ONOMÁZEIN

Revista semestral de lingüística, filología y traducción

Pontificia Universidad Católica de Chile
Facultad de Letras

Perception of natural and enhanced non-native contrasts in clear speech

Silvia Carmen Barreiro Bilbao
Universidad Nacional de Educación a Distancia (UNED)
España

ONOMÁZEIN 27 (junio de 2013): 207-219

CC BY ND

27
Junio
2013

Silvia Barreiro: Departamento de Filologías Extranjeras y sus Lingüísticas, Facultad de Filología, Universidad Nacional de Educación a Distancia (UNED).
Correo electrónico: sbarreiro@flog.uned.es / Calle Senda del rey n° 7, 28040, Madrid, España

Fecha de recepción: julio de 2012
Fecha de aceptación: febrero de 2013

Abstract

If learning phonetic contrasts of a language is considered the result of selective attention, it then may be possible to redirect listeners' attention towards non-native contrasts. In this paper we present an experiment carried out in order to investigate the perception of non-native contrasts by Spanish listeners, in particular, we want to analyse the effects of cue-enhancement on their perceptual performances of 25 different English words containing natural and enhanced sibilants, all presented in clear speech. The results of the experiments showed that the effects of the enhancement varied greatly among the consonants, and across the different vocalic contexts. Moreover, the results did not seem to correlate with subjects' variables, such as subject's age, time period of L2 learning or age of L2 learning, although error patterns could be related to the phonological system of Spanish listeners.

Keywords: Spanish perception; English sibilants; cue-enhancement.

1. Introduction

It is well known that an L2 learner will encounter perceptual difficulties when trying to differentiate speech contrasts which are not functionally distinctive in the mother tongue, or which are phonemic in the native language, but differ in the phonetic realisation in the L2.

Perceptual difficulties with non-native speech categories have been explained by different approaches, including the *Perceptual Assimilation Model* (Best & Strange, 1992), the *Speech Learning Model* (Flege, 1995), the *Perceptual Learning Model* (Pisoni et al., 1994) or the *Native Language Magnet Model* (Kuhl & Iverson, 1995). All these models varied greatly in relation to a deeper issue, that is, if the underlying neural mechanisms used in speech perception becoming finely tuned to the distinctive contrasts used in the native language is a reversible or non-reversible process. Nowadays, it seems that the second position is more broadly accepted: "perceptual difficulties are not due to a loss of sensory capabilities, but rather reflect perceptual attunement to phonetic information that is phonologically relevant in their native language" (Strange, 1995: 79). This is the approach followed in the present work—supported by Flege's ideas (1995)—, that implies that if learning phonetic contrasts of a language is the result of selective attention (Pisoni et al., 1994), it is possible to redirect listeners' attention towards non-native contrasts.

In all this process of redirecting attention, there are different variables that interact in the perception of non-native contrasts. First of all, the *contrast* factors, some contrasts are more difficult to differentiate perceptually than others (Lasky et. al., 1975; Werker & Logan, 1985; Flege, 1998), for instance, a lack of experience in L1 to *voicing* contrasts would imply a great perceptual difficulty in differentiating L2 phonemic contrasts based on *voicing* differences. Also, L2 learners seem to weigh differently the information available in the signal from the way L1 learners do in making a linguistic distinction (Strange & Jenkins, 1978; Underbakke et al., 1988; Yamada & Tohkura, 1992; Flege, 1984; Bohn, 1995; Hazan & Boulakia, 1993; or Fledge & Eefting, 1987; and Williams, 1977, for Spanish studies). Leaving aside these contrast variables, there are also *subject* factors that do seem to contribute to the ability to distinguish non-native contrasts, as *L1 background, L2 experience* or *age of the learner*, to mention a few (as shown by MacKain et al., 1981; Ocke-Schwen Bohn, 1995; Mayo et al., 1997; Flege, 1998; or Bradlow & Pisoni, 1999).

Different auditory training techniques have been applied to improve listeners' performance with non-native contrasts. One of the first works was carried out by Jamieson & Morosan (1986), in which francophone adults were trained in non-native VOT identification, using natural and synthetic fricative tokens. Since then, enhancement techniques have been applied to help in auditory training for different populations (L2 learners, hearing-impaired listeners, children with language disorders...) in clear speech or in noise (or Lombard) speech (Gordon-Salant, 1986; Hazan & Shi, 1992; Jamieson, 1995; Hazan & Simpson, 1996a, 1996b, 1997; Ortega-Llebaria & Hazan, 1999; Ortega-Llebaria & Huckvale, 2000; Skowronski & Harris, 2005).

Some of these techniques include cue-enhancement involving the amplification of selective regions that contain important cues in order to improve listeners' intelligibility due to the fact that the manipulation of intensity ratios had shown the greatest effect on intelligibility in comparison with that obtained as a result of spectral or temporal enhancements (Revoile et al., 1986; Bunnell, 1990). It is worth mentioning the studies carried out by Hazan & Simpson (1998a, 1998b, 2000) which showed that all the listeners, including Spanish, improved the recognition of enhanced consonants in the presence of noise, showing an influence of their L1 background. Analysing the Spanish results in detail, it is worth mentioning that /p, b, g, f, v/ were the least intelligible consonants. As far as the sibilant fricatives were concerned, /s/ had better results than /z/, whereas the palato-alveolar ones were not analysed. The results were an average over speakers and vowel contexts.

