English consonant confusions by Greek listeners in quiet and noise and the role of phonological short-term memory

Angelos Lengeris, Katerina Nicolaidis

Department of Theoretical and Applied Linguistics, Aristotle University of Thessaloniki, Greece

`lengeris@enl.auth.gr, knicol@enl.auth.gr`

Abstract

This study investigated English consonant identification by Greek listeners and the role of phonological short-term memory (PSTM) in listeners' identification ability. Twenty Greek university students who had received formal instruction in English identified 24 English consonants (embedded in VCV syllables) presented in quiet and in two noise types, a competing talker at a signal-to-noise ratio (SNR) of -6dB and an 8-speaker babble at an SNR of -2dB. Participants' PSTM was assessed via a serial non-word recognition task in Greek. The results showed that identification scores in quiet were significantly higher than in noise. There was no difference in scores between the two noise conditions. PSTM correlated with English consonant identification in quiet and in the two types of noise; listeners with greater PSTM capacity were also better in identifying English consonants in quiet and noise, a finding that extends previous research in quiet to L2 perception in adverse listening conditions. English consonant confusion patterns are interpreted as caused by a combination of first-language interference (at both the phonetic and phonological levels) and spectral/articulatory factors.

Index Terms: L2 consonants, identification, PSTM, noise

1. Introduction

Second-language (L2) learners often have difficulty in perceiving speech sounds that do not exist in their native language (L1) [e.g. 1, 2, 3, 4, 5, 6]. Well-documented factors related to success in L2 sound learning include the relationship between the L1 and L2 inventories [e.g. 7, 8, 9], the age of L2 learning [e.g. 2], the length of residence in an L2 setting [e.g. 10] and the degree of ongoing L1 use [e.g. 11]. Factors concerned with the learner's cognitive abilities such as phonological short-term memory (PSTM) have not received much attention in the L2 speech perception literature.

PSTM has been found to play a role in L2 vocabulary and grammar learning [e.g. 12, 13] and in L2 fluency and proficiency (e.g. 14, 15, 16, 17). A few phonetic studies that have begun exploring the relationship between PSTM and L2 sound learning have also found some links between PSTM and L2 consonant [6] and vowel [18, 19] perception. [6] for example, examined the identification of English consonants by native speakers of Italian as a function of, among other variables, participants' PSTM scores (evaluated via a non-word repetition task in Italian). The results showed a negative correlation between PSTM scores and percentage of errors in word-initial and word-final English consonant identification. In addition, PSTM scores independently accounted for 8% and 15% of the variance in word-initial and word-final consonant identification scores respectively. On the other hand, [20] provided evidence against the relationship between PSTM and L2 vowel identification. In their study, Catalan learners of English identified /iː/ vs. /ɪ/ in English CVC minimal pairs.

Minimal pair stimuli contained natural vowels and vowels with manipulated durations (equated across /iː/ and /ɪ/). No advantage of learners with a greater PSTM capacity in English vowel identification over those with lower PSTM capacity in either task was found. The results of previous research are therefore inconclusive as to whether and to what degree PSTM correlates with L2 speech perception.

In addition, we still do not know whether PSTM plays a role in tasks that simulate situations closer to everyday communication such as speech-in-noise-perception. There is evidence that L2 perception is more challenging for the learner when encountering L2 speech in the presence of noise in tasks such as sentence intelligibility [21], word identification [22] and phoneme identification [23, 24] (but see [25] for evidence against the view that the non-native disadvantage is greater in noise than it is in quiet at least when using phoneme identification tasks that involve a large degree of inter-token variability).

The goals of the current study are therefore to (a) explore the role of PSTM in L2 consonant perception, (b) examine the influence of quiet vs. different noise conditions on L2 consonant perception, and (c) identify those English consonants that pose difficulties to Greek listeners since, apart from general predictions based on a phonemic comparison of the two systems, there is no data in the literature examining English consonant identification by Greek listeners either in quiet or in noise. According to current L2 learning models such as the Perceptual Assimilation Model (PAM) [7, 26], the Speech Learning Model [8], and the Native Language Magnet model [9, 27] the relationship between the L1 and L2 sound inventories can predict whether or not a specific L2 sound will pose difficulty to the learner. PAM for example predicts that when two L2 categories are perceptually mapped into a single L1 category, the learner will have difficulty differentiating the two L2 categories. Because English has alveolar /s, z/ and postalveolar fricatives /ʃ, ʒ/ while Greek has only the alveolar /s, z/ pair, it is predicted that Greek listeners will encounter difficulty in distinguishing between the two places of articulation. When, on the other hand, two L2 categories are mapped into different L1 categories, the learner is expected to have no difficulty in perceiving the sounds even when they are acoustically/articulatory different to the native ones. Because English and Greek employ a distinction between a rhotic sound and the lateral /l/, Greek listeners are not expected to have difficulty in differentiating the two despite the fact that the Greek rhotic is a tap while the English rhotic is an approximant.

