The identification and production of English consonants by Greek speakers

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Abstract
This study examined the identification and production of English consonants by Greek learners of English. Consonant identification was examined in quiet and in two types of noise, a competing talker and an 8-speaker babble. Consonant production was assessed by having English listeners identify the English consonants produced by Greek speakers. Greek speakers achieved higher identification scores in quiet than in noise and the 8-speaker babble had a more detrimental effect in their scores than the competing speaker. Difficulties with specific English consonants were not always similar across modalities; some consonants proved easy to identify but difficult to produce and vice versa.

Keywords: English consonants, perception, production, noise, Greek

1. Introduction

Adult second language (L2) learners often have difficulties perceiving and producing vowels and consonants in the language that they are acquiring (e.g. Flege, Mackay & Meador 1999; Flege & MacKay 2004; Iverson & Evans 2007; Lengeris 2009; Polka 1995 for vowels and Best, McRoberts & Goodell 2001; Flege, Munro & MacKay 1995; Guion et al. 2000; Hattori & Iverson 2009; Iverson et al. 2003; Mackay, Meador & Flege 2001 for consonants). L2 perception and production, however, are not equally difficult across L2 sounds; current L2 learning models such as the Perceptual Assimilation Model (Best 1995; Best & Tyler 2007), the Speech Learning Model (Flege 1995, 2002), and the Native Language Magnet model (Kuhl et al. 1992; Kuhl et al. 2008; Kuhl 2000) agree that the relationship between native (L1) and L2 sound inventories can predict whether or not a specific L2 sound will pose difficulty to the learner. For example, Japanese speakers are very poor at perceiving the English /r/ - /l/ distinction because they lack such a contrast in their L1, having a single category in their inventory (Goto 1971; Iverson et al. 2003).

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The difficulties that learners encounter in perceiving L2 speech are greater when the listening conditions are not ideal as it is the case when L2 speech is heard in the presence of noise (Cooke et al. 2010; Hazan & Simpson 1998). Research examining L2 perception in noise has shown that, even when early bilinguals are tested, their perception suffers more from noise than L1 perception in tasks such as sentence intelligibility (Bradlow & Bent 2002; Cooke, Garcia Lecumberri & Barker 2008; Mayo, Florentine & Buus 1997), word identification (Nabelek & Donahue 1984) and phoneme identification (Cutler, García Lecumberri & Cooke 2008; García Lecumberri & Cooke 2006).

The perception of L2 sounds can be improved via the use of intensive training procedures that have been developed in the laboratory over the past years. The most successful procedures stress the importance of exposure to natural minimal pairs spoken by various talkers in multiple environments. The so-called high-variability phonetic training (HVPT) has been found to significantly improve the perception of L2 vowels and consonants (e.g. Hazan et al. 2005; Iverson & Evans 2009; Iverson, Pinet & Evans 2012; Lively et al. 1994; Logan, Lively & Pisoni 1991; Nishi & Kewley-Port 2007, 2008). This improvement generalizes to words and talkers that were not heard during training and transfers to speech-in-noise perception (Lengeris & Hazan 2010). Importantly, HVPT in the domain of perception improves not only the perception but also the production of vowels (Lambacher et al. 2005; Lengeris & Hazan 2010) and consonants (Bradlow et al. 1997; Hazan et al. 2005).

This paper is part of a project examining the learning of English vowels and consonants by Greek learners of English. The project employs HVPT to improve the perception and production of English sounds by Greek university students. The current study aims at identifying English consonants that are difficult for Greek speakers to perceive and produce and will be appropriate for the computer-based training. English consonant perception was assessed by having Greek speakers identify English consonants in quiet and in two types of noise, a competing talker and an 8-speaker babble. English consonant production was assessed by having English speakers identify the English consonants produced by Greek speakers. Apart from impressionistic data and general predictions based on a phonemic comparison of the two consonant systems (e.g. English has both alveolar /s, z/ and postalveolar fricatives /ʃ, ʒ/ while Greek has only alveolar ones /s, z/ which makes it difficult for Greek speakers to differentiate and produce the two places of articulation), there are no experimental studies in the literature examining the identification and production of the full set of English consonants (all 24 consonants) by Greek speakers.

