature [coronal], which is available in the feature geometry of both languages. Recall that this contrast served as a control contrast to check whether subjects' poor performance on the experimental tasks is because of the difficulty of the task itself. The fact that all the subjects performed extremely well on this contrast in particular is a clear indication that the experimental tasks did not pose any difficulty to the subjects. Accordingly, poor performance on non-native pairs of contrasts can be taken as evidence of the effect (or interference) of the subjects' LI feature geometry on their perception of non-native contrasts.

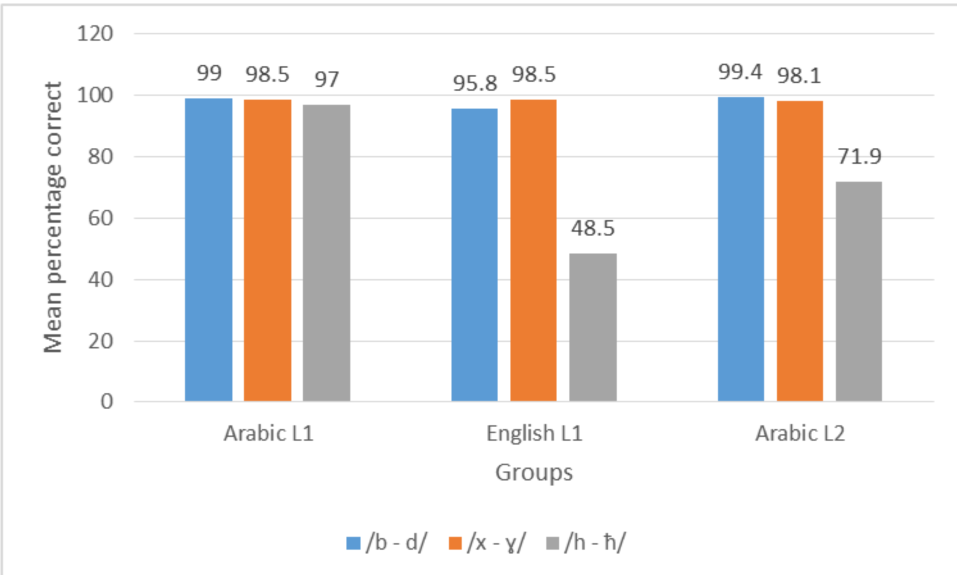

Figure 3. Overall Mean Performance Accuracy on Each Task by Group

As for the Arabic contrast /x – ɣ/, in spite of the fact that both sounds are non-native in English, the English subjects in both experimental groups (i.e., the English L1 group and the Arabic L2 group) were able to discriminate this contrast as accurately as the native control subjects (i.e., the Arabic L1 group). This comes as no surprise for it was predicted prior to conducting the experiment that the English speakers would be able to perceive this contrast as accurately as native Arabic speakers because the sounds in this contrast are distinguished by the features [dorsal, voice, continuant], all of which are readily available in the English feature geometry. Thus, the mere presence of a feature in the feature geometry of a language facilitates the perception (and consequently the production) of non-native sounds that are distinguished by that particular feature.

Finally, the results of the Arabic contrast /h – ħ/ show that there were striking differences between the three groups. In this contrast, /h/ exists in English, whereas /ħ/ in addition to being non-native in English is also distinguished from /h/ by the feature [RTR], which is unavailable in the English feature geometry. Thus, /ħ/, unlike the Arabic contrast /x – ɣ/, is a sound that is completely alien to the English sound system. The results show that as predicted prior to conducting the experiment, the English L1 group, who had no prior knowledge of Arabic, performed quite poorly and were unable to accurately distinguish between the two sounds. Their mean percentage of accuracy was only 48.5%, compared to the near-perfect score of the control group. In contrast, the mean percentage of accuracy of the Arabic L2 group, who had been studying Arabic for at least a year, was 71.9%, which is considerably higher than the English L1 group but also considerably lower than the Arabic L1 control group. This, strongly suggests that while the English L1 poor performance follows directly from the lack of the feature [RTR] in their feature geometry, the subjects in the Arabic L2 group appear to be in an intermediate acquisition stage in which they are in the process of establishing the feature in question (i.e., [RTR]) in their feature geometry, however, it has not been fully developed as of yet.

In order to determine whether there were any statistically significant differences between the three groups on each task, a t-test was run to compare the mean performance on each task between each two groups separately. The results of the t-test, given in Table 4 below, show that there were no statistically significant differences between the performance of three groups on the /b – d/ and the /x – ɣ/ tasks. As for the /h – ħ/ task, the performance difference between the Arabic L1 control group and the English L1 group (with no prior knowledge of Arabic) was extremely statistically significant ($t(13) = 6.8381$, $p = 0.0001$). Similarly, the difference in performance between the English L1 group and the Arabic L2 group (with some previous knowledge of Arabic) on the /h – ħ/ task was statistically significant ($t(12) = 2.1927$, $p = 0.0488$). In contrast, the difference between the Arabic L1 group and the Arabic L2 group on the /h – ħ/ task was not quite statistically significant ($t(7) = 2.3597$, $p = 0.0504$).