There were three test conditions in the study: English consonants were presented for identification in quiet and in two noise types, a competing talker and an 8-speaker babble. PSTM was assessed in Greek via a serial non-word recognition task because it does not contain an articulatory component [28, 16, 17].

14–18 September 2014, Singapore

2. Method

2.1. Participants

The participants were 20 female Greek university students who had received formal instruction in English in a foreign language setting for 10-14 years. They had a mean age of 19.8 years old (aged range 19 to 20 years) and their language proficiency level was relatively uniform (Cambridge FCE, CPE). None of the participants had lived in an English-speaking country for more than one month and they all reported normal hearing and no language impairment.

2.2. Stimuli

2.2.1. PSTM

The serial non-word recognition task consisted of 144 CV syllables conforming to Greek phonotactic constraints recorded by a female native Greek speaker. The syllables were organized into eight pairs of sequences at each of three lengths: five, six and seven for a total of 24 pairs of sequences. Half of the pairs contained the same sequence of syllables presented to participants one after the other. In the other half of the pairs, one syllable in the second sequence was transposed compared to the first sequence.

2.2.2. English consonants

The perceptual stimuli were taken from a free corpus (available at http://www.odettes.dds.nl/challenge_IS08/) recorded for the Interspeech 2008 Consonant Challenge [29]. The stimuli were VCV tokens (V = iː/, /æ/, /uː/) containing all 24 English consonants in all 9 possible combinations. Each CVC token was spoken with stress on the first or second syllable (e.g. /ˈiːðæ/, /iːˈbiː/, /ˈæmuː/) by four native speakers of British English (2 female and 2 male). As already said, the CVC tokens were presented in quiet (QUIET) and in the presence of two noise types, a competing speaker (COMP) and an 8-speaker babble (BABBLE). 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 contained two instances of each consonant from four English speakers resulting in 192 VCV items per test condition.

2.3. Procedure

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). In the PSTM task, participants were asked to decide whether the presentation order of the two sequences of syllables was the same or different. In the English identification task, designed in PRAAT [30], English consonants were presented using orthographic symbols (e.g. B, CH, D) and appeared on the screen together with an example word for each consonant (e.g. Bee, CHart, Dog). Following each VCV item presentation participants indicated which consonant they heard by clicking on a computer screen one of 24 consonant options. QUIET was always presented first, followed by the two noise conditions (half of the times QUIET was followed by COMP and half of the times QUIET was followed by BABBLE). A practice task with 24 VCV tokens for each condition preceded testing to familiarize participants with the procedure.

3. Results

Figure 1 shows mean percent correct identification scores pooled over English consonants in each test condition. Greek listeners' scores in QUIET were fairly high at 83.3% correct. Using the same perceptual stimuli, [29] report a mean of
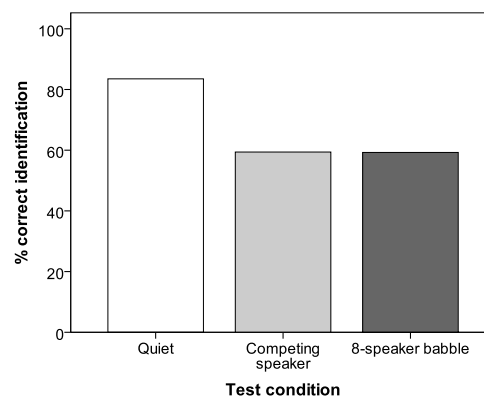

Figure 1: *Mean percent correct identification across English consonants by Greek listeners in three test conditions.*

Stimulus	1st response		2nd response	
	Consonant	%	Consonant	%
p	p	100	-	-
b	b	79	p	20
t	t	84	tʃ	13
d	d	65	t	28
k	k	100	-	-
g	g	73	k	20
tʃ	tʃ	86	ʒ	7
dʒ	dʒ	54	tʃ	31
f	f	84	θ	14
v	v	75	f	16
θ	θ	91	s	4
ð	ð	69	θ	16
s	s	76	ʃ	21
z	z	89	ʒ	11
ʃ	ʃ	88	s	9
ʒ	ʒ	65	z	28
h	h	91	y	7
m	m	99	-	-
n	n	94	l	4
ŋ	ŋ	83	n	8
l	l	100	-	-
ɹ	ɹ	98	-	-
y	y	83	w	15
w	w	77	y	14

