Prosodic conditioning of pre-sonorant voicing

Conference or Workshop Item

PROSODIC CONDITIONING OF PRE-SONORANT VOICING

Zsuzsanna Bárkányi[1] and Štefan Beňuš[2]

[1]Eötvös Loránd University, Budapest & Hungarian Academy of Sciences, Research Institute for Linguistics
[2]Constantine the Philosopher University, Nitra & Institute of Informatics, Slovak Academy of Sciences
sbenus@ukf.sk, bzsu@nytud.hu

ABSTRACT

The present study investigates the influence of prosodic structure on pre-sonorant voicing in Slovak. Our results demonstrate that prosodic boundaries as well as accent interact in a meaningful way with voicing assimilation. If a major boundary intervenes, the role of accent is eliminated, while in other contexts the presence of contrastive focus induces less voicing. A novel finding of the study is that sonorant consonants and vowels differ considerably in this assimilation process. It is also demonstrated that pre-sonorant voicing in Slovak is categorical but optional and is close to being completely neutralizing.

Keywords: Slovak, pre-sonorant voicing, voicing assimilation, prosodic structure.

1. INTRODUCTION

1.1. Pre-sonorant voicing

Pre-sonorant voicing (PSV) is a type of regressive voicing assimilation (VA) whereby a word-final voiceless obstruent is assimilated in voicing to a following sonorant consonant or vowel in the next word. In the past years a debate has evolved around the phonetic or phonological nature of pre-sonorant voicing [1, 2]. Phonetically considered, sonorants may be suitable triggers of VA as they are phonetically voiced and rather resistant to devoicing. Yet, typologically, PSV is much less frequent than pre-obstruent voicing. In phonetically-based phonological models this is due to the passive phonation of sonorants as opposed to the active voicing of voiced obstruents [3].

There are interesting restrictions that seem to apply to PSV, which do not apply to “regular”, pre-obstruent VA. First, PSV typically occurs in languages with final devoicing. However, we do not find PSV in all languages with word-final devoicing. Second, PSV is also generally restricted to the word-final (or syllable-final) position.

Slovak displays both pre-obstruent and pre-sonorant voicing assimilation [4, 5]. In Slovak, obstruents are realized voiced if followed by a voiced obstruent; this process is operative within the word as well as across a word-boundary. An obstruent is also voiced if it is followed by a sonorant consonant or a vowel in the next word: e.g. *vták letí* [ftaːglɛciː] ‘bird is flying’, *vták istí* [ftaːgisciː] ‘bird secures’. This latter process also applies to clusters, but is not operative within the word. According to the literature sonorant consonants and vowels display the same voicing properties in Slovak.

As far as the trigger and target of PSV is concerned, significant variation is observed among languages [6, 7].

1.2. Research questions

A recent acoustic study [8] has shown that word-final coronal obstruents and coronal obstruent clusters are completely neutralized for voicing in Slovak within the same accentual and intonational phrase: they are voiced before any voiced segment and voiceless before voiceless ones and pause. There are no acoustic studies investigating the laryngeal properties of labial and velar obstruents in assimilatory contexts. Neither are there studies comparing the voice-triggering propensity of vowels and sonorant consonants in this language.

The interaction between VA and prosodic structure is also plausible; e.g. [9, 10]. First, the degree of disjuncture between two words (prosodic boundary strength) might affect both the tendency to devoice word-finally, and to assimilate across the words. Also, the presence of pitch prominence on a word might affect the degree of its faithfulness to the underlying representation and thus contribute to the resistance to voicing assimilation. Finally, gottalizations accompanying vowel-initial words have been shown to correlate with the strength of the prosodic boundary preceding such words and with the degree of prominence on these words [11]. In a combined EMA and acoustic study on Slovak it has been observed [12] that spontaneous prosodic boundaries induced by variation in speech rate and hyper-articulation tended to be realized as silences before *a* initial words, while *i* initial tokens more frequently co-occurred with glottalization. If this is so, we expect less PSV before *i* than before *a*. Therefore, the present study aims to contribute to our understanding of PSV with focus on the following issues:

- How does prosodic structure (the strength of prosodic boundary and the presence of pitch accent) influence PSV and voicing neutralization?
- Is PSV completely neutralizing in Slovak (a language for which experimental studies are lacking)?
- Do vowels and sonorant consonants trigger voicing in the same way?
- Do the vowels *a* and *i* influence voicing in the same way?

