Title: The Musical Notation of Speech: First Movement

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Abstract
This study argues that music notation is an efficient and insightful alternative to describe speech events as a dynamic and static system. In order to illustrate how musical notation works in the analysis of speech events, we ran an acoustic experiment. Two previous studies (Simões 2014, Simões and Meireles 2016) provided us with the groundwork for this illustrative experiment. In our experiment, we analysed stress patterns in terms of pitch notes (f0) and duration (quantity) in connected speech. Two female and two male speakers of Mexican Spanish and Brazilian Portuguese recorded two sonnets for this acoustic analysis. The results show that a) higher fundamental frequency predicts a greater probability of stress in the case of the Brazilian and Mexican males, but not the Brazilian and Mexican females; b) in predicting fundamental frequency from duration, fundamental frequency is significantly greater for 1/32 notes than for 1/8 notes. This experiment based on the used of musical notation confirms traditional acoustic research that speakers employ different acoustic cues to mark linguistic events. Musical notation, however, is able to go further in the analysis of speech by dealing with the dynamics of speech and predicting speech events relative to the preceding ones. Such a predictive system can contribute for instance to research based on Markov Chains Theory.

Keywords
prosody; musical notation; fundamental frequency (f0); duration; stress; strong syllable; Spanish; Portuguese

1.0 Introduction

This study presents the first results of our research program, which is based on the use of musical notation to analyze speech prosody. Before this study, our initial work was of an exploratory and organizational nature (Simões 2014, Simões and Meireles 2016). Our goal is to establish the grounds on which to develop multilingual research in speech prosody. The term **prosody** means everything that extends beyond vowels and consonants segments, namely intonation, word stress, sentence stress, speech rhythm, voice quality, duration and phonological processes such as linking speech stress, rhythm, intonation, sound quality, and phonological processes. This series of analyses are products of two previous publications (Simões 2014, Simões and Meireles 2016). The present analysis focuses on the interplay of two of the correlates of stress, duration and fundamental frequency, in Brazilian Portuguese and Mexican Spanish. Although we use musical notation to analyze speech, this is not a musical study. This is a study entirely focused on speech, more especifically on speech prosody.

We emphasize the importance of understanding our study in terms of the phonetic (physical) predictability of speech events occuring relative to another speech event. We do not attempt to predict stress in terms of phonological rules of stress assignment. We work on phonetic grounds, despite the interesting descriptions of stress prediction in phonological theory. As Simões (2014) points out, stress assigment in phonological theory requires opacity of different degrees depending on the language.

Although musical theory and musical notation is not new in the rendering of speech, and it is at the heart of all versions of metrical theory (e.g. the underlying descriptions of syllable weight as a sequence of stronger and weaker syllables is clearly based on the beats of a time signature), it has had sporadic or non-existent actual use in speech research. The work of Steele (1775) in the XVIII Century is probably the only systematic work that uses musical notation to transcribe speech. Vainiomäki (2012 162) suggests that the interest in musical notation and musical theory in the transcription of speech existed during the Renaissance and Baroque periods. Famous composers have sporadic examples of such transcriptions according to Vainiomäki (2012 162). The examples below are Beethoven's according to Vainiomäki (2012 163ff).

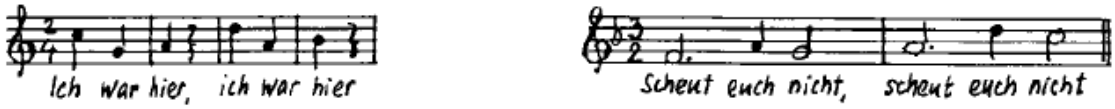

Figure 1. *Example of Beethoven's transcription of speech.*

The Czech composer Leoš Janáček has probably used musical notation to transcribe speech more than any other composer as an extension of his use of Speech Melodies (Vainiomäki 2012 144-162). The Czech poet Jan Neruda also used musical notation to transcribe speech (Vainiomäki (2012, page 163), as in the transcription of street-slang, in Prague, shown in Figure 2.