These encouraging results seem to open a new door for L2 training, and this made us think that it would be interesting to find out whether Spanish listeners benefit from the cue-enhancement in clear speech, and in a similar way to those reported in previous works, that is, the lower the initial intelligibility of the listener, the greater the improvement produced by the enhancement.

An experiment was set up to observe what perceptual benefits for Spanish listeners would have enhancing consonantal regions which contain a high density of acoustic cues to two phonemic contrasts in English, in clear speech: /s/ vs. /z/ and /s/ vs. /ʃ/. The difference between the alveolar fricatives is based on the "voicing" feature. This contrast is phonemic in English but phonetic in Spanish, that is, the voiced fricative is an allophone in Spanish that only occurs when followed by a voiced consonant, as in the word *mismo*. In the second contrast, the difference between the fricatives is founded on the "place of articulation" feature. The contrast is phonemic in English whereas the second phoneme does not exist in Spanish.

2. Method

The approach adopted to increase the intelligibility of clear speech was by enhancing salient acoustic cues known to encode phonemic contrasts in fricative consonants, using the same enhancement techniques described in the previous studies by Hazan mentioned above.

Stimuli were recorded in a sound-proof room and digitised at a 16 kHz sampling rate with 16-bit amplitude quantisation. The stimuli of this experiment were produced by a female talker with a RP accent. The digitised stimuli were, then, annotated using a waveform editing tool to mark the regions for amplification. These regions comprised the formant transitions at the release of the constriction, and the cues at release or of during the constriction, the weakest voicing cycles being given the most amplification. The same enhancement technique was applied to both contrasts, /s/-/z/ and /s/-/ʃ/.

Both the consonantal region and the formant transition regions at vowel onset were manipulated:

a) For the *transitions regions*[1], the reduced amplitude, as the consonant constriction was released, was counteracted by amplifying the 3 cycles of the following vowel, by 4, 3, and 2 dB, respectively.

b) The consonantal *frication region* was amplified by 6 dB.

Filtering was not used to change the spectral content of the regions which were perceptually relevant in order to make them more discriminable.

2.1. Test Material

14 CV(C)(C) English minimal pairs (a total of 25 different words) were used as the stimuli of the experiment (table 1). They comprised the consonants /s/, /z/ and /ʃ/ in prevocalic positions with /ɪ, e, æ, iː, uː, eɪ, əʊ/.

TABLE 1
Minimal pairs used for the experiment

/s/ vs. /z/	/s/ vs. /ʃ/
Sue/zoo	Sue/shoe
sip/zip	so/show
said/zed	seen/sheen
sap/zap	sip/ship
sink/zinc	said/shed
sing/zing	same/shame
seal/zeal	sin/shin

1 Formant-transition cues were amplified to counterpart the reduction in amplitude near the constriction.

2.2. Listeners

Listener selection was mainly based on the fact that it was required word comprehension by the informants. 26 Spanish monolingual listeners with normal hearing were chosen as the subjects of the experiment. They all used Spanish (Castilian) as their L1 language. The average age was 26 years old, 11 years was the average of L2 learning, and the average length of studying English was 15 years. Therefore, none of them have problems of word comprehension.

2.3. Test Procedure

The group of Spanish listeners was tested in the *Laboratorio de Fonética* from León University (Spain). They listened to the *DAT* tape through headphones, presented in a comfortable level. The test called "Sue-zoo-shoe" comprised 200 stimuli (see appendix). Listeners had 4 blocks of 50 minimal pairs on their response sheet. In each block there were 2 repetitions of each word: 1 natural and 1 enhanced. The identification test was preceded by six examples of natural realisations of the three words contained in the test title to make the role of enhancement even more enlightening.

3. Results[2]

3.1. /s/ results

In the *natural* condition (44 presentations per consonant per listener), the number of listeners who identified this consonant correctly above 90% of the times[3] was 22 subjects, whereas in the *enhanced* condition (44 presentations) that number decreased slightly going down to 19.

As first impressions, it seemed that the enhancement was not beneficial for these Spanish listeners. Moreover, when analysed the data from the 7 people who had identification problems, it seemed that there was a significant difference between the natural and the enhanced according to the results of the t-test. In fact, the enhancement had decreased the intelligibility of this consonant, compared to the natural ones [$t = 2.91$, $df = 6$; $p < 0.05$].

On examining the data in relation to the adjacent vowel in *all* the speakers who had *any* problem of identification, it was revealed that the enhancement had different effects on the listeners depending on the vocalic context. Table 2 shows the number of people who improved, got worse or was not affected by the enhancement.