2. Method

2.1 Participants

The participants were 20 female speakers of Greek with a mean age of 19.8 years old (age range 19 to 20 years), all students at the Aristotle University of Thessaloniki Department of Linguistics. They had received formal instruction in English for 10-11 years, their language proficiency level was relatively uniform (Cambridge FCE, CPE) and none had lived in an English-speaking country for more than one month. All participants reported normal hearing and no language impairment.

2.2 Perceptual stimuli

The perceptual stimuli used for the experimental part of this study were those recorded for the Interspeech 2008 Consonant Challenge (Cooke & Scharenborg 2008); these stimuli have since been used in several studies examining the perception of English consonants by both native and non-native speakers of English (e.g. Broersma & Scharenborg 2010; van Dommelen & Hazan 2010). The stimuli consisted of VCV tokens containing all 24 English consonants (/p, b, t, d, k, g, f, v, θ, ð, s, z, ʃ, ʒ, h, ʧ, ʤ, m, n, ŋ, l, ɹ, j, w/) in the context of 3 vowels (/iː, æ, uː/) in all 9 possible combinations. Each CVC token was spoken with stress on the first or second syllable (e.g. /'ækiː /, /u'ʃiː/) by four native speakers of British English (2 female and 2 male). The VCV tokens were presented in quiet (QUIET) and in the presence of two noise types, a competing speaker (COMP) and an 8-speaker babble (BABBLE). Maskers were randomly chosen from sentences spoken by eight British English speakers. COMP was presented to participants at a signal-to-noise ratio (SNR) of -6 dB and BABBLE at an SNR of -2 dB. Each of three test conditions (QUIET, COMP, BABBLE) contained two instances of each of the 24 consonants from the four British English speakers resulting in 192 VCV items per test condition.

2.3 Procedure

2.3.1 English consonant identification

Participants were tested individually in the Phonetics Laboratory of the School of English, Aristotle University using a laptop computer and high-quality headphones (Sennheiser HD 280 Professional). The identification test was designed in PRAAT (Boersma & Weenink 2012). Participants heard the VCV tokens and identified the consonants by clicking on a computer screen one of 24 options (Figure 1) using a mouse. English consonants were presented using orthographic symbols (e.g. B, CH, K) and appeared on the screen together with an example word for each consonant (Bee, CHart, Key). QUIET was always presented first, followed by the two noise conditions (half of the times COMP was presented after QUIET and before BABBLE and half of the times BABBLE was presented after QUIET and before COMP).

