in: Speech Production and Speech Modelling
(William J. Hardcastle & Alain Marchal, eds.)
(=Nato ASI Series, Series D, Vol. 55),
Dordrecht, Boston, London: Kluwer 1990,
pp. 69-92

SEGMENTAL REDUCTION IN CONNECTED SPEECH IN GERMAN: PHONOLOGICAL FACTS AND PHONETIC EXPLANATIONS

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ABSTRACT. This paper deals with /r/ vocalization, weak forms, elisions and assimilations in connected speech in German and provides phonological rules within the generative framework for the derivation of any observable reduction forms, given certain phonetic environments. Some syntactic constraints are also discussed. This phonological description is then supplemented by an enquiry into the production and perception constraints of real speakers and real listeners to find answers to the questions as to why certain articulatory modifications occur and others do not, and why they take particular directions. This phonetic explanation is sought in a minimization of energy expenditure in relation to the perceptual demands of the communicative situation.

1. INTRODUCTION

The Sanskrit grammarians provided a very elaborate corpus of rules of combination, rules of *putting together*, i.e. *Sandhi* rules [1], distinguishing those that apply to the internal make-up of a word, by the addition of derivative and inflectional endings to roots and stems, from the ones that apply to the more external putting together of stems to make compound stems, and the yet looser and more accidental collocation of words in the sentence. In both classes, the general principles of combination are the same, namely hiatus, deaspiration, assimilation, which provides by far the greatest body of combinatorial changes in Sanskrit, extension and abbreviation of consonant groups, permitted finals in words, increment and decrement, i.e. strengthening or weakening processes. These Sanskrit rules were described as synchronic sound structure rules.

The diachronically oriented linguists of the 19th and the early 20th century worked with the same rule types, especially assimilation, strengthening and weakening, but now in the diachronic perspective (of historical sound change), which, by subsuming individual instances of

phonetic changes in words under these general principles, purported to explain them. The more fundamental and far more interesting explanatory question as to why particular sound changes occur whereas others do not was, of course, not solvable by this attribution of tokens to tpyes of change. The static surface phonetic descriptions attached to these categories of change, in terms of places and modes of articulation as well as types of phonation, as for instance in Grammont's *Traité de Phonétique* [2], did not capture the dynamic processes of speech production and its variability, as constrained by the human vocal apparatus and its degrees of freedom, but simply constituted identification tags for changes in the graphic representation of speech phenomena.

Besides this dominant stream of historical linguistics we find the development of practical phonetics in connection with foreign language teaching, which led to the foundation of the International Phonetic Association in 1886. Learning modern foreign languages beside or instead of Latin and Greek also made a concern for pronunciation mandatory, at the level of isolated words as well as their concatenation in utterances. So assimilations and reduction phenomena were studied in the European languages, especially in English because the English School of Phonetics from Henry Sweet and Daniel Jones to their later successors assumed a leading role in this development of practical phonetics. But its association with foreign language teaching set the following severe limitations to the scientific goals.

1. The correct empirical observation and description of speech phenomena were at stake, not their explanation. Practical phonetics did not, and did not want to, explain why the observed reductions occurred and no others.
2. Empirical observation and description were impressionistic, based on the techniques of ear and articulation training. Instrumental and experimental techniques played a very minor role.
3. Although it is extremely important for learners of a foreign language to learn the rules that govern the use of phonetic reductions - namely sociolinguistic, stylistic, pragmatic situational, semantic, syntactic and phonetic contextual constraints - practical phonetics of the English School largely limited itself to the ad hoc enumeration of instances of assimilations, elisions and weak forms. It was left to the learner to internalise the rules in the practical performance by induction. This was partly due to educational principles, but largely to the anchoring of practical phonetics in the tradition of English linguistic scholarship, which, until quite recently, excelled in the provision of large data bases, of which Murray's *Oxford English Dictionary* and all its followers and derivatives are outstanding examples, and which treated the elaboration of rules for linguistic behaviour as something marginal, rather than central, and often with great suspicion.
4. The orientation towards the foreign language learner also necessitated the restriction to standard social and stylistic forms of pronunciation, imparted under class room conditions, which lack the more extreme types of phonetic reductions. Therefore the lists of observed phenomena of assimilations, elisions and weak forms in the

standard works by Jones [3] and Gimson [4] are highly incomplete. So, although practical phonetics dealt with the synchronic aspects of sound reduction it did not do so adequately and it provided no more illuminating accounts than did diachronic linguistics.

With the advent of phonology and the polarization of the study of spoken language into an arts discipline called phonology, and a science discipline called phonetics, the latter was relegated to an ancillary function of filling the primary phonological categories with phonetic substance. The explanation of language phenomena became the main goal, but it rested on phonological structures, established according to linguistic principles such as otherness, i.e. differentiation rather than identification, not on measurable phonetic phenomena, which were denied any explanatory power in their own right in linguistic analyses. This standpoint received its most extreme and at the same time formalised expression in generative phonology. The dichotomization of language into performance and competence, and the restriction of linguistics proper to the latter excluded, or at least confined to a minor place, all enquiries into phonetic variation determined by sociolinguistic, physiological and perceptual factors, lying outside the phonological system. Thus reduction phenomena were not a primary concern.

The sociolinguistic and stylistic studies by Labov [5] and Trudgill [6] stayed outside the mainstream of generative phonology and its various descendants, and questions into the biological foundations of phonological structures and processes did not enter into phonological explanations within generative phonology. In the phonological literature common sound patterns were and still are "explained" by reference to phonology-internal concepts such as "markedness", leading to statements of the sort "obstruents tend to devoice because voicelessness is the unmarked case, i.e. it is normal for obstruents to devoice." As Ohala [7] has rightly pointed out, such statements are worthless as explanations since they reduce to the tautology "X because X". Instead, the explicandum should be referred to explanans categories that are independently motivated, and among these the constraints the human vocal apparatus and hearing exert on observable phonological facts are of prime inportance. Just as there have been departures from the all-embracing dominating paradigm of generative phonology with regard to the sociolinguistic aspects of sound systems, there have been similarly new explorations into their biological foundations in the writings of Lindblom [8-11] and Ohala [7,12-15].

What we need is the application of this new way of thinking to sound reduction phenomena at the sentence level in connected speech in order to provide a principled explanation for their occurrence and manifestation in synchronic sound systems. Questions to be answered are whether segmental reduction is rooted solely in the variability of speech production, governed by an economy of effort principle, and/or whether perceptual constraints intervene to filter out those articulatory processes from among the possible ones that then become established in a speech community. In this connection, we must also give an answer as to whether diachronic sound change follows from the same principles that determine segmental reduction in the synchronic

perspective. Sound change may be viewed as a changed sociolinguistic grouping of the phonetic variability caused by biological factors, and as the result of a deviant articulatory reinterpretation of auditory impressions received from speech productions of others, involving successive generations of language users. Synchronic articulatory reductions, on the other hand, occur within the same speakers under various contextual and situational conditions. So the acoustic and perceptual aspects of speech may play a much more prominent role in the diachronic shifts than in the synchronic processes.

