THE CHARACTER OF /r/-SOUNDS: ARTICULATORY EVIDENCE FOR DIFFERENT REDUCTION PROCESSES WITH SPECIAL REFERENCE TO GERMAN

N. O. Schiller and C. Mooshammer
Max-Planck-Institute for Psycholinguistics, Nijmegen, The Netherlands
and Forschungsschwerpunkt Allgemeine Sprachwissenschaft, Berlin, Germany

ABSTRACT

The class of /r/-sounds is quite heterogeneous from the acoustic and the articulatory point of view. Many /r/-allophones are the result of phonetic reduction processes. In contemporary standard German /r/ can be realized as an apical or uvular trill, a fricative, an approximant or a vowel. In the experimental study presented here, two German subjects were investigated by means of EMA and spectrography. The results provide articulatory evidence for the gestural affinity between the different /r/-allophones.

1. INTRODUCTION

Laterals and /r/-sounds (or so-called rhotics) have many phonological and phonetic similarities (cf. [1], [2]) (e.g. distribution in the syllable, behaviour in sound change, articulatory, acoustic and perceptual features) and therefore belong to the class of liquids. The liquids constitute a small sound class; but nevertheless, they are represented in the majority of languages (cf. [3], [4]). For instance, /r/-sounds can be found in 76% of the UPSID languages (cf. [3]: 73). But the subclass of rhotics is phonetically quite heterogeneous (cf. [5]: 114) and a definition of /r/-sound is not available. Beside a set of core elements (e.g. trills, taps and flaps), there are some fricatives, approximants and vocalized allophones of /r/. The reason why there are so many allophones of /r/ is to be found in the phonetic nature of the rhotics: some /r/-sounds, e.g. trills, are quite complex in their articulation. They are learned relatively late by children, and their articulation causes serious problems for many adult speakers (cf. [6]). That is why trills are not very stable sounds; they are prone to undergo sound change resulting in different allophones.

In German, e.g., historically there was (presumably) only an apical-alveolar trill [r] (cf. [7], [8]); a uvular-postdorsal trill [R] developed later (cf. [9]) and was considered to be a sub-standard allophone of /r/ for a long time (cf. [10]: 51). In contemporary Standard German there are different fricatives, approximants and vocalized forms called /r/-sounds (cf. [11], [12]). Whereas acoustic analyses of different /r/-sounds have already been published (cf. [2], [13]), to our knowledge articulatory studies are not yet available. One of the few experimental studies on the production of /r/-sounds was provided by Recasens ([14]). He found in an EPG study that "[...] an alveolar tap and an alveolar trill show contrasting degrees of resistance to coarticulation from the adjacent vowels" ([14]: 279). Recasens concluded that taps and trills are produced by means of two different gestures.

The aim of this paper is to show that the different allophones of /r/ in German are closely related to each other articulatorily. Our hypothesis was that the constriction location for a certain class of /r/-sounds, e.g. uvular /r/s, is the same, and that the allophones of that particular class differ only in the constriction degree. To give articulatory evidence for the relatedness of superficially different looking /r/-sounds an EMA experiment was carried out.

2. EXPERIMENT

An experimental investigation was carried out to examine the articulatory relatedness of different forms of /r/-reduction in German.

2.1. Subjects

Two German speakers served as subjects. Subject 1 was a male speaker of standard German with an uvular variant of /r/. Subject 2 (the second author) was a female speaker of standard German but spoke an apical allophone of /r/ because of her Bavarian dialectal background.

2.2. Speech material

Test utterances were designed to test several aspects of /r/ articulation in German: coarticulatory effects, position dependent reductions and articulatory similarities between sounds with a similar place of articulation. Accordingly, the first part of the corpus consisted of items including /r/ in varying vowel contexts, e.g. /bara/, /bari/, /bira/ etc. The effect of syllable position was tested by means of pairs such as /rup/ vs /bur/, /rip/ vs /bir/ and /rap/ vs /bar/. To compare /r/ with neighbouring sounds, items like /tap/, /sap/, /pat/, /pas/ were tested for [r]. [R] was compared with /kap/, /pak/, /xap/, /pax/. Both subjects produced the test items in the carrier utterance "Ich habe ____ erwähnt" ("I mentioned ____ "). 50 test utterances were designed in total. Five repetitions were run with the test utterances randomised in all repetitions.

