# Articulatory dynamics of vowels and consonants in speech communication[1]

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**Abstract**

This paper provides a statistical account of schwa elision and vowel nasalization, and of nasalization and deletion of plosives in a large corpus of German spontaneous dialogues in comparison with an equally large data base of read speech (sentences and texts) from large groups of North German speakers. The phonetic variability of these phrase-level processes is projected onto the articulatory dynamics in global opening and closing gestures, which are taken to be basic phonetic structures of speech communication. Trends for gesture reorganization are derived from statistics, and related to external control factors of word boundary, word class, speech style as well as internal phonetic conditions of gestural make-up and of reduction of articulatory complexity. These synchronic facts of one language are compared with parallel instances from other languages and linked to congruent diachronic data of sound change, thus laying the foundation for generalisable phrase-level patterns of human speech production.

## 1. Diachronic perspectives of phonetic variability: historical sound change

Voltaire defined etymology as "une science où les voyelles ne font rien et les consonnes fort peu de chose". Looking at the sometimes distant spelling - sound relationships of present-day English place names one may feel inclined to agree with the French philosopher's biting remark. Especially the phonetically uninitiated, be they linguists or not, can see nothing but the whims of an individual case history of sound change when they come across the name of the castle and hamlet near Chester in Cheshire, England: ***Cholmondeley*** **[ˈtʃʌmlɪ]**. This name has preserved Middle English spelling. Its written form presumably represented the sound values of orthographic letters in Middle English quite systematically and corresponded to a pronunciation somewhat like **[ˈtʃɔlmɔndəleɪ]**. The final syllable is connected to Old English ***le(a)h*** 'lea (=pastureland)' and its Middle English forms ***leigh***, as well as ***-lei, -lai*** in place names (Jordan 1934:109; cp. *Grindlea*, *Grindly* (= 'green lea') and *Wesley* (= 'west lea')), i.e. the name means 'Cholmund's lea' (Horn/Lehnert 1954: 1180). The Middle English spelling *leigh* is kept in another place name of the same origin and with the same present-day pronunciation in Devonshire ***- Chulmleigh***. In these place names the sound changed in historical evolution over more than a millenium, but the written

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forms were handed down unchanged in their first and/or second parts from medieval times through the generations.

Is this sound change ad hoc, tied to this individual word, or does it fit into general phonetic patterns of speech production and perception? The Neogrammarians would have favoured the second alternative, and would have done so most emphatically, because they established a new scientific study of language by not just looking for regular patterns of historical sound change in genetically related languages, but by postulating exceptionless physical sound laws, which may only be blocked by other laws, or by analogy and lexical borrowing (Osthoff & Brugman 1878), and they tried to capture these phonetic modifications over time through minute instrumental analyses of synchronic variation. L'Abbé Rousselot wrote a two-volume compendium "Principes de phonétique expérimentale" (1897-1901) and a monograph "Les modifications phonétiques du langage, étudiées dans le patois d'une famille de Cellefrouin (Charante)" (1891). This research paradigm was later pooh-poohed as atomistic positivism, lacking the concept of sound systems of linguistic structuralism. Of course, these researchers' poor methodology and naive confidence in instrumental records did not help their cause. But I think nevertheless that a grave injustice has been done to their work.

I would like to show in this paper how the application of modern data processing techniques to this old question put forward by the Neogrammarians can help us solve the relationship between synchronic variation and diachronic change, by reducing both to the same phonetic driving forces of speech communication in short and long term perspectives and explaining them with reference to constraints of speech production and perception of homo loquens in communicative situations within sociolinguistic environments. The procedure also implies a redressing of the balance between the structural principle in the segment-dominated approach of many paradigms in phonology, on the one hand, and the phonetic principle in the parameter-based analysis of constituents of larger production and perception patterns, on the other.

## 2. Reorganization of opening-closing movements in speech

As a point of departure, the discussion can refer to the founding father of the International Phonetic Association, Paul Passy, who provided an account of the general characteristics of phonetic change in his PhD thesis at the Sorbonne, "Étude sur les changements phonétiques et leurs caractères généraux" (Paris 1890). Passy puts forward very modern views on phonetic principles in speech communication under synchronic and diachronic perspectives, which predate Lindblom's H&H theory (Lindblom 1990, Kohler 1979) by several decades:

"...des tendances phonétiques que nous avons constatées, se dégagent bien nettement deux principes fondamentaux:
1° Le langage tend constamment à se débarasser de ce qui est superflu.
2° Le langage tend constamment à mettre en relief ce qui est nécessaire.
...tous les changements ... ont pour résultat une économie dans l'activité des organes. ... On parle pour être compris ... Tout ce qui est nécessaire pour être compris et bien compris, on le conserve soigneusement, on l'accentue, on l'exagère; le reste, on le néglige, on le laisse aller, on l'omet." (pp. 227-229)

