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# Testing the Effects of Segmental and Suprasegmental Phonetic Cues in Foreign Accent Rating: An Experiment Using Prosody Transplantation

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## Abstract

In this study the prosody transplantation (PT) method is used to compare the effects of segmental and prosodic information on the perception of foreign-accented English. The main hypothesis is that segmental information has the strongest effect in the perception of foreign accent (FA), followed by segmental duration and intonation. PT is used to manipulate a set of read sentences produced by Italian speakers of English L2 and native British English speakers in both possible directions: native prosody was transplanted on non-native segments and non-native prosody on native segments. Duration and  $f_0$  values were transplanted both as a bundle (full prosody transplant) and selectively.

The stimuli were presented to 21 British English native listeners in a perception experiment, where the subjects were asked to rate the degree of foreignness.

The results showed that segmental information has the strongest effect in FA perception. However, the two prosodic cues tested also played a role: duration and  $f_0$  changed significantly the perception of FA, not only when transplanted together, but also when transplanted selectively. However, the results showed

that duration has only a slightly stronger effect when compared to intonation. Further research is required to verify if this tendency means that segmental duration is a stronger cue when compared to intonation in the detection of Italian accent in English.

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The main phonetic cues for prosody, namely, duration, intensity and  $f_0$  certainly play important roles in foreign accent detection. However, it is very difficult to determine a hierarchy in their importance and to quantify their relative impact in foreign accent detection. In addition, only a few studies have tried to compare the effects of segmental versus suprasegmental information in the detection and rating of foreign-accented speech. The aim of this study is to tackle both these issues by answering the following research questions: (1) what is the relative importance of segmental and suprasegmental cues in the perception of foreign (Italian) accent in English? (2) What is the most important prosodic cue between duration and pitch?

This paper first gives a brief overview of the methods used and the results obtained in experimental studies comparing the effects of segmental and suprasegmental dimensions. Particular attention is given to the description of the prosody transplantation method and its main characteristics. It then presents an experimental study aimed at investigating the role of segmental and suprasegmental cues in the perception of foreign (Italian) accent in English. Finally, it concludes by suggesting directions for further research.

When testing the impact of prosody on the perception of foreign accent, the main problem lies in the fact that in natural speech the segmental and the suprasegmental dimension are deeply intertwined with one another. One way to deal with this problem is to separate the two streams of information by acoustically manipulating the speech signal. This is normally done by degrading or removing part of the segmental information while preserving the suprasegmental one or vice versa, in order to create stimuli used in perception tests where native listeners are asked to rate the foreignness of the speech samples they are presented with.

In order to study the relative importance of different prosodic cues, a variety of techniques have been applied. These techniques aim for the delexicalization of speech, that is, stripping speech from the meaning normally conveyed by the segmental information. Common content-masking techniques that have been used in experimental studies are the

application of low-pass filtering (e.g. van Els & de Bot, 1987; Munro, 1995; Jilka, 2000; Holm, 2007), and reverse speech and splicing (Munro et al., 2010). All these methods allow judging prosody by limiting the influence of segments. However delexicalized stimuli have the disadvantage of severely reducing the sensitiveness of listeners to foreign accent. Since fine-grained distinctions are obviously difficult to make when judging degraded speech, forced-choice tasks are usually preferred to rating tasks. Content-masked stimuli therefore result more suitable for language identification tasks (Ohala & Gilbert, 1981; Ramus et al., 1999), native/non-native status detection (Rognoni, 2012) or attitude judgments (Signorello et al., 2012).

There are also signal manipulation techniques that are aimed to remove the influence of intonation, such as pitch monotonization (Van Els & de Bot, 1987), where  $f_0$  is flattened to a fixed value, resulting in monotone speech samples where the rises and falls of melody are neutralized. In recent studies, monotonization has been combined with delexicalization techniques in order to define the impact of the single prosodic elements in foreign accent detection (Jilka, 2000; Rognoni, 2012), yielding inconsistent results. One reason for this inconsistency could be that the impact of the single prosodic aspects is defined only indirectly. Unlike what was done for intonation and segments, the relevance of temporal aspects is difficult to test on stimuli specifically designed to modify duration (see Drullman & Collier, 1991). As a result, in both Jilka (2000) and Rognoni (2012) the impact of temporal aspects was calculated by considering the difference between the scores obtained with delexicalized only stimuli as opposed to stimuli that were both delexicalized and monotonized.