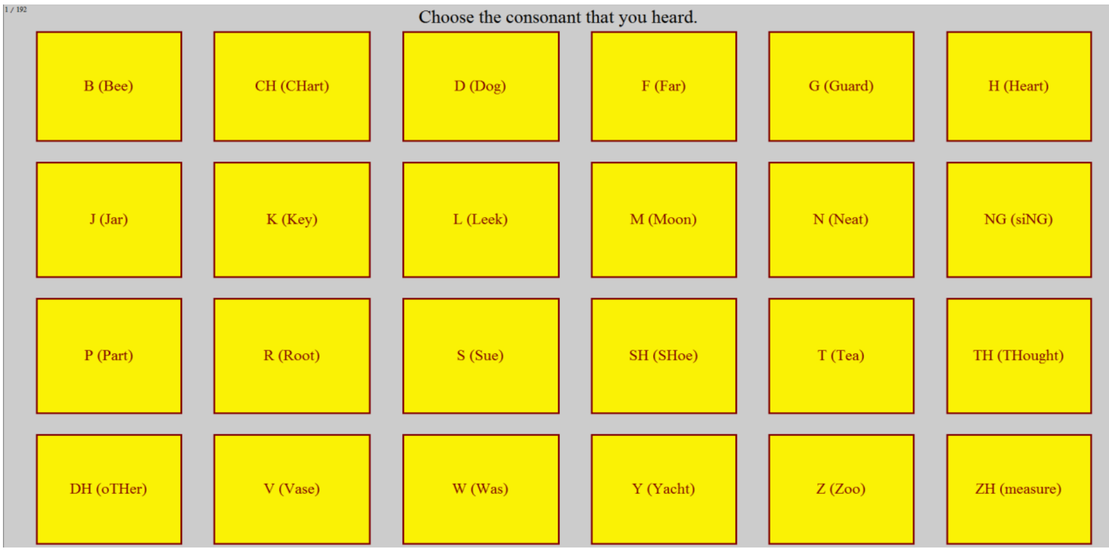

Figure 1. Screenshot of the experiment layout

2.3.2 English consonant production

Participants were recorded reading each of the VCV non-words using a Rode NT1-A cardioid condenser microphone. The recordings were presented to four Southern British English listeners for identification; each British English listener identified tokens by five Greek speakers (4 English listeners × 5 Greek speakers × 24 consonants = 480 VCV tokens in total) using the same interface as the Greek speakers (Figure 1).

3. Results

3.1 English consonant identification

Mean percent correct identification scores pooled over English consonants were calculated in each test condition and are shown in Figure 2. Identification scores in QUIET were relatively high (83.3% correct) with scores in noise conditions showing a considerable drop of about 24% points (COMP = 59.2% and BABBLE = 59% correct). A

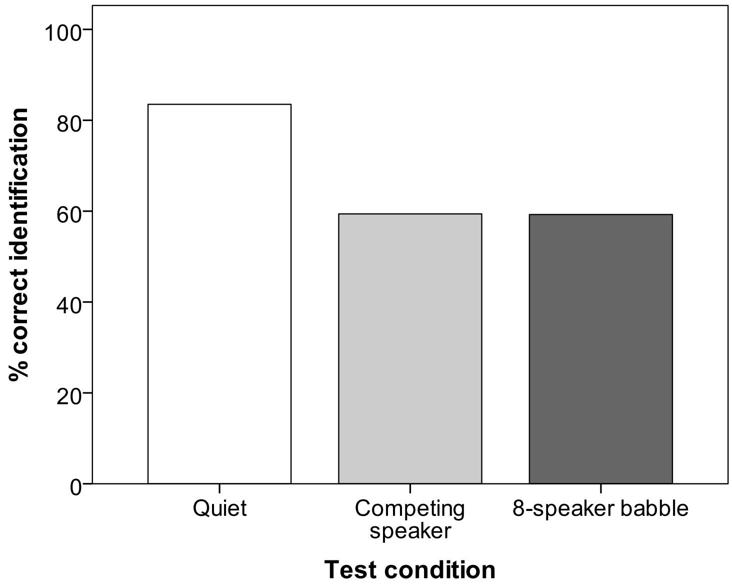

Figure 2. Mean percent correct identification of English consonants by native Greek speakers for each test condition

repeated-measures ANOVA confirmed a significant effect of noise on identification scores [F(2, 38) = 289.55, $p < 0.001$]. Pairwise comparisons showed that native Greek speakers obtained lower identification scores in the two noise conditions than they did in QUIET ($p < 0.001$) with no difference in scores between the two noise conditions. However, since COMP had a much lower SNR value than BABBLE (SNR = -6 dB vs. -2 dB respectively) the latter had a larger deteriorating effect in native Greek speakers' identification of English consonants than the former.

Figure 3 shows percent correct identification for each English consonant in each test condition. A repeated-measures ANOVA with Noise and Consonant as factors showed a significant main effect of consonant, [F(23, 437) = 14.51, $p < 0.001$] and a significant noise × consonant interaction [F(46, 847) = 11.27, $p < 0.001$], indicating that some English consonants were more difficult to identify than others and that identification scores for some consonants were more affected by noise than others.

