PART II:

STUDIES ON CONSONANTS
1. Introduction

The notion of perceived similarity between nonnative sounds and corresponding native phonological categories is widely recognized as an important element for any account of L2 speech perception. In psycholinguistic models such as Flege’s Speech Learning Model (SLM) and Best’s Perceptual Assimilation Model (PAM) (Flege 1987, Flege 1995, Guion, Flege, Akahane-Yamada and Pruitt 2000, Best 1995, Best, McRoberts and Sithole 1988, Best, McRoberts and Goodell 2001, Best and Tyler 2007; see also Munro and Bohn 2007), L2 perceptual processing is conceived of as a process of mapping L2 sounds onto L1 speech categories. The ease or difficulty of a nonnative contrast depends on the perceived similarity to the corresponding sounds of the native phonology. For example, within the PAM (Best 1995), different types of perceptual assimilation are specified, based on the probability of a nonnative speech contrast being assimilated to a native phonological contrast. If an L2 contrast is assimilated to an L1 contrast, it is predicted that discrimination will be excellent (“Two Category”: TC); on the other hand, if two contrasting L2 sounds are perceived as belonging to a single L1 phonological category, it is predicted that discrimination will be poor (“Single Category”: SC). A further case is represented by those L2 contrasts whose members tend to be assimilated to a single L1 phonological category, but one fits better while the other is perceived as a bad exemplar of that category (“Category Goodness”: CG). In such cases, it is predicted that discrimination will be quite good, but not as good as in the case of TC. This basically means that (a) formal instruction will be of great help, and (b) other – even speech-external – factors will play a role in
determining the possibility of a learner succeeding in the discrimination task.

Concerning this, the models based on perceived similarity fail to give a satisfactory account of the most critical aspects of perceptual mapping. First of all, as others have suggested, phonological relations need to be viewed as a more nuanced domain than is often assumed in the speech perception literature (Hume and Johnson 2003). It is difficult to determine what such categories as “a varying goodness of fit” and “a good to very good discrimination” actually mean. One possibility for getting rid of this ambiguity, which involves both the phonetic and the psychological levels of analysis, could be to have an L1-oriented look at the problem of L2 correspondences. This might sound paradoxical, yet there are good grounds for attempting to do so.

Consider in particular the phenomenon of allophonic variation, a form of phonetic variation arising from historical as well as synchronic conditions and widely discernible throughout the languages of the world. We unfortunately know little about the psychological status of allophones in speech processing. However, for allophonic variation we can appeal to an enormous amount of linguistic facts which are in themselves theoretically clear: they constitute a rich and highly specified body of linguistic data which may be exploited for experimental purposes. Could it not be the case that the perceptual discrimination of two L1 allophones has something to do with a more general perceptual process where two members of a speech pair are assimilated to a single phonological category, but one fits better than the other?

If we look at the cross-linguistic problem from such an L1-oriented perspective, we may have at least two advantages. First, we can reduce the problem of the “partially categorizable” speech contrasts to a problem of allophonic contrasts, which patently has taxonomic and heuristic advantages. Second, we will have a methodological improvement, since we will be clarifying some crucial aspects of L1 speech perception, before addressing similar and very controversial aspects of L2 speech perception. This second point would thus be in accordance with Morrison’s (2006) view that, unless one has a detailed model of native L1 speech perception, it is impossible to solve the problem of whether an experimental result in L2 speech perception is due to L1 transfer or to some general L2 learning mechanisms independent of the L1. In particular, following Morrison and colleagues, one should rigorously investigate the native perception of the speech contrast of interest, in terms of native categories, before attempting to understand the perception of the same speech contrast by nonnative listeners, in terms of L2 categories.
The study of L2 speech perception may thus benefit from research in L1 allophonic processing. This would allow us to take a closer look at what exactly happens when a hearer is confronted with two different-in-quality members of one and the same phonological category. As the specific purpose of the present study, I will address the question of whether experience with a neutralization rule in the L1 affects perception of a corresponding consonant contrast in an L2.