An essential component of this economy principle is the reorganization of articulated speech, whose characteristic feature is the alternating temporal sequencing of decreasing and increasing

stricture formation of the vocal tract. These are the ***opening and closing gestures*** of connected speech, which may follow a direct transition from a contoid to a vocoid articulation (Pike 1943) or vice versa, as in [tin], or may move through a sequence of contoid configurations to or from a vocoid, or through a vocoid series, on a scale of increasing vocal tract opening or closing, respectively, as in [tʃɪn] or [graɪnd], and may also involve more than one articulator. The global opening and closing gestures of the vocal tract as well as their synchronization and sequencing may be regarded as the primary constituents of speech production. Their reorganization entails a series of adjustments in vocoid and contoid targets, which range from vowel centralization and elision to consonantal stricture changes, manner and place assimilations (nasalization, labialization etc.) and deletions, in all cases reducing the magnitude, the number or the timing of opening and closing gestures as well as the articulators involved. Phonological vowels and consonants are integrated into these articulatory dynamics, and coarticulation and all types of assimilation and reduction of speech movements are a natural fall-out from this global temporal organization, in language-independent as well as in language-specific tenedencies. The segmental representations of historical language records in alphabetic writing, therefore, have to be translated into larger articulatory movements, from which they are phoneme-type abstractions for an economic reduction of languages to writing.

Applying these principles to the historical sound change in the Cheshire and Devonshire place names from Middle English to the present day, we can argue as follows. In the unstressed medial second and third syllables the openings into the vowels would show typical undershoot, and eventually tend towards schwa, as is so characteristic of English unstressed non-final vowels generally. But the narrowing of opening-closing movements does not stop there: the opening into the vowel may be absent altogether, as is evidenced by modern English *totally*, where the central tip or blade contact with the alveolar ridge may be unbroken, albeit with a syllabic lateral; but even that may be reduced in natural connected speech. So the global articulatory pattern represented by the linear segmental sequence [ndəl] in the place names would naturally reduce to a continuous apical/laminal closure, only changing from complete to central contact. In this articulatory constellation the timing of velic opening-closing is variable, resulting in presence or absence of a stop, as in the personal names *Fin(d)lay*, or in words like *friendly*, or with the opposite process of plosive insertion in *Grindlea* (= 'green lea').

The opening-closing movement of the second syllable follows the same pattern, with interlocking of labial and apical/laminal closures, or even just one closure, executed by one of the two active articulators, usually by the dominant labial one (Kohler 1990). So [mlɪ] instead of [məndəlɪ] in the second and third syllables of the place name is a natural development in speech production constrained by a reorganization of opening-closing gestures to reduce their extent and the participating articulators under lack of stress in medial syllables.

The Old and Middle English forms *le(a)h* and *leigh*, respectively, as well as the spelling *Chulm-leigh* in the Devonshire place name, refer to a final dorsal fricative (cp. Old High Germ. *loh*, *-loh(e)* in German place names, e.g. *Hohenlohe*). This is parallelled in O.E. *heah*, M.E. *heigh*, Mod. E. *high*, Scottish dialect of Buchan [hiç], Germ. *hoch*, *hohe*. The various forms of *high* in English show that the dorsal fricative in the syllable coda was fronted after front vowels in English, lost its fricative stricture in a curtailing of the dorsal closing movement and then joined the diphthongization of M.E. [iː]. In unstressed *-leigh* in place names this stricture reduction occurred quite early, hence the Middle English spellings *-lei*, *-lai*, as well as *-ley* in *Cholmondeley*.

Lastly, as regards the first opening-closing gesture of the Middle English form of the place names, we may refer to the absorption of apical laterals in a back vowel to labial or dorsal movement in the history of English, as in *palm*, *holm*, *Holborn*, *chalk*, *folk*, and to an [ɔ] > [ʌ] change in a fair section of the English vocabulary, e.g. *Monday, month, brother, mother.*

Thus the modern pronunciation of *Cholmondeley*, in relation to its medieval spelling, becomes transparent as the result of freezing one spoken form from among a large array of phonetic variability of a word occuring in connected speech communication. This variability is, on the one hand, constrained by the reorganization of opening and closing gestures for greater articulatory economy on the part of speakers, but since speech is addressed to listeneres, who require situation-related perceptual distinctivity for message decoding (Lindblom 1990), the opposed tendencies of facilitating speaking and listening must strike a balance, dependant on context. That means that articulatory reduction is tolerated the more easily by the speech community the less it deviates perceptually from more elaborated speech production. The acoustic-auditory corrective of gesture simplification applies, for instance, to place assimilation of nasals to preceeding plosives/nasals in syllabe-final position (Kohler 1990): in *Cholmondeley* as well as in German *-en* words (see 3.3), the intrinsic place cues for the distinction of [n] from [mŋ] are weak, especially so when they are not supported by formant transitions into a following vowel. Gestural variability, resulting from the economy of effort principle, is thus enhanced or restrained by perceptual boundary conditions.