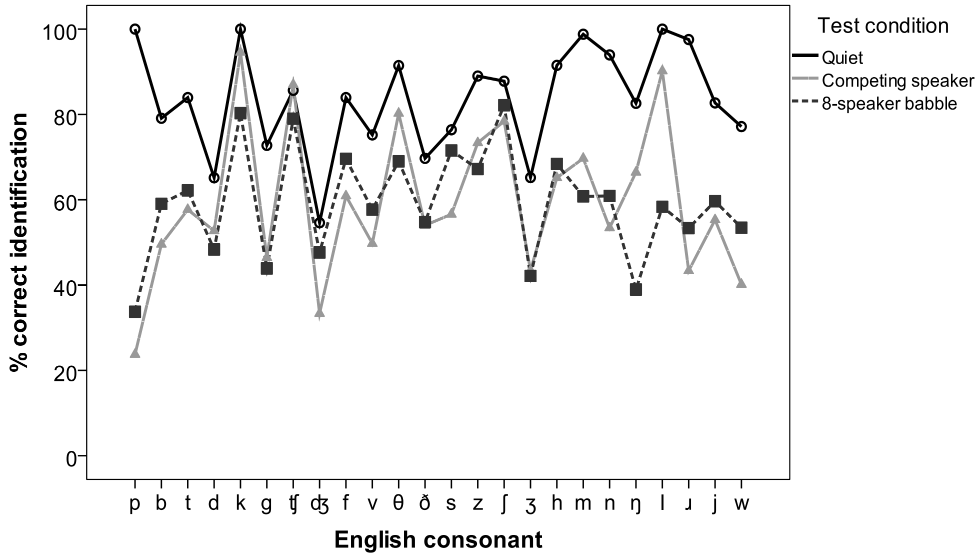

Figure 3. Percent correct identification of 24 English consonants by native Greek speakers for each test condition

	Response																							
St.	p	b	t	d	k	g	ʧ	ʤ	f	v	θ	ð	s	z	ʃ	ʒ	h	m	n	ŋ	l	ɹ	j	w
p	**100**																							
b	20	**79**		1			1																	
t			**84**	2			13							1		1								
d		1	28	**65**	4	1														1		1		
k					**100**																			
g					20	**73**														8				
ʧ			2				**86**	3							3	7								
ʤ						3	31	**54**						2	1	9								
f								1	**84**	1	14													
v								1	16	**75**	4	4										1		1
θ			3								**91**	1	4		1									
ð			1	1						9	16	**69**		2		1								
s							1				1		**76**	1	21									
z												1		**89**		11								
ʃ							1	1					9	1	**88**		1							1
ʒ								1					1	28	3	**65**							3	
h							1					1					**91**						7	1
m						1												**99**	1					
n																			**94**	1	4	1		
ŋ					1	5	2												8	**83**	1			
l																					**100**			
ɹ										1												**98**		1
j						1		1															**83**	15
w						1				1												7	14	**77**

Table 1. English consonant confusion patterns by native Greek speakers in QUIET. Responses have been pooled over participants, consonant contexts and stress position

To examine identification scores for individual English consonants in more detail, Tables 1-3 display confusion matrices of Greek speakers' identification scores in QUIET, COMP and BABBLE. In QUIET (Table 1), identification scores ranged from 100% to 54% correct. Greek speakers achieved very high scores (> 90% correct) for /p/, /k/, /θ/, /h/, /m/, /n/, /l/ and /ɹ/. The most problematic English consonants (<70% correct) were /d/ (mostly confused with /t/), /ʤ/ (mostly confused with /ʧ/), /ð/ (mostly confused with /θ/) and /ʒ/ (mostly confused with /z/).