2. The perceptual status of L1 allophonic contrasts

Before addressing the question of the influence of L1 rules of allophonic variation on L2 speech perception, it is necessary to recall briefly the problem of the perceptual status of allophonic contrasts in the native language.

Since the mid-nineties, various experiments have shown that the perception of an allophonic contrast tends to be less accurate than the perception of a phonemic contrast (Pegg and Werker 1997, Whalen, Best and Irwin 1997, Peperkamp, Pettinato and Dupoux 2003, Shea and Curtin 2005, Boomershine, Hall, Hume and Johnson 2008). The “allophonic effect” proved true for some kinds of context-dependent allophony, i.e., for those allophones standing in complementary distribution. Some examples of this are the alternation between aspirated and unaspirated voiceless stops in English, and the alternation between voiced and voiceless uvular trills in pre-consonantal position in French. The acquisition of allophonic rules with complementary distribution of variants has also been investigated by means of statistical learning algorithms aimed at demonstrating the bottom-up nature of the process of phonological acquisition by infants (Peperkamp, Le Calvez, Nadal and Dupoux 2006, Le Calvez, Peperkamp and Dupoux 2007, Peperkamp 2003).

More recently, evidence of an allophonic effect was also found for allophones stemming from a neutralization rule and standing in free alternation in a specific context (with one variant generally being preferred over the other). This type of phonological relation is called “partial contrast” by Hume and Johnson (2003). While Hume and Johnson (2003) dealt with suprasegmentals, drawing on perception data on Mandarin tones, Celata (2007, 2008) dealt with a consonant contrast, similar to those involved in context-dependent allophony.

In particular, the research focused on the Western Tuscan postsonorant affrication process by which /s/ → [ts] when preceded by /n l r/, both word-internally and in sandhi condition (Standard Italian orso →
Western Tuscan [ɔrtso] “bear”, Standard Italian il sole → Western Tuscan [il 'tsole] “the sun”). This process is said to have natural articulatory and aerodynamic motivations and may be considered as one instance of the phenomenon of stop epenthesis/emergence within nasal-fricative clusters (Ohala 1997). The rule in Western Tuscan is in principle exceptionless, but since Standard Italian frequently alternates with Tuscan dialect in the speech of Tuscan speakers (also due to structural and superficial similarities between the two idioms), the [s]-variant may be realized as well, as a minority variant. From a phonetic point of view, there is complete neutralization between the allophonic [ts] in words like orso [ɔrtso] “bear” and the phonological /ts/ in words like varianza [va'ɾjantsa] “variance” (see Turchi and Gili Fivela 2004, regarding duration, rise time and energy contour). These points are summarized in Figure 4-1. The question mark on the left of [ansa] means that the non-affricated form, as specified above, is a minority variant.

<table>
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<th>Phonetic Form</th>
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<tr>
<td>ʔ[ansa]</td>
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<td>[antsa]</td>
<td>/antsa/</td>
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**Figure 4-1.** Phonetic outputs and phonological correspondences for the Western Tuscan post-sonorant affrication rule.

In Celata (2007, 2008), the existence of an allophonic effect for native speakers of a Tuscan dialect was borne out in two identification and discrimination tasks in which phonemic labeling and categorical perception (following Gerrits 2001) were involved, but not when a continuous mode of discrimination was called for. Three experiments were conducted, using different experimental paradigms: an AX discrimination experiment, an AXB discrimination experiment, and an identification experiment with gating paradigm (AX and AXB discrimination also differed for inter-stimulus interval, which was longer in ABX with respect to AX). Such a complex procedure was considered necessary in order to test the effective nature and strength of the presumed allophonic effect under different perceptual circumstances. Although the degree of phonetic