It is important to mention that for both kinds of techniques, the degree of artificiality of the stimuli is very high, and experimental studies relying on such unnatural stimuli might not always reflect the impression that a listener could have when listening to the kind of speech naturally occurring in face-to-face conversation (Munro, 1995).

A possible solution to the problems involved in delexicalization and monotonization techniques is the adoption of a method allowing for the manipulation of prosodic cues while keeping the segmental dimension intact, such as prosody transplantation (PT). The principle of PT is that the prosodic aspects of a native speaker can be imposed on non-native segments, and *vice versa*. This makes it possible to maintain perfectly intelligible stimuli while selectively manipulating prosodic cues. The resulting stimuli can still present artefacts, but they are certainly more ecological than the delexicalized or monotonized ones, and they allow the

listeners to resort to their fine-grained sensitivity in rating foreign-accented speech.

PT has been applied in a variety of experimental studies published in recent years, and it has also been referred to as ‘prosody cloning’ (Yoon, 2007) or ‘prosodic transplantation’ (Gili Fivela, 2012). The method has been implemented in a variety of software tools and instruments, but its underlying mechanism is always the same, and it is based on speech resynthesis using the PSOLA algorithm. PT has been extensively described in the literature (Yoon, 2007; Pettorino & Vitale, 2012), but it will be useful to summarize here the basic steps involved in the method.

First of all, the method requires at least two sentences, one produced by a native speaker and one by a non-native speaker. The number of native and non-native segments must match perfectly; it is therefore advisable to use highly controlled speech samples, normally read speech (Yoon, 2007). After the collection and careful segmentation of the two sets, paying particular attention to the possible presence of silent pauses (Pettorino & Vitale, 2012), the transplantation of prosody can be applied using a signal manipulation software, such as Praat (Boersma & Weenink, 2013) or Tandem-Straight (Kawahara & Morise, 2011). Through the application of the PSOLA algorithm as implemented in the software, it is then possible to automatically superimpose the duration and  $f_0$  of one sentence (the ‘donor’) on the segments of the other (the “recipient”). The segments of the recipient sentence are first stretched or shrunk in order to match the duration of the donor sentence, and then the  $f_0$  contour of the donor sentence is superimposed on the recipient segments. Selective transplants are also possible: the process can be stopped after the first step (duration transplant) and the  $f_0$  contour can be adapted to the original duration of the recipient segments ( $f_0$  transplant). The main drawback of the PT method is that the transplants are uniformly applied segment by segment, leaving the subphonemic level untouched (Yoon, 2007). This could affect the stimuli leaving artefacts, resulting in a somewhat limited naturalness.

PT has been established and adopted as a method for foreign accent rating in several experimental studies published throughout the last decade, to test both the effects of segmental vs. suprasegmental information and to rank the importance of the prosodic cues involved in foreign accent perception. One of the first notable applications of the method is Jilka (2000), where the author presented stimuli with superposed prosody, testing the effect of full prosody transplant on foreign accent perception and the effect of segmental versus suprasegmental information. The results showed that PT has a significant

impact on the perceived foreign accent, and that segmental information plays a greater role than prosody when judging foreignness.

The works by Boula de Mareuil and colleagues on foreign-accented French, Spanish and Italian tested widely the possibilities of the method, fixing the label 'prosody transplantation' for future reference (Boula de Mareuil et al., 2004a, 2004b, 2006). In general, the results of their studies showed a greater effect of segmental information as compared to prosody. The only study reporting a stronger effect of prosody versus segmental information is Boula de Mareuil et al. (2004a). Here the authors transplanted Italian intonation on Spanish segments and *vice-versa*, finding that the suprasegmental information was more important than the segmental one in a language identification task. However, as in the case of the Anderson-Hsieh et al. (1992) (see below), the study is based on a somewhat idiosyncratic setup. The experiment reported was replicable only in the Italian-Spanish combination, where sentences can be produced with very similar chains of segments; also, while collecting the data, the speakers were explicitly asked to limit the segmental differences between the two languages, resulting in a not very ecological data collection. When changing the experimental procedure in a follow-up study based on the same speech material, the same author found that the effects of prosody were much more limited (Boula de Mareuil et al. 2006). The strong effect of segmental information was also reported for foreign-accented Dutch in another study based on PT by Quené & van Delft (2010), where the selective transplant of duration alone was not enough to overrule the influence of segments. Winters & O'Brien (2012) applied the PT method to intelligibility and accentedness rating tasks for English and German, finding a cumulative effect of PT: the more the tokens were manipulated, the more they become accented and less intelligible. As for Italian, PT has been recently used to study attitudinal meaning of intonation in foreign-accented Italian, namely credibility (De Meo et al., 2012) and was preferred to delexicalization techniques also in the categorization of English pitch contours (Gili Fivela, 2012).