Table 1. *Most frequent and second most frequent response and percentage of total opportunities for English consonants in QUIET.*

Stimulus	1st response		2nd response	
	Consonant	%	Consonant	%
p	p	24	b	14
b	b	49	p	14
t	t	58	tʃ	23
d	d	53	t	13
k	k	94	ŋ	3
g	g	46	k	28
tʃ	tʃ	87	dʒ	6
dʒ	tʃ	36	dʒ	33
f	f	61	θ	23
v	v	49	b	11
θ	θ	80	s	6
ð	ð	54	v	20
s	s	56	ʃ	23
z	z	73	ʒ	11
ʃ	ʃ	78	s	10
ʒ	ʒ	43	z	39
h	h	65	g	13
m	m	71	ŋ	5
n	n	53	l	14
ŋ	ŋ	66	n	20
l	l	90	b	3
ɹ	ɹ	43	v	16
y	y	55	w	13
w	w	40	p	14

Table 2. *Most frequent and second most frequent response and percentage of total opportunities for English consonants in* COMP.

Stimulus	1st response		2nd response	
	Consonant	%	Consonant	%
p	p	34	b	8
b	b	59	p	20
t	t	62	tʃ	22
d	d	48	t	26
k	k	80	g	5
g	g	44	k	16
tʃ	tʃ	79	dʒ	7
dʒ	dʒ	48	tʃ	34
f	f	69	θ	24
v	v	58	b	10
θ	θ	69	f	14
ð	ð	54	v	9
s	s	71	ʃ	16
z	z	67	ʒ	7
ʃ	ʃ	82	s	10
ʒ	ʒ	42	z	29
h	h	68	g	6
m	m	61	n	9
n	n	61	l	8
ŋ	ŋ	39	g	16
l	l	58	b	9
ɹ	ɹ	53	b	10
y	y	59	w	11
w	w	53	y	10

Table 3. *Most frequent and second most frequent response and percentage of total opportunities for English consonants in* BABBLE.

93.8% correct for native English listeners. Greek listeners' scores in the two noise conditions were much lower, at 59.2% correct in COMP and at 59% in BABBLE. In [29], English listeners achieved mean scores of 79.5 and 76.5% respectively. Taking into consideration that two different studies are compared, this seems to suggest a smaller noise-induced drop in native listeners' performance (around 15% across noise conditions) compared to non-native listeners' performance (around 25% across noise conditions).

A repeated-measures ANOVA on identification scores confirmed that the effect of noise was significant [$F_{(2, 38)} = 289.55$, $p < 0.001$]. Pairwise comparisons showed that Greek listeners achieved higher identification scores in QUIET than in the noise conditions, $p < 0.001$ and showed no difference in scores between the noise conditions. However, since COMP had a much lower SNR value (-6 dB) than BABBLE (-2 dB), this suggests that the latter had a larger detrimental effect on Greek listeners' identification of English consonants than the former.

Tables 1-3 show the most frequent and the second most frequent identification response for English consonants in QUIET, COMP and BABBLE respectively. In QUIET (Table 1), identification scores ranged from 100% to 54% correct. The most difficult English consonants (<70% correct) proved to be /d/ (mostly confused with /t/), /dʒ/ (mostly confused with /tʃ/), /ð/ (mostly confused with /θ/) and /ʒ/ (mostly confused with /z/). In COMP (Table 2), identification scores ranged from 94% to 24% correct. The most difficult English consonants (<50%

correct) were /p/ (mostly confused with /b/), /b/ (mostly confused with /p/), /g/ (mostly confused with /k/), /dʒ/ (mostly confused with /tʃ/), /v/ (mostly confused with /b/), /ʒ/ (mostly confused with /z/), /ɹ/ (mostly confused with /v/) and /w/ (mostly confused with /p/). In BABBLE (Table 3), identification scores ranged from 82% to 34% correct. The most difficult English consonants (<50% correct) were /p/ (mostly confused with /b/), /d/ (mostly confused with /t/), /g/ (mostly confused with /k/), /dʒ/(mostly confused with /tʃ/), /ʒ/ (mostly confused with /z/) and /ŋ/ (mostly confused with /g/). It therefore seems that across noise conditions, English consonant confusions mostly concerned plosives (more frequently voiced ones perceived as their voiceless counterparts than the other way round), affricates (again voiced /dʒ/ usually perceived as voiceless /tʃ/) and fricatives (especially /ð/ and /ʒ/).