TABLE 2
The effect of cue-enhancement on /s/ perception depending on the vowel: no. of people

	[æ]	[e]	[ɪ]	[iː]	[uː]	[eɪ]	[əʊ]
Improvement	2/8	2/5	3/12	2/13	0/6	2/5	0/10
No effect	0/8	1/5	0/12	1/13	2/6	1/5	0/10
Worsening	6/8	2/5	9/12	10/13	4/6	2/5	10/10

It can be noticed that the enhancement decreased the intelligibility in all vocalic contexts. However, according to the t-test, there was not a significant alteration of the results produced by the enhancement, except when the voiceless alveolar sibilant was followed by the vowels [iː] [$t(12) = 3.12$, at $p > 0.05$], [uː] [$t(5) = 2.71$, at $p > 0.05$], and [əʊ] [$t(9) = 6.33$ at $p > 0.001$].

3.2. /z/ results

The number of listeners who managed to identify the consonant above 90% or more of the times presented in the *natural* condition (22 presentations) was 22, almost the same number as in the *enhanced* one, 21 subjects. Therefore, it seemed that the enhancement may have a very mild effect, if any, on the listeners' perception.

When the data from the 5 subjects with identification problems was analysed, it was clear that the enhancement had a benefit on the per-

2 The data was analysed manually.
3 It was considered that 90% correct would be the baseline to say that a listener had no perceptual problems in identifying the consonants.

ception of the consonant, although, as a whole, these improvement were not statistically significant. Nevertheless, its effect differed across the vocalic contexts (table 3):

TABLE 3
The effect of cue-enhancement on /z/ perception depending on the vowel: no. of people

	[æ]	[e]	[ɪ]	[iː]	[uː]
Improvement	4/6	3/5	3/9	1/1	2/3
No effect	0/6	1/5	0/9	0/1	0/3
Worsening	2/6	1/5	6/9	0/1	1/3

In all cases, except when followed by [ɪ], the enhancement increased the number of correct identification although in none of the contexts a significant difference was observed in the results as a consequence of the enhancement.

3.3. /ʃ/ results

In the *natural* condition 20 listeners identified /ʃ/ correctly 90% or more of the 22 presentations of this consonant, whereas in the enhanced condition, there was a slight increase to 21 subjects. Consequently, only 6 subjects had not been able to identify the consonant within that percentage. Furthermore, the results of t-test with that group showed that the enhancement, as a whole, improved significantly the intelligibility of this consonant, compared to the natural ones, [$t(5) = 3.29$, significant at $p > 0.05$].

The analysis of the data by contexts showed that the effect of enhancement on listeners' perception of the palato-alveolar consonant varied across the vocalic contexts (table 4).

TABLE 4
The effect of cue-enhancement on /ʃ/ perception depending on the vowel: no. of people

	[e]	[ɪ]	[iː]	[uː]	[eɪ]	[əʊ]
Improvement	5/7	6/7	4/6	4/5	2/3	2/6
No effect	2/7	1/7	1/6	1/5	0/3	1/6
Worsening	0/7	0/7	1/6	0/5	1/3	3/6

It seemed that, overall, a consonant intelligibility benefit was observed across contexts, although there was little evidence of statistically-significant improvements except when the voiceless palato-alveolar sibilant was followed by the vowels, [e] and [ɪ], [$t(6) = 2.65$,] and [$t(6) = 3.33$ at $p < 0.05$], respectively.

4. Discussion

This experiment aimed to bring more light to the effects of cue-enhancement on improving consonant intelligibility for L2 learners in those cases where the target sound contrasts were likely to be difficult due to the listeners' L1 background. In particular, the primary aim was to see the effects of cue-enhancement on Spanish listeners' sibilant identification. In view of the results of previous studies, it was initially predicted that there would be clear benefits from the cue-enhancement. However, the results of our experiment differed slightly from the initial prediction, at least for the consonants under investigation in this study: the increase in intelligibility due to cue-enhancement was smaller than that obtained in studies such as Hazan & Simpson (1998a, 1998b, 2000), or even Ortega-Llebaria & Huckvale (2000).

As a whole, there was a general trend for higher intelligibility to be obtained for the enhanced conditions for /z/ and to a greater extend for /ʃ/, but the cue enhancement decreased the number of correct responses for /s/ (figure 1).

It seemed that the cue-enhancement was only beneficial for the consonants (/z/ and /ʃ/) that were not phonemes in the listeners' native language, bringing, consequently, more confusion than benefit in the case of /s/. Furthermore, as the initial intelligibility of the listeners was not low, the improvement produced by the enhancement was not as great as one would have been expected, although its effect on /ʃ/ was statistically-significant.