	Response																							
St.	p	b	t	d	k	g	ʧ	ʤ	f	v	θ	ð	s	z	ʃ	ʒ	h	m	n	ŋ	l	ɹ	j	w
p	**24**	14	8	1	12	7	4		4	1	1		1	1			13	1		1		1	1	1
b	14	**49**	8	4	1	5	1		1	6		4		1			1			4				1
t	1	2	**58**	3		1	23		3	1	7	1	3											
d		1	13	**53**	13	4		1		1		1	10		1		1		1	1	1			
k				1	**94**	1				1	1				1					3				
g	1	4	6		28	**46**														14				
ʧ			6		1		**87**	6							1									
ʤ			7	3	3	2	36	**33**			1		1	4	1	4		1	1	3		1		
f							1		**61**		23		10	1	2		2	1						
v	2	11	3	2	6	3	1		4	**49**	3	9					1	1	1	1	1	1	2	2
θ			1	1					4	1	**80**	2	6	3	3									
ð	1	3	6	4	1				1	20	4	**54**		1					1		3	1	2	1
s			1		1		1		4	1	6		**56**	4	23	1	2					1		
z		1			1		2	1	3	3	1	3	1	**73**	1	11						1		1
ʃ			1				4	1					10	3	**78**	3			1				1	
ʒ		1	1				3	2		3		2	1	39	5	**43**					1			
h	1	1			5	13			1	3		1					**65**		1	5			3	1
m		4		1	2	2			2	4	1	1	3		1		1	**71**	3	5	1		1	
n		2	2	2	1	1			1	0	1	3	1				3	13	**53**	6	14		1	
ŋ			1		2	9			1										20	**66**				
l		3	2	1		1													1	1	**90**			1
ɹ		5	1	1	1	4		1		16		6	2	2		1	6		1	1	2	**43**	4	4
j		2	2	3	2	4			1	3	1			1	1			1	3	3	4	3	**55**	13
w		14	4		1	1			1	11		4	1				1	1		1	3	8	11	**40**

Table 2. English consonant confusion patterns by native Greek speakers in COMP. Responses have been pooled over participants, consonant contexts and stress position

In COMP (Table 2), identification scores ranged from 94% to 24% correct. Greek speakers showed relatively high identification scores (≥80% correct) for /k/, /ʧ/, /θ/ and /l/. The most problematic English consonants (<50% correct) were /p/ (mostly confused with /b/), /b/ (mostly confused with /p/), /g/ (mostly confused with /k/), /ʤ/ (mostly confused with /ʧ/), /v/ (mostly confused with /b/), /ʒ/ (mostly confused with /z/), /ɹ/ (mostly confused with /v/) and /w/ (mostly confused with /p/).

	Response																							
St.	p	b	t	d	k	g	ʧ	ʤ	f	v	θ	ð	s	z	ʃ	ʒ	h	m	n	ŋ	l	ɹ	j	w
p	**34**	10	3	1	17	3			8	1	4	1	4	1	4	1	9	1		1				1
b	20	**59**	3	3	3	1			1	1	1	4		1					1	1	1		1	
t	1	1	**62**		8		22	1	1	1	1		1	1			1	1			1			
d			26	**48**	4	7		1			1	1	4		1	1		1		6				
k	2	1	1	1	**80**	5	1		1	1	3				1	1	1			4				
g	3	8	1	3	16	**44**	1			1	1									23				1
ʧ			6		3		**79**	7	1						3	1								
ʤ			2	1	1	1	34	**48**		1	1	1		1	1	4		1	1	1	2		1	1
f				1				1	**69**	1	24	1	2				1	1						
v	3	10	1	2	2	4		1	2	**58**	3	9					1			1	1	1	1	1
θ			1		3	2			14	1	**69**	7	1	1	1		1			1				
ð	1	3	4	4	4	1			1	9	5	**54**	1	6	1		1	1		1	1		1	1
s	1	1					1		3		2		**71**	3	16	2	1	1						
z			1	2	1	1	1		2	1	4	6	1	**67**	1	7				1	6	1		
ʃ							1						10	3	**82**	2	1	1		1				
ʒ	1		1			3	3	5	1	1		1	2	29	8	**42**	1			1	1	2	2	
h		2	1	1	5	6	1	1	1	2	3			1	1		**68**		1	3			5	1
m	1	6		1	1	1				3	1	1	6		1		1	**61**	9	4	5			1
n	1	1	3	4		1	1		1	3	1		1	3	1	1		4	**61**	1	8	1		3
ŋ	1	7	2	3	8	16	2		6	3	3	1	1	1			1	1	4	**39**	2			1
l	1	9	1	6					1	4	1	4	3	1		1	1	3		2	**58**	2	1	1
ɹ	1	10	1	1		5		1		8		1	2	4	1	1	1		2		3	**53**	5	3
j	1	3	3	1	3	5			1	3	1	1	1	1			2		1	1	6		**59**	11
w		4	1	5	1	2		1	2	4			1	4		1	1	1		2	2	8	10	**53**