Finally, the selection, by a speech community, of one, or possibly more than one, specific phonetic form from the class of perceptually delimited production variants of a word as its canonical representative(s), is governed by social factors and leads to historical lexicalization. This is what happened in the case of the place names *Cholmondeley* and *Chulmleigh.* Similarly, German *zu dem* 'to the' fluctuated between [tsu dem] and [tsʊm] under conditions of gesture reduction, in different phonetic, syntactic and situational contexts, e.g. speaking styles, but one form became lexicalized, namely [tsʊm], by the side of [tsu dem] and its various contextual satellites. Lexicalization means that although the form has its origin in phonetic constraints of contextual environments in the widest sense, it is eventually detached from these conditions and becomes a new name or lexical item in its own right through sociolonguistic selection. In the case of the complete parallel of German *mit dem* 'with the' - from [mɪt dem] to [mɪm] - the lexicalization process of [mɪm] is not complete yet.

In the theoretical framework presented here, phonetic variability is considered to be controlled by a complex interplay of articulatory economy in speech production, of perceptual distinctiveness for speech recognition and of social acceptance in speech communication. At the phrase level, the contextual phonetic variation of speech is regarded as being primarily tied to production. It is seen as the statistical outcome of production along a scale of articulatory expenditure, driven by the linguistic message, the speech organs, the demands of the situation and the social and individual attitudes. Variable effort results in opening and closing gestures that vary in magnitude, timing and participating articulators in set physical patterns. Perceptual factors only intervene in so far as the speaker has to produce signals that are distinctive enough for a listener to decode. And as listeners' needs are proportional to the 'a priori' probabilities of perceptual confusion in different communicative situations, the latter control speech output, all the more the greater the cost speakers attribute to a failure of communication (Kohler 1979).

This theoretical position differs from Ohala's, which associates a more active role with the acoustic-auditory domain in, e.g., place assimilation (Ohala 1990): the articulatory changes [pt], [kt] > [tt] would be due to "less experienced listeners lacking the perceptual ability to integrate the weaker place cues [of [pk] as against [t]] in the VC transition" (p. 265). Kohler (1990: 87ff) has referred to articulatory factors as the primary source of change, supplemented by a perceptual corrective, in explaining synchronic contextual place assimilation of plosives at the phrase-level (across word and morpheme boundaries), and has pointed out that the regressive apical assimilations, although perceptually very similar to the unassimilated forms, do not occur in connected German speech, whereas the equally similar [tp] > [pp] and [tk] > [kk] do. "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." (p. 89) Of course, Ohala's statement was not based on synchronic contextual phrase-level assimilation, but on historical sound change of the type Latin *scriptu*, *nocte* > Italian *scritto*, *notte*, i.e. on canonical form selection (lexicalization) by the speech community and its transmission through the generations. In this selection process the perceptual factor is bound to play an additional prominent role, and Ohala's position and the one advocated here converge.

## 3. Linking historical segmental spellings cross-linguistically with the temporal organization of synchronic acoustic records

### 3.1 Methodological considerations

What was said about the alphabetic abstraction from speech in the diachronic perspective also applies to the making of segmental phonetic transcriptions, e.g. within the IPA framework (IPA 1999). In the extreme case of a phonemic-type transcription Pike's 'technique for reducing languages to writing' (Pike 1947) also holds as a special case of abstraction for economy of symbolization at the isolated word level. In the case of narrow phonetic transcriptions within the same framework the basic, segmental character is kept, but various componential markers for, e.g., nasalization [˜], glottalization [ ̰], breathy voice [ ̤], secondary articulations of labialization, palatalization, velarization [ʷ][ʲ][ˠ], may be added to it. Even so, such a phonetic transcription is still a static symbolic abstraction from the signal dynamics of speech. However, both the phonemic and the more narrow phonetic transcriptions of synchronic speech data can be linked to the time courses of their acoustic records and analyses (speech wave and spectral analysis) in an interactive visual and auditory labelling procedure (cp. Zwirner's 'Zuordnung', Zwirner & Zwirner 1936).

The requirements for such an annotation procedure are a structured symbol inventory and systematic conventions for its use, including componential markers by the side of segmental ones, as part of a symbol-to-signal processing platform, nowadays within an electronic environment. If these are complemented by standardized canonical word representations and categories for modifying these in relation to the actual pronunciations to be labelled - deletions, insertions, replacements of canonical symbols - the labelling becomes a powerful tool for processing large speech data bases and integrating them into a structured data bank. Such a data bank then makes it possible to sort and access speech data via their symbolic categorizations, to perform classifications and statistical evaluations on the latter, and to analyse classes of speech records that have been selected for specific phonetic questions through their symbolic processing. So, for example, classes can be

formed automatically of all the instances of specific manner or place or phonation modifications or deletions in symbolically specified contexts. The link of the static symbolic abstractions with the dynamic speech signals in these classes not only allows quick access to, and analysis of, the latter but also the setting up of hypotheses about the variability of certain global patterns of articulatory dynamics in synchronic data of a particular language.