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1 As a matter of fact, the process of post-sonorant /s/ affrication is not restricted to some Tuscan dialects; on the contrary, it is widespread in the speech of many central and southern areas of Italy. The strength and modality of application may however vary cross-dialectally.
(dis)similarity between native and nonnative sounds is the main predictor of perceptual difficulty, it has been shown that a number of task variables actually affects the learners’ performance (see, for example, Beddor and Gottfried 1995, Gerrits and Schouten 2004, Mora 2005, 2007). Among them, task type, lexical status of the stimuli and ISI appear to determine to a large extent the success of the learners’ performance in categorical perception tasks. Exploring several design paradigms in testing the nature of allophonic perception proved very useful, since different results were found in the AX discrimination experiment (in which allophones appeared to be as easily discriminated as phonemes), with respect to the ABX discrimination and the gating identification experiment (in which an allophonic effect was consistently found). This result was interpreted as a consequence of the fact that different tasks involve different mechanisms of short-term memory. The allophonic effect surfaced only if some degree of categorical perception was required by the experimental task, i.e., when subjects could rely on pre-existing mental representations of sounds. By contrast, it failed to emerge in tasks which allowed listeners to compare the stimuli in the auditory sensory memory.

To sum up, the perception of allophones in neutralization processes appeared to be affected by an allophonic effect, similar to the effect found for allophones in complementary distribution. This finding is relevant, since allophones in a neutralization context are phonemes in other phonotactic contexts, and their perceptual discrimination is nevertheless less accurate than phonemic discrimination.

3. Experiment: The perception of nonnative post-sonorant [s]/[ts] contrast by Tuscan speakers

In this experiment, discrimination of [ns]/[nts] and [rs]/[rts] clusters was tested in Russian, a language of which the participants had no knowledge whatsoever. The hypothesis was that experience with the neutralization rule in their native language (whereby /s/ → [ts] when preceded by /n l r/) might influence the discrimination of similar consonant clusters when subjects were perceiving speech in a foreign language.

Fifty-two Tuscan and Northern Italian subjects were given a two-alternative forced-choice identification task (2AFC), mixed with a procedure of word recognition in noise (Lane 1963). The 2AFC paradigm was chosen because the explicit reference to phoneme categories in the instructions is assumed to promote a phoneme-labelling strategy, perception therefore tending to be categorical (Gerrits 2001:30). Moreover, the gating technique used in the previous experiment for native allophonic
perception (see Section 2) did not prove to be duplicable for nonnative perception. In fact, when stimuli are presented as isolated fragments, using either Italian or Russian should not produce different reactions in subjects’ performance. By contrast, word recognition in noise allowed us to provide subjects with full word (or nonword) stimuli; moreover, stimuli were encapsulated in full sentences (or nonsense sentences), which provided subjects with a specific linguistic background (either native or nonnative). Half of the stimuli were presented in quiet, half in noise. Various studies have shown that the effect of noise on the intelligibility of foreign-accented speech is somewhat greater than that on native-produced speech (Munro 1998, Cutler, Cooke, Garcia-Lecumberri and Pasveer 2007). It is assumed therefore that if an allophonic effect shapes the perceptual discrimination of nonnative sounds or sound sequences, this effect would be more salient in a case of degraded input.

3.1. Participants

Twenty-six Tuscan speakers (Livorno and Pisa varieties) and 26 Northern Italian speakers (Piemonte, Lombardia, Veneto, Friuli varieties) were recruited as subjects for the experiment from among students of Università di Pisa, and were paid for their participation. Since Northern Italian speech preserves the phonemic opposition between /s/ and /ts/ in both intervocalic and post-sonorant position, Northern Italian speakers were used as control group. Henceforth, TUS and NOR will be used to designate the two groups of subjects.