I am now going to present reduction rules for German in a series of steps that retrace the historical stages of dealing with reduction phenomena, which I have just presented. I shall begin with ad hoc utterances in careful and in casual pronunciation, list the differences, refer them to general phonological rules covering any German utterance and finally explain their occurrence with reference to production and perception constraints. I shall also include some remarks about syntactic/semantic and sociolinguistic/pragmatic/stylistic conditions, the main stress, however, being on biological constraints.

2. REDUCTION RULES

The reduction processes in connected speech in German have been described in great detail in a number of publications [16-20]. Some of the rules have been incorporated by this author into the INFOVOX [21-25] German text-to-speech system to improve the intelligibility and naturalness of its output. The synthesis sounds very satisfactory, providing additional support to the model derived from the analysis of production data. Let me start the presentation and discussion of this model with a few examples comparing careful and reduced pronunciations in IPA phonetic transcription in relation to standard orthography. The sentences in Table 1 illustrate the four linguistic categorizations of reduction phenomena: */r/ vocalization*, *weak form*, *elision* and *assimilation* to be dealt with in 2.1 - 2.4.

2.1. /r/ vocalization

When /r/ is not followed by a vowel it is vocalized to [ɐ]; /ər/ in this context also develops to [ɐ]. This rule still applies when /ə/ is deleted after /r/, as in 'gefahren'.

2.2. Weak form

Function words (pronouns: 'ich', 'du', 'er', 'sie', 'mir'; articles: 'dem' (definite, dative), 'einen' (indef., accusative); auxiliary verbs: 'bin', 'hast', 'hat'; prepositions: 'mit', 'nach'; conjunctions: 'und') are reduced when unstressed. This reduction involves duration changes, opening, centralization and monophthongization of vowels, vowel and consonant elision, and often results in several phonetic realisations of the same lexical item forming a reduction hierarchy, where the degree of reduction correlates with the lowering of the stylistic level and with the degree of familiarity in the communicative situation, with extreme

reductions also being less common at utterance beginning or after pause.

TABLE 1. Orthography and IPA transcription of German sentences in careful and reduced pronunciations (stress marks, ' = primary, " = secondary, in front of stressed vowel); English translations

Orthography

(1) Ich bin mit dem Wagen nach Bonn gefahren.
"I went to Bonn by car."
(2) Er hat mir geholfen.
"He has helped me."
(3) Sie hat jedem zehn Mark gegeben.
"She has given each one ten marks."
(4) achtundvierzig
"48"
(5) Hast du einen Moment Zeit?
"Have you got a moment to spare?"

Careful

(1) ʔɪç bɪn mɪtʰ de:m v'a:gən na:χ b'ɔn gəf"a:ʁən.
(2) ʔe:ɐ hatʰ mi:ɐ gəh'ɔlfən.
(3) zi: hatʰ j'e:dəm ts'e:n m'aʁkʰ gəg"e:bən.
(4) ʔ'aχtʰ ʔunt f"ɪʁtsɪç.
(5) hastʰ du: ʔaɪnən mo:m'ɛntʰ ts'aɪtʰ?

Reduced

(1) ç ɸɪ mɪ m v'a:ŋ naχ ɸ'ɔŋ gəf"a:ɐn.
(2) ɛɐb mɐ gəh'ɔlfŋ.
(3) zɪ at ç'e:m ts'e: m'aɐ ɡ̊əg"e:m.
(4) ʔ'aχtnf"ɪɐtsɪç.
(5) hasp m mom'ɛn ts'aɪtʰ?

For example, the inflected definite and indefinite articles 'dem' and 'einen' undergo the following progressively stronger reductions:

(1) de:m → dem → dɐ̨m → dəm → dm → bm → m
(2) ʔaɪnən → anən → an → ən → n
→ ənən → nən

The articles 'einem' and 'dem' (dat.) or 'einen' and 'den' (acc.) can be reduced to the same extreme forms [m] or [n] so that there may be coalescence of definite and indefinite articles. In the case of 'Ich bin mit _____ Wagen nach Bonn gefahren.' the probability for the indefinite

article is very low, whereas in 'Sie ist mit _____ Freund in Urlaub gegangen.' ("She has gone on holiday with a boy friend.") it is very high because otherwise one would expect the possessive pronoun 'ihrem' instead of the definite article 'dem'. In 'Hast du _____ Moment Zeit.' the definite article is ruled out, whereas in 'Er macht _____ besten Eindruck ("He gives the best impression.") it is the only possible form. So, in all these cases the extreme reductions are tolerated in spite of formal coalescence. When syntactic and semantic redundancies do not weight one word class more highly than the other and when a differentiation is essential for effective speech communication, the reductions stop at points where the phonetic forms are still distinct.

The reduction of 'dem' to [m] is of very old standing because here the orthography has partly followed suit: 'im' ← 'in dem', 'am' ← 'an dem', 'zum' ← 'zu dem', 'beim' ← 'bei dem', 'überm' ← 'über dem', 'unterm' ← 'unter dem'; even 'auf'm' and 'aus'm' are possible spellings in the representation of more colloquial speech. [mɪm] for 'mit dem' is, however, different from these because one would expect [mɪtm] or [mɪpm], i.e. the plosive should still be represented. Its disappearance constitutes the same further development as in 'guten Tag' ("good day"): [gu:tn] → [gʊdn] → [gʊn], which will be dicussed in 3.3.

Since there is an orthographically represented reduction 'zum' beside 'zu dem', the two forms can be used for different syntactic and semantic purposes, the latter in an anaphoric function, as in

(3) 'Er kam zu dem Schluß, daß alles verloren war.'
("He reached the conclusion that everything was lost.")
[tsʊdɐm → tsʊdəm]

(4) 'Er kam zum Schluß, die andern waren schon da.'
("He arrived last, the others were already there.")
[tsʊm]

(5) 'Nach vielen Abschweifungen kam er endlich zum Schluß.'
("After many digressions, he finally came to the end of his speech.")
[tsʊm]

If there is no anaphoric function, 'zu dem' [tsʊd(ɐ)m] is impossible.