Such a research environment is provided by *xassp* (***A***dvanced ***S***peech ***S***ignal ***P***rocessor under the ***X*** Window System; IPDS 1997b) and by *KielDat* (Kiel data bank utilities; Pätzold 1997) as well as by the CD-ROMs of the *Kiel Corpus of Read/Spontaneous Speech* for Standard North German (IPDS 1994, 1995, 1996, 1997a). The labelling framework is basically linear segmental phonemic, with reference to the phonological elements of German, in modified SAMPA notation, but includes symbols for the glottal stop and for plosive release (+aspiration), as well as for componential elements, such as nasalization (**-~**), glottalization (**-q**) and a general marker of secondary articulation (**-MA**). In actual labelling of signal files by trained phoneticians, the broad phonetic segmental categories are linked to segments of the speech wave, i.e. signal durations are attributed to them. On the other hand, the narrow componential category additions for the symbolization of vowel nasalization (in the case of nasal consonant deletion), of glottalization instead of, or in addition to, glottal stops or plosives, and of secondary articulation residues (in the case of segment deletions) are associated with points in time, but are not given durations, i.e. they only refer to places in signals where the parameters symbolized by them occur, with unspecified extensions to their left and/or right (Helgason, Kohler 1996; Kohler 1994, 1999; Rodgers, Helgason, Kohler 1997). Further narrow phonetic features, e.g., specific places on the palate for tongue dorsum articulations, are ignored (e.g. [kgŋ] stand for dorsal, not velar). Segmental uncertainties in labelling are succeefully resolved (a) by applying a broad, rather than a very narrow, symbolization system, and (b) by the use of **-MA** and other componential markers, as they avoid the need for segmentation and segment categorization, but at the same time supply information on linguistically relevant 'suprasegmental' traces, and also allow a systematic renewal of connection with the speech files.

The label files generated with this processing platform do not have the status of descriptive accounts of the phonetics of connected speech in German, but are heuristic devices for systematically retrieving data from large databases for further data analysis, statistical evaluation and interpretation of a large spectrum of phonetic questions. For this goal, the construct of canonical forms is invaluable, and so are the constructs of segmental labelling, segment modification, segment deletion, segment insertion, as well as componential addition. They assure the grouping of extremely variable phonetic data round lexical items for comparative and context-sensitive symbolic processing, for easy and systematic access to the associated speech files and their analysis. Labelling is thus symbolic preprocessing of speech, facilitating repeated controlled speech wave examination.

Relying on these tools and constructs the question of variable articulatory dynamics in opening and closing movements of German connected speech will be discussed in the following sections with reference to the categories of schwa deletion, place assimilation, nasalization and deletion. Whereas the phonological frame of reference is by definition language specific, the phonetic interpretation of the articulatory dynamics of vowels and consonants is not, but connects the German data to the physical structures of the human vocal tract and to its articulatory constraints, as well as to the principle of economy along an H&H scale in speaker-hearer communication (Lindblom 1990).

This extra-linguistic reference makes it possible to link the similarly interpreted diachronic phenomena round the English place name, quoted initially, to the synchronic data base of German, and to buttress the interpretation of the historical sound changes through a symbol-signal connection in the synchronic data that is rooted in modern phonetic theory (Kohler, Pätzold, Simpson 1995) and thus has explanatory power which the attempts of the first experimental phoneticians lacked. As a first step, there will be a discussion of the phonetic variability that occurs in a structure that is very similar to the one found in the English place name: the phonetics of the word *eigentlich* ('really') in the spontaneous speech data base. Subsequent paragraphs will then deal with the overall statistics of schwa deletion, place assimilation, plosive nasalization and deletion in the data bases of read and of spontaneous speech and compare the results with reference to different stylistic levels and their demands on phonetic explicitness for speech communication. The two data bases used for this paper contain 31,382 (read) and 37,437 (spontaneous) lexical items, respectively.

### 3.2 Phrase-level phonetics of German "eigentlich" in dialogue

The German lexical item *eigentlich* represents the same type of opening-closing sequence as the English place name. The recorded forms of its multifarious phonetic manifestations in dialogue can be ordered into structural patterns of articulatory dynamics. They constitute the synchronic variability in parallel to diachronic lexicalization, and these two linguistic data domains can be linked under the same phonetic principles of human speech, independent of the individual language.

The canonical lexicon citation form of *eigentlich* is **[ˈʔaɪgəntlɪç]**, with a sequence of two opening-closing gestures in the second and third syllables **[gən]** and **[tlɪç]**. The word occurs 68 times in the Kiel Corpus of Spontaneous Speech, and its various phonetic realizations are related to the canonical form as the descriptive reference. There is not a single occurrence of a form containing schwa. There are 9 instances with dorsal and velic closures for [g]; 8 of these have dorsal adjustment for the nasal ([gŋ]), which in one case extends to the subsequent plosive ([k]). 56 cases have early velic lowering during the dorsal occlusion, i.e. no plosive [g], but only [ŋ], or [n], with articulator adjustment to the following opening-closing gesture. In the remaining three instances the velic lowering precedes the oral dorsal or apical occlusion, i.e. the vowel of the first syllable is nasalized, and there is no nasal consonant.