3.2 Materials

The experiment aimed at comparing the discrimination of native and nonnative sound pairs, with all other things being equal. As a wealth of previous research has shown, listeners make use of lexical knowledge in the phonological categorization of sounds (e.g., Samuel 2001, Norris, McQueen and Cutler 2003). Consequently, possible lexical biases were avoided by using nonword stimuli for native discrimination and by submitting the task to subjects inexperienced in Russian.

\[2\] Different levels of both energetic and informational masking may exhibit different effects on perceptual accuracy. However, masking conditions which cause most misperceptions for native listeners are also those which cause the additional nonnative disadvantage (see, for example, Garcia Lecumberri & Cooke 2006).
Six minimal pairs of disyllabic Italian pseudo-words were created and embedded in nonsense frame sentences. There were both experimental (e.g. /ansa/-/antsa/, /issa/-/ittsa/) and control items (e.g. /anta/-/anda/, /etta/-/etta/). Experimental items included the sibilant vs. affricate consonant contrast, in intervocalic and post-sonorant position; control items included the voiceless vs. voiced alveolar stop contrast, in intervocalic and post-sonorant position. Since /t/ and /d/ are phonemically distinct in all positions for each group of subjects, both post-sonorant (/nt/-/nd/, /rt/-/rd/) and intervocalic (/t:/, /d/) contrasts were phonemic for both TUS and NOR participants.

Six minimal pairs of Russian words, embedded in frame sentences, were also created, matching the Italian ones as far as vocalic context was concerned (e.g. experimental items romansa - livantsa, melissa - te liitsa; control items dva banta - ta banda, obed dam -banket tam). Examples of the frame reference are *rapo triparsa la tufi* for Italian and the corresponding *Ya tebe’ povtorja’ju tri barsa čětko* for Russian. The full list of words is reproduced in the Appendix.

The 12 Russian sentences were uttered by a native Russian female speaker while the 12 Italian sentences were uttered by a native Italian female speaker, recorded in a sound-attenuated room and digitized at 22kHz using an Edirol 4-Channel Portable Recorder and Wave Editor 4-R.

Total duration, duration of the consonant cluster and mean intensity were measured for every sentence. Afterwards, intensity was scaled in order to have uniform values across the sentences (70dB intensity, 0.063Pa RMS amplitude). A silence phase was added at the beginning and the end of every sentence in order to produce an overall duration of 4 sec for the sentence stimuli. These were the sentence stimuli in quiet. In addition, an equal number of sentence stimuli in noise was also prepared, as follows. A segment of babble noise with corresponding duration and intensity values was extracted from the Signal Processing Information Base (SPIB: http://spib.rice.edu/) (4 sec, 70dB, 0.063Pa). The sentence stimuli and the babble noise fragment were then combined additively to form a stereo file which was finally converted into a mono file. The SNR in the overlapped region was a rather adverse one (0 dB).

### 3.3 Procedure

The perception test employed a two-alternative forced choice identification task (2AFC), mixed with a procedure of word recognition in noise and elicitation of confidence judgments (see Kabak and Maniwa 2007 for a similar procedure). Subjects were first exposed to the Italian
sentences, then to the Russian ones. The procedure was the same in both cases.

Subjects looked at a computer screen where two written alternatives (e.g., ANSA and ANZA) appeared, written in capitals in the centre of the screen. Immediately after visual presentation of the stimuli, a sentence stimulus containing one of the two (non)word stimuli was presented on headphones (e.g., rapo tripansa la tufl). Subjects had to decide which stimulus was contained in the sentence they heard, and press the corresponding button on the keyboard. After that, the numbers from 1 to 9 appeared on the computer screen, and subjects had to press the key corresponding to the estimated confidence level of their response: 1 for totally uncertain responses, 9 for totally confident responses, 2 to 8 for intermediate confidence levels. Half of the stimuli were presented in quiet, half in noise (random order). There were no time limits for response. Two completely balanced lists were created.

Subjects performed an initial identification task as a training phase (four sentence stimuli, containing two /pː/-/bː/ contrasting nonwords), in order to familiarize themselves with the experimental procedure.

3.4 Analysis

The number of errors and the mean confidence judgments were analysed. In the error rate analysis, the dependent variable \textsc{error} (correct vs. incorrect response) was crossed with the three-level variable \textsc{consonant} (nC vs. rC vs. VC) in order to test the significance of the main effect. The other relevant variables were \textsc{noise} (noise vs. quiet condition), \textsc{group} (NOR vs. TUS), \textsc{condition} (experimental vs. control), \textsc{language} (native vs. nonnative), \textsc{list} (list 1 vs. list 2).