As these inflected article forms illustrate, the centralization of vowels in function words goes as far as [ə] for /e:/ and /aɪ/, and like any other [ə], it can be elided before /n/. In the case of /e:r/ in 'er' and 'der', the central half-open vowel [ɐ] may result as an extreme reduction, which is more common in the article than in the pronoun. In the pronoun its probability of occurrence is higher in postverbal than in preverbal position (commonly [ɛɐ] in 'er hat' vs. [ɐ] in 'hat er'). That means that preverbal [ɛɐ] occupies the same stylistic position as postverbal [ɐ].

/i:ɐ/ in 'ihr' (poss. pron. or pers. pron. 2nd pers. pl. nom. or pers. pron. 3rd pers. sing. fem. dat.), 'mir' (pers. pron. 1st pers. sing. dat.), 'dir' (pers. pron. 2nd pers. sing. dat.), 'wir' (pers. pron. 1st pers. pl. nom.), as well as /y:r/ in 'für' (prep.) can be weakened to [ɐ], but this does not apply to the possessive pronoun 'ihr' (e.g. 'ihr [ɪɐ] Kleid' "her dress") and is far less likely in the dative than in the nominative personal pronouns (e.g. 'Er hat ihr [ɪɐ]

geholfen.' "He has helped her."). With regard to the pre- and postverbal positions of the nominative personal pronouns 'wir', 'ihr' the same holds as for 'er'.

'du' (pers. pron. 2nd pers. sing. nom.) can be reduced to [də] with the same restriction in proclitic position. In 'ihm' /i:m/ and 'ihn' /i:n/ (pers. pron. 3rd pers. sing. masc. dat./acc.) the vowel may develop to [i] → [ɪ] → [ə] and even be lost, but in the latter case a syllabic nasal is retained; 'ihnen /i:nən/ (pers. pron. 3rd pers. pl. dat.) can, however, only be weakened as far as [ɪnn]. The conjunction 'und' /ønt/ is generally reduced to [øn] and further to [ən], particularly in compound numerals, where [ə] may also be deleted.

2.3. Elision

Elision covers the cases of /ə/ deletion in endings and weak forms, the reduction of geminates to single consonants and the elimination of aspiration between stops, as well as before nasals after /ə/ deletion.

In /ə(nə)n,m,l/ the first /ə/ is deleted, except after a sequence of obstruent + nasal. The deletion is illustrated by the words of Table 2.

TABLE 2. Examples of /ə/ deletion

(a) from the sentences of Table 2
'Wagen' [v'a:gn], 'gefahren' [gəf'a:ʁn]
'geholfen' [gəh'ɔlfn], 'jedem' [j'e:dm]
'gegeben' [gəg'e:bn]
(b) further instances illustrating additional contexts
'ebenen' "even" (inflected) ['e:bənən] → ['e:bnən]
'lernen' "to learn" [l'ɛʁnən] → [l'ɛʁnn]
'zeichnen' "to draw" [ts'aɪçnən]
'Adel' "nobility" ['a:dəl] → ['a:dl]

Both /ə/ of /ənən,m/ can be deleted if the sequence occurs in function words, cf. 'hast du einen' [hastdənən] → [hastnn] in sentence 5 of Table 1.

The reduction of geminates is a general process in German and even applies to those cases that arise through /ə/ deletion if syntactic conditions do not interfere (cf. 2.2.). Geminate reduction is blocked if it causes a semantic confusion by eliminating a function word altogether, e.g. in compound numerals. For example, in the numeral "98" ['aχtnn'oɪntsɪç] a geminate is necessary to differentiate it from the short form for the money amount "8 Mark 90 Pfennig", i.e. "8.90" ['aχtn'oɪntsɪç] with single [n]. In sentence 5 of Table 1 the [m] representing the function word 'einen' is likely to stay, except in very fast and relaxed speech. The first stop in a sequence of two stops is not aspirated, even across word boundaries. Table 3 lists some instances of geminate reduction and elimination of aspiration.

TABLE 3. Examples of geminate reduction and elimination of aspiration

(a) from the sentences of Table 1
'mit dem' [mɪtd̥əm] → [mɪd̥əm], hat mir [hatmɪɐ]
'Mark gegeben' ['maɐkg̊əg"e:bn] → ['maɐg̊əg"e:bn]
'hast du einen' [hastn]
'Moment Zeit' [mom'ɛnt ts'aɪt] → [mom'ɛn ts'aɪt]
(b) further instances illustrating additional contexts
'lernen' [l'ɛɐn]
'98' [a/χtnn'oɪntsɪç]
'Er hat ihnen geholfen.' "He has helped them."
[ɛɐt ɪnən gəh'ɔlfən] → [ɛɐt ɪnn gəh'ɔlfn]
'Er will ihn nehmen.' "He wants to appoint him."
[ɛɐ vil ɪn n'e:mən] → [ɛɐ vɪlɲ n'e:m]

TABLE 4. Examples of assimilation

(a) progressive, place
'Wagen' [v'a:gn] → [v'a:gŋ]
'geholfen' [gəh'ɔlfn] → [gəh'ɔlfm̩]
'gegeben' [gəg'e:bn] → [gəg'e:bm]
(b) regressive, place
'bin mit' [bɪn mɪt] → [bɪmmɪt] (→ [bɪmɪt], see 2.3.)
'mit dem' [mɪtm] → [mɪpm]
'hat mir' [hat mɐ] → [hap mɐ]
'jedem' [j'e:dm] → [j'e:bm]
'zehn Mark' [ts'e:n m'aɐk] → ['ts'e:m m'aɐk]
(→ [ts'e: maɐk], see 2.3.)
'hast du einen Moment' [hastn mom'ɛnt] → [haspm mom'ɛnt]
(c) regressive, manner
'mit dem' [mɪpm] (→ [mɪbm], see (e)) → [mɪmm]
(→ [mɪm], see 2.3.)
'Wagen' [v'a:gŋ] → [v'a:ŋŋ] (→ [v'a:ŋ], see 2.3.)
'jedem' [j'e:bm] → [j'e:mm] (→ [j'e:m], see 2.3.)
'gegeben' [gəg'e:bm] → [gəg'e:mm]
(→ [gəg'e:m], see 2.3.)
(d) progressive, devoicing
'ich bin' [ɪç bɪn] → [ɪç p̥ɪn]
'hat jedem' [hat j'e:m] → [hat ç'e:m]
'Mark gegeben' [maɐk gəg'e:m] → [maɐk g̊əg'e:m]
(e) regressive, voicing, in unstressed syllables and function words
'mit dem' [mɪpm] → [mɪbm]

2.4. Assimilation

Assimilation may be progressive or regressive and may affect place and manner of articulation as well as phonation. Table 4 lists tokens of the different types occurring in German.