As regards the second opening-closing gesture, the plosive may be present as [t], or [d], with continued voicing in a short occlusion phase, or [k], with a carry-over of the dorsal articulator, or it may be absent, due to delayed raising of the velum in relation to the oral articulation, or, finally, it may be manifested by glottalization during velic opening (Kohler 2001). (The last-mentioned phonetic exponent is another example of productively triggered and perceptually enhanced gesture reduction: the most elementary stoppage or reduction of oral air flow is achieved by glottal closure or very low frequency pulsing, which is at the same time the most economical form since all supraglottal configurations can stay unaltered, but at the same time glottal stop or glottalization auditorily resemble a fortis stop.) In [lɪç] a very complex articulatory sequencing is needed: [l] requires back lateral opening and central front closure, for the remaining gesture it is the opposite. This reversal of oral strictures, particularly when it follows complete oral closure, demands high coordination, and is therefore easily reduced to more homogeneous movements for the sake of articulatory economy. Thus the lateral gesture is removed, and the dorsal tongue elevation, which is combined with it, is integrated into the palatality of the whole syllable. If the closing stricture at the end is

relaxed we get an approximant of a rather high front tongue position, instead of a fricative. The same development is found for the structure [ɪlç] of the word *Milch* 'milk' in Bavarian dialects. A recent example from English is *George W.* [ˈdʌblju] *(Dubya* [ˈdʌbjə]*) Bush.*

In the production of this German lexical item the sequence of two opening-closing movements involving two oral articulators - tongue dorsum and tongue tip - have to be coordinated with each other and with velic and glottal actions. The variability in the synchronization of these five components (number of opening-closing movements, two oral articulators, velic action, glottal activity) leads to a multitude of phonetic variants. In addition, laterality has to be inserted at a very specific point in the whole articulatory sequence for a less reduced form.

The most extreme form found in the records is [aɪŋɪ], where the two successive movements have been reduced to one that is incorporated into a global dorsal up and down gesture for the whole word, where velic lowering and raising intervenes round the extreme oral stricture (extending well into the vocoids on either side), and where modal voice is on from beginning to end. A less extreme reduction is [aɪnɪ], where the apicality of the second opening-closing unit is kept and not integrated into the global dorsal movement.

In [aɪŋɪ] the formation of a complete oral dorsal closure may be relaxed, leaving only nasalised vocoids instead of a nasal consonant: [ãĩĩ], where vocoid nasalization now fulfils a phonological function. This form may finally be shortened to [ãĩ]. The latter two realizations have not been found in the corpus, but are expected to have the potential of occurring.

Some of these diverging forms[2] occur within the same speaker under different contextual and prosodic conditions, such as speech rate and fluency. For example, speaker MAW in g42 has rather slow [aɪgŋnɪç] by the side of faster [aɪnɪ], and [aɪŋlɪç] with very weak [l]. In view of this large variability produced by the same speaker it is inconceivable from the point of view of a mental lexicon that these forms are different lexicalizations for this speaker which he accesses under different situational and contextual conditions. These forms must refer to the same lexical item in this speaker's mental lexicon, with phonetic adjustments under contextual and situational conditions, and statistical variation within the degrees of freedom in the synchronization of the articulatory components outlined above.

These degrees of freedom may be set at different values by different (groups of) speakers and may even define different coexistent 'canonical' forms for the same lexical items within a speech community. Thus for a small number of German speakers (e.g. elocutionists) the canonical form of *haben* 'have' may still be [haːbən], whereas for the majority it is [haːbm] (see 3.3), with [haːbən] being a reinforcement, yet for some speakers it may even be [haːm], with both other forms being reinforcements. These (groups of) speakers then start their contextual and situational adjustments from different canonical bases. What these different settings are we do not know, because we have pooled the variation across the whole speaker population. We would need sufficient data of phonetic

[2] Graphic signal representation and speech output of some *eigentlich* utterances referred to here can be found at the following URL:
www.ipds.uni-kiel.de/kjk/pub_exx/kk2001_1/kk_01a.html

variation in the same lexical items from individual speakers and then compare their ranges of phonetic manifestation. This is certainly a task for the future. But irrespective of this there is no denying the fact that we have to work with phrase-level adjustment rules beside phonetic lexical representations, no matter whether we deal with individual speakers or groups of speakers.