It could have been the case that the spectral characteristics of the adjacent vowel and,

FIGURE 1

Test 'Sue-zoo-shoe'

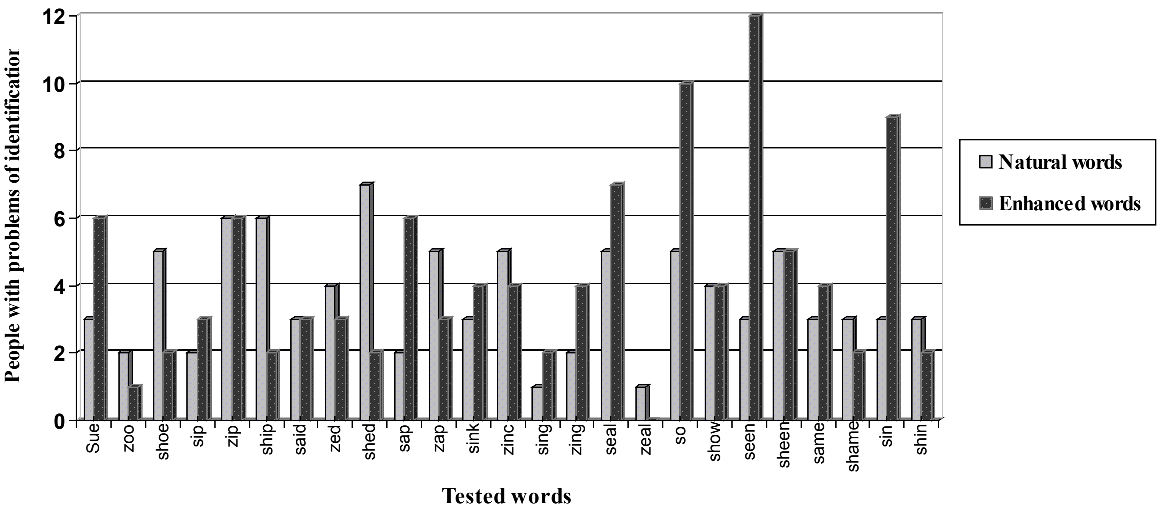
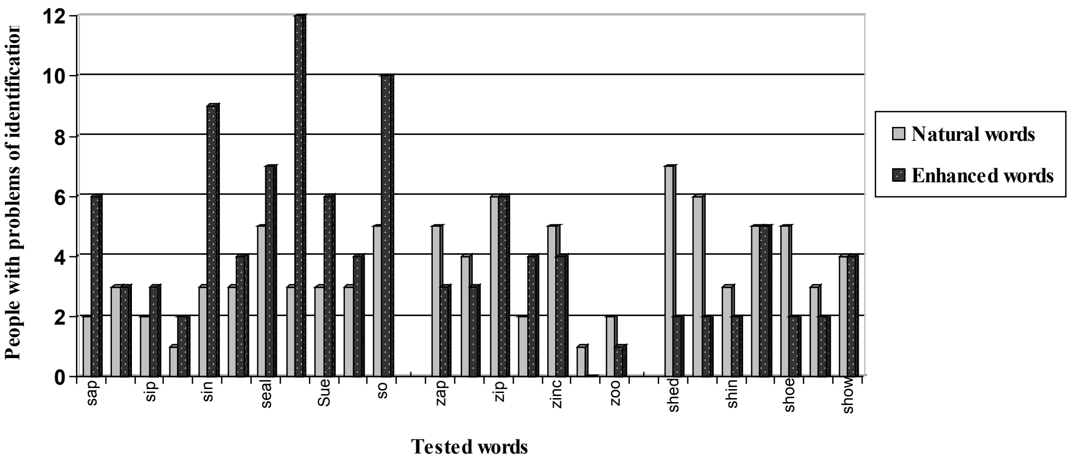


FIGURE 2

Test 'Sue-zoo-shoe'



perhaps the peculiarities of the consonant itself should have been taken into account when applying the cue-enhancement since its effects varied across consonants and contexts.

The analysis of the vocalic contexts (figure 2) revealed that the three consonants were more easily identified in some contexts than others, although little patterning was found across the consonants:

a) The enhancement was beneficial when the consonants /z/ and /ʃ/ were followed by /e/ whereas it had no effect on /s/ identification.

b) It was clearly detrimental when the adjacent vocalic element to /s/ was /əʊ/, but neutral for /ʃ/.

c) The identification of the alveolar fricatives worsened when followed by /ɪ/, in contrast to the palato-alveolar, /ʃ/.

d) When the following vowels were /æ, iː,

uː/, /s/ scores worsened, in contrast to the improvement with the other two consonants.

e) When the voiceless sibilant was followed by /eɪ/ the scores became worse whereas they became better for the palato-alveolar /ʃ/.

The analyses of variance carried out on the intelligibility data to test for the effects of test condition (natural vs. enhanced) varied across the consonants and the contexts, as mentioned above.

A review of the articulatory and acoustic characteristics of the consonants in both languages to see other possible effects of L1 background on the outcome showed that in Spanish the voiceless sibilant /s/ tends to be described as having an apico-alveolar place of articulation, whereas in English, it is lamino-alveolar, that is, it is the blade, and not the tip, the part of the tongue that gets close to the alveolar ridge. This articulatory difference between both sounds could produce a clear perceptual difference. Furthermore, Spanish /s/ can have different realisations; moving further back or forward[4] within the alveolar region, and it is sometimes taken as /ʃ/ for English listeners (Stockwell & Bowen, 1965; Quilis & Fernández, 1973; Nash, 1977; Finch & Ortíz Lira, 1982; Alarcos Llorach, 1983 [1950]; Mott, 1996 [1991]; and Navarro Tomás, 1999 [1918], among others).