2.5. Generative rules

2.5.1. Formalism. The reduction phenomena presented as observational data in 2.1. - 2.4. can now be accounted for by a set of ordered rules that generate correctly any weak forms, elisions and assimilations that may occur in Standard German, and thus add descriptive to observational adequacy. Only the most general rules will be given. They need further specifications for syntactic, semantic and pragmatic conditions, and they are, of course, not necessarily applicable to all dialectal varieties of German.

The formalism follows that of generative phonology [26] and has the following characteristics.

1. Rules are of the form

(1) $X \rightarrow Y \;/\; W \_\_\_\_ Z,$

where X, Y, W, Z are (strings of) symbols corresponding to sequential sound units and boundaries, and where X is rewritten as Y after the left-hand context W and before the right-hand context Z. If W and Z are missing the rule is a context-free rule. If Y is missing, the rule is a deletion rule, in the absence of X, it is an insertion rule.

2. Each symbol is composed of a phonetic segment or boundary name (e.g. i:, n, ʔ; # for word boundary; V or C for the whole class of vowels or consonants) and binary phonetic features marked as + or - (e.g. + STOP, + NASAL, - VOICE, +/- CORONAL, +/- ANTERIOR, +/- HIGH, +/- LOWSTRESS to separate [ə] from other vowels, +/- OBSTRUENT to distinguish obstruents from sonorants; +/- FUNC, function/ non-function word marker). Features are arranged in vertical order, with the symbol name at the top (when given), and enclosed in square brackets.

(2) $$\begin{bmatrix} -\text{CONT} \\ -\text{NAS} \\ +\text{VOICE} \end{bmatrix} \rightarrow [+\text{NAS}] \;/\; \underline{\quad} \; \begin{bmatrix} \text{C} \\ +\text{NAS} \end{bmatrix}$$

3. Symbols in the rule context may be optional and are then enclosed in parentheses. If a symbol is to occur a variable number of times it is followed by (m,n) with m, n=0, 1, 2... The first figure refers to the minimal, the second to the maximal number of repetitions. (,) means "any number of occurrences", (m,) "m or more occurrences".

(3) $V \rightarrow ə \;/\; \begin{bmatrix} \# \\ +FUNC \end{bmatrix} C(,) \_\_\_\_$

(4) $ə \rightarrow \;/\; V\ C \_\_\_ (n\ (d)\ ə) \begin{bmatrix} C \\ +NAS \end{bmatrix}$

4. Several symbols may constitute context alternatives for rule application. The alternatives are enclosed in braces.

(5) $ə \rightarrow \begin{bmatrix} V \\ \\ -LSTR \end{bmatrix} \;/\; \left\{ \begin{array}{l} \begin{bmatrix} C \\ +VOC \end{bmatrix}(0,1)\ C \\ \\ (C)\ C \begin{bmatrix} C \\ -NAS \end{bmatrix} \end{array} \right\} \_\_\_\_ \; n$

5. To indicate agreement or disagreement between the signs of features in different symbols, variables α, ß, ... are used. This symbolization is particularly useful in assimilation rules.

(6) $\begin{bmatrix} C \\ +COR \\ +ANT \\ +NAS \end{bmatrix} \rightarrow \begin{bmatrix} -COR \\ \alpha ANT \end{bmatrix} \;/\; \begin{bmatrix} C \\ -COR \\ \alpha ANT \\ +STOP \end{bmatrix} \_\_\_\_$

6. Rules are applied in ordered sequence, the output of one rule being the input to the following one. In the case of optional contexts, the longest string is tried first, i.e. (4) expands into the ordered sequence

(7a) $ə \rightarrow \;/\; V\ C \_\_\_\_ n\ d\ ə \begin{bmatrix} C \\ +NAS \end{bmatrix}$

(7b) $ə \rightarrow \;/\; V\ C \_\_\_\_ n\ ə \begin{bmatrix} C \\ +NAS \end{bmatrix}$

(7c) $ə \rightarrow \;/\; V\ C \_\_\_ \begin{bmatrix} C \\ +NAS \end{bmatrix}$

7. Any one rule is successively tried for application on each symbol of an input string, starting with the left-most one.

2.5.2. System of reduction rules in German

(1) $\begin{bmatrix} C \\ +OBST \\ +VOICE \end{bmatrix} \rightarrow \begin{bmatrix} -VOICE \\ +DEVOICED \end{bmatrix} \;/\; \begin{bmatrix} C \\ -VOICE \end{bmatrix} \#(0,1) \_\_\_\_$

Devoicing of voiced stops and fricatives after voiceless consonants

(2a) ʒ → ʂ

(2b) ʐ → s

Coalescence of the devoiced non-labial fricatives with their fortis counterparts

(3) $t^h \rightarrow / \begin{bmatrix} \# \\ +FUNC \end{bmatrix}$ ɷ n ____

[t] elision in the function word 'und'

(4) ʔ → / $\begin{bmatrix} \# \\ +FUNC \end{bmatrix}$ ____

Elision of glottal stop in function words

(5) ɪ → / $\begin{bmatrix} \# \\ +FUNC \\ +INITIAL \end{bmatrix}$ ____ ʂ

Elision of utterance-initial [ɪ] in the function word 'ich'

(6) V → ə / $\begin{bmatrix} \# \\ +FUNC \end{bmatrix}$ C(,) ____

Vowel reduction in function words

(7a) ə → / $\begin{bmatrix} V \\ \\ -LSTR \end{bmatrix}$ $\left\{ \begin{matrix} C \\ \begin{bmatrix} C \\ +VOC \end{bmatrix} C \\ (C)\ C \begin{bmatrix} C \\ -NAS \end{bmatrix} \end{matrix} \right\}$ ____ $\begin{bmatrix} C \\ +NAS \end{bmatrix}$

(7b) ə → / $\begin{bmatrix} \# \\ +FUNC \end{bmatrix}$ (C) ____ $\begin{bmatrix} C \\ +NAS \end{bmatrix}$

[ə] elision before nasal consonant after a vowel that is not [ə]; in function words the latter restriction does not hold

(8) ə → / C___l

[ə] elision before [l]

(9) $\text{ɐʁ} \rightarrow \text{ɐ} \;/\; \_\_\_\_ \begin{Bmatrix} C \\ \# \end{Bmatrix}$

(10) $\text{ʁ} \rightarrow \text{ɐ} \;/\; \_\_\_\_ \begin{Bmatrix} C \\ \# \end{Bmatrix}$

[ʁ] vocalization before consonant or word-final

(11) $\begin{bmatrix} C \\ +ASP \end{bmatrix} \rightarrow \begin{bmatrix} -ASP \end{bmatrix} \;/\; \_\_\_\_ \; \#(0,1) \; \begin{bmatrix} C \\ -CONT \end{bmatrix}$