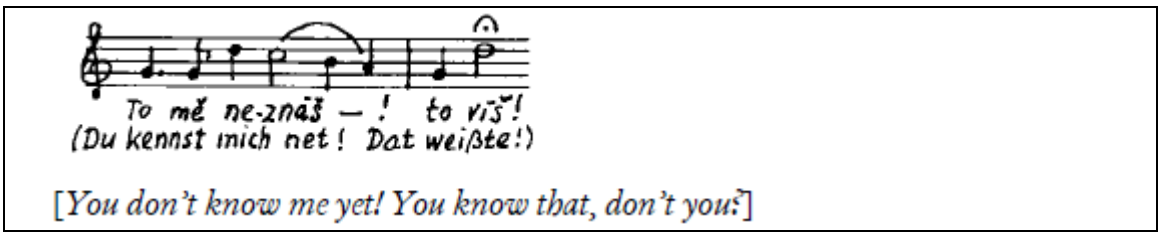

Figure 2. *Example of a 1874 street-slang transcription in Prague, as notated by Czech poet Jan Neruda (image reproduced from Vainiomäki (2012 163))*

Our research using musical notation has different goals and greater reach, compared to the predecessors of musical notation in speech mentioned above. Through musical notation we (…)

(…)

Table 2: *A sample of data entry made with the quantification of notes and rests in the musical notation of a female Mexican speaker. Abbreviations in each column: MF means Mexican female, the column Text shows the linguistic units of the sonnet as recorded by the subject, O means order of the elements of speech units, H1 through H8 means the note values in f0, D1-D8 the duration, ST1-ST8 is the binary strength of each syllable, and R1-R4 means the values of rests*.

MF	Text	O	H1	H2	H3	H4	H5	D1	D2	D3	D4	D5	ST1	ST2	ST3	ST4	ST5	R1	R2	R3
2	El soneto	1	208	208	208	220		16	32	16	16		0	0	1	0				
2	nocturno	2	196	196	156			16	16	4			0	1	0			4	8	16
2	La lu<__na	1	196	233	233	233		32	32	8	32		0	1	1	0				
2	era	2	220	220				16	32				1	0						
2	ese parpado	3	220	220	196	196	208	8	32	16	32	8	0	0	1	1	0			
2	cerrado	4	175	185	185	233	233	32	16	32	16	32	0	1	1	0	0	0		
2	que	1	208					32					0					32		
1	flotaba	2	185	196	196	220		16	32	32	16		0	1	1	0				
2	en el cir	3	185	185	196			16	32	16			0	0	1			32		
2	co	4	196					32					0							
2	de la nada	5	175	165	165	156		32	16	32	16		0	0	0	1		4	16	32

(…)

Table 4. *Logistic regression predicting stresses from f0 and duration*.
EST = estimate, SE = standard error.

Model Parameter Predicting Logit of Stresses	EST	SE	*p* <
f0 Slopes:			
Brazilian Female (BF)	−0.013	0.007	.072
Brazilian Male (BM)	0.031	0.013	.015
Spanish Female (SF)	−0.002	0.005	.743
Spanish Male (SM)	0.037	0.011	.001
f0 Slope Differences:			
BF vs BM	0.044	0.015	.003
BF vs SF	0.012	0.009	.176
BF vs SM	0.050	0.013	.000
BM vs SF	−0.032	0.013	.017
BM vs SM	0.006	0.017	.712
SF vs SM	0.038	0.012	.002
Duration Means:			
Note 1/4	0.533	0.465	.252
Note 1/8	0.980	0.320	.002
Note 1/16	0.556	0.233	.017
Note 1/32	0.391	0.230	.090
Duration Mean Differences:			
Note 1/4 vs 1/8	0.447	0.471	.343

Note 1/4 vs 1/16	0.023	0.436	.957
Note 1/4 vs 1/32	−0.142	0.435	.744
Note 1/8 vs 1/16	−0.424	0.250	.091
Note 1/8 vs 1/32	−0.589	0.252	.020
Note 1/16 vs 1/32	−0.165	0.157	.292

