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# Cross-Linguistic Effects on Voice Quality: A Study on Brazilians' Production of Portuguese and English

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## Abstract

This article aims to present the results from a pilot study designed to compare voice quality in Brazilians speaking Portuguese and English. Esling (2000) claims that each language has its own pattern of physiological behavior in which articulators are trained to operate in different ways based on the language's phonetic constituent. The study compared L1 and L2 speech production, analyzing intra-speaker variation in phonation types using acoustic measures. Three proficient Brazilian speakers of English were recorded performing a reading task in Portuguese and English, with three repetitions, in a soundproofed room. Also, a native English speaker was recorded in both English and Portuguese. The acoustic analysis was based on LTAS measures, f0, H1-H2 and noise-to-harmonics ratio (HNR). Preliminary results show different LTAS values, greater inclination of the spectral slope for L2 than the L1, and higher f0 in L2 than in L1.

When we speak a foreign language (L2), we almost certainly sound different from how we sound in our native language (L1). The aspects of our speech that produce this effect may depend on the angle we look at

the phenomenon. Analyzing such differences through voice quality may reveal how speakers manage to adjust their voices to produce L2 utterances. The aspects of our speech that produce this effect manifest the linguistic and paralinguistic uses of our voice, through which our psychosocial characteristics are also revealed. The quality of our voice is also determined by the physiological composition of our vocal tract, since the shape and position of the articulators such as the lips, tongue and jaw influence the production of speech sounds. Thus, the intention of this study is to compare voice quality when Brazilians speak their native language, Brazilian Portuguese (BP), and English as L2 in order to verify what really changes in our voice when we speak another language.

Research on the acquisition of English phonetic and phonological aspects by Brazilian learners has developed greatly in the last two decades. However, it has mainly focused on describing how learners cope with different and similar sounds, usually based on Flege's Speech Learning Model (1987, 1995, 2003) and Eckman's Markedness Differential Hypothesis and Structural Conformity Hypothesis (1977,1991 respectively). In Brazil, research has presented some answers with respect to L2 sounds learning and teaching processes in both production and perception (Baptista & Silva Filho 1997; Baptista 2000; Koerich 2002, 2006; Kluge 2004; Rauber 2006; Nobre-Oliveira 2007; Silveira 2004, Becker 2007; Ferreira, 2007). Suprasegmentals have been left aside, except for some studies on lexical stress (Brawerman, 2006; Braweman-Albini, 2012). The effect of such negligence can also be seen in the scarce teaching materials that bring activities about suprasegmentals, with mostly deductive and rule-based exercises. Jones & Evans (1995, p. 244) claim that it is very hard to find materials that "*attempt to link rhythmic patterns to discourse, degree of formality, or the emotional state of the speaker*". Because little attention has been given to prosodic features of L2 acquisition, including the use of different voice qualities, little is known about how people change and what differs when they speak a foreign language.

Concerning research about voice quality in Brazil, the focus has been mainly on quality alterations in clinical cases (Camargo, 1996, 2002, 2004; Camargo i.e., 2003, 2012; Lima 2008, 2012; Oliveira 2011; Pessoa et al. 2012).

Thus, the present study compared L1 and L2 speech production in relation to intra-speaker voice qualities, more specifically concerning phonation types, with the aid of acoustic instrumental analysis in order to better understand what changes when we speak different languages.

## VOICE QUALITY: DEFINITION AND MEASUREMENT

Voice quality was once described by Laver (1980, p.1) as "*the characteristic auditory coloring of an individual speaker's voice*". Abercrombie (1967, p. 91) defines it as "*those characteristics which are present more or less all the time that a person is talking: it is a quasi-permanent quality running through all the sound that issues from his mouth*". Such features or coloring, besides characterizing the person's voice, also convey meaning as to the physical, psychological and social state of the individual. Although we as listeners somehow perceive all these elements that voices reveal, our judgment is not always accurate; still, we can tell by their voices whether a person is a man or a woman, if they are tired or angry, ill or excited. Kreiman & Sidtis (2011, p. 7) state that "*voice quality is by definition a perceptual response to an acoustic signal*", also claiming that the interaction between the listener and the signal will depend on the acoustic information and the perceptual goal to be achieved. Moreover, voice quality has been studied by different disciplines—such as linguistics, medicine, biology, speech sciences, physics, and others. This interdisciplinary characteristic makes it difficult to establish a single definition.