Table 3. English consonant confusion patterns by native Greek speakers in BABBLE. Responses have been pooled over participants, consonant contexts and stress position

In BABBLE (Table 3), identification scores ranged from 82% to 34% correct. Greek speakers showed relatively high identification scores (>70% correct) for /k/, /ʧ/, /s/ and /ʃ/. The most problematic English consonants (<50% correct) were /p/ (mostly confused with /k/), /d/ (mostly confused with /t/), /g/ (mostly confused with /ŋ/), /ʤ/ (mostly confused with /ʧ/), /ʒ/ (mostly confused with /z/) and /ŋ/ (mostly confused with /g/). Across noise conditions, native speakers had therefore most difficulty with English plosives (mostly voiced ones being identified as their voiceless counterparts), affricates (especially /ʤ/) and fricatives (especially /ʒ/).

3.2 English consonant production

Mean percent identification scores obtained by native English listeners when judging Greek speakers' productions of English consonants were at 78% correct. English consonant production proved therefore slightly more difficult than English consonant identification in QUIET discussed in Section 3.1 (83.3% correct). Table 4 displays the identification accuracy for each English consonant. Identification scores ranged from 100% to 36% correct. The most successful English consonants (>90% correct) for Greek speakers to produce were, as judged by native English listeners, /b/, /n/, /l/, /ɹ/, /j/ and /w/. The most problematic English consonants (<70% correct) were /p/ (mostly

	Response																							
St.	p	b	t	d	k	g	ʧ	ʤ	f	v	θ	ð	s	z	ʃ	ʒ	h	m	n	ŋ	l	ɹ	j	w
p	**45**	55																						
b		**91**																						9
t			**36**	55		9																		
d				**91**								9												
k					**64**	36																		
g						**100**																		
ʧ			27				**64**							9										
ʤ				18			9	**64**								9								
f									**100**															
v										**100**														
θ									18		**55**		18											
ð										18		**73**		9										
s													**64**	18		18								
z														**82**		18								
ʃ													27	9	**64**									
ʒ														27		**73**								
h					18												**82**							
m																		**100**						
n																		9	**91**					
ŋ						27													9	**55**				
l																			9		**91**			
ɹ				9																		**91**		
j																							**100**	
w																	9							**91**

Table 4. Identification patterns of English consonants produced by native Greek speakers as judged by native English listeners. Responses have been pooled over participants, consonant contexts and stress position

confused with /b/), /t/ (mostly confused with /d/), /k/ (mostly confused with /g/), /ʧ/ (mostly confused with t/), /dʒ/ (mostly confused with /d/), /θ/ (mostly confused with

/f/ and /s/), /s/ (mostly confused with /z/ and /ʒ/), /ʃ/ (mostly confused with /s/) and /ŋ/ (mostly confused with /g/).

When comparing these results with the results obtained by Greek speakers in English consonant identification, it can be seen that difficulties with specific English consonants were not always similar across modalities; some English consonants proved easy to identify in quiet but difficult to produce (e.g. /p/, /k/ and /θ/) and others proved difficult to identify but easy to produce (e.g. /d/).

4. Discussion

This study examined the identification and production of English consonants by native Greek speakers with the goal of identifying the English consonants that will be appropriate for the computer-based training in later stages of our research. English consonant identification was assessed in quiet and in two types of noise, a competing speaker at an SNR of -6dB and an 8-speaker babble at an SNR of -2dB.