It is interesting to point out that, besides the studies based on PT, few studies have focused on the direct comparison of the effects of segmental vs. suprasegmental information in foreign accent detection or rating. In this regard, a notable exception is the widely cited study by Anderson-Hsieh et al. (1992), where the authors claimed the supremacy of prosody in the perception of foreign accent. However, the scope of this claim needs to be reconsidered in light of the peculiar setup of the perception test: the

judges involved were only a few (namely 3) highly trained listeners (they were all language instructors) rating natural speech samples.

As for the relative importance of the prosodic factors, the extensive studies by Jilka (2000) and Holm (2007) have shown how the hierarchy of prosodic factors changes in function of the L1-L2 combination investigated. In order to study the degree of foreignness of Italian-accented English, it is therefore necessary to single out the best prosodic candidates. Based on previous studies, one of these candidates seems to be duration. On the one side, vowel duration has been proven to be one of the strongest phonetic cues in Italian-accented English, together with lack of vowel reduction (Busà, 1995; Flege et al., 1999); on the other side, the presence of the Italian geminate consonants, notably longer than their English counterparts, is another well-known cause of phonological transfer for Italian speakers of English L2 (Duguid, 1997). The second prosodic factor to be taken into consideration was pitch, based on Rognoni (2012)'s delexicalization and monotonization pilot study, showing that pitch might be an important perceptual cue in the detection of Italian accent in English.

This study was designed to investigate the relative importance of segmental and suprasegmental cues in the perception of foreign (Italian) accent in English, and to determine whether it is duration or pitch that is a more important prosodic cue in this perception. The experiment was set up to test the following two hypotheses:

H1: Segmental information is the strongest cue for foreign accent perception;

H2: Segmental duration is a stronger cue as compared to intonation.

## METHODOLOGY

### Data Set

**Speakers.** Two groups of four speakers each were recorded: a group of Italian speakers of English L2 and a group of English native speakers.

The Italian native speakers were all recruited from the Veneto region, in the North-East area of the country, and their average age was 22.5 years. Their level of proficiency in English was intermediate to upper intermediate (levels B1/B2 of the European Common Framework of Reference). In a previous study based on the same speakers, their English had been judged distinctly foreign-accented (Rognoni, 2012).

The English native speakers were exchange students at the University of Padua (Italy) coming all from the Southern counties of the United Kingdom, and they were all speakers of the Southern Standard British English (SSBE) variety. Their average age was 21.5 years.

**Speech Material.** The speakers of both groups were asked to read an English version of Aesop's fable "The Fox and the Crow", adapted by the first author of this paper. The speech samples were recorded using a Sony DAT system with a Shure SM58 microphone in a sound-treated room at a frequency rate of 48 kHz (16-bit). Then the following four sentences were selected from each speaker's productions, presenting a variety of intonation patterns and syntactic structures:

- A: Hi, Crow, how are you?
- B: Will you sing a song for me?
- C: Once upon a time there was a crow.
- D: The crow was very hungry.

The resulting set of selected speech samples consisted in a total of 32 sentences, 16 per group.

**Stimuli Preparation.** All sentences were manually segmented and annotated using Praat. This procedure is particularly important, as pointed out in Pettorino and Vitale (2012), because the perfect matching of the number and succession of annotated intervals and silent pauses between donor and recipient sentences is the fundamental requirement for a successful prosody transplantation (see Introduction). The same program was used to transplant prosody on the segments running the Praat script written by Yoon (2007). Native and non-native duration and  $f_0$  values were transplanted both together and selectively, resulting in 8 different conditions, summarized in Table 1.

**Table 1.** Summary of the eight experimental conditions generated with prosody transplantation

Condition	Duration	f0	Segments	Number of stimuli
1	native	native	native	16
2	non-native	non-native	native	16
3	non-native	native	native	16
4	native	non-native	native	16
5	non-native	native	non-native	16
6	native	non-native	non-native	16
7	native	native	non-native	16
8	non-native	non-native	non-native	16

The resulting set of stimuli consisted in a total of 128 tokens. It is worthwhile to note that conditions 1 and 8, where the native/non-native status of prosody and segments matched, were also treated with transplantation. In these cases the native and non-native prosody were transplanted on native and non-native segments respectively from another speaker from the same group, following the example found in Boula de Mareuil and Vieru-Dimulescu (2004) and Holm (2007). This was done in order to obtain stimuli that could be comparable to the manipulated stimuli, thus avoiding the risk of a natural bias towards untreated speech, reported in a similar experiment by the same Boula de Mareuil et al. (2004).