Besides being hard to define, voice quality is also hard to measure, given its perceptual nature: "*It is the psychological impression created by a physical stimulus, and thus depends on both the listener and the voice*" (Kreiman et al. 2005, p. 345). Because this psychological impression is difficult to measure, research in the field has focused on developing lists of labels to describe voices through the presence or absence of specific qualities. Many of these lists have been created to address the problem of the lack of a standardized model for voice quality description, but most of them present more or less the same qualities. Another problem presented by these lists is that they are redundant and ambiguous most of the time, causing researchers to group sets of qualities in factors, which consist of a small set of semantic differential scales. The factor analysis is considered more economical and more effective than lists of terms, because factors are independent of one another and capture much of the information in the scalar ratings. However, this method of analysis may not be fully adequate since it depends on the input scales and the stimuli, limiting the extent to which results can be generalized. Indeed, what has been seen as an alternative to the lists of terms and the factor analysis is the multidimensional scaling (MDS), which allows listeners to assess similarities in voice stimuli directly, and produces an n-dimensional perceptual space for the similarities, as explained by Kreiman et al. (2005).

There are, however, limitations in the use of the MDS, since it does not account for part of the invariance presented by the stimuli. This usually happens because of the small number of stimuli used in studies.

As a reaction to these limitations, the Vocal Profile Analysis Protocol (VPAS), developed by Laver et al. (1991), Laver (2000) and Mackenzie-Beck (2005), proposed a model for the analysis of voice qualities that included their phonetic and physiological configuration. Such protocol is based on a phonetically-grounded description of voice quality in which the 'setting'[1] acts as the analytic unit. The perceptual judgment of voice quality is done based on variations from a group of settings used as reference called the "neutral setting". The VPAS is considered a sensitive measure of vocal quality as its parameters give information about the contribution of the whole vocal apparatus (Mackenzie Beck, 2005a), and not only about phonation types. The model has been criticized though in respect to its complexity and poor reliability, since the perceptual assessment is based on the underlying physiological configuration of what might be done by the speaker. However, Mackenzie-Beck (2005a) notes that degree of training is an indispensable factor for building confidence and, consequently, increasing reliability.

Kreiman et al. (2004, p. C166) claim that the "*development of instrumental protocols for measuring quality ultimately depends on our ability to define quality in a way that accounts for cognitive factors that introduce measurement variability*". They argue that no model can account precisely for the physiological and acoustic features of vocal quality through the relationship between instrumental analysis and perceptual differences. For this reason, appropriate acoustic measures should be used to complement the interpretation of the perceptual judgments of voice quality settings. Kent & Ball (2000) state that instrumental methods, despite being quantitative and objective, are not the only ones at work: the perceptual judgment is necessary for the identification of voice quality settings.

One of the most relevant acoustic measures used in studies about voice quality is the Long Term Average Spectrum (LTAS), which is a derivate spectrum from several spectra during a fairly long period of time (generally 30 seconds or more). Differences in the averages of spectra profiles in the same speech sample presumably reflect long term settings,

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[1] A setting can be defined as a "long-term muscular tendency", related to the phonatory (modes of vibration), supralaryngeal (articulatory) and tension (laryngeal and vocal tract) dimensions (Camargo & Madureira, 2008).