These phrase-level adjustment rules also have to include something like a reduction coefficient (Kohler 1991), whose value is set by a speaker or a group of speakers in accordance with the different demands of the communicative situation. As the lexical item *eigentlich* can become a modal particle, devoid of lexical meaning, this reduction coefficient can be very high, hence the large spread and the extreme degree of reductions found in the corpus. Given the same types and sequences of closing and opening gestures in other lexical items and given the same linguistic status of these items, the hypothesis is that the degree and variability of reduction is the same across this section of the vocabulary, i.e. it is assumed that the variation is not word-specific, but generalisable as a rule-governed process. The German word *irgendwie* 'somehow' is comparable to *eigentlich* in respect of gestural organization as well as phraseology and shows the same variety of gesture modification in the German Corpus of Spontaneous Speech. These data are, moreover, exactly parallel to the comparable Swedish lexical item *naturligtvis* ('naturally'), which ranges from [naˈtʰʉːɭɡ tviːs] via [naˈtʰʉːltviːs] and [naˈtʰʉːs] to [nats]/[nas].[3]

The quantification of this concept of a reduction coefficient is again an enormous task for the future. However, looking at the pooled data of a large population and data base, even without these finer specifications, can already give us important insights into phrase-level phonetics, and allow us to propose hypotheses about phonetic patterning in speech communication, which in turn enable us to link phonetic synchrony and diachrony.

### 3.3 Schwa elision and nasalization/deletion of plosives in German

Some of the phonetic patterns I have described in connection with German *eigentlich* come under the concept of lenition, which is well known from studies on historical sound change, and refers to the weakening of fortis to lenis plosives, of plosives to fricatives and of both to approximants, and to their complete disappearance in certain contexts (Helgason 1996). A special case is nasalization of plosives in nasal environments, particularly in 'plosive+schwa+apical nasal' after schwa elision, and nasal consonants may also disappear as oral occlusions but stay as nasalization in the vocoid environment. All these types of articulatory reduction exemplify the reorganization of opening and closing movements under the principle of economy.

#### 3.3.1 Variability of German poststress 'plosive+schwa+apical nasal' syllables

In the poststress sequence of 'plosive+schwa+apical nasal', schwa elision as a prerequisite for place assimilation and nasalization is very regular after lenis and fortis plosives in both speaking styles, but slightly less in read speech. Left-to-right place assimilation affecting the apical nasal after labial and velar plosives is also very frequent in both speaking styles, but again somewhat less in read speech. From a gestural point of view, the opening-closing movement in this type of articulatory structure is optimally simplified if the opening is not only eliminated but the gesture is limited to

[3] Personal communication from Olle Engstrand.

one oral articulator, either the lips or the tongue dorsum; in segmental terms this implies schwa elision and place assimilation of the following nasal. This reorganization of the opening-closing movement is restricted to word-final schwa syllables after stress. It does not apply to prefixed words like *genommen* [gəˈnɔmən] ('taken'), *benommen* [bəˈnɔmən] ('behaved'), where the execution of an opening-closing by two articulators is preserved, however much its extent may be reduced. Nor is it found when another opening gesture follows the poststress schwa syllable in the same word, as in *eigene* [ˈaɪgənə] ('own', adj., inflected), where the first schwa may get elided but the apical nasal, which starts a new opening gesture, stays, and if assimilation does occur the assimilated (dorsal) nasal is, in turn, still followed by an apical nasal, i.e. [ˈaɪgŋnə] with syllabic [ŋ], or even [ˈaɪŋnə] with plosive nasalization (see below), where the first nasal may or may not be syllabic. (The Corpus of Spontaneous Speech contains *eigenen* [ˈaɪŋnən].) Thus the condition for this articulatory simplification is that it applies to an integrated weak gestural unit, excluding the beginning of a subsequent gesture within a word.

Nasalization can take gesture reduction further by equalizing velic action across homorganic or heterorganic plosive-nasal sequences right-to-left, i.e. to the lowered position of the nasal. In the case of concomitant place assimilation, this completes the gestural integration. It is quite common in the lenis context, but far less so than the other processes, and it is a great deal more common in spontaneous than in read speech. It is rare for fortis in both speaking styles, and only occurs a little more frequently for /t/, e.g. in compound ordinal numerals with unstressed *-zehnten* [tseːnn] ('-teenth'), and in unaccented *guten* [gʊn] ('good (morning)') of greetings. The synchronization of velic opening and oral occlusion is more vulnerable for short durations of stop phases, either in lenis plosives or in unaccented (function) word reductions. Nasalization is most likely for the labial place, especially in the very frequent function word *haben* [haːm] 'have', and least likely for apical, in both speaking styles. Nasalization of alveolar lenis plosives is more commonly associated with function words, i.e. *werden* [vɛɐn]('will'), *würden* [vʏɐn] ('would'), *worden* [vɔɐn] ('(has/have) been' (+ past part.)). Table 1 gives an overview of schwa elision, place assimilation and plosive nasalization in 'plosive+schwa+apical nasal' syllables in the two German data bases.

These data suggest that schwa-less and at the same time place-assimilated forms have become the canonical lexical entries for the speaker group as a whole; the presence of schwa is a reinforcement, typical in a more formal reading style, rather than the absence being a reduction. But over and above this we have to reckon with phrase-level processes that are, among other things, triggered by phonetic environment and speaking style. The inflected word *-tägigen* in combination with numerals, e.g. *zweitägigen* ('lasting two days') has a sequence of two unstressed opening-closing gestures [gɪg] and [gən], involving the tongue dorsum and the tongue tip, which may, however, be conflated into a single dorsum gesture [gɪgŋ], whose opening phase is small and may be further reduced, resulting in [ggŋ], or even in [gŋ] with closure shortening in phrase-internal position. All these forms occur in the spontaneous speech corpus.