2. METHODOLOGY

2.1. Material

We report results from seven participants. Stimuli for the study were designed to assess the effect of prosody on VA for vowels and sonorants as triggers and plosives as targets. First, six target words were selected, each with the same vowel and a single plosive in the coda: *strop* [strop] 'ceiling', *škrob* [ʃkrob] 'starch', *pot* [pot] 'sweat', *bod* [bod] 'point', *šok* [ʃok] 'shock', *smog* [smog] 'smog' covering both underlyingly voiced and voiceless stops at three major places of articulation. The target words were followed by one of four given names (*Adam*, *Igor*, *Milan, Marek*) with the initial sound of the names serving as the trigger of assimilation {[a], [i], [m]}.

Prosody manipulation included the boundary between the trigger and the target of assimilation and the presence of pitch accent on the target word. Three types of boundaries were elicited with the goal of producing three levels of boundary strength. First, 'no boundary (nb)' was assumed to be the weakest boundary with minimal disjuncture between the target and trigger words. Syntactically, a subject of a prompt sentence formed a possessive construction so that the target word was modified by the trigger word, e.g. *pot Igora* 'sweat of Igor'. Second, 'medial boundary (mb)' was designed to occur in O(bject) S(ubject) V(erb) constructions with the target (O) and trigger (S) using identical marking of nominative and accusative in this paradigm and relatively free word order of Slovak, e.g. *pot Igor hodnotil* 'sweat-Acc Igor-Nom evaluated'. Finally, 'pause boundary (pb)' was designed to elicit the greatest disjuncture between the trigger and the target realized as silence, it corresponds to an I-boundary. The target word ended a clause while the trigger word initiated another clause. The accent on the target words was manipulated by contrastive focusing.

This design produced 108 stimuli (6 targets, 3 triggers, 3 boundaries, 2 accents), subjects produced 4 times for a total of 432 intended tokens per subject. The stimuli were presented in blocks with identical boundaries to prevent confusion and facilitate the consistent realization of the boundaries.

2.2. Measurements

Data were recorded using the SpeechRecorder interface [13] with a head-mounted condenser microphone in a quiet room and digitized at 44.1 kHz. The acoustic signal was then labelled in Praat [14] by 3 trained anotators following the agreed upon guidelines that included standard procedures for labeling the vowel before the target, the target‘s closure and release, optional period or silence or glottalization, and the trigger segments. The interval of voicing (if any) during the plosive closure phase was marked and used for calculating the major dependent variable of this study (i) Voicing Ratio as the percentage of voicing during the closure. We also measured (ii) the absolute length of the voiced interval, (iii) duration of the vowel preceding the target, (iv) duration of the target consonant and (v) vowel-to-consonant duration ratio.

Statistical analysis included one-way and two-way repeated measures ANOVA, paired t-tests and linear mixed-effects models in R [15].

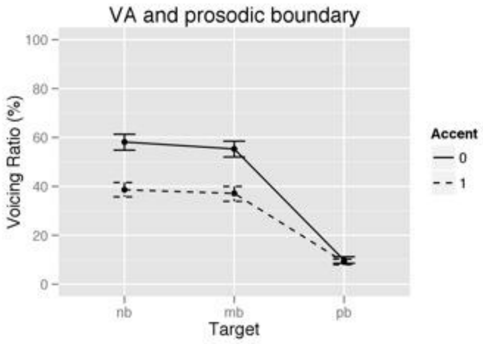
3. RESULTS AND DISCUSSION

A mixed-models test with our major factors (boundary, accent, target, trigger) and Subject and Repetition as random factors showed a significant effect of all the factors as well as the interactions boundary x trigger and boundary x accent (F values > 10). In the following we examine these effects in more detail.

3.1. Boundary and Accent

The effect of the two prosodic variables on voicing assimilation is illustrated in Fig. 1. In both the 'no boundary' (nb) and 'medial boundary' (mb) contexts, accented target words are less voiced by the following voiced segment than non-accented target words ('nb': $F(1,6) = 30.19$, $p = 0.0015$; 'mb': $F(1,6) = 18.31$, $p = 0.0052$). The Voicing Ratio of these two environments is not significantly different, though (accent context: $F(1,6) = 0.73$, $p = 0.43$; no accent: $F(1,6) = 1.04$, $p = 0.34$). Hence, the presence of the target and the trigger in the same or different syntactic phrases does not seem to make a difference in Slovak with regard to PSV as long as they belong to the same intonational phrase.

Figure 1: The Voicing Ratio of final stops for all subjects across three prosodic boundaries (nb, mb, pb) and two accent conditions (0- unaccented, 1 accented target word). Error bars: 95% CI.