and it is expected that they capture the essential differences in voice quality (Keller, 2004). However, according to the same author, the LTAS approach has limitations and should be used together with other measures which capture characteristics related to pitch and phonation types. The fundamental frequency (f0) refers to the rate of vocal fold vibration, and its measure is directly related to the perceived pitch of a voice. According to Keating & Kuo (2012) f0 range is an arbitrary aspect of speech and is determined by the language's phonetic characteristics. Phonation types can be assessed through measures which relate to periodicity in vocal fold vibration. Ladefoged and Gordon (2001) displayed the phonation types on a glottal constriction continuum, as in Figure 1:

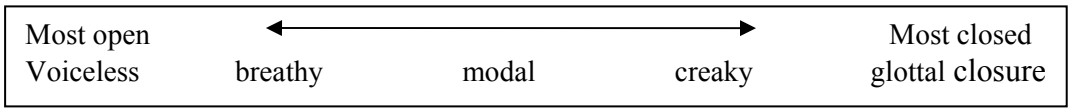


**Figure 1.** Glottal constriction continuum from Gordon & Ladefoged (2001).

Modal phonation refers to regular, periodic vocal fold vibration. To the left, vocal folds gradually open during phonation, allowing air to pass through, resulting in breathy voice. When vocal folds are completely open, no vibration is produced (voiceless sounds). To the right, vocal folds gradually close, while vibrating at low frequencies, producing creaky voice.[2] Certain acoustic measures are used to assess vocal fold activity, helping to estimate glottal aperture. To analyze breathy voice, the acoustic measures used are Harmonics to Noise Ratio (HNR) and H1-H2. HNR is the proportion between vocal fold vibration and noise in phonation. Higher HNR values should indicate a more harmonic, less breathy voice. H1-H2 represents the difference between the first (f0) and second harmonics (2 times f0); if the difference is negative, it indicates creaky voice; if it is positive, it indicates breathy voice; if it is close to zero, it indicates modal phonation.

In the present study, all four measures—LTAS, f0, H1-H2 and HNR—were used to analyze phonation types produced in BP and English in order to verify whether participants presented any differences when switching to this foreign language.

[2] There are other phonation types—falsetto, harsh voice—which will not be presented or discussed in this article.

## CROSSLINGUISTIC ASPECTS OF VOICE QUALITY

Esling (2000) claims that each language has its own pattern of physiological behavior in which articulators are trained to operate in different ways based on the language's phonetic constituent. According to Honikman (1964, apud Esling 2000), articulatory postures and patterns are activated differently in relation to the sounds of languages, and for that reason such activation should be different from language to language. There is a switch in voice quality settings when we speak other languages, mainly because of an articulatory relaxation, which is defined by settings related to places of articulation from most vowel and consonant sounds. This implies that a shorter distance between the central axis of articulations in different languages defines how easily one will achieve the L2's articulation. Harmegnies & Landercy (1986, apud Esling, 2000) state that when a bilingual produces a phonetically balanced utterance in one language, the switch to the other language introduces a systematic alteration in LTAS. Also, Bruyninckx et al. (1991), Harmegnies et al. (1991) e Bruyninckx et al. (1994) studied bilinguals (Spanish-Catalan) in relation to voice quality using LTAS measures. Their participants had fairly equal knowledge in both languages, but showed a degree of dominance in one of them. Results showed a clear division between the two languages, set by the systematic change in long-term characteristics, with L2 showing greater consistency than L1.

## METHODOLOGY

The present article shows the results of a pilot study, designed to evaluate methodological procedures for larger doctorate research. The participants were three female Brazilians, proficient speakers of English, aged 45 to 47, professors at a federal university in Curitiba, Parana, Brazil. They all learned English as a foreign language (in Brazil) and have vast English teaching experience (form 25 to 30 years). The other participant, included in the research for speculative reasons, was a female American aged 26, proficient speaker of Portuguese, originally from Louisville, Kentucky. All four participants were recorded in a sound proof cabin, reading a version of the fable "The Ant and the Grasshopper" and "A Cigarra e a Formiga". Each text was recorded three times by each participant.

For the LTAS measures, a sample of speech of around 30 seconds[3] from the beginning of each audio file was analyzed. For the f0, H1-H2 and HNR, the key segments for the analysis were stressed open vowels (as in *can**ta**va* in BP and **bo**ther, in English).