Also, another potential cause for the reduction in the effect of cue-enhancement could have the level of amplifications. First of all, it has also been reported in the literature (Gurlekian, 1979, 1981) that there are intensity differences in the fricative of both languages: Spanish sibilants tend to be produced with more intensity than the English ones (around 6 dB). As far as English is concerned, previous works reveal that the alveolar sibilants are more intense than the palato-alveolar ones (Han-Yong, 1979; Jassem, 1987; Behrens & Blumstein, 1988). Secondly, as regard to voicing differences, voiced sounds are believed to have an overall lower intensity than their counterparts due to a lower air pressure in the vocal tract (Jassem, 1987), or most manuals like Cruttenden (2008 [1962]) or Roach (2009 [1983]). Therefore, certain key regions could have been not adequately amplified, being necessary to apply different levels of amplification across sibilants, or even consonants regions, in order to avoid an increase in errors, as happened in the past with other sounds (Hazan & Simpson, 1998a, 1998b; Ortega-Llebaria & Huckvale, 2000).

All in all, Spanish listeners were clearly affected by their L1 production and perception, and maybe, the amplification of the enhancement (precisely 6 dB in the consonantal portion) could have led to an increase in consonant confusion in the case of /s/. It would be interesting to analyse the production and perception of these listeners, when talking in each language. A possible additional task could be the analysis of the effects of native-language background on consonant intelligibility by examining the kinds of features that might be confusable on the basis of the L1 background in order to find out whether these were resolved as a result of the enhancements. Information Transfer analyses (Miller & Nicely, 1955; Wang & Bilger, 1973) could be carried out in order to determine how well these three consonants were recognised in terms of the features of voicing and place of articulation in the different conditions.

The statistical analysis of other intervening variables showed that the effect of enhancement on the words was not related to their frequency of use in the L2 language. There were very common words, such as *so*, which had more problems of being identified than less common words, like *sap*, for instance. Also, there was no correlation between the other subject variables analysed (*length of L2 learning, age of L2 learning*, or *age of the listener*) and the results obtained in this experiment. However, as also shown

4 This variability in its realisation may be due to the lack of phonemic contrast in the palato-alveolar region.

in previous studies, there was clear individual variability in the effect of enhancement, with some listeners showing little to no improvement in score in the enhanced condition whilst others showed significant increases.

Finally, it is fair to say that overall, there was not much perceptual confusion among the realisations of the chosen words for the tested Spanish ensemble[5]. Most of Spanish listeners obtained ceiling (or near-ceiling) intelligibility scores. The number of people who had difficulties in consonantal identification below the 90% mark varied between 5 and 7, varying slightly on the two conditions (natural vs. enhanced): For the alveolar sibilants, that number was a bit higher in the enhanced realisations than in the natural ones, whereas for the palato-alveolar was the opposite. Furthermore, as also shown in previous studies, there was clear individual variability in the effect of enhancement, with some listeners showing little to no improvement in score in the enhanced condition whilst others showed significant increases.

Its explanation could be two-fold: Firstly, the person who uttered the words to be recorded was an expert phonetician and a teacher, and may have pronounced the test-words too clearly[6]. And secondly, and most probable explanation, the fact that stimuli were not presented under degraded listening conditions (noise) but in clear speech could have also been beneficial to these listeners. To the light of previous works (Bradlow & Bent, 2002; Smiljanic & Bradlow, 2007; or Grynpas et al., 2011), clear speech is not only an effective enhancement strategy for native listeners but also for those with an extensive experience with the sound structure of the target language, as could have been the case of our informants whose level of English may have been higher than the one required to participating in such an experiment. It would be interesting then to investigate the perception of listeners with clear differences in their English level, and under different conditions (clear vs. noise).

In sum, this experiment produced only a limited set of results; therefore, more detailed experiments are needed for conclusive answers. It is therefore suggested that the future cue-enhancement techniques need to be tailored to the context, the consonant itself, and the target group (listeners' language background) so that it is possible to redirect listeners' attention towards non-native contrasts adequately.

Nevertheless, as the findings of this study demonstrated that the cue-enhancement technique could provide improvement in some cases, such technique should clearly be considered very useful for training L2 learners. Its correct application needs further study with more contrasts, listeners and contexts to be able to make a clear statement about the effects of cue-enhancement.

5. Bibliographic References

Alarcos Llorach, Emilio, 1983 [1950]: *Fonología española*, tercera edición, Madrid: Gredos.

Behrens, Susan & Sheila E. Blusmtein, 1988: "On the role of the amplitude of the fricative noise in the perception of place of articulation in voiceless fricative consonants", *Journal of the Acoustical Society of America* 84, 861-867.

Best Catherine T. & Winifred Strange, 1992: "Effects of experience and phonetic factors on cross-language perception of approximants", *Journal of Phonetics* 20, 305-330.

Bohn, Ocke-Schwen, 1995: "What determines the Perceptual Difficulty encountered in the Acquisition of Nonnative Contrasts?" in *Proceedings of in Proceedings of the 13th International Congress of Phonetic Sciences*, Stockholm, vol. 4, 84-91.