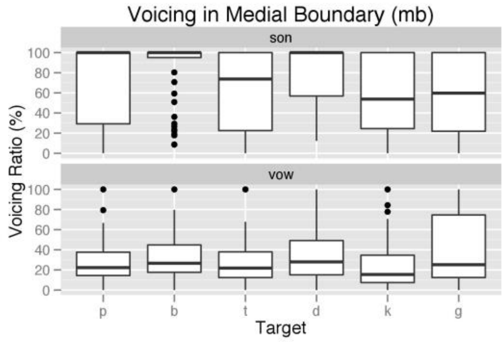
In the 'pause boundary' context, target obstruents undergo final-devoicing, which makes the voicing properties of target segments significantly different from 'nb' and 'mb' context (in paired t-tests always $p < .05$), as well as eliminates the influence of accent ($F(1,6) = 0.50$, $p = 0.5$). Note that in the latter context the silent phase between the target and the trigger is over 200 ms on average, while it is 20-30 ms in the other two contexts. The length of the pause/glottalization phase shows a strong correlation with Voicing Ratio (Pearson's $r = -0.646$ for all contexts across all subjects). This means that the longer the pause/glottalization, the shorter the voiced portion of the stop. Thus the lack of assimilation in a voicing context might serve as a prosodic marker enhancing the perception of major prosodic boundaries.

3.2. Vowel and Sonorant Triggers

As we have seen above, the 'pause boundary' context eliminates the difference between the 'accent' and 'no accent' environments due to final devoicing. Similarly, the strong devoicing effect of 'pb' wipes out any potential effect of the trigger type (vowel vs. sonorant) (no accent: $F(1,6) = 1.4$, $p = 0.28$; accent: $F(1,6) = 0.69$, $p = 0.43$).

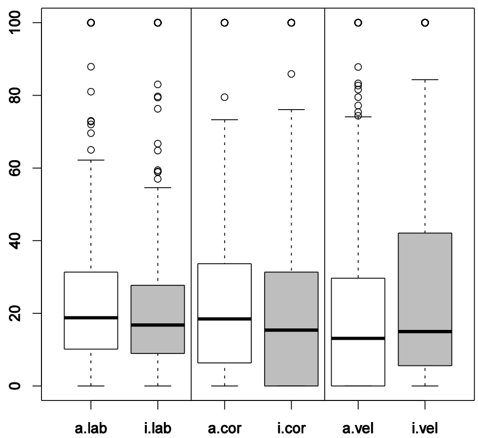
In the other contexts sonorants trigger significantly more voicing: $F(1,6) = 20.12$, $p = 0.004$, (see Fig.2.). This is a novel finding regarding PSV in Slovak since according to the literature both vowels and sonorant consonants are supposed to trigger VA across word-boundaries if no major silent period intervenes. Our results are very different: obstruents in pre-vowel context are only around 30% voiced on average, while they are around 80% voiced before sonorant consonants when the three places of articulation are pooled together. Separately, sonorant triggers induce voicing in labials slightly more than in coronals or velars probably due to homorganicity since our trigger sonorant was [m].

Figure 2: Voicing Ratio by targets and (son)orant vs. (vow)el triggers in rows in 'medial boundary' context.



The propensity of the two vowels to trigger voicing, however, does not differ in any of the examined prosodic contexts. The absence of this difference is also stable and robust for all subjects. There is marginal interaction with place of articulation in that *a* voices slightly more for labials and coronals but slightly less for velars (mixed models, e.g. coronals vs. velars: $F = 6.4$, $p = 0.0036$; estimated with MCMC sampling).

Figure 3: Voicing Ratio at three places of articulation triggered by /a/ vs. /i/.



In this study we have not analyzed in detail the intervals between target releases and trigger onsets. We note, however, that the length of this silent interval in 'nb' context is significantly different for the two vowels ($F(1,6) = 15.75$, $p = 0.007$) being longer for /a/ than for /i/. This difference, however, is not big enough to cause a significant difference in their voicing "aggressiveness". We can conclude that vowel height does not have bearings on VA in this dataset.

3.3. Voicing neutralization

Fig. 4 shows the effect of targets' underlying voicing specification on their Voicing ratio for vowel and sonorant triggers. It seems that underlyingly voiced obstruents are more voiced in PSV than their voiceless counterparts, especially before sonorant consonants. This difference, however, does not turn out to be significant in any prosodic condition for any place of articulation.

Figure 4: Voicing Ratio of voiced and voiceless stops before vowels and sonorants.