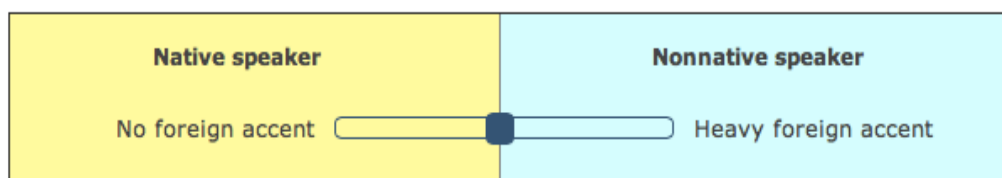
### The Perception Test

**Subjects.** 21 British English native speakers participated in the perception test. Their average age was 40 years, and their professional background was varied. None of them reported any hearing problems. At the moment of taking the test none of them claimed to know Italian nor was living or had lived in Italy.

**Experimental procedure.** The stimuli were presented to the listeners using the online survey platform LimeSurvey (Schmitz, 2012). Before starting the experiment, the subjects were asked to fill in a consent form and to complete a brief questionnaire to collect information regarding their geographical origin, age, profession and language background. Then the listeners were presented explicit instructions on-screen about the



experimental setup and procedure. First they were asked to use a headphone or headset and to take the test in a silent room and in a single session. The listeners were then asked to listen to the stimuli at their own pace, and to rate them using the full length of a slider scale, where they could rate at the same time the degree of foreign accent in a continuum from “no foreign accent” to “very heavy foreign accent” and the native vs. non-native status of the speakers (Fig. 1).



**Figure 1.** Sliding scale used in the perception test to rate foreign accent.

The scores in the sliding scale ranged from 0 to 100, but they were not visible to the listeners, who were asked to move the handle of the slider from the default central position (i.e., 50) towards one of the two extremes of the scale as a function of the perceived severity of foreign accent. This solution was preferred to a Likert scale following the example of Jilka (2000), who also presented his perception experiments with the aid of an online platform.

All 128 stimuli were played to each listener in a single block in randomized order. The running time of the experiment was approximately 20 minutes.

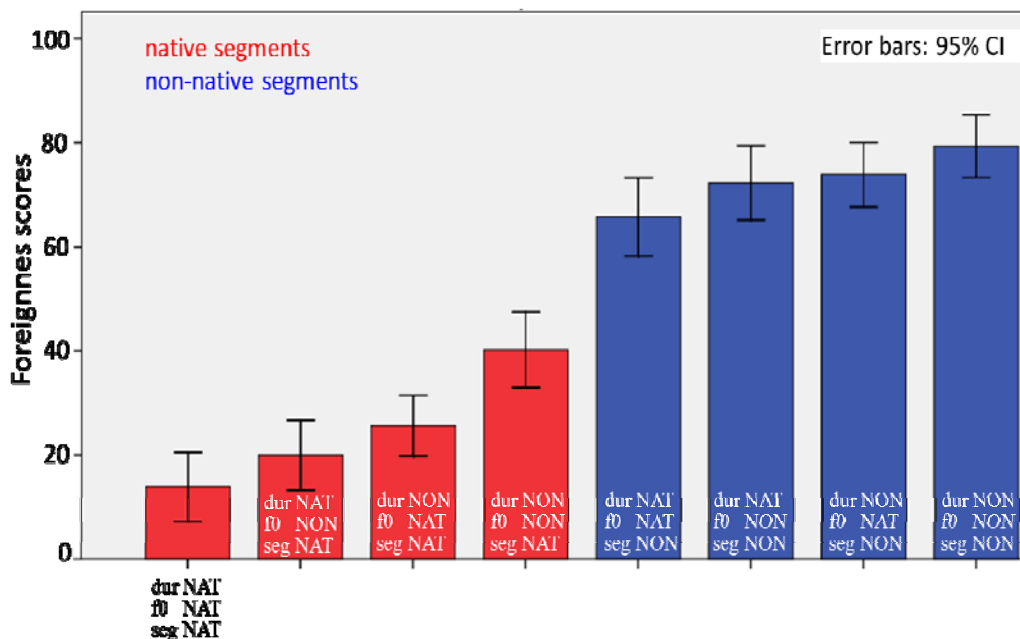
## RESULTS

The foreignness scores were analysed by a repeated measure Analysis of Variance (RM-ANOVA) with condition (8 levels) as within-subjects factor while aggregating over speakers and over sentences. The RM-ANOVA shows a significant effect for condition on foreignness scores ( $F(1,20)=203,62$ ,  $p<0,01$ ). Pairwise comparisons (with Bonferroni adjustment) between the eight different conditions showed significant differences in all cases except the ones between transplanted duration and transplanted pitch, both on native and non-native segments.