Elimination of aspiration before stops and nasals (which are both categorised as -CONTINUANT), also across word boundaries

(12) $\text{h} \rightarrow \;/\; \begin{bmatrix} \# \\ +FUNC \\ -INITIAL \end{bmatrix} \_\_\_\_$

[h] elision in the various forms of the function word 'haben' when it is not utterance-initial

(13) $\text{ə} \rightarrow \;/\; \text{ɐ} \begin{bmatrix} \# \\ +FUNC \end{bmatrix} \_\_\_\_$

Vowel elision initially in function words after /r/ vocalization in the preceding word, e.g. in 'hat' of 'er hat' and in 'es' of 'hat er es'

(14) $\begin{bmatrix} C \\ +COR \\ +ANT \\ -CONT \\ -ASP \end{bmatrix} \rightarrow \begin{bmatrix} -COR \\ \alpha ANT \end{bmatrix} \;/\; \_\_\_\_ \begin{bmatrix} C \\ +COR \\ +ANT \\ -CONT \end{bmatrix}(,) \; \#(,) \; \begin{bmatrix} C \\ -COR \\ \alpha ANT \\ -CONT \end{bmatrix}$

Assimilation of apical nasals and unaspirated stops to following labial or dorsal nasals or stops; cf. the extreme example 'mit bunten Papierschlangen' ("with coloured paper streamers") [mɪt b'ʊntn pap'i:ɐ ʃl"aŋn] → [mɪpb'ʊmpm pap'i:ɐ ʃl"aŋŋ].

(15) $$\begin{bmatrix} C \\ +COR \\ +ANT \\ -CONT \\ -ASP \end{bmatrix} \rightarrow \begin{bmatrix} -COR \\ \alpha ANT \end{bmatrix} / \begin{bmatrix} C \\ -COR \\ \alpha ANT \\ -CONT \end{bmatrix} \_\_\_\_ \begin{Bmatrix} \# \\ C \end{Bmatrix}$$

Assimilation of apical nasals and unaspirated stops to preceding labial or velar nasals or stops; e.g. 'Hemden' ("shirts") [h'ɛmdn] → [h'ɛmbm], 'Beamten' ("civil servants") [bə?'amtn] → [bə?'ampm], 'behaupten' ("assert") [bəh'aɷptn] → [bəh'aɷpm]. This assimilation also occurs after fricatives, but less frequently, e.g. 'geholfen' ("helped") [gəh'ɔlfŋ], 'rauchen' ("to smoke") [ʁ'aɷxŋ], 'achten' ("to pay attention") [?'axkŋ]. To cover these cases as well, -CONT has to be deleted from the rule context.

(16) $$\begin{bmatrix} C \\ \alpha COR \\ \beta ANT \\ -NAS \\ +OBST \\ \varepsilon CONT \\ -VOICE \end{bmatrix} \rightarrow / \_\_\_\_ \# \begin{bmatrix} C \\ \alpha COR \\ \beta ANT \\ -NAS \\ +OBST \\ \varepsilon CONT \\ -VOICE \end{bmatrix}$$

Reduction of double consonants that are voiceless or devoiced

(17) $$\begin{bmatrix} C \\ +STOP \\ -VOICE \end{bmatrix} \rightarrow [+VOICE] / \begin{bmatrix} \# \\ +FUNC \end{bmatrix} C(,) \begin{bmatrix} V \\ -STRESS \end{bmatrix} \begin{bmatrix} \# \\ +FUNC \end{bmatrix}^{(0,1)} \begin{bmatrix} \# \\ +FUNC \end{bmatrix}^{(0,1)} \_\_\_\_ \begin{bmatrix} -OBST \\ -STRESS \end{bmatrix}$$

Voicing of plosives in unstressed function words

(18) $$\begin{bmatrix} C \\ -CONT \\ -NAS \\ -COR \\ +VOICE \end{bmatrix} \rightarrow [+NAS] / \_\_\_\_ [+NAS]$$

Nasal assimilation of voiced non-coronal stops before nasals; coronal stops assimilate far less readily, except in function words, e.g. 'werden' [vɛɐn] vs. 'reden' [ʁ'e:dn].

(19) $$\begin{bmatrix} C \\ \alpha COR \\ ßANT \\ \gamma NAS \\ \partial OBST \\ \varepsilon CONT \\ \zeta VOICE \end{bmatrix} \rightarrow / \_\_\_\_ \# \begin{bmatrix} C \\ \alpha COR \\ ßANT \\ \gamma NAS \\ \partial OBST \\ \varepsilon CONT \\ \zeta VOICE \end{bmatrix}$$

Reduction of double consonants

2.5.3. Application of the rules. The rules listed in 2.5.2. are certainly more adequate than an ad hoc list of collected reduction forms because they provide a model for the generation of any reduced segmental pronunciations in German, and since the algorithm may be stopped at different points, we get a great variety of alternative forms, all actually occurring in various styles of German. As has been pointed out in 2.2., further refinements and restrictions have to be introduced in accordance with semantic, syntactic and stylistic factors, e.g. different degrees of approximation to [ə] in the function word vowel reduction of rule (7), whereby the competing forms [e·ɐ, eɐ, ęɐ, ɛɐ] besides [ɐ] are generated from /e:r/. In certain styles and under particular semantic and syntactic conditions, some of these purely phonetic rules are blocked. These restrictions will have to be investigated and incorporated in the rule system. Ultimately, this will result in a number of modules for segmental reduction which represent different speaking styles and are internally coherent with regard to the stylistic level, combining all the rules that concur to generate a particular style.

Such a generative model is of great value in the development of text-to-speech systems, although it has very little explanatory power beyond its observational and descriptive adequacies, because it does not explain why these rules rather than others occur. But its segmental orientation and linear rule application constitute a powerful device for the successful transformation of strings of alphabetic symbols, through various levels of phonetic transcription, into acoustic patterns. It is irrelevant for this task that human speech production does not proceed along the same lines. What counts is the success of such systems in their practical application, and the English and German versions of INFOVOX, among others, testify to the feasibility of the approach. The concept of stylistic modules has also been introduced into the INFOVOX framework, first for English [27], and it is now being pursued for German.

The working of the rules presented in 2.5.2. will now be illustrated by applying them to some data of Table 1.