Table 4. Mean Score Differences between the Three Groups by Task (p = 0.05)

Groups Compared	/b – d/ Task	/x – ɣ/ Task	/h – ħ/ Task
	P Value	P Value	P Value
Arabic L1 vs. English L1	0.0738	1.0000	*0.0001
Arabic L1 vs. Arabic L2	0.7589	0.7589	0.0504
English L1 vs. Arabic L2	0.0600	0.7615	*0.0488

Note. The asterisk (*) denotes statistical significance.

A t-test was also run to evaluate whether the performance differences between each two tasks within the same group were statistically significant. The results, given in Table 5 below, show that there were no statistically significant differences between the tasks within the Arabic L1 group and the Arabic L2 group. As for the English L1 group, the difference between the performance on the /b – d/ task and the

/h – ħ/ task was extremely statistically significant (t (18) = 9.4385, p = 0.0001). Similarly, the difference between the performance on the /x – ɣ/ and the /h – ħ/ tasks was also extremely statistically significant (t (18) = 10.0808, p = 0.0001). However, the difference between their performance on the /b – d/ and the /x – ɣ/ tasks was not quite statistically significant (t (18) = 2.0925, p = 0.0508).

Table 5. Mean Score Differences between the Three Tasks by Group (p = 0.05)

Tasks Compared	Arabic L1	English L1	Arabic L2
	P Value	P Value	P Value
/b – d/ vs. /x – ɣ/	0.7286	0.0508	0.2070
/b – d/ vs. /h – ħ/	0.1796	*0.0001	0.0629
/x – ɣ/ vs. /h – ħ/	0.3022	*0.0001	0.0729

Note. The asterisk (*) denotes statistical significance.

To sum up this section, the results obtained from this experiment are consistent with the results of Brown's experiments (1988, 2000) on three related points. First, although the sounds in the /x – ɣ/ contrast do not exist in English, the data from this experiment show that the subjects in all three groups (and particularly the English speakers) were able to perceive this contrast with a very high degree of accuracy and no statistical significant differences between their performances. This expected result is due to the fact that the sounds in this contrast are distinguished by the features [dorsal, voice, continuant], all of which are available in the feature geometry of English, as they are needed to distinguish other sounds in the English phonemic inventory. As a result, the English speakers can accurately perceive this non-native contrast with native-like accuracy. This particular finding is consistent with Brown's finding with Chinese speakers who were able to accurately perceive the /l – r/ contrast (distinguished by the feature [coronal]) in spite of the fact that it is not contrastive in Chinese. The Chinese speakers' ability to perceive this contrast is due to the presence of the feature [coronal] in the Chinese feature geometry. Thus, the results of the /x – ɣ/ contrast in this experiment confirm Brown's proposal that the presence of a distinctive feature in the feature geometry of a language is necessary to perceive non-native contrasts.

Second, the results from the /h – ħ/ contrast, where only the former sound exists in English, show that the subjects in the English L1 group (who had no prior knowledge of Arabic) performed significantly poorer than the subjects in both the Arabic L1 control group and the Arabic L2 group. Moreover, their performance on this contrast was significantly poorer than their performance on the other two contrasts. Once again, this expected result is due to the fact that the sounds in this contrast are distinguished by the feature [RTR], which is unavailable in the feature geometry of English. This finding is consistent with Brown's finding with Japanese speakers who were unable to accurately perceive the English /l – r/ contrast due to the absence of the feature [coronal] in the Japanese feature geometry. Thus, the results of the /h – ħ/ contrast in this experiment confirm Brown's proposal that the absence of a distinctive feature in the feature geometry of a language constrains the ability of its speakers to accurately perceive non-native contrasts.

Third, the results of the subjects from the Arabic L2 group (who have had prior knowledge of Arabic) on the /h – ħ/ contrast show that they performed significantly better than the subjects of the English L1 group with no prior knowledge of Arabic, but poorer than the Arabic L1 control subjects (though the difference was not statistically significant). As mentioned earlier, this particular finding strongly suggests that the subjects in the Arabic L2 group are in effect constructing the feature [RTR] and adding it to their feature geometry, though it has not been fully developed yet. This finding strongly confirms Brown's claim that a new feature geometry for the L2 can be established within the learners' mental grammar through time and formal training and instruction. We now turn to the subjects' reaction times in the following section

4.2 Reaction Time

The graph in Figure 4 below shows the mean reaction time of the three groups on each of the three experimental tasks. The same pattern of results observed earlier in Figure 3 above with respect to performance accuracy is also observed here with reaction time. That is, there were no considerable differences in the reaction times between the subjects in all three groups on the /b – d/ and /x – ɣ/ tasks. As for the /h – ħ/ task, there were striking differences between the three groups. As can be seen, the mean reaction time for the English L1 group on the /h – ħ/ task was considerably higher than the Arabic L1 group, whereas the mean reaction time for the Arabic L2 group was slightly higher than the Arabic L1 group but lower than the English L1 group.