The results showed that native Greek speakers' identification scores in quiet were significantly higher than their scores in noise. There was no difference in identification scores in the two types of noise but since the competing speaker had a lower SNR than the babble the latter had a more deteriorating effect in participants' identification of English consonants than the former. This can be attributed to the fact that babble noise produces more energetic and informational masking than a competing speaker (García Lecumberri & Cooke 2006; Simpson & Cooke 2005; van Dommelen & Hazan 2010).

Native Greek speakers' difficulties with specific English consonants can be attributed to a variety of reasons. The first reason concerns the relationship between the L1 (Greek) and the L2 (English) phoneme inventories mentioned in the Introduction. When two L2 sounds are perceptually mapped by the listener into a single L1 sound, the learner is expected to have difficulty differentiating the L2 sounds. For example, Greek listeners had some difficulty with the English postalveolar fricatives /ʃ/ and /ʒ/ (especially the latter). When there was inaccurate perception for these consonants, the confusion was with their alveolar counterparts /s/ and /z/ respectively. This can be explained by the fact that Greek lacks the alveolar-postalveolar distinction and only employs alveolar fricatives whose place of articulation is somewhat in between English alveolar and postalveolar fricatives

(Arvaniti 2007; Nicolaidis 2001; Panagopoulos 1991). Another source of difficulty concerns cases where there are differences in the phonetic realization of sounds that occur in both languages; both Greek and English employ a voiced-voiceless distinction in plosives but Greek distinguishes voiceless unaspirated vs. fully voiced stops (Botinis, Fourakis & Prinou 2000; Arvaniti 2001, 2007; Kainada 2012) whereas English distinguishes voiceless aspirated vs. not fully voiced stops (i.e., although English /b, d, g/ are phonologically described as voiced they are phonetically realized as voiceless in initial position, see e.g. Docherty 1992). This difference in phonetic realization between Greek and English plosives results in Greek listeners' tendency to identify English voiced plosives /b, d, g/ with their voiceless counterparts /p, t, k/. One final source of difficulty concerns acoustic/articulatory similarities between two L2 consonants, similarities that are more clearly revealed when consonants are perceived in the presence of noise. For example, the English labiodental fricative /f/ was confused with the dental fricative /θ/ and the English labiodental fricative /v/ was confused with the English bilabial plosive /b/.

A comparison of native Greek speakers' difficulties with specific English consonants in perception vs. production revealed several discrepancies between the two modalities. This finding seems incompatible with a view that supports a perception-production link in L2 phonetic learning (Flege 1999; Flege et al. 1999). One explanation for our findings would be that such alignment may be difficult for L2 learners in a foreign language setting because learners usually receive a greater amount of L1-accented input than authentic input (if any). This is in agreement with previous research in formal foreign language settings showing that even L2 exposure at a young age and several years of L2 experience may not lead to better pronunciation (see Singleton & Ryan 2004 for a review). Along the same line, in a HVPT study examining the training of English vowels for Greek learners of English in a foreign setting, Lengeris & Hazan (2010) found that L2 identification correlated with L2 production only after training (i.e., only after participants had been exposed to a large amount of authentic L2 input spoken by multiple native English speakers). Another explanation relates to both the relationship between L1 and L2 sound inventories and to differences in the phonetic realization of sounds that occur in the two languages. Take, for example, the case of English /p/; because /p/ is aspirated in English it may sound unusual to the Greek listeners' ears but it is very unlikely to be misidentified with another consonant category which is why it received a relatively high identification score (contrary to what happens in the case of English /b/ which is phonetically quite close to Greek /p/). In production, however, the picture is reversed; an English /p/ spoken by a Greek speaker sounds very close to English /b/ to the native English listeners' ears and thus receives a low identification score (whereas an English /b/ spoken by a Greek speaker may sound unusual to the ears of an English listener but would not be identified with another English category).

In conclusion, the results of this study provide a large source of data on English consonant identification and production by native Greek speakers that can be interpreted as caused by a combination of L1 interference (at both the phonetic and phonological levels) and spectral/articulatory factors.

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