Crosstabulations, Pearson’s \( \chi^2 \) (asymptotic 2-sided) and Fisher’s Exact test for cells with expected count less than 5 (1-sided and 2-sided tests) were run.

The confidence judgments were initially treated as interval variables but they did not pass Levene’s test for the homogeneity of variance across groups. Therefore an ordinal level of measurement was chosen and the non-parametric Kruskal-Wallis one-way analysis of variance by ranks was run. The significance of the factors \textsc{context} (intervocalic vs. post-sonorant) and \textsc{consonant} (nC vs. rC vs. VC) was investigated with respect to the dependent variable \textsc{judgment}. 
4. Results

As a first step, the effect of noise was checked: that is, whether the masking condition had an impact on discrimination.

The NOISE factor was significantly correlated with the error rate, both in general ($\chi^2 (1) = 10.929, p < .01$; the percentages of correct and incorrect answers were 41.1 and 8.9 for the noise condition, and 44.3 and 5.7 for the quiet condition, calculated on the overall total) and for the Italian and Russian stimuli separately ($\chi^2 (1) = 8.201, p < .01$ and $\chi^2 (1) = 5.431, p < .05$, respectively). The NOISE factor was also significant in the analysis of the confidence judgments ($\chi^2 (1) = 135.140, p < .01$), with higher scores assigned to the stimuli in quiet than to those in noise condition (7.76 vs 6.16, respectively). Therefore, the prediction about the additional difficulty provided by noise in word recognition was fully supported.

Non-significant factors, on the whole data set, were LIST, GROUP and CONDITION, while LANGUAGE was significant, with the Russian stimuli producing, in general, more errors ($\chi^2 (1) = 16.081, p < .01$) and lower confidence scores ($\chi^2 (1) = 135.039, p < .01$) than the Italian stimuli.

The main effect was then investigated. As far as error rates are concerned (CONSONANT * ERROR), the control condition was analyzed first. No comparison proved significant within this subset of data, nor within the lower levels of analysis (noise vs. quiet condition; for noise, native vs. nonnative stimuli, and TUS vs. NOR speakers). The next step was the analysis of the main effect in the experimental condition.

Due to the noise effect found earlier, the only subset of stimuli in noise was analyzed. For NOR, no significant effect of the consonant contrast on the error rate was found. For TUS, on the contrary, the effect was strongly significant ($\chi^2 (2) = 10.438, p < .01$). The graphs in Figure 4-2 show (in percentages) that the error rate for the post-sonorant contexts is significantly higher than for the intervocalic context, as far as TUS subjects are concerned.
The allophonic effect was therefore found in the general performance of TUS, as compared with that of NOR. A further test was however necessary, in order to clarify whether it was the native or the nonnative language or both which caused the effect, and also to investigate whether, for the NOR, a similar effect might be found in at least one of the two cases (recall that the two levels of LANGUAGE are completely independent).

For the TUS group of subjects (see Figure 4-3), the allophonic effect was clearly borne out for discrimination of the nonnative stimuli ($\chi^2 (2) = 9.102, p < .05$), while it only approached significance for the native ones ($\chi^2 (2) = 5.275, p = .062$). On the other hand, no effect was found for NOR, either for the Italian or for the Russian stimuli.

As is evident from the graph on the right in Figure 4-3, however, the effect found in the /nC/ context has a different magnitude with respect to that found in the /rC/ context. In other words, some imbalance has to be taken into account between the post-nasal and the post-trill stimuli, where the allophonic effect is concerned. Orthogonal tests were therefore run in order to clarify this point.
For the native stimuli, both comparisons (nC vs. VC, and rC vs. VC) turned out to be significant ($\chi^2 (1) = 5.879, p < .05$ for the post-nasal context; $\chi^2 (1) = 5.532, p < .05$ for the post-trill context), thus suggesting that in this specific case the allophonic effect, even if weaker on the whole, is caused uniformly by the /nC/ and the /rC/ contexts. On the contrary, in the case of the nonnative stimuli, discrimination in the /rC/ context was not significantly worse than in the intervocalic context: the allophonic effect thus appears to be restricted to the /nC/ context ($\chi^2 (1) = 6.584, p < .05$).