2.3. Method

Electromagnetic articulography (EMA, AG100, Carstens Medizinelektronik, Göttingen, Germany) was used to monitor tongue movements (cf. [15]). For this method three transmitter coils (mounted on a helmet) are used to generate an alternating magnetic field at three different frequencies. Five sensor coils, attached to the subjects' articulatory organs by means of physiological glue, detect the magnetic field strength which is roughly inversely proportional to the cube of the distance between sensor and transmitter (cf. [16] for details). The raw distance signals are then converted to the x-y coordinates in the mid-saggital plane. Three coils were mounted on the mid-saggital line of the tongue from about one to five cm from the tongue tip (coil 1 was placed one cm behind the apex, coil 2 was attached to the tongue blade and coil 3 was positioned approximately five cm from the tongue tip on the tongue dorsum). To compensate for head movements two reference coils were attached to the upper incisors (coil 4) and to the bridge of the nose (coil 5).

Simultaneously to the EMA recordings, acoustic recordings were made. Subjects read the corpus of 50 test utterances five times to get 250 recordings from each of the two subjects.

3. RESULTS

In this chapter, due to space limitations, we will mainly relate to the observed reductions of uvular /r/.

3.1. Acoustic analyses

The acoustic analyses were run with the XHADES program on a VAX computer at the NICI[1].

On the whole, it can be said that the uvular trill was rarely realized by speaker 1. [R] was only produced in initial position or in initial C-clusters. Most often, /r/ is reduced to a fricative (see figure 1). In final position after a long stressed vowel, /r/ is realized as a vowel [ɐ] (see figure 2).

The apical /r/ is initially realised either as a trill or as an approximant. Apical /r/ is not pronounced as a fricative because [z] already has phonological status in German. In syllable final position, apical /r/ is most often vocalized or articulated as an approximant.

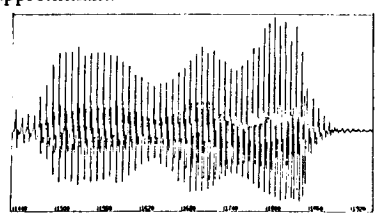

Figure 1. Wave form of the test stimulus /rip/ [ʁip].

[1] Nijmegen Institute for Cognition and Information, Nijmegen, The Netherlands.

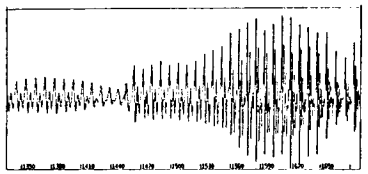

Figure 2. Wave form of the test stimulus /bir/ [biɐ].

3.2. Articulatory analyses

Articulatory data were rotated in such a way, that the line from the upper incisors to the bridge of the nose was parallel to the y-axis. Due to problems with the hardware, some recordings were lost or expelled from the data analyses.

Articulatory analyses of uvular /r/ were carried out for all repetitions of /bar/, /bir/, /bur/, /rap/, /rip/ and /rup/. Therefore, steady states of the movement signals of coil 3 served as the criterion for the target positions of uvular /r/. As can be seen in figures 3 and 4, the position of the tongue dorsum was higher when /r/ was in initial position in the vicinity of high vowels (/u/ and /i/) and lower when /r/ was produced in final position. No dependency on syllable position could be observed when /r/ was adjacent to the low vowel /a/ (see figure 5).

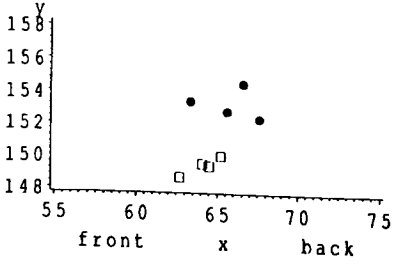

Figure 3. Plot of the tongue body position (coil 3) for initial vs final uvular /r/ (V=[u]). • = syllable initial position, □ = syllable final position.

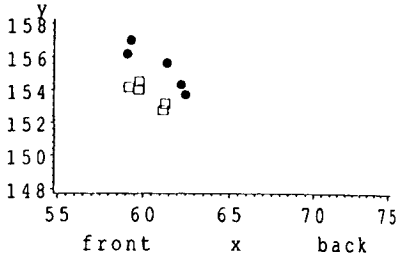

Figure 4. Plot of the tongue body position (coil 3) for initial vs final uvular /r/ (V=[i]). • = syllable initial position, □ = syllable final position.

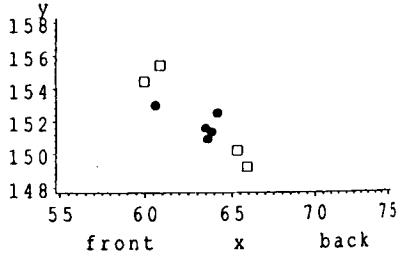

Figure 5. Plot of the tongue body position (coil 3) for initial vs final uvular /r/ (V=[a]). • = syllable initial position, □ = syllable final position.