Figure 2 shows mean percent correct identification of English consonants as a function of the three dimensions along which consonants are characterized, namely voicing, place and manner of articulation. These were coded as follows: Voicing had two values, voiced and voiceless. Place of articulation had five values, labial, alveolar palatal, velar and glottal. Manner of articulation had six values, plosive, fricative, affricate, glide, liquid and nasal. It can be seen that voicing proved to be a very robust feature across test conditions (second in QUIET, first in COMP and BABBLE). Across noise conditions, voicing was followed by manner of articulation which was in turn followed by place of articulation.
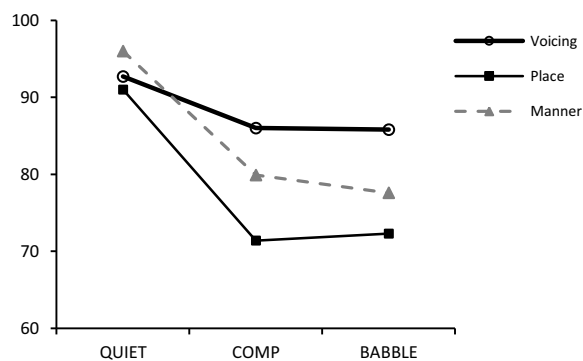
Figure 2: *Mean percent correct identification for voicing, place-of-articulation and manner-of-articulation in each test condition.*

Finally, the relationship between PSTM and identification scores in the three test conditions was examined. PSTM was found to be correlated with English consonant identification scores in QUIET, $r = 0.41$, $p < 0.05$ and in the noise conditions ($r = 0.45$, $p < 0.05$ in COMP; $r = 0.46$, $p < 0.05$ in BABBLE). This indicates that those learners with greater PSTM capacity were more successful in identifying English consonants than learners with lower PSTM capacity not only in quiet as previous research suggests but also in more realistic listening conditions such as perception of speech in the presence of a single competing speaker and of an 8-speaker babble.

4. Discussion

This study examined English consonant confusions by Greek learners of English in three listening conditions: in quiet, in the presence of a competing speaker at an SNR of -6 dB and in the presence of an 8-speaker babble at an SNR of -2dB. Learners' PSTM capacity was measured in an attempt to explore a possible source of individual differences in Greek listeners' identification of English consonants in quiet and noise listening conditions.

The results showed that Greek listeners' identification of English consonants in quiet was significantly higher (83.3% correct) than in the two noise conditions which did not differ from each other (59.2 vs. 59% correct). However, if we take into consideration that COMP had a much lower SNR value than BABBLE, the latter had a more deteriorating effect in L2 consonant identification than the former. This result can be interpreted as due to the fact that babble noise produces a combination of more energetic and more informational masking than a competing speaker [24, 31, 25]. When comparing our results with [29], who tested native English listeners using the same stimuli, it seems that the drop in scores was smaller for native listeners (from 93.8% in QUIET to 79.5% in COMP and 76.5% in BABBLE) than for our L2 listeners (from 83.3% in QUIET to 59.2 in COMP and 59% in BABBLE). This seems in line with previous research suggesting that the native advantage in speech perception is greater in noise than in quiet [23, 24].

English consonant confusions by Greek listeners can be explained as caused by two factors (a) the relationship between the L1 and the L2 phoneme inventories and (b) acoustic/articulatory similarities between English consonants. One example demonstrating the first factor, already discussed

in the Introduction, is the identification of English /ʃ/ and /ʒ/ with their alveolar counterparts /s/ and /z/ and vice versa. This happens because Greek lacks the alveolar-postalveolar distinction and has only alveolar fricatives whose place of articulation is somewhat in between English alveolar and postalveolar fricatives [32, 33]. This therefore constitutes a case whereby two L2 categories assimilate to a single L1 category. Another example is the difficulty caused in cases where the phonetic realization of sounds that occur in both languages differs; both Greek and English employ a voiced-voiceless distinction in plosives but Greek distinguishes voiceless unaspirated vs. fully voiced stops [34, 35] 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). This difference in phonetic realization between Greek and English plosives results in Greek listeners' identification of English voiced plosives /b, d, g/ with their voiceless counterparts. Examples demonstrating difficulties not caused by L1 interference but due to acoustic/articulatory similarities between L2 consonants are the identification of English labiodental fricative /f/ with dental fricative /θ/ and that of English labiodental fricative /v/ with English bilabial plosive /b/ (the non-sibilant fricatives are known to be difficult to identify, see e.g. [36, 37]). Across test conditions, voicing proved to be a very robust feature, followed by manner of articulation and finally place of articulation [cf. 36, 38, 37].