1. mɪtʰ de:m v'a:gən
   mɪtʰ ɖe:m v'a:gən (1)
   mɪtʰ ɖəm v'a:gən (6)
   rule (6) is blocked in [mɪt]
   mɪtʰ ɖm v'a:gn (7a,b)

mɪt	d̥m	v'a:gn	(11)
mɪp	b̥m	v'a:gn	(14)
mɪp	b̥m	v'a:gŋ	(15)
mɪ	b̥m	v'a:gŋ	(16)
mɪ	bm	v'a:gŋ	(17)
mɪ	mm	v'a:ŋŋ	(18)
mɪ	m	v'a:ŋ	(19)

2. ʔe:ʁ hatʰ mi:ʁ gəh'ɔlfən

e:ʁ	hatʰ	mi:ʁ	gəh'ɔlfən	(4)
ɛʁ	hətʰ	məʁ	gəh'ɔlfən	(6) modified
ɛʁ	hətʰ	məʁ	gəh'ɔlfn	(7a)
ɛʁ	hətʰ	mɐ	gəh'ɔlfn	(9)
ɛɐ	hətʰ	mɐ	gəh'ɔlfn	(10)
ɛɐ	hət	mɐ	gəh'ɔlfn	(11)
ɛɐ	ət	mɐ	gəh'ɔlfn	(12)
ɛɐ	t	mɐ	gəh'ɔlfn	(13)
ɛɐ	p	mɐ	gəh'ɔlfn	(14)
ɛɐ	b	mɐ	gəh'ɔlfn	(17)

Rules (18), (19) are blocked in [ɛɐbmɐ] (although they are applied in [mɪbm] of 1.) because the syntactic cohesion between the auxiliary verb 'hat' and the dative pronoun 'mir' is weaker than between the preposition 'mit' and the article 'dem'.

3. PHONETIC EXPLANATIONS

In spite of the usefulness phonological observations and generative rules can be put to in, e.g., text-to-speech systems, they do not explain the occurrence of reduction phenomena because they do not refer them to general principles of speech behaviour that determine certain processes and rule out others. To gain these insights into the ways speech functions phonetically, and thus to achieve explanatory adequacy we have to turn to the physiological, articulatory and perceptual constraints of speech and to the social conditions that impose selection and codification on biological potentials. I shall be concerned solely with the former, and shall restrict myself to a discussion of only a few rules under these general phonetic aspects, namely (1) vowel reduction in function words and [ə] shortening, (2) deletion of [ə] and aspiration, and assimilation of place, (3) shortening of consonants: nasalisation, lenition of stops and reduction of geminates.

In dealing with phonetic processes rather than changes of strings of phonetic symbols in a sequence of rules, we can also avoid a serious defect of generative phonology, namely the decomposition of a unitary process into a series of segmental steps. For example, the change from [kʰən] to [kŋ] is achieved by the reorganization of articulatory gestures which eliminates an opening-closing movement involving two articulators - the tongue dorsum and the tongue apex -, replaces it by a long oral closure of the dorsum and transfers the stop release to the velum. This new coordination of articulatory structures and processes results in the simultaneous deletion of aspiration, schwa and apical

closure, which is misrepresented by the segmental sequence [kʰən] → [kʰn] → [kn] → [kŋ] provided by the rules.

3.1. Vowel reduction in function words and [ə] shortening

In unstressed function words the distances the articulators travel are reduced to spaces closer to their neutral positions. This results in schwa-like vowel productions, which are at the same time shorter than the unreduced forms they are related to because of the shorter trajectories into and out of the more central vowel targets and because of the general shortening in unstressed position. This follows from the stress-timing principle of a language such as German, i.e. from the tendency to make stressed syllables follow each other at similar intervals [28]. Although this isochrony cannot be complete, it is a strong factor in the language, achieved by the compressibility of function words, and of unstressed syllables in general, especially those containing [ə].

It has been shown [28,29] that [ə] adjusts its duration reciprocally to the duration of a preceding stressed syllable: it is shorter after long than after short syllables. In the phonetic structure C + ə + NASAL, the durational variability of [ə] may be even more extreme and result in the total elimination of the vowel when velic opening and oral occlusion for the nasal are so much advanced in time that they are established at the offset of the preceding C. As regards the timing of nasal offset, it may be equally advanced, or it may stay the same. In the former case, the total duration of the sequence is decreased by curtailing the movement in and out of [ə]; in the latter case, the deletion of [ə] is compensated for by a lengthening of the nasal. Thus the structure C + ə + NASAL + ə may either be reduced to one syllable or remain disyllabic with a syllabic nasal (e.g. 'die verbotene Partei' "the forbidden party" [tʰənə] → [tnə], [tn̩nə]). This temporal plasticity of unstressed syllables is a strong indication of a tendency towards isochronous timing.

3.2. Deletion of [ə] and aspiration, and assimilation of place

In addition to the durational variability of [ə] discussed in 3.1., a reorganization of articulatory gestures may take place in the phonetic structure STOP or NASAL + ə + NASAL if there is not a word boundary before the second nasal [n] or [m]. In such a non-initial position in the word, where articulations tend to be temporally less well defined and less precise (as is also evidenced by sound changes affecting final rather than initial consonants, cf. [15]), the closing movement for the nasal may be completely integrated into the preceding consonantal gesture. This is achieved in two ways:

(a) The oral closure for the final nasal is advanced to such an extent that coarticulation results, i.e. partial overlap of two closures. So the labial occlusion precedes the dorsal release in the type D examples of Table 5, whereby the schwa vowel and also the aspiration are deleted. In the type E examples of Table 5, an opening-closing movement between two identical closure places is simply cut out,

without any further adjustments of the articulators.

TABLE 5. STOP (+STOP) + ə + NASAL, NASAL (+ STOP) + ə + NASAL combinations in German

A

labial + apical

[bən] → [bm] 'eben' ("even"), but: 'ebene' (inflected) [bnə], [bm̩nə]
[pʰən] → [pm] 'Lappen' ("cloth")
[ptʰən] → [pm] 'behaupten' ("to assert")
[mən] → [mm] 'kommen' ("to come")
[mdən] → [mbm] 'Hemden' ("shirts")
[mtʰən] → [mpm] 'die Beamten' ("the civil servants")

B

apical + labial

[dəm] → [bm] 'mit jedem' ("with everybody")
[tʰəm] → [pm] 'mit fettem Speck' ("with greasy bacon")
[nəm] → [mm] 'mit schönem Geschwätz' ("with nice blether")

C

dorsal + apical

[gən] → [gŋ] 'Regen' ("rain"), but: 'gelegene' ("situated", inflected) [gnə], [gŋnə]
[kʰən] → [kŋ] 'trocken' ("dry"), but: 'trockene' (inflected) [knə], [kŋnə]
[ŋən] → [ŋŋ] 'die langen Hosen' ("the long trousers")

D

dorsal + labial

[gəm] → [gm] 'mit ewigem Geschwätz' ("with continual blether")
[kʰəm] → [km] 'mit welkem Gras' ("with dried-up grass")
[ŋəm] → [ŋm] 'mit langem Gesicht' ("with a long face")