Table 1
Absolute frequencies of German final 'plosive+schwa+apical nasal' syllables and their subdivisions into lenis/fortis and 3 places of articulation as well as into f(unction)w(ords) and c(ontent)w(ords); relative frequencies of (a) schwa elision (-@) in each of these classes, (b) place assimilation in the non-alveolar cases of (a), and (c) nasalization in (a); separate for spontaneous and read speech
- refers to 'not applicable'

| | **spontaneous speech** | | | | **read speech** | | | |
|---|---|---|---|---|---|---|---|---|
| | **total, abs.** | **-@ %** | **ass %** | **nasal %** | **total, abs.** | **-@ %** | **ass %** | **nasal %** |
| **lenis** | 1309 | 98.5 | 95.0 | 38.9 | 1632 | 95.8 | 93.5 | 11.8 |
| fw | 224 | 99.6 | 98.8 | 55.8 | 262 | 99.2 | 93.2 | 8.4 |
| cw | 1085 | 98.3 | 94.2 | 35.3 | 1370 | 95.1 | 93.6 | 12.4 |
| **/b/** | 361 | 99.7 | 96.4 | 51.1 | 449 | 97.1 | 90.8 | 14.0 |
| fw | 154 | 100.0 | 98.7 | 70.1 | 69 | 97.1 | 97.0 | 13.4 |
| cw | 207 | 99.5 | 94.7 | 36.9 | 380 | 97.1 | 89.7 | 14.1 |
| **/d/** | 250 | 95.6 | - | 16.3 | 422 | 91.2 | - | 8.1 |
| fw | 52 | 98.1 | - | 27.5 | 114 | 100.0 | - | 4.4 |
| cw | 198 | 94.9 | - | 13.3 | 308 | 88.0 | - | 9.6 |
| **/g/** | 698 | 99.0 | 94.2 | 40.4 | 761 | 97.5 | 95.2 | 12.4 |
| fw | 18 | 100.0 | 100.0 | 16.7 | 79 | 100.0 | 89.9 | 10.1 |
| cw | 680 | 99.0 | 94.1 | 41.0 | 682 | 97.2 | 95.8 | 12.7 |
| **fortis** | 2030 | 98.7 | 90.0 | 6.9 | 742 | 95.3 | 77.5 | 4.7 |
| fw | 275 | 99.6 | 0.0 | 3.6 | 40 | 100.0 | 0.0 | 5.0 |
| cw | 1755 | 98.5 | 90.0 | 7.4 | 702 | 95.0 | 77.5 | 4.6 |
| **/p/** | 5 | 100.0 | 100.0 | 0.0 | 14 | 78.6 | 100.0 | 0.0 |
| fw | 0 | - | - | - | 0 | - | - | - |
| cw | 5 | 100.0 | 100.0 | 0.0 | 14 | 78.6 | 100.0 | 0.0 |
| **/t/** | 1989 | 98.7 | - | 7.0 | 643 | 97.5 | - | 5.1 |
| fw | 275 | 99.6 | - | 3.6 | 40 | 100.0 | - | 5.0 |
| cw | 1714 | 98.5 | - | 7.6 | 603 | 97.3 | - | 5.1 |
| **/k/** | 36 | 97.2 | 88.6 | 0.0 | 85 | 81.2 | 73.9 | 1.4 |
| fw | 0 | - | - | - | 0 | - | - | - |
| cw | 36 | 97.2 | 88.6 | 0.0 | 85 | 81.2 | 73.9 | 1.4 |

### 3.3.2 Nasalization and deletion of German plosives in other contexts

The nasalization of plosives is not limited to the schwa syllable contexts of 3.3.1: the German data bases also provide instances for post-nasal position, word-internally and across word boundaries. Inside words (e.g. *Nove<u>mb</u>er* [mb] > [mm], *wu<u>nd</u>erbar* 'wonderful' [nd] > [nn]), the percentage of nasalization of lenis plosives approaches that found in lenis-schwa-nasal syllables. Across word boundaries it is much smaller and shows a strong bias in unstressed function words, e.g. *in die* ('in the'). This reduction is practically absent in fortis plosives, due to the different timing constraints

of velic movement in relation to oral closing-opening gestures in the two plosive types. Tables 2 and 3 provide overviews of nasalization and deletion of lenis and fortis plosives, respectively, after nasals and fricatives, word-initially across boundaries, word-medially and word-finally, for the two German data bases. In the nasal context, complete deletion of the lenis plosive is less frequent than nasalization, and again more frequent inside words than across their boundaries.

Fortis plosives in word-initial position are almost never reduced in any form (nasalization, deletion), irrespective of the preceding context (NAS, FRIC). Word-internally, plosive realization again predominates, but deletion after nasal does occur with some frequency in the context before fricative or lateral, e.g. *ent<u>s</u>chuldigen* ('excuse'). *ganz* ('completely'), *em<u>p</u>fangen* ('receive'); *eigen<u>t</u>lich* ('really'), *hoffen<u>t</u>lich* ('hopefully'). It is in word-final position after nasal or fricative that deletion is quite regular, especially in unstressed function words, e.g. *und* ('and'), *ist* (is'), *nicht* ('not').