The results concerning PSTM replicate previous research showing a positive correlation between PSTM capacity and speech perception [18, 19, 6]. Our results also show a link between PSTM and English consonant identification in COMP and BABBLE extending previous research in quiet to L2 perception in adverse listening conditions. Along with research showing a link between PSTM and other aspects of learning such as vocabulary, grammar and fluency [14, 15, 12, 13, 16, 17], the results of this study provide further support for the importance of PSTM in L2 learning.

5. Conclusions

Our results provide a large source of data on English consonant confusions by Greek learners of English under different listening conditions. They also support a link between PSTM and English consonant identification in quiet and in two types of noise extending previous research in quiet to L2 perception in adverse listening conditions. In line with previous literature, this suggest that PSTM may play a role in L2 speech learning.

6. Acknowledgements

7. References

[1] Best, C. T., McRoberts, G. W. and Goodell, E., "Discrimination of non-native consonant contrasts varying in perceptual assimilation to the listener's native phonological system", J. Acoust. Soc. Am., 109:775-794, 2001.

[2] Flege, J. E., Mackay, I. R. A. and Meador, D., "Native Italian speakers' production and perception of English vowels", J. Acoust. Soc. Am., 106:2973-2987, 1999.

[3] Hattori, K. and Iverson, P., "English /r/-/l/ category assimilation by Japanese adults: Individual differences and the link to identification accuracy", J. Acoust. Soc. Am., 125:469-479, 2009.

[4] Iverson, P. and Evans, B. G., "Learning English vowels with different first-language vowel systems: Perception of formant targets, formant movements, and duration", J. Acoust. Soc. Am., 122(5):2842-2854, 2007.

[5] Lengeris, A., "Perceptual assimilation and L2 learning: Evidence from the perception of Southern British English vowels by native speakers of Greek and Japanese", Phonetica, 66:169-187, 2009.

[6] MacKay, I. R. A, Meador, D. and Flege, J. E., "The Identification of English Consonants by native speakers of Italian", Phonetica, 58:103-112, 2001.

[7] Best, C. T., "A direct realist view of cross-language speech perception", in W. Strange [Ed], Speech perception and linguistic experience: Issues in Cross-language Research, 171-204, York Press, 1995.

[8] Flege, J. E., "Second language speech learning: Theory, findings, and problems" , in W. Strange [Ed], Speech perception and linguistic experience: Issues in Cross-language Research, 233-277, York Press, 1995.

[9] Kuhl, P. K., "A new view of language acquisition", Nat. Acad. Sciences USA, 97:11850-11857, 2000.

[10] Flege, J. E., Bohn, O.-S. and Jang, S., "Effects of experience on non-native speakers' production and perception of English vowels", J. Phon., 25:437-470, 1997.

[11] Flege, J. E. and MacKay, I. R. A., "Perceiving vowels in a second language", Stud. second Lang. Acquis., 26:1-34, 2004.

[12] Martin, K. I. and Ellis, N. C., "The Roles of Phonological STM and Working Memory in L2 Grammar and Vocabulary Learning", Stud. Second Lang. Acquis., 34(3):379-413, 2012.

[13] Masoura, E. V. and Gathercole, S. E., "Phonological short-term memory skills and new word learning in young Greek children", Memory, 13:422-429, 2005.

[14] Hummel, K. M., "Aptitude, phonological memory, and second language proficiency in nonnovice adult learners", Appl. Psycholing., 30:225-249, 2009.

[15] Kormos, J. and Sáfár, A., "Phonological short-term memory, working memory and foreign language performance in intensive language learning", Bilingualism: Language and Cognition, 11(2):261-271, 2008.

[16] O'Brien, I., Segalowitz, N., Collentine, J. and Freed, B., "Phonological memory and lexical, narrative, and grammatical skills in second language and production by adult learners", Appl. Psycholing., 27:377-402, 2006.