5 This is the reason why we decided not to test English speakers to establish a comparison. The results of the test would have not been enlightening due to a likely ceiling effect.

6 Markham & Hazan explained in detail the effects of talker-factors on speech intelligibility (2004) which could be applied to our experiment.

Bohn, Ocke-Schwen & James E. Flege, 1990: "Interlingual identification and the role of foreign language experience in L2 vowel perception", *Applied Psycholinguistics* 11, 303-28.

Bradlow, Ann R. & Tessa Bent, 2002: "The clear speech effect for non-native listeners", *Journal of the Acoustical Society of America* 112 (1), 272-284.

Bradlow Ann & David B. Pisoni, 1999: "Recognition of spoken words by native and non-native listeners: Talker-, listener-, and item-related factors", *Journal of the Acoustical Society of America* 106, 2074-2085.

Bunnell, Timothy H., 1990: "On enhancement of spectral contrast in speech for hearing-impaired listeners", *Journal of the Acoustical Society of America* 88, 2546-2556.

Cruttenden, Alan, 2008 [1962]: *Gimson's Pronunciation of English*, seventh edition, London: Hodder Arnold Publication.

Finch, Diana, F. & Héctor Ortiz Lira, 1982: *A Course in English Phonetics for Spanish Speakers*, London: Heinemann Educational Books.

Flege, James E., 1984: "The effects of linguistic experience of Arabs' perception of the English /s/ vs. /z/ contrast", *Folia Linguistica* 18, 117-138.
Flege, James E., 1995: "Second language learning: theories, findings and problems" in Williams Strange (ed.): *Speech Perception and Linguistic Experience: Theoretical and Methodological Issues*, Timonium MD: York Press, 229-273.
Flege, James E., 1998: "Second-Language Learning: The Role of Subject and Phonetic Variables" in *Proceedings of the ESCA-StiLL 98*, Marholmen, Sweden, 1-8.

Flege, James E. & Wieke Eefting, 1987: "Production and perception of English stops by native Spanish speakers", *Journal of Phonetics* 15, 67-83.

Glicksman, Laura B. & Kenneth N. Stevens, 1988: "Some parameters affecting the perception of voicing for fricatives", *Journal of the Acoustical Society of America* 84 (S1), 58-59 (A).

Gordon-Salant, Sandra, 1986: "Recognition of natural and time/intensity altered CVs by young and elderly subjects with normal hearing", *Journal of the Acoustical Society of America* 80 (6), 1599-1607.

Grynpas, Jeremy, Rachel Baker & Valerie L. Hazan, 2011: "Clear Speech strategies and speech perception in adverse listening conditions" in *Proceedings of the 17th International Congress of Phonetic Sciences*, 779-782.

Gurlekian, Jorge A., 1979: "On the recognition of the Spanish Fricatives /s/ and /f/", *Journal of the Acoustical Society of America* 66 (S1), S88 (A).
Gurlekian, Jorge A., 1981: "Recognition of the Spanish Fricatives /s/ and /f/", *Journal of the Acoustical Society of America* 70 (1), 1624-27.

Han-Yong, You, 1979: A*n Acoustic and Perceptual Study of English Fricatives*, unpublished MSc dissertation, Canada: University of Edmonton.

Hazan, Valerie L. & Bay Shi, 1992: "Listener variability of synthetic and natural speech", *Speech, Hearing and Language: work in progress, U.C.L.*, vol. 6, 75-88.

Hazan, Valerie L. & Georges Boulakia, 1993: "Perception and production of a voicing contrast by French-English bilinguals", *Language and Speech* 36, 17-38.

Hazan, Valerie L. & Adrian P. Simpson, 1996a: "Cue-enhancement strategies for natural VCV and sentence materials presented in noise", *Speech, Hearing and Language: Work in Progress, UCL*, vol. 9, 43-55.
Hazan, Valerie L. & Adrian P. Simpson, 1996b: "Enhancing information-rich regions of natural VCV and sentence materials presented in noise" in *Proceedings of International Conference of Speech and Language Processing*, Philadelphia, vol. 1, 161-164.
Hazan, Valerie L. & Adrian P. Simpson, 1997: "Enhancing in the intelligibility of natural VCV stimuli:

speaker effects", *Speech, Hearing and Language: work in progress, U.C.L.*, vol. 10, 79-91.
Hazan, Valerie L. & Adrian P. Simpson, 1998a: "The effect of cue-enhancement on consonant perception by non-native listeners: preliminary results" in *Proceedings of Speech Technology in Language Learning (StiLL) Workshop*, Stockholm, 119-22.
Hazan, Valerie L. & Adrian P. Simpson, 1998b: "The effect of cue-enhancement on the intelligibility on nonsense word and sentence materials presented in noise", *Speech Communication*, 24/3, 211-226.
Hazan, Valerie L. & Adrian P. Simpson, 2000: "The effect of cue-enhancement on consonant intelligibility in noise: Speaker and listener effects", *Language & Speech*, 43, 273-294.