E

apical + apical, labial + labial

[dən] → [dn] 'leiden' ("to suffer"), but: 'geladene' ("invited", inflected) [dnə], [dn̩nə]
[tʰən] → [tn] 'leiten', ("to lead"), but: 'verbotene' ("forbidden", inflected) [tnə], [tn̩nə]
[nən] → [nn] 'nennen' ("to name")
[bəm] → [bm] 'mit gelbem Papier' ("with yellow paper")
[məm] → [mm] 'mit dummem Geschwätz' ("with stupid blether")

(b) In the type A and type B examples of Table 5 the apical occlusion is superseded by the dominant labial or dorsal one, which is established at the beginning of the sequence and kept right to the end, provided the structure C + ə + NASAL is clearly final, i.e. followed by a consonant or a word boundary, not by a vowel. In the latter case, the articulatory restructuring either follows (a), if [ə] is deleted and the nasal stays non-syllabic (e.g. 'ebene' ['e:bənə] → ['e:bnə]), or - if a syllabic nasal develops (see 3.1) - it follows (b) as far as the nasal syllable nucleus, but leaves an

apical nasal off-glide to the following vowel (e.g. 'ebene' ['e:bənə] → ['e:bm̩nə].
The release of a stop is taken over by velic action. If its timing, as well as that of voice onset, stay the same as in the unadjusted pronunciation, a fortis stop will not have nasal aspiration, because the lowering of the velum and voice onset only occur after the aspiration phase. This in turn means that the fortis stop closure duration is longer before nasal than before oral plosion, which is supported by empirical data.

TABLE 6. STOP, NASAL # STOP, NASAL combinations in German

A

labial + dorsal, dorsal + labial

[p#g] 'abgeben' ("to hand over")
[p#k] 'abkaufen' ("to buy from")
[k#b] 'Deckblatt' ("cover")
[k#p] 'Packpapier' ("wrapping paper")
[m#g] 'umgehen' ("to go round")
[m#k] 'rumkriegen' ("to win over")
[ŋ#b] 'Sprungbrett' ("diving board")
[ŋ#p] 'Rangplatz' ("rank")
[k#m] 'zurückmelden' ("to report back")
[ŋ#m] 'rangmäßig' ("by rank")

B

labial + apical, dorsal + apical

[p#d] 'abdrehen' ("to turn off")
[p#t] 'abtreten' ("to retire")
[k#d] 'zurückdrehen' ("to turn back")
[k#t] 'zurücktreten' ("to resign")
[m#d] 'umdrehen' ("to turn over")
[m#t] 'rumtreiben' ("to flit around")
[ŋ#d] 'Gangdecke' ("corridor ceiling")
[ŋ#t] 'Jungtier' ("young animal")
[p#n] 'abnehmen' ("to lose weight")
[k#n] 'zurücknehmen' ("to take back")
[m#n] 'kaum noch' ("hardly")
[ŋ#n] 'das ging nicht' ("it did not work")

C

apical + labial, apical + dorsal

[t#b] → [p#b] 'mitbringen' ("to bring along")
[t#p] → [p#p] 'mitpfeifen' ("to join in the whistling")
[t#g] → [k#g] 'mitgehen' ("to go with")
[t#k] → [k#k] 'mitkommen' ("to come with")
[n#b] → [m#b] 'anbringen' ("to attach")
[n#p] → [m#p] 'Bahnpreise' ("train fares")
[n#g] → [ŋ#g] 'angeben' ("to declare")
[n#k] → [ŋ#k] 'ankommen' ("to arrive")
[t#m] → [p#m] 'mitmachen' ("to join")
[n#m] → [m#m] 'anmelden' ("to register")

TABLE 6, continued

	D
	labial + labial, apical + apical
[p#b]	'abbitten' ("to apologise")
[p#p]	'abputzen' ("to clean")
[t#d]	'Raddampfer' ("paddle-streamer")
[t#t]	'mittanzen' ("to join in the dancing")
[k#g]	'zurückgeben' ("to give back")
[k#k]	'zurückkehren' ("to return")
[p#m]	'abmachen' ("to take down")
[t#n]	'mitnehmen' ("to take along")
[m#m]	'Strommenge' ("amount of electricity")
[n#n]	'annehmen' ("to accept")

The two types of articulatory restructuring also occur in sequences of stops and nasals across word boundaries. (a) is represented by the type A, B and D examples, (b) by the type C examples of Table 6. The structures of Table 6 differ from those of Table 5 by having a word boundary before the second consonant. Since initial consonants are articulated more precisely than final ones the articulatory reorganization only affects the first, not the second consonant. Otherwise the principle is the same: the apical occlusion is cancelled and superseded by the dominant labial or dorsal one, which is kept right through the sequence thus creating a new integrated consonant gesture. This implies that the release and aspiration of a stop in first position are suppressed, or contrariwise, the articulatory adjustment does not take place if aspiration is present.

The following restrictions apply to the articulatory reorganization in (b):

(1) Only stops and nasals are affected; fricatives do not assimilate (e.g. 'Ausfahrt' ("exit") and 'Auffahrt' ("entry") are always distinguished as [sf] and [(f)f]).
(2) Only apicals are changed; i.e. the sequences LABIAL # DORSAL and DORSAL (#) LABIAL stay unaltered.
(3) Apicals in APICAL # LABIAL, DORSAL are assimilated, whereas the sequences LABIAL, DORSAL # APICAL are not affected.
(4) Apicals in APICAL + ə + LABIAL NASAL and in LABIAL, DORSAL (+ APICAL) + ə + APICAL NASAL are assimilated.

The questions that have to be answered with regard to these restrictions are:

- Why are apical, rather than labial or dorsal gestures eliminated?
- Why is this process restricted to stops and nasals?
- Why does it only occur <u>before</u> labials and dorsals across word boundaries and not to stops <u>after</u> labials and dorsals?

Some of the answers are found in speech production, others in acoustics and perception.