One could conclude from this imbalance that the supposed allophonic effect is in fact a purely acoustic effect, whereby different post-sonorant contexts are discriminated differently because of the lower saliency of the target consonant with respect to the intervocalic contexts. However, this should not be the case. If an acoustic effect was involved, we should have found a similar result in the control condition (for the /t/-/d/ contrast), but it was not found. On the other hand, it is worth noting that the different saliency of the post-nasal vs. post-rhotic contexts appears precisely in the discrimination of nonnative stimuli, and not in the discrimination of the
Allophonic Variation Can Affect L2 Speech Perception

native ones. Therefore, even if the allophonic effect appears to influence the discrimination of both native and nonnative consonant contrasts (see Figure 4.2 right), in the perception of nonnative speech some phonetic factors must play a role as well, affecting the discrimination of different types of consonant contrasts in different ways.

As far as the confidence judgments are concerned (CONSONANT* JUDGMENT), no allophonic effect was found either for the TUS or for the NOR, when the two languages of the stimuli were considered together. When only the Italian stimuli were considered, however, the effect approached significance for the TUS group of subjects ($\chi^2 (2) = 5.837, p = .054$).

To sum up, a significant allophonic effect was found for the discrimination of both native and nonnative post-sonorant stimuli by Western Tuscan subjects. The effect was not always equally strong and appeared sometimes to be conditioned by the interplay of acoustic factors such as the type of the preconsonantal sonorant, but it was consistently present in the performance of Tuscan as opposed to non-Tuscan subjects (who did not show any additional difficulty in the perceptual discrimination of post-sonorant contexts).

5. Conclusions

Two points deserve a final comment, the first regarding the perception of allophones stemming from neutralization processes, the other regarding the influence of native allophonic processes on the discrimination of similar sound contrasts in a nonnative language.

As far as the first point is concerned, the presence of an allophonic effect was borne out for the perceptual processing of Tuscan speakers in an identification task with noise masking. In this respect, neutralizations appear to behave exactly like other allophonic processes, whose variants are in complementary distribution. This result may be supported at least when a categorical mode of perception is involved (see Section 2).

As to the second point, the allophonic effect appears to influence in some way the discrimination of similar nonnative consonant contrasts as well. However, as far as nonnative speech is concerned, some acoustic/phonetic factors seem to play a role, affecting the discrimination of different types of consonant contrasts in different ways. Further studies, possibly using different experimental techniques, should investigate whether this difference between native and nonnative perception is related to different strategies or modalities of speech processing. It could be the case that, in nonnative speech perception, a greater sensitivity to low-level
acoustic information is developed by the listener, in order to better capture salient cues for discrimination. It appears from the present study that allophonic rules of neutralization in the L1 have an impact on the discrimination of similar consonant sequences in an L2; however, the two perceptual conditions show a gap as far as some additional (possibly acoustic) factors are concerned, shaping overall performance in nonnative speech perception.

Acknowledgments

This research was supported by the Italian Government funding PRIN05/07 (UR Scuola Normale Superiore, Pisa). Technical assistance was kindly provided by C. Bertini and I. Ricci at the Laboratorio di Linguistica of Scuola Normale Superiore, Pisa. Useful comments and suggestions for the research project on perception of allophonic contrasts came, as early as in February 2005, from S. Peperkamp and I. Vendelin, and more recently from P.M. Bertinetto and G. Marotta. Thanks to P. Boersma, S. Hamann and K. Dziubalska-Kołaczyk for useful comments to the oral presentation given at New Sounds 2007.

References


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## Appendix

### Russian words

<table>
<thead>
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<th>Words</th>
<th>Phonetic transcription</th>
<th>Sentence duration (sec)</th>
<th>Cluster duration (msec)</th>
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<td>bankjet:am</td>
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### Italian pseudo-words

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