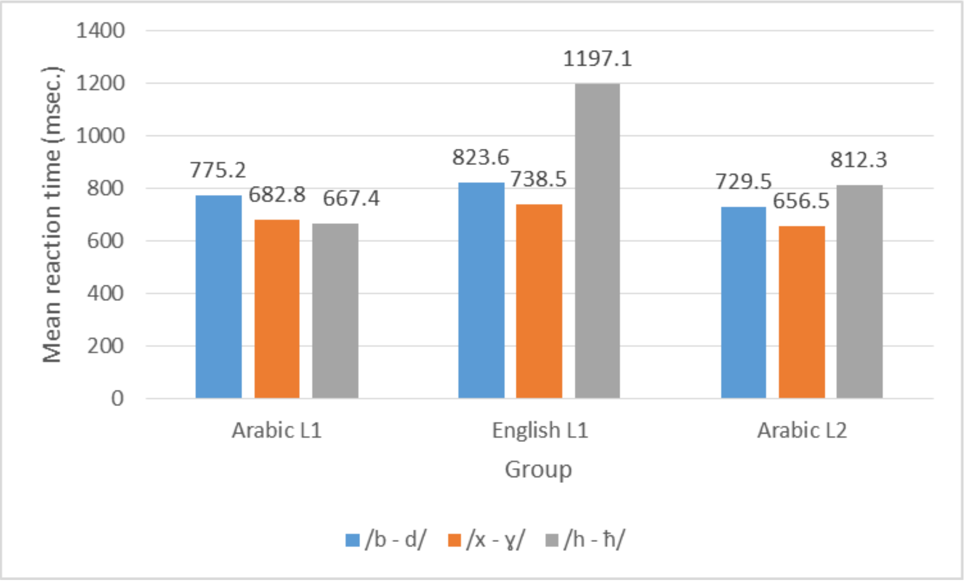

Figure 4. Mean Reaction Time for Each Task by Group

Once again, to determine whether there were any statistically significant differences between the three groups on each task, a t-test was run to compare the mean reaction time of each task between each two groups separately. The results of the t-test, given in Table 6 below, show that there were no statistically significant differences between the reaction time of three groups on the /b – d/ and the /x – ɣ/ tasks. As for the /h – ħ/ task, the reaction time difference between the Arabic L1 control group and the English L1 group was extremely statistically significant (t (13) = 7.8838, p = 0.0001). Similarly, the reaction time difference between the English L1 group and the Arabic L2 group on the /h – ħ/ task was also extremely statistically significant (t (12) = 5.1644, p = 0.0001). In contrast, the difference between the Arabic L1 group and the Arabic L2 group on the /h – ħ/ task was not statistically significant (t (7) = 2.2065, p = 00.0631).

Table 6. Reaction time Differences between the Three Groups by Task (p = 0.05)

Groups Compared	/b – d/ Task P Value	/x – ɣ/ Task P Value	/h – ħ/ Task P Value
Arabic L1 vs. English L1	0.6515	0.6228	*0.0001
Arabic L1 vs. Arabic L2	0.7474	0.8588	0.0631
English L1 vs. Arabic L2	0.3610	0.4418	*0.0002

Note. The asterisk (*) denotes statistical significance.

A t-test was also run to evaluate whether the reaction time differences between each two tasks within the same group were statistically significant. The results, given in Table 7 below, show that there were no statistically significant differences between the tasks within the Arabic L1 group and within the Arabic L2 group. As for the English L1 group, the difference between the reaction time on the /b – d/ task and the /h – ħ/ task was extremely statistically significant (t (18) = 5.4645, p = 0.0001). Similarly, the difference between the reaction time on the /x – ɣ/ and the /h – ħ/ tasks was also extremely statistically significant (t (18) = 6.4968, p = 0.0001). However, the difference between their reaction time on the /b – d/ and the /x – ɣ/ tasks was not statistically significant (t (18) = 1.0886, p = 0.2907).