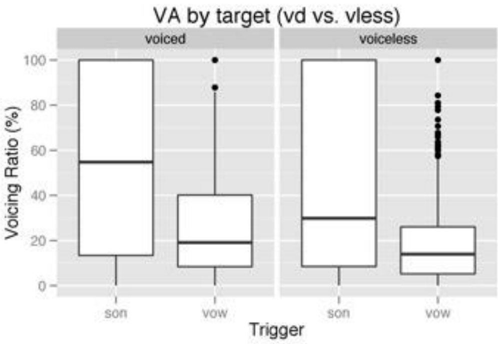
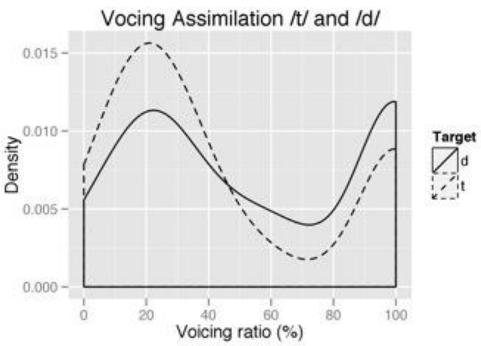


Fig. 4 also suggests that PSV in Slovak, especially before sonorants, is a gradient process with considerable variation in the amount of voicing. This is not the case. As Fig. 5 shows, Slovak PSV is clearly bimodal: it either applies or it does not. That is to say, the process is categorical but optional.

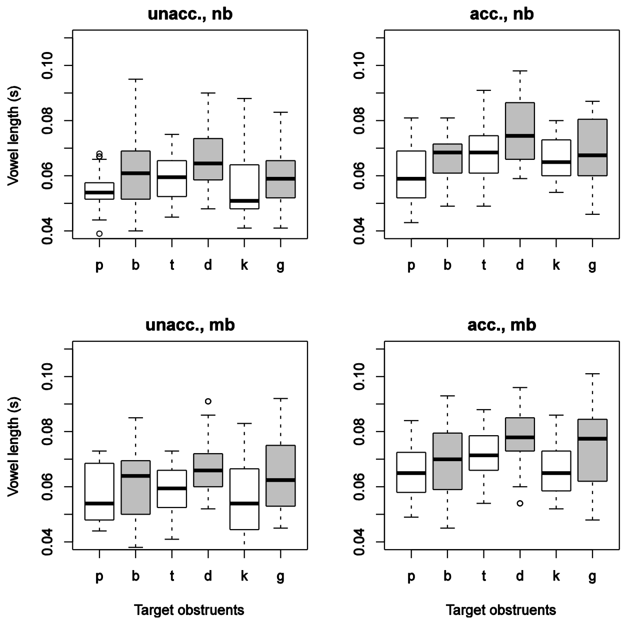
Figure 5: Density plot showing the Voicing Ratio of coronal stops in 'nb' environment.



The fact that phonation is not fully contrastive does not necessarily mean that there is complete neutralization between voiced and voiceless stops in Slovak in this context. In many languages contrast-preservation despite the loss of a primary acoustic cue (such as phonation itself) might be fairly robust due to other phonetic parameters like duration, intensity, or spectral characteristics of the surrounding vowels. In this study besides voicing we only examined duration-related parameters.

The duration of the vowel preceding underlyingly voiced stops systematically tends to be slightly longer than the vowel before voiceless stops (Fig. 6.). The phenomenon is known as "pre-fortis clipping" [16] and is mostly attested in aspirating languages (unlike Slovak).

Figure 6: Vowel length before voiced and voiceless stops.



This length difference although systematically present, is not significant in all prosodic conditions for all places of articulation. Whether this subtle phonetic difference is robust enough to be perceived by speakers, that is, whether it is a case of incomplete neutralization, can only be answered with follow-up perception experiments.

4. CONCLUSIONS

Prosodic variables do affect PSV in Slovak but not in a uniform way. The strong devoicing effect in 'pause boundary' context wipes out the effect of pitch accent as well as that of trigger type. The other two contexts do not differ in a meaningful way: pitch accent induces less voicing assimilation and more final devoicing. A novel finding of the study is that vowels and sonorant consonants significantly differ in their capability of triggering voicing: vowels trigger much less PSV than previously claimed, but vowel height does not play a role. PSV in Slovak shows traces of incomplete neutralization as underlyingly voiced stops seem to co-occur with phonetically longer preceding vowels than their voiceless counterparts, but the issue is in need of further research. possible.

ACKNOWLEDGMENT

This research was supported by grant 104897 by the Hungarian National Research Fund and in part by grant 2/0197/15 by Scientific Granting Agency.

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