All the reduction processes of lenis and fortis plosives discussed in 3.3.2 are more prevalent in the spontaneous dialogues than in the read sentences and texts.

Table 2
Absolute frequencies of del(etion), nas(alization), plos(ive) for lenis plosive category after NAS(al), at initial W(ord)B(oundary), W(ord)M(edial) in c(ontent) w(ord) or f(unction)w(ord) outside word-final 'plosive+schwa+apical nasal' syllables; relative frequencies of realizations within each of the totals; separate for German spontaneous and read speech; - refers to non-existent structure

| | **spontaneous speech** | | | **read speech** | |
|---|---|---|---|---|---|
| | **WB** | **WM** | | **WB** | **WM** |
| | **NAS** | | | **NAS** | |
| **total** | 1666 | 586 | **total** | 1259 | 833 |
| fw | 861 | - | fw | 349 | - |
| cw | 805 | 586 | cw | 910 | 833 |
| **del** | 35 | 58 | **del** | 77 | 179 |
| % | 2.1 | 9.9 | % | 6.1 | 21.5 |
| fw | 28 | - | fw | 14 | - |
| % | 3.2 | - | % | 4.0 | - |
| cw | 7 | 58 | cw | 63 | 179 |
| % | 0.9 | 9.9 | % | 6.9 | 21.5 |
| **nas** | 265 | 253 | **nas** | 66 | 227 |
| % | 15.9 | 43.2 | % | 5.2 | 27.3 |
| fw | 223 | - | fw | 61 | - |
| % | 25.9 | - | % | 17.5 | - |
| cw | 42 | 258 | cw | 5 | 227 |
| % | 5.2 | 43.2 | % | 0.5 | 27.3 |
| **plos** | 1366 | 275 | **plos** | 1116 | 427 |
| % | 82.0 | 46.9 | % | 88.7 | 51.3 |
| fw | 610 | - | fw | 274 | - |
| % | 70.9 | - | % | 78.5 | - |
| cw | 756 | 275 | cw | 842 | 427 |
| **%** | 93.9 | 46.9 | % | 92.5 | 51.3 |

Table 3
Absolute and relative frequencies for fortis plosive category, also after FRIC(ative) & W(ord)F(inal)

| ***spont*** | **WB** | | **WM** | | **WF** | |
|---|---|---|---|---|---|---|
| | **NAS** | **FRIC** | **NAS** | **FRIC** | **NAS** | **FRIC** |
| **total** | 923 | 646 | 1617 | 1764 | 985 | 1896 |
| fw | 172 | 294 | 143 | 48 | 810 | 860 |
| cw | 751 | 352 | 1474 | 1716 | 175 | 1036 |
| **del** | 27 | 44 | 229 | 81 | 490 | 944 |
| % | 2.9 | 6.8 | 14.2 | 4.6 | 49.7 | 49.8 |
| fw | 6 | 29 | 2 | 0 | 446 | 688 |
| % | 3.5 | 9.9 | 1.4 | 0 | 55.1 | 80.0 |
| cw | 21 | 15 | 227 | 81 | 44 | 256 |
| % | 2.8 | 4.3 | 15.4 | 4.7 | 25.1 | 24.7 |
| **nas** | 0 | - | 4 | 0 | 0 | 0 |
| % | 0 | - | 0.2 | 0 | 0 | 0 |
| fw | 0 | - | 1 | 0 | 0 | 0 |
| % | 0 | - | 0.7 | 0 | 0 | 0 |
| cw | 0 | - | 3 | 0 | 0 | 0 |
| % | 0 | - | 0.2 | 0 | 0 | 0 |
| **plos** | 896 | 602 | 1384 | 1683 | 495 | 952 |
| % | 97.1 | 93.2 | 85.6 | 95.4 | 50.2 | 50.2 |
| fw | 166 | 265 | 140 | 48 | 364 | 172 |
| % | 96.5 | 90.1 | 97.9 | 100.0 | 44.8 | 20.0 |
| cw | 730 | 337 | 1244 | 1635 | 131 | 780 |
| **%** | 97.1 | 95.7 | 84.4 | 95.3 | 74.9 | 75.3 |

| ***read*** | **WB** | | **WM** | | **WF** | |
|---|---|---|---|---|---|---|
| | **NAS** | **FRIC** | **NAS** | **FRIC** | **NAS** | **FRIC** |
| **total** | 742 | 379 | 1061 | 1930 | 1203 | 1603 |
| fw | 105 | 79 | 32 | 313 | 622 | 574 |
| cw | 637 | 300 | 1029 | 1617 | 581 | 1029 |
| **del** | 22 | 18 | 219 | 48 | 448 | 442 |
| % | 3.0 | 4.7