These results mean that both full prosodic transplant (duration and pitch) and selective transplants (duration or pitch) had a significant impact on the foreignness scores. Respectively, they decreased the degree of perceived foreign accent in the case of native prosody transplantation

and increased foreignness in the case of non-native prosody transplantation. However, the non-significant difference between the scores of the two selective transplants limits the informative power of the statistical analysis.

The results of the statistical analysis are visually summarized in Fig. 2. As the figure shows, the greatest difference in foreignness scores is between native and non-native segments. The hierarchy of the effects of duration and pitch is the same for native and non-native segments, although the overlap of the error bars shows that the differences between the selective transplants are not statistically different.



**Figure 2.** Bar chart showing foreignness scores (0-100) by condition, where 0 corresponds to “no foreign accent” and 100 to “heavy foreign accent”

## DISCUSSION

The results of the perception test show that segments have the greatest effect in foreign accent rating, confirming the first hypothesis tested in this study, that is, that segments provide the strongest cue for accent perception. The second hypothesis, that segmental duration is a stronger cue in accent rating as compared to pitch, was not confirmed by the experimental data: the results showed a tendency for segmental duration to be a stronger cue, but the difference between the scores obtained with selective transplants of duration and pitch was not statistically significant. This was probably due to the intrinsic limits of the PT method, through

which duration can only be manipulated by stretching or shrinking the borders of the segments, without touching the subphonemic level and the spectral structure of the phones (see Introduction). Duration differences between Italian and English are intertwined with the phenomenon of vowel reduction (see Busà, 1995), which works at both the temporal and spectral levels. The lack of modification in the formant structure of vowels has probably reduced the listeners' sensitivity to vowel duration as a major phonetic cue to foreignness. However, it should be observed that this tendency was noted in both directions of the transplant (native on non-native, non-native on native), suggesting a more important role of duration as compared to pitch.

## CONCLUSION

This study was aimed to compare the effects of segmental and suprasegmental phonetic cues in the perception of Italian accent in English using the PT method. The results showed that segmental information has a stronger effect as compared to prosodic information, in accordance with the results of similar studies performed on a variety of language combinations (see Introduction). The present data also replicate the cumulative effect of prosody transplantation found by Winters & O'Brien (2012): the more native cues are transplanted on non-native speech, the more accented it gets, and *vice versa*. Finally, the results of the present experiments show that prosodic cues are relevant to the perception and rating of foreign accent, even though no clear hierarchy was found between the effects of segmental duration and pitch.

A follow-up study is in progress, where the same experimental paradigm will be applied to the same language combination (English and Italian) but in the opposite direction, that is, dealing with English speakers of Italian L2 compared to Italian native speakers. The subjects of the perception experiment will be Italian native listeners. It is expected that, while the greater effect of segmental information compared to prosody will be confirmed, the prosodic cues will not necessarily present the same hierarchic pattern. This would reflect a difference in the relative importance of prosodic cues based not only on the L1-L2 combination, but also on the L1-L2 direction. This would be in accordance with the results reported by Holm (2007) in a cross-linguistic study of foreign-accented Norwegian, where the language background of the listeners was shown to be crucial in determining the impact of the different prosodic factors.

Another possible future line of research could involve the testing of prosody-transplanted speech in L2 learning. Indeed, the robustness of prosody transplantation as a method to manipulate and study the perception of foreign accent in English L2 has potential for implementation in EFL instruction. Yoon (2007) proposes that a PT module could be used in self-study activities by providing learners with automatic online feedback. Learners would record their voice and compare their actual productions with a correct version where native prosody would be transplanted on the learners' own segmental productions. The perspective is certainly fascinating, but it should be considered with caution: hearing one's own acoustically modified voice could result more estranging than helpful. More studies in this regard are needed to found evidence on the suitability of the method as a teaching/learning tool.

To conclude, the PT paradigm proved to be a suitable methodological tool to test the main experimental question, although further research is needed to determine the relative importance of duration and pitch in foreign accent perception and rating.

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