## RESULTS AND DISCUSSION

From the LTAS measures, some differences were found between BP and English speech production. The figures show the sound pressure energy (dB) in the y-axis and frequency (Hz) in the x-axis. The highest peaks of energy are located in lower frequencies (especially in f0), though there might be others in higher frequencies, e.g., 2000 to 3000 Hz, range in which fricatives are produced. Figures 2, 3 and 4 refer to Brazilian Speakers 1, 2 and 3 (BS) and figure 5 reports results for the American Speaker (AS).

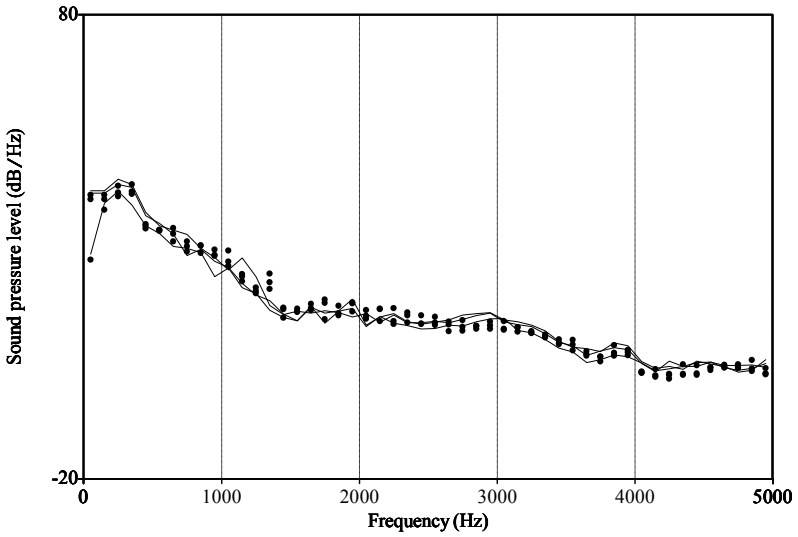


**Figure 2.** BS1—PB (lines), English (speckles).

[3] "*Em um campo, num dia de verão, uma cigarra saltitava e cantava alegremente com todo seu coração Uma formiga passou levando consigo uma espiga de milho com grande esforço, e ia em direção ao ninho*" in Portuguese, and "In a Field, one summer's Day, a Grasshopper was hopping about, chirping and singing to its heart's content. An ant passed by, bearing along with great toil, an ear of corn it was taking to the nest" in English.