Speech articulation makes continuous use of dorsal tongue and of lip movements in temporally varying ways. Superimposed on these continuously ongoing basic articulatory processes are additional apical

tongue movements in certain limited cases, mainly in consonants. Tongue dorsum and lip gestures, in close connection with jaw movements, constitute large, global processes, associated with, e.g. the large extrinsic tongue muscles. Tongue apex articulations, on the other hand, require much more finely controlled and more precisely tuned, and therefore also more costly, adjustments, linked with the smaller intrinsic tongue muscles. When, for perceptual reasons, the fine control is not absolutely necessary and can thus be neglected without harm to the communicative goal, it may be dispensed with under certain situational conditions of, e.g., higher speech rate or relaxed speech, when there is less time for finer control or when the energy expenditure per unit time [9] is reduced to the minimum necessary for a successful speech act. Thus, it is the additional, occasional and special apical gestures, requiring greater precision of timing and muscular coordination than the basic, continuously present labial and dorsal movements, that are weakened and eliminated. This reference to an economy of speech effort within the physiological conditions of the vocal apparatus can explain why only sequences containing apicals are affected by these assimilation processes, and why they do not result in the preservation of the apicals. Thus type D of Table 5 and type A of Table 6 are only coarticulated, not assimilated in either direction, and types A, B, C of Table 5 and type C of Table 6 show the assimilation of apicals to labials and dorsals, not vice versa.

Furthermore, these assimilations do not affect word and syllable initial apicals because especially the initial position in a word has a high signalling value for a listener and thus demands greater articulatory precision from a speaker than the final position. There are thus stronger and more numerous cues as to the identity of place of articulation, particularly for stops, which are differentiated by spectral characteristics of the burst and (in the case of voiceless ones) of the aspiration, over and above the differences in formant transitions. Thus, whereas type C of Table 6 shows assimilation, type B does not, and although there is progressive assimilation in types A and C of Table 5 (besides regressive assimilation in type B), it only applies to nasals and unreleased stops, and an apical gesture stays if a vowel follows. So, we get 'eben' ['e:bm], but 'ebene' ['e:bnə] or ['e:bm̩nə], and always 'Akt' ("act") ['akt^{h}], 'Abt' ("abbot") ['apt^{h}], 'Beamter' ("civil servant") [bə?'amt^{h}ɐ], although [mpm] without oral release and aspiration of [p] is possible in 'Amtmann' ("head of administrative office") and 'Beamten' ("civil servants").

Finally, fricatives are not assimilated under any conditions, because they are acoustically and auditorily far more distinct than nasals and unreleased plosives with regard to place cues so that their articulatory reduction would be too salient and is, therefore, not tolerated.

It has been argued that the synchronic place assimilation processes observable in German can be connected with an articulatory restructuring due to a minimization of energy expenditure which limits the extent of movements and reduces the number of moving organs involved in speech production. So in 'mit dem' becoming [mɪpm] the apical gesture is eliminated altogether and replaced by a labial occlusion, which has

to be carried out anyway, and the lowering of the velum, which is necessary for the nasal consonant, now at the same time takes over the plosive release and thus dispenses with an oral opening and closing movement. But all these articulatory reductions are checked by the perceptual demands of the communicative situation. They are only accepted (1) if they bear an auditory similarity to their points of departure and (2) if the situational context does not force the speaker to rate the cost of a misunderstanding or a break-down of communication very high.

In view of this acoustic and auditory corrective, it may be objected that these reduction phenomena are not primarily caused by physiological and articulatory conditions, but are entirely constrained in the acoustic and auditory domains. Ohala has voiced such an opinion with regard to historical sound change involving places of plosives in, e.g., Lat. octo - Ital. otto, Lat. aptu - Ital. atto [13,15], where he assumes coarticulatory adjustments which, because of their acoustic and auditory similarity, are mistaken for apical geminates by the listener and then introduced into production. But I think these cases are not comparable at all to the synchronic processes found in German and in lots of other language, including English. Coarticulated [dm] in 'jedem' is certainly very similar to [bm] and may be mistaken for the latter by a listener, but the same applies to coarticulated [gm] in 'regem' ("alert", inflected) and assimilated [bm]. However, the former process occurs in synchronic assimilations, the latter does not. Similarly, coarticulated [tk] in 'mitkommen' or coarticulated [kt] in 'wegtun' ("to remove") are very similar to [kk] and [tt], respectively, but again only the former constitutes a synchronic reduction process. So there must be something beyond acoustic and auditory similarity that constrains the observable productions. And it is at least very plausible that the driving force lies in speech production itself and in a general economy of effort principle that simplifies complex articulations, e.g. apical gestures, whenever the demands of communication do not impose extra precision on speech production. This means that synchronic reduction processes and diachronic sound changes are not always reducible to the same causes, the former being primarily determined by physiological and articulatory constraints on variability in the speaker, the latter more by transmission from speaker to hearer and by the tranformation of auditory impressions into articulations.

3.3. Shortening of consonants

The nasal assimilations of rule (18) are tied to lenis stops, which have short closure durations. If in fast or relaxed speech the raising of the velum for a stop before an immediately following nasal consonant is weakened because the trajectories are shortened, the short stop closure may be decreased still further and eliminated altogether. This does not happen in fortis stops outside function words, because here the closure, and therefore the temporal safety zone, is much longer. What may happen, however, is a lenition and voicing through a shortening of the closure duration.

In unstressed function words, articulatory movements are weakened

even more, resulting in reduced closure durations and less firm contacts for voiceless stops so that passive voicing may continue through the occlusion. Thus 'mit dem' [mɪpm] may change to [mɪbm], and this lenis stop may then be subject to nasal assimilation. The same applies to content words that have become devoid of meaning in set phrases, such as adjectives in greetings, e.g. 'guten [gʊn] Tag'. The fact that [mɪpm] may develop to [mɪm] whereas 'Lappen' always retains a stop closure can therefore find its explanation in a greater reduction of articulatory energy expenditure under lack of stress, and in the higher probability of lenis stops, rather than the much longer fortis ones, losing their closure before nasals.

Geminate consonants that occur across word boundaries or as the result of [ə] deletion are shortened to the durations of single consonants. This is a language-specific process in German of very high frequency and is the more complete the faster and/or the more relaxed speech production is. This process can also be related to a minimization of energy expenditure, but whereas the reductions discussed in 3.1. and 3.2. are very wide-spread and, for instance, also apply to English, geminate shortening seems to be more restricted.

4. CONCLUSION

It will have become clear after this presentation and interpretation of reduction rules in German that the phenomena of articulatory weakening in fluent colloquial speech in German can, at least partly, be explained with reference to a criterion of motor economy in relation to the demands of the communicative situation. The vocal apparatus is not put to more effort than is necessary in order to maintain the linguistic contrasts in the particular listener-oriented goal. Its tendency to reduce articulatory movements to a minimum is checked by perceptual and social constraints, of which only the former have been the subject of this paper. The listener decides whether reductions are permissible in certain speech situations or whether they interfere with the transmission of information, and the linguistic group judges the stylistic and social acceptability. To explore further the biological foundations of speech production and perception as well as their integration with sociolinguistic theories of sound variability is a challenging task for phoneticians, and reduction phenomena are a particularly rewarding area for trying out new, unorthodox, and even "un-linguistic" ways of dealing with speech and language.

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