4. DISCUSSION

The acoustic analyses of the productions of uvular /r/ revealed several forms of articulatory reduction. In syllable initial position, uvular /r/ is often produced as a post-dorsal fricative. In syllable final position after a stressed long vowel, however, uvular /r/ is often vocalized. This is in accord with previous studies on the reduction of /r/ (cf. [11]). The articulatory analyses carried out by means of EMA showed that, in general, the tongue body position is higher when uvular /r/ is syllable initial and lower when it is syllable final. This is true when /i/ or /u/ was the nucleus of the syllable; when /a/ was the nucleus, the situation was rather unclear.

These findings are in accord with the hypothesis that the different forms of articulatory reduction for uvular /r/ result from different degrees of tongue body constriction in the post-dorsal area. In the framework of *Articulatory Phonology* developed by Browman and Goldstein (cf. [17]) this can be described in a very simple way. It seems that the uvular trill and its forms of reduction (fricative, approximant and vowel) all belong to the same gestural family, e.g. a post-dorsal constriction gesture. The only difference between these allophones lies in the degree of tongue body constriction.

Acknowledgements

The authors are indebted to P. H. H. M. van Lieshout (NICI, Nijmegen, The Netherlands) for his great help with running the acoustic analyses. Furthermore, we would like to thank Jörg Dreyer (FAS, Berlin, Germany) for having been subject 2 and for his technical support in the articulatory analyses and Daniel Swingley (Stanford University, Stanford, USA) for proof-reading the paper.

5. REFERENCES

[1] Bhat, D. N. S. (1974), "The phonology of liquid consonants", *Working Papers on Language Universals*, vol. 16, pp. 73-104.

[2] Ladefoged, P., Cochran, A., Disner, S. (1977), "Laterals and trills", *Journal of the International Phonetic Association*, vol. 7, pp. 46-54.

[3] Maddieson, I. (1984), *Patterns of sound*, Cambridge et al.: Cambridge University Press.

[4] Göschel, J. (1971), "Artikulation und Distribution der sogenannten Liquida r in den europäischen Sprachen", *Indogermanische Forschungen*, vol. 76, pp. 84-126.

[5] Lindau, M. (1980), "The story of /r/", *UCLA Working Papers in Phonetics*, vol. 51, pp. 114-119.

[6] Luchsinger, R., Arnold, G. E. (1970), *Handbuch der Stimm- und Sprachheilkunde. Zweiter Band: Die Sprache und ihre Störungen*. Third edition, Wien, New York: Springer.

[7] Lehmann, W. P. (1951), "The distribution of Proto-Indo-European /r/", *Language*, vol. 27, pp. 13-17.

[8] Penzl, H. (1961), "Old High German ⟨r⟩ and ist phonetic identification", *Language*, vol. 37, pp. 488-496.

[9] Moulton, W. G. (1952), "Jacob Böhme's uvular r", *The Journal of English and Germanic Philology*, vol. 51, pp. 83-89.

[10] Siebs, T. (1898), *Deutsche Bühnenaussprache*, Berlin: de Gruyter.

[11] Hildebrandt, B. F. O., Hildebrandt, L. M. (1965), "Das deutsche R. Regelhaftigkeiten in der gegenwärtigen Reduktions-Entwicklung und Anwendung im Fremdsprachenunterricht", *Linguistics*, vol. 11, pp. 5-20.

[12] Hall, T. A. (1993), "The phonology of German /R/", *Phonology*, vol. 10, pp. 83-105.

[13] Meyer-Eppler, W. (1959), "Zur Spektralstruktur der /r/-Allophone des Deutschen", *Acustica*, vol. 9, pp. 247-250.

[14] Recasens, D. (1991), "On the production characteristics of apico-alveolar taps and trills", *Journal of Phonetics*, vol. 19, pp. 267-280.

[15] Schönle, P. W. (1988), *Elektromagnetische Artikulographie. Ein neues Verfahren zur klinischen Untersuchung der Sprechmotorik*, Berlin et al.: Springer.

[16] Perkell, J. S., Cohen, M. H., Svirsky, M. A., Matthies, M. L., Garabieta, I., Jackson, M. T. T. (1992), "Electromagnetic midsagittal articulometer systems for transducing speech articulatory movements", *Journal of the Acoustical Society of America*, vol. 92, pp. 3078-3096.

[17] Browman, C. P., Goldstein, L. (1989), "Articulatory gestures as phonological units", *Haskins Laboratories Status Report on Speech Research*, vol. SR-99/100, pp. 69-101.