Jamieson, Donald G., 1995: "Techniques for training difficult non-native contrasts" in *Proceedings of 13th International Congress of Phonetic Sciences*, vol. 4, 100-107.

Jamieson, Donald G. & David E. Morosan, 1986: "Training non-native contrasts in adults: Acquisition of the English /d/-/t/ contrast by francophones", *Perception and Psychophysics* 40, 205-215.

Jassem, Wiktor, 1987: *The Phonology of Modern English*, Warszawa: Pantwowe Wydawwnictwo Naoukowe.

Jongman, Allard 1989: "Duration of frication noise required for identification of English fricatives", *Journal of the Acoustical Society of America* 85, 1718-25.

Lasky, Robert E., Ann Syrdal-Lasky & Robert E. Klein, 1975: "VOT discrimination by four to six and a half month old infants from Spanish environments", *Journal of Experimental Child Psychology* 20, 215-225.

Kuhl, Patricia K. & Paul Iverson, 1995: "Linguistic Experience and the "Perceptual Magnet Effect" in Winifred STRANGE (ed.): *Speech Perception and Linguistic Experience: Theoretical and Methodological Issues*, Timonium MD: York Press, 121-153.

Mackain, Kristine N., Catherine T. Best & Winifred Strange, 1981: "Categorical perception of English /r/ and /l/ by Japanese bilinguals", *Applied Psycholinguistics* 2, 360-390.

Markham, Duncan & Valerie L. Hazan, 2004: "The effect of talker- and listener-related factors on intelligibility for a real-world, open-set perception test", *Journal of Speech, Language and Hearing Research* 47 (4), 725-37.

Mayo, Lynn H., Mary Florentine & Søren Buus, 1997: "Age of Second-Language Acquisition and Perception of Speech in Noise", *Journal of Speech, Language and Hearing Research* 40, 686-693.

Miller, George A. & Patricia E. Nicely, 1955: "Analysis of perceptual confusions among some English consonants", *Journal of the Acoustical Society of America*, vol. 27, 338-353.

Mott, Brian, 1996 [1991]: *A course in Phonetics and Phonology for Spanish Learners of English*, second edition, Barcelona: EUB.

Nash, Rose, 1977: *Comparing English and Spanish: Patterns in Phonology and Orthography*, New York: Regents Publishing Company.

Navarro Tomas, Tomás, 1999 [1918]: *Manual de pronunciación española*, 27th edition, Madrid: Consejo Superior de Investigaciones Científicas.

Ortega-Llebaria, Marta & Valerie Hazan, 1999: "Enhancing acoustic cues to aid L2 speech perception" in *Proceedings of 14th International Congress of Phonetics Sciences*, San Francisco, vol. 1, 117-120.

Ortega-Llebaria, Marta, Valerie Hazan & Mack Huckvale, 2000: "Automatic cue-enhancement of natural speech for improved intelligibility", *Speech, Hearing and Language: Work in Progress*, London: UCL, 12, 43-56.

Pisoni, David B., Scott E. Lively, & John S. Logan, 1994: "Perceptual Learning of Nonnative Speech Contrasts: Implications for Theories of Speech Perception" in Judith C. Goodman & Howard C. Nusbaum, (eds.): *The development of speech perception: the transition from speech sounds to spoken words*, Cambridge Mass: MIT Press, chapter 5.

Quilis, Antonio & Joseph A. Férnandez, 1973: *Curso de fonética y fonología españolas*, Madrid: Consejo Superior de Investigaciones Científicas.

Revoile, Sally G., Lisa Holden-Pitt, James M. Pickett & Fred Brandt, 1986: "Speech cue enhancement for the hearing impaired: I. Altered vowel durations for perception of final fricative voicing", *Journal of Speech, Language and Hearing Research* 29, 240-255.

Roach, Peter, 2009 [1983]: *English Phonetics and Phonology*, fourth edition, Cambridge: C.U.P.

Skowronski, Mark D. & John G. Harris, 2005: "Applied principles of clear and Lombard speech for automated intelligibility enhancement in noisy environments", *Speech Communication* 48, 549-558.

Smiljanic, Rajka & Ann Bradlow, 2007: "Clear speech intelligibility: Listener and speaker effects" in *Proceedings of 16th International Congress of Phonetics Sciences*, Saarbrücken, vol. 2, 661-664.

Stockwell, Robert P. & J. Donald Bowen, 1965: *The Sounds of English and Spanish*, Chicago: The University of Chicago Press.

Strange, Winifred, 1995: "Phonetics of Second-Language Acquisition: Past, Present, Future" in *Proceedings of 13th International Congress of Phonetic Sciences*, Stockholm, vol. 4, 76-83.

Strange, Winifred & James J. Jenkins, 1978: "The role of linguistic experience in the perception of speech" in Richard D. Walk & Herbert L. Pick (eds.): *Perception and Experience*, New York: Plenum Press, 125-169.

Wang, Marilyn D. & Robert C. Bilger, 1973: "Consonant confusions in noise: a study of perceptual features", *Journal of the Acoustical Society of America*, vol. 54, 248-1266.