(…)

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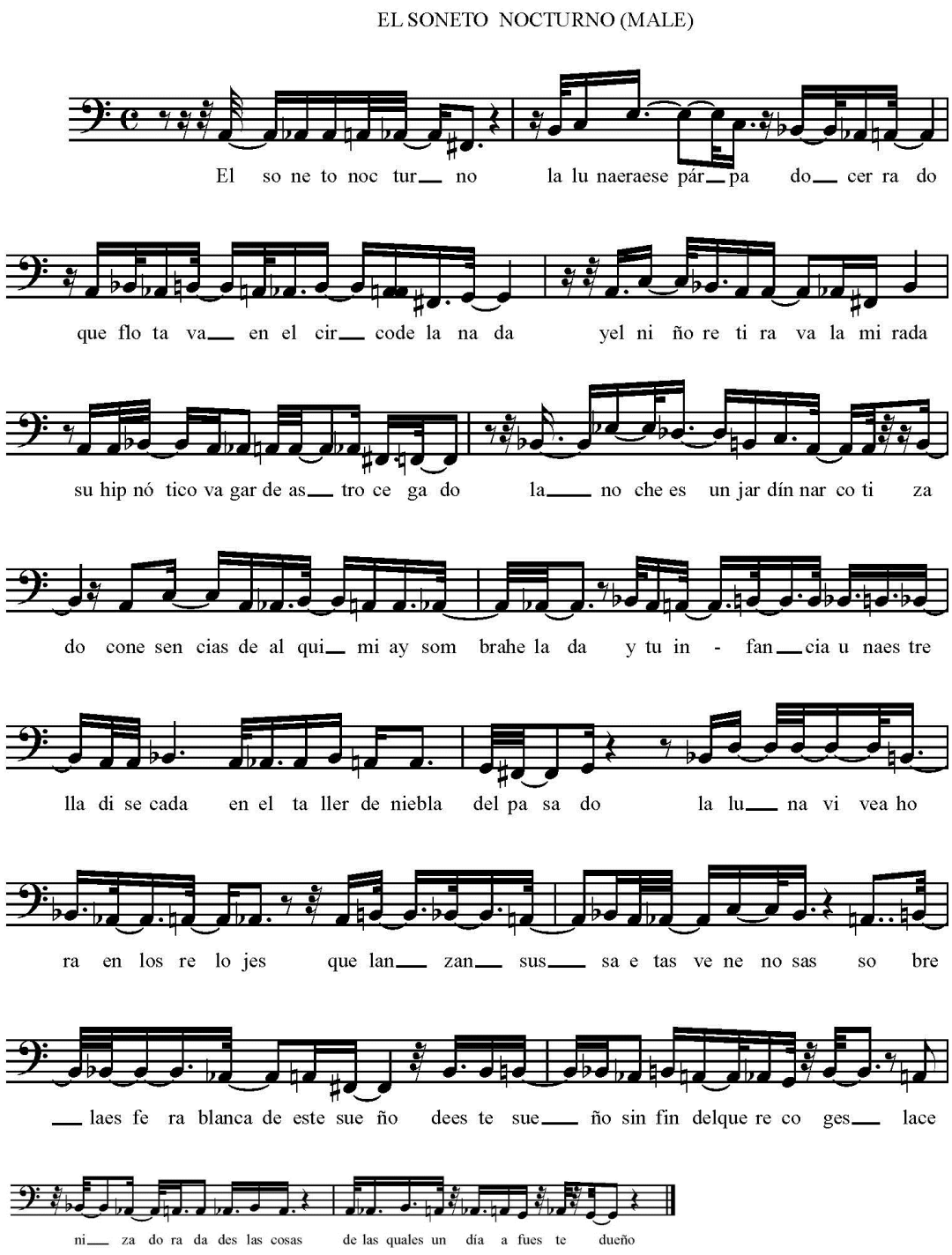
(…)

Appendix C: Musical notation of the male speaker of Mexican Spanish



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