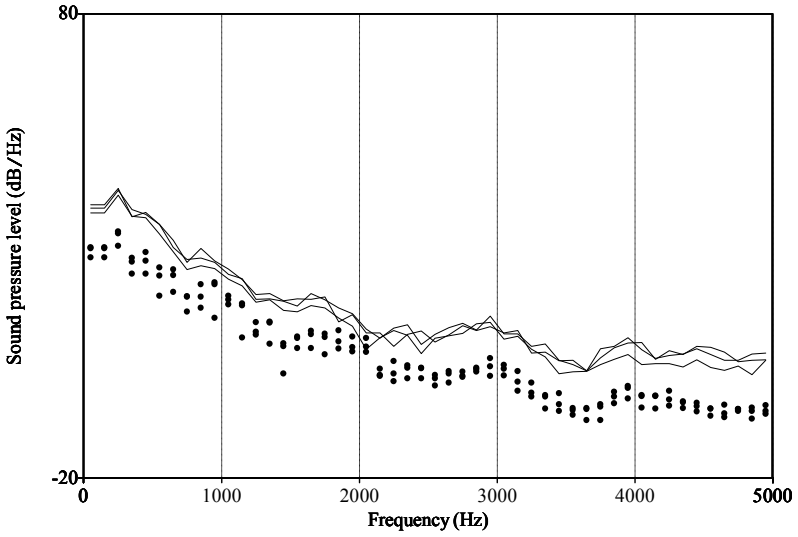


**Figure 3.** BS2—PB (lines), English (speckles).

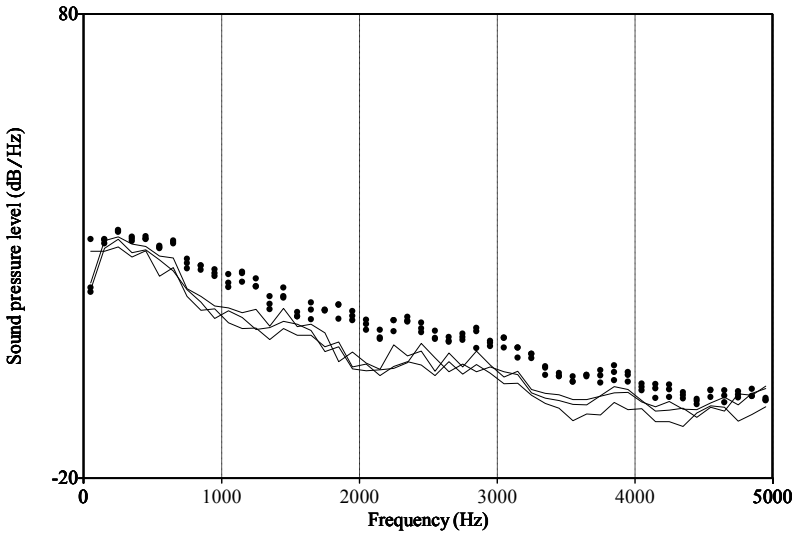


**Figure 4.** BS3—PB (lines), English (speckles).

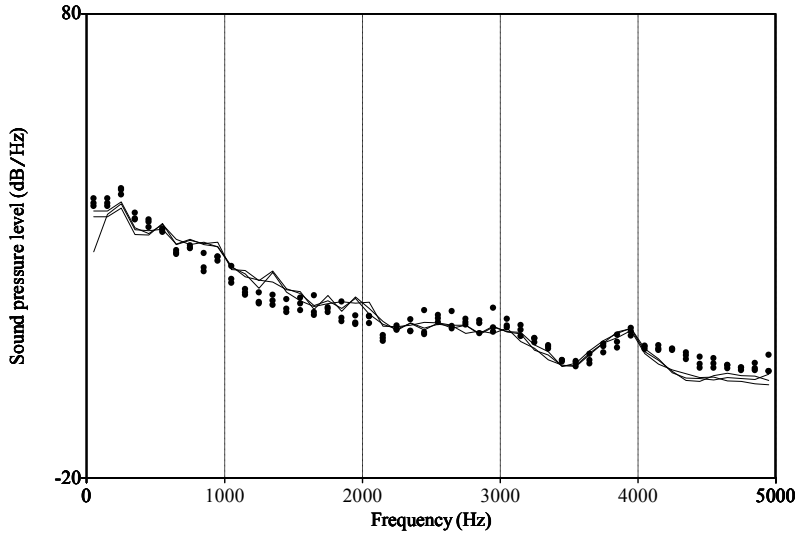


**Figure 5.** AS—English (lines), PB (speckles).

For both BS1 and AS1, LTAS measures indicate similar patterns of energy in the production of the texts spoken BP and English. However, AS produces English with a higher concentration of energy between 1000 and 2000 Hz, where some vowel formants are usually placed. According to Laver (1980) the flatter the slope, with less peaks of energy, the more non-harmonic and full of noise the signal is, which seems to be the case of BS1 and AS. BS2 and BS3 show more significant differences in the concentration of energy in BP and English, but in opposite directions. They both produce more harmonic speech since there are more prominent peaks in all frequencies.