Werker, Janet F., & John S. Logan, 1985: "Cross-language evidence for three factors in speech perception", *Perception and Psychophysics* 37, 35-44.

Williams, Lee, 1977: "The perception of stop consonant voicing by Spanish-English bilinguals", *Perception and Psychophysics* 21 (4), 289-297.

Underbakke, Melva, Linda Polka, Terry L. Gottfried & Winifred Strange, 1988: "Trading relations in the perception of /r/-/l/ by Japanese learners of English", *Journal of the Acoustical Society of America*, vol. 84, 90-100.

Yamada, Reiko A. & Yoh'ichi Tohkura, 1992: "The effects of experimental variables on the perception of American English /r/-/l/ by Japanese listeners", *Perception and Psychophysics* 52, 376-379.

6. Appendix

The Sue/zoo/shoe Test

You will hear one word at a time, please, underline the word you identify from each pair. Please, do NOT leave any blank answer. GUESS when you are not sure. Thank you!

BLOCK 1

1. same	shame	20. Sue	zoo
2. so	show	21. sap	zap
3. said	zed	22. so	show
4. sin	shin	23. so	show
5. Sue	shoe	24. sip	zip
6. said	zed	25. said	shed
7. same	shame	26. seal	zeal
8. seal	zeal	27. sing	zing
9. sap	zap	28. sink	zinc
10. seen	sheen	29. seen	sheen
11. sink	zinc	30. seen	sheen
12. sin	shin	31. sip	ship
13. sin	shin	32. said	zed
14. said	shed	33. seen	sheen
15. same	shame	34. sip	zip
16. seal	zeal	35. sing	zing
17. same	shame	36. sink	zinc
18. sap	zap	37. Sue	shoe
19. sap	zap	38. sip	zip

39. sing	zing
40. sip	ship
41. seal	zeal
42. sink	zinc
43. said	zed
44. sing	zing
45. sin	shin
46. sip	zip
47. so	show
48. Sue	zoo
49. Sue	zoo
50. Sue	zoo

BLOCK 2

1. same	shame
2. Sue	shoe
3. sin	shin
4. sink	zinc
5. sing	zing
6. seen	sheen
7. sing	zing
8. Sue	zoo
9. same	shame
10. so	show
11. sink	zinc
12. sin	shin
13. sap	zap
14. said	shed
15. Sue	zoo
16. sin	shin
17. said	zed
18. sap	zap
19. said	shed
20. seen	sheen
21. same	shame
22. said	zed
23. seal	zeal
24. sing	zing
25. sip	ship
26. so	show
27. seen	sheen
28. Sue	zoo
29. sap	zap
30. same	shame
31. seal	zeal
32. sing	zing
33. sip	zip
34. seen	sheen
35. so	show
36. sap	zap
37. said	zed
38. seal	zeal
39. Sue	shoe
40. sip	zip
41. sip	zip
42. sip	zip
43. so	show
44. Sue	zoo
45. sink	zinc
46. seal	zeal
47. said	zed
48. sip	ship
49. sin	shin
50. sink	zinc

BLOCK 3

1. sap	zap
2. same	shame
3. so	show
4. said	shed
5. seal	zeal
6. seal	zeal
7. sip	zip
8. said	zed
9. sin	shin
10. seal	zeal
11. seen	sheen
12. sink	zinc
13. sing	zing
14. sing	zing
15. same	shame
16. same	shame
17. sin	shin
18. sap	zap
19. sin	shin
20. sap	zap
21. so	show
22. sin	shin
23. Sue	shoe
24. sap	zap
25. said	zed
26. seen	sheen
27. sip	zip
28. seen	sheen
29. same	shame
30. seen	sheen
31. seal	zeal
32. sing	zing
33. Sue	zoo
34. sink	zinc
35. sip	zip
36. sink	zinc
37. said	shed
38. Sue	zoo
39. sip	ship
40. so	show
41. sip	ship
42. sip	zip
43. Sue	shoe
44. Sue	zoo
45. sing	zing
46. Sue	zoo
47. said	zed
48. sink	zinc
49. so	show
50. said	zed

BLOCK 4

1. same	shame
2. seen	sheen
3. seen	sheen
4. sink	zinc
5. sing	zing
6. said	zed
7. sin	shin
8. seal	zeal
9. sin	hin
10. said	shed
11. said	shed
12. seen	sheen
13. Sue	zoo
14. sink	zinc
15. seen	sheen
16. sing	zing
17. same	shame
18. Sue	zoo
19. sap	zap
20. seal	zeal
21. same	shame
22. said	zed
23. sap	zap
24. so	show
25. sap	zap
26. sip	zip
27. sip	zip
28. same	shame
29. sink	zinc
30. sin	shin
31. so	show
32. sip	zip
33. sink	zinc
34. said	zed
35. Sue	zoo
36. sip	zip
37. seal	zeal
38. seal	zeal
39. so	show
40. Sue	zoo
41. so	show
42. sing	zing
43. sin	shin
44. said	zed
45. sip	ship
46. Sue	shoe
47. Sue	shoe
48. sip	ship
49. sing	zing
50. sap	zap