SCHWA VOCALIZATION IN THE REALIZATION OF /r/

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ABSTRACT

The realization of the phoneme /r/ is commonly identified in terms of trills, taps, approximants, fricatives, vowels, and devoicing. An experimental investigation in Hungarian revealed a heretofore not discussed variant: [r] with a schwa on-vocalization ([ᵊr]) or off-vocalization ([rᵊ]). In Cr clusters the occurrence of schwa was more frequent in homorganic than in heterorganic clusters, while in the case of rC clusters the occurrence of schwa was more frequent in heterorganic than in homorganic clusters. The [ᵊr] realization was found before vowels (onset position), [rᵊ] before consonants or word finally (coda position). These facts are explained on the basis of articulatory / aerodynamic principles.

Keywords: /r/ realizations, schwa-on vocalizations, schwa-off vocalizations, /r/ clusters.

1. INTRODUCTION

The consonant /r/ is rather common in the languages of the world. As reported by Maddieson [11], some 75% of the languages have some type of /r/; about half of these are trills, almost all of which are articulated in the dental or alveolar region (see [8, 15]). The articulatory, acoustic, and aerodynamic characteristics of trills are relatively well-understood; see, among others [1, 2, 3, 4, 5, 8, 9, 10, 12, 13, 14, 18, 19], and references cited by these authors.

Aside from trills, the most common realizations of /r/ in terms of manner of articulation are taps, approximants, fricatives, vowels, and devoicing ([1, 8, 10]). Barry [1] goes as far as to claim that within the scheme of possible /r/ realizations trills are relatively rare cross-linguistically (contradicting [8, 11, 15]). Research studies have dealt mostly with articulation configurations resulting in various rhotic sounds and with analyzing their acoustic cycles in the typical repetition frequencies between 26 and 32 Hz, including the upper frequencies of trills.

Based on an experiment involving Hungarian, this paper reports on another possible variant of /r/, one that has escaped systematic investigation: [r] with schwa vocalization ([ᵊr] or [rᵊ]).

2. SUBJECTS, MATERIAL, METHOD

Seven native Hungarian speakers (5 women, 2 men) with no known speech or hearing defects read isolated words in a sound-proofed chamber. Their ages ranged from 22 to 32. The word lists were recorded and digitalized up to 22,000 Hz. Acoustic-phonetic analysis was carried out by Praat software, 5.4 version. The consonant /r/ was defined in each word for each speaker. Altogether, 1645 /r/ realizations were recorded. 4.6% of all data showed no /r/ – meaning that the speaker did not pronounce this consonant in a certain word. The remaining data could be correctly analyzed.

The /r/ phoneme of Hungarian is customarily identified as a (laminal) dental trill (see for example [7, 16]). In our experiment, the input data contained /r/ in all positions permitted by the phonology (phonotactics) of the language (cf. [7, 17, 20]); see Table 1 (ignoring trilateral clusters).

Table 1: Phonological positions of /r/.

Phonological position	Example
Word initial: #rV	róka ‘fox’
Word initial Cr cluster: #CrV	kréta ‘chalk’
Intervocalic: VrV	gyerek ‘child’
Intervocalic rC cluster: VrCV	birka ‘sheep’
Intervocalic Cr cluster: VCrV	szőrme ‘fur’
Word final: Vr#	tér ‘square’
Word final rC cluster: VrC#	arc ‘face’

There were no problems in the identification of /r/ in the various phonological positions. All subjects’ performances in all tasks were analyzed and compared. To test statistical significance, various methods were used, such as the t-test, analysis of variance (ANOVA), and post-hoc tests (using the SPSS 12.0.1. for Windows software package). In all cases the confidence level was set at the conventional 95%.

3. RESULTS

An unexpected result of our study was that the neutral vowel [ə] appeared in the realization of the /r/ phoneme in all but intervocalic contexts. The neutral vowel (schwa) is produced with the vocal tract in its neutral configuration while, in the case of Hungarian, the lips are unrounded (F1=550 Hz, F2=1800 Hz, F3=2700 Hz, on average). (No neutral sounds are associated with intervocalic /r/ because the transitional phases between /r/ and the neighboring vowels "replace" the schwa.) It should be noted that the [^{ə}r] and [r^{ə}] variants are distinct from a syllabic realization of /r/; the latter is claimed to be [^{ə}r^{ə}] (alternatively, [^{a}r^{a}] in Sanskrit by Hock ([6]), to cite one example.

Table 2 shows the ratio of the occurrence of schwa in the realization of /r/ in the various phonological positions (except intervocalic).

Table 2: The ratio of schwa occurrences in the realization of /r/.