[17] O'Brien, I., Segalowitz, N., Freed, B. and Collentine, J., "Phonological memory predicts second language oral fluency gains in adults", Stud. Second Lang. Acquis., 29:557-582, 2007.

[18] Aliaga-Garcia, C., Mora, J. C. and Cerviño-Povedano, E., "Phonological short-term memory and L2 speech learning in adulthood", in K. Dziubalska-Kołaczyk, M. Wrembel and M. Kul [Ed], New Sounds 2010: Proceedings of 6th International Symposium on the Acquisition of Second Language Speech, 12-18, 2010.

[19] Cerviño-Povedano, E. and Mora, J. C., "Investigating Catalan learners of English over-reliance on duration: Vowel cue weighting and phonological short-term memory", Proceedings of New Sounds 2010, 53-64, 2011.

[20] Safronova, E. and Mora, J. C., "Acoustic and phonological memory in L2 vowel perception", Proceedings of 22nd EUROSLA, 384-390, 2012.

[21] Mayo, L. H., Florentine, M. and Buus, S., "Age of second-language acquisition and perception of speech in noise", J. Speech Hear. Res., 40:686-693, 1997.

[22] Nabelek, A. K. and Donahue, A. M., "Perception of consonants in reverberation by native and non-native listeners", J. Acoust. Soc. Am., 75:632-634, 1984.

[23] Cutler, A., Garcıa Lecumberri, M. and Cooke, M., "Consonant identification in noise by native and non-native listeners: effects of local context", J. Acoust. Soc. Am., 124:1264-1268, 2008.

[24] Garcıa Lecumberri, M. and Cooke, M. P., "Effect of masker type on native and non-native consonant perception in noise", J. Acoust. Soc. Am., 119:2445-2454, 2006.

[25] van Dommelen, W. A. and Hazan, V., "Perception of English consonants in noise by native and Norwegian listeners", Speech Commun., 52:968-979, 2010.

[26] Best, C. T. and Tyler, M. D., "Non-native and second-language speech perception: Commonalities and complementarities", in M. Munro and O.-S. Bohn [Ed], Second language speech learning, 13-34, John Benjamins, 2007.

[27] Kuhl, P. K., Conboy, B. T., Coffey-Corina, S., Padden, D., Rivera-Gaxiola, M. and Nelson, T., "Phonetic learning as a pathway to language: new data and native language magnet theory expanded (NLM-e)", Philosoph. Trans. Royal Society, B, 363:979-1000, 2008.

[28] Gathercole, S. E. and Pickering, S. J., "Estimating the capacity of phonological short-term memory", Inter. J. Psych., 34:378-382, 1999.

[29] Cooke, M. and Scharenborg O., "The Interspeech 2008 Consonant Challenge", Proceedings of Interspeech, Brisbane, Australia, 1765-1768, 2008.

[30] Boersma, P. and Weenink, D., "Praat: doing phonetics by computer" [Computer program]. Version 5.3.07. Online: http://www.praat.org, accessed on 15 Mar 2012.

[31] Simpson, S., and Cooke, M., "Consonant identification in N-talker babble is a nonmonotonic function of N", J. Acoust. Soc. Am., 118:2775-2778, 2005.

[32] Nicolaidis, K., "An Electropalatographic Study of Greek Spontaneous Speech", J. Inter. Phon. Assoc., 31(1):67-85, 2001.

[33] Panagopoulos, L., "A comparison of English and Greek Alveolar Fricatives", Proceedings of XIIth International Congress of Phonetic Sciences, 326-328, 1991.

[34] Botinis, A., Fourakis, M. and Prinou, I., "Acoustic structure of the Greek stop consonants", Glossologia, 11-12:167-200, 2000.

[35] Kainada, E., "The acoustics of post-nasal stop voicing in Standard Modern Greek", in Z. Gavriilidou, A. Efthymiou, E. Thomadaki and P. Kambakis-Vougiouklis [Ed], Selected Papers of 10th International Conference on Greek Linguistics, 320-329, 2012.

[36] Miller, G. A. and Nicely, P. E., "An analysis of perceptual confusions among some English consonants", J. Acoust. Soc. Am., 27: 338-352, 1955.

[37] Wang, M. D. and Bilger, R. C., "Consonant confusions in noise: a study of perceptual features", J. Acoust. Soc. Am., 54:1248-1266, 1973.

[38] Phatak, S. and Allen, J. B., "Consonant and vowel confusions in speech-weighted noise", J. Acoust. Soc. Am., 121(4):2312-2326, 2007.