Table 7. Reaction Time Differences between the Three Tasks by Group (p = 0.05)

Tasks Compared	Arabic L1 P Value	English L1 P Value	Arabic L2 P Value
/b – d/ vs. /x – ɣ/	0.5569	0.2907	0.5392
/b – d/ vs. /h – ħ/	0.3632	*0.0001	0.4134
/x – ɣ/ vs. /h – ħ/	0.8991	*0.0001	0.1487

Note. The asterisk (*) denotes statistical significance.

To sum up this section, the results of the subjects' reaction times show that the lack of the feature [RTR] in the feature geometry of the English L1 group results in significantly longer reaction times compared to the subjects in both the Arabic L1 group and the Arabic L2 group. Thus, the English L1 group not only performed significantly worse than the other two groups, but also required significantly longer times to respond.

5. Conclusion

This study was attempted as a replica of Brown's study of Japanese and Chinese speakers' perception of English contrasts (1998, 2000). The main purpose was to further test the claims and predictions put forward by Brown's model of phonological interference by applying them to another language, namely Arabic, thereby reaffirming or otherwise Brown's model of L2 speech perception. One of the major strengths of this experiment is the careful selection of Arabic contrasts which are divided into sounds which exist in English /b – d/; sounds which do not exist in English but are distinguished by features available in the English feature geometry /x – ɣ/; and sounds which are distinguished by features unavailable in the English feature geometry /h – ħ/, where in the last pair /h/ exists in English whereas /ħ/ is totally alien to English. Another major strength of this study is that native speakers of English who have been learning Arabic for at least a year were included in the study as the Arabic L2 group of subjects, for the purpose of correlating the results of "high-level learners" and "non-learners" of Arabic. Overall, the results obtained in this study provide overwhelming support to Brown's argument that the presence/absence of feature(s) in the L1 feature geometry facilitates/constrains the perception of L2 non-native contrasts. The findings of this study are consistent with the findings of her study relating to the fact that non-native contrasts are not equally difficult to perceive by L2 learners. That is, while some non-native contrasts are perceived by L2 learners as accurately as native speakers (e.g., /x – ɣ/), others are extremely difficult to perceive by L2 learners. Specifically, data from the /h – ħ/ contrast confirm Brown's hypothesis that non-native speakers do in fact find the most difficulty in identifying and discriminating novel segments which consist of feature(s) which are lacking in the feature geometry of the L1, viz., [RTR]. In this study, the performance of the English L1 group, as predicted by Brown's model, was significantly worse than the other two groups on the /h – ħ/ contrast and also significantly worse than their own performance on the other two contrasts. In addition, the time they took to respond to the /h – ħ/ task was significantly longer than the other two groups on the same task and also significantly longer than their own reaction time to the other two tasks. Thus, the absence of the feature [RTR] in the feature geometry of the English L1 subjects constrains or hinders their perception of this contrast.

In comparison, the Arabic L2 group of subjects, an equivalent of Brown's "high-level" subjects, showed a statistically significant level of awareness of the target contrasts as compared to the English L1 group. That is, the Arabic L2 subjects performed significantly better than the English L1 subjects on the /h – ħ/ contrast and also took significantly less time to respond. As explained earlier, Brown found conclusive evidence in her research with Japanese and Chinese speakers' perception of English contrasts to support the fact that L2 learners can be trained to distinguish contrasts which are alien to the L1 feature geometry. In other words, there is a process of establishing a new L2 feature geometry. Thus, the results of this study strongly support Brown's argument for the establishment of a new feature geometry of the L2 as learners are trained to distinguish the phonemic features that are distinctive in the L2.

Finally, the English subjects in both the English L1 group and the Arabic L2 group were able to perceive the non-native contrast /x – ɣ/, whose contrastive features are present in the English feature geometry, as accurately as the Arabic L1 control subjects. There were no statistical differences between the three groups neither in performance nor in reaction time. Thus, the presence of the features [dorsal, voice, continuant] in the feature geometry of the English L1 and the Arabic L2 subjects facilitates their perception of this contrast.

Perhaps one minor limitation of this study is the number of subjects who participated in the experiment, particularly the Arabic L2 group, which consisted of only four subjects. Thus, in order to obtain results that are more representative statistically, future studies should take into consideration recruiting more subjects. Moreover, the subjects in the Arabic L2 group could be further divided into three sub-groups according to the subjects' level: beginners, intermediate, and advanced learners. This may provide vital insight on the developmental stages that L2 learners go through.

Finally, it is recommended that future studies include a fourth Arabic contrast: /ʔ – ʕ/, which is analogous to the /h – ħ/ contrast. That is, in both contrasts only the former sound exists in English. In addition, both contrasts are distinguished by the feature [RTR], which is absent from the English feature geometry. If both of these contrasts produce the same results, then this can be taken as evidence that provides even further support to Brown's model of phonological interference.

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