In relation to f0 values, means were extracted from the aforementioned open vowels of each language's three repetitions, as shown in Table 1:

**Table 1.** Mean and SD Values for f0

| Speaker | F0 (Hz) | SD |
|---|---|---|
| BS1 Portuguese | 210 | 20,1 |
| BS1 English | 222 | 5,3 |
| BS2 Portuguese | 233 | 1,2 |
| BS2 English | 252 | 3,4 |
| BS3 Portuguese | 217 | 3,7 |
| BS3 English | 227 | 9,1 |
| AS English | 188 | 4,3 |
| AS Portuguese | 195 | 0,7 |

All participants produced lower f0 values in their native languages in relation to their foreign language. The standard deviation values show that there was little variation in f0 ranges, except for BS1 in Portuguese. Keating & Kuo (2010, p.4) claim that differences in f0 values and f0 range can be physiologically motivated by the speech community people have lived in, but also that "*individual language learners can learn that certain pitch settings are appropriate for one language as opposed to another*". However, f0 mean values shown here suggest a native/foreign language motivation for the differences rather than a language specific one.

H1-H2 values show the degree of harmonicity of the signal, indicating the phonation type the speaker produces, which usually range from breathy, then modal, and finally up to creaky voices. H1-H2 values which are higher than 0, indicate breathy voice; around 0, modal voice; and lower than 0, creaky voice. Measures were pitch-corrected for women f0 ranges (150 to 300 Hz) and are therefore represented by H1*-H2*:

**Table 2.** Mean and SD Values for H*1-H2*

| Speaker | H1*-H2* (dB) | SD |
|---|---|---|
| BS1 Portuguese | 10,8 | 3,6 |
| BS1 English | 5 | 2,4 |
| BS2 Portuguese | 7,9 | 0,5 |
| BS2 English | 4,9 | 2,1 |
| BS3 Portuguese | 5,2 | 1,6 |
| BS3 English | -2,2 | 2,6 |
| AS English | 2,2 | 0,8 |
| AS Portuguese | 7,6 | 0,6 |

H1*-H2* means show that all speakers produce Portuguese utterances with a more open glottis, allowing more air through, thus resulting in a breathier voice. In English utterances, H1*-H2* values are closer to 0, indicating a tendency toward modal voice, except from BS3, who produced negative values, which suggest the use of creaky voice.

HNR corresponds to the proportion of harmonics in relation to noise (inharmonic energy) in the acoustic signal. Breathy voice is characterized by lower HNR values, while modal voice is expected to present higher HNR values. HNR mean values are shown in Table 3:

**Table 3.** Mean and SD Values for HNR

| Speaker | HNR (dB) | SD |
|---|---|---|
| **BS1 Portuguese** | 19,3 | 0,5 |
| **BS1 English** | 14,3 | 1,5 |
| **BS2 Portuguese** | 19,5 | 1,6 |
| **BS2 English** | 21,7 | 3,6 |
| **BS3 Portuguese** | 18,2 | 1,6 |
| **BS3 English** | 16,9 | 2,9 |
| **AS English** | 21,9 | 2,8 |
| **AS Portuguese** | 15,7 | 5,1 |

Values in Table 3 suggest that BS1 and BS3 produced breathier voices in English if compared to their production in Portuguese. BS2 and AS presented lower HNR values in Portuguese, producing more harmonic phonation in English. Based on these data, there is no clear tendency concerning the use of a breathier voice in either language.

## FINAL REMARKS

Through the analysis of these four acoustic measures to describe phonation types in English and Portuguese languages by Brazilian speakers, some possible tendencies can be suggested concerning the use of different voice qualities in different languages. LTAS and HNR measures showed much variation and no generalizations could be drawn from the mean values. However, f0 and H1*-H2 presented values that could suggest a tendency; f0 was lower for speakers' native languages and H1*-H2* values were lower for Portuguese language in all speakers' utterances. The main objective of the present study was to confirm or refute methodological choices in terms of text type, task type, participants' profile (age, place of birth, age of English acquisition), and relevant measures to assess voice quality. Data presented in this article are clearly not enough to build any further conclusions, but certainly contribute to more accurate design in the main research.

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