Phonological position	Occurrence of schwa (%)	
	mean	std. dev.
#rV	98.67	4.59
#CrV	76.85	23.37
VCrV	67.01	30.36
VrC#	53.06	37.08
VrCV	56.53	38.85
Vr#	76.59	21.61

The difference of schwa vocalization depending on the 6 phonological positions is significant (F(5, 1187) = 21,845, p<0.0001). The actual difference between the #rV and #CrV cases is also significant; this is supported by the Tukey post hoc test. The explanation of the low percentage occurrence of schwa in #CrV words, relative to #rV, is that the data included words where the initial C was voiceless. In these cases the aerodynamic transitioning into [r] does not always favor schwa articulation. For some speakers, there can be a voiceless period between the initial voiceless consonant (stop or spirant) and the onset of the rolling articulation of [r]. (This voiceless period contains noise of various lower frequencies and of various intensities.) The period of voicelessness precludes the formation of a transitional vowel, which requires voicing. The perceptual impression of [r] as a voiced sound is based on psychoacoustic patterns: The voiced phonetic context has an impact on /r/, resulting in its perception as a voiced consonant.

3.1. Schwa in /r/ clusters

Statistical analysis showed that there were significant differences in the presence of schwa in C clusters containing /r/ on the basis of two variables: (a) whether the cluster is homorganic or heterorganic, and (b) whether /r/ precedes or follows the adjacent C. In the case of Cr clusters, the occurrence of schwa was more frequent in homorganic than in heterorganic clusters, while in the case of rC clusters, the occurrence of schwa was more frequent in heterorganic than in homorganic clusters; see Table 3. One-way ANOVA analysis showed that the occurrence of schwa significantly depended on the type of cluster, i. e. whether it was homorganic or heterorganic (F(7, 1055) = 45,000, p<0.0001). In one case, that of the VrCV position, Tukey post-hoc testing revealed no significant difference in this regard.

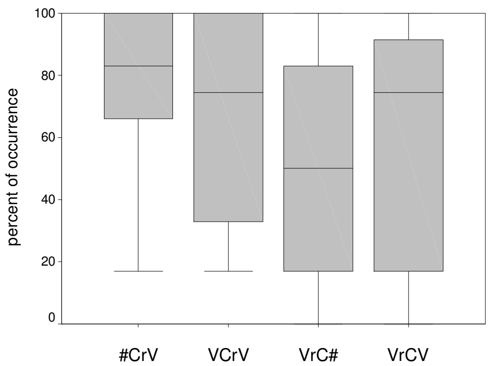
Table 3: The ratio of schwa occurrences in the realization of /r/.

Phonological position	Occurrence of schwa (%)	
	mean	std. dev.
Homorganic VrC#	35.13	33.77
Heterorganic VrC#	68.66	32.15
Homorganic VCrV	80.68	11.93
Heterorganic VCrV	60.54	34.98
Homorganic #CrV	84.61	16.58
Heterorganic #CrV	75.18	25.61
Homorganic VrCV	49.86	43.56
Heterorganic VrCV	61.04	40.03

How might the results be explained? On the one hand, in the articulation of heterorganic rC clusters it takes time for the tongue to be repositioned in transitioning from the production of [r] to that of the following consonant. Vocalization in neutral position (schwa) is the result of this transitioning movement. And on the other hand, the blade of the tongue is not involved in the articulation of a consonant preceding [r] in a heterorganic cluster; consequently, apical trilling can commence immediately following the articulation of the preceding consonant. In homorganic Cr clusters the tongue blade moves away to enhance the aerodynamic conditions for the onset of trilling action. Again, this period of transitioning into the articulation of [r] is realized as a schwa. In all cases, the presence vs. absence of schwa is expected to correlate with slower vs. faster speech tempos, respectively; however, this has to be verified by independent investigation.

In /r/ clusters, the voicing characteristics of consonants adjacent to /r/ might have an effect on the occurrence of schwa (see Figure 1). The mean ratio of the occurrence of schwa in clusters containing voiced consonants was 75.3%, as opposed to 50.55% of all occurrences in clusters containing voiceless consonants. Analysis confirmed that voiced consonants elicited the occurrence of the neutral vowel more frequently than unvoiced consonants; the difference proved to be significant in all clusters ($F(1, 1087) = 1054{,}506$, $p<0.0001$).

Figure 1: Occurrence of schwa in /r/ clusters containing a voiced consonant.

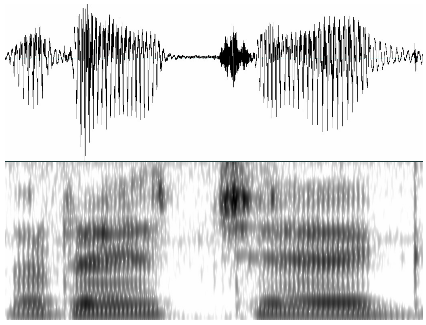


Devoiced counterparts of /r/ next to voiceless consonants can be spotted in some German dialects as free variations; Barry's [1] explanation is that devoicing is a less complex mode of articulation than "rolling" the /r/. We suppose that the lack of occurrence of schwa in Hungarian clusters containing /r/ and a voiceless consonant can also be interpreted as a simpler, or preferred, mode of articulation, in light of the lack of voicing of the consonant next to /r/.

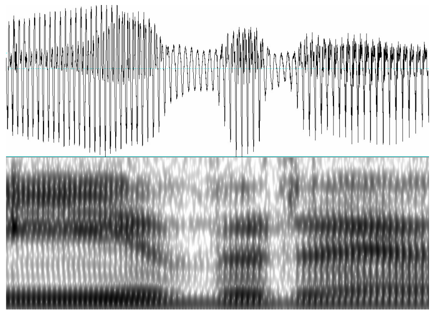
3.2. Location of schwa

As for the question of the relative location of schwa with respect to [r], schwa preceded [r] if [r] was prevocalic (onset position), but followed [r] if [r] was preconsonantal or word final (coda position). Paired-sample t-test showed significant differences between the possible location sites of schwa ($t(1239) = 7{,}206$, $p<0.000$). Figure 2 shows the schwa occurrences preceding and following the [r]-realizations.

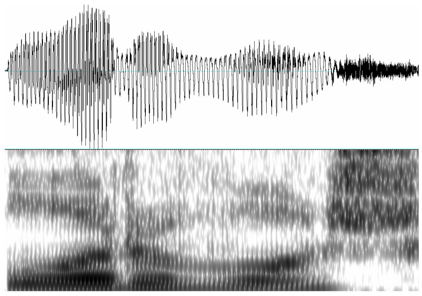
Figure 2: Schwa occurrences before and after [r].



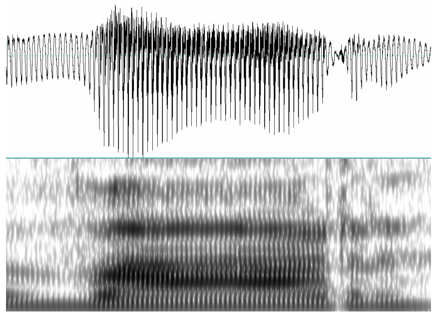
[ə r ɛ tʃ ɛ g]
recseg 'grates'



[eː v ə r ɛ]
évre 'for (the) year'



[o r ə v o ʃ]
orvos 'doctor'



[v aː r ə]
vár 'castle'

The average of schwa vocalization preceding [r] was 82% of all occurrences (sd = 25.83); it was 63.2% of all occurrences (sd = 34.31) following

[r]. That is, schwa occurred more frequently (in a larger proportion) preceding [r] than following [r]. Why should this be the case? For the articulation of a trill, a preceding vowel-like transition state is required on the basis of aerodynamics. In words like *róka* 'fox' (#rV) and *bronz* 'bronze' (#CrV) there is no vowel-like vocal tract configuration, so speakers create one; this is the schwa transition. However, in words like *arc* 'face' (#VrC) and *kar* 'arm' (Vr#) a vowel-like articulation is *in situ* before the /r/; hence, there is no need for a schwa transitioning state into the [r]. Why, then, is there an "after schwa" effect in these cases?

A possible explanation might be that there is an acoustic effect of moving the tongue away from the alveolum / upper dental area, coupled with ceasing rolling the air. Once the [r] is identified unambiguously (via initial vowel-state and trilling), what happens after the articulation, i.e. coming off the trill, is less important. Hence the occurrence of off-vocalization (following [r]) is not encountered as frequently as the occurrence of on-vocalization (before [r]).

4. CONCLUSION

Previous research has established that the articulation of /r/ varies across speakers and phonological contexts. Based on an experiment involving the consonant /r/ in Hungarian, another possible variant is to be added to the repertoire of /r/ realizations: [r] with either a preceding or following schwa. In clusters the frequency of the on-vocalization or off-vocalization is dependent on the relative order between /r/ and the adjacent consonant, and on whether the cluster is homorganic or heterorganic. Further, schwa precedes [r] in syllable onset position, while schwa follows /r/ in syllable coda position. Ultimately, these facts find their explanation in articulatory and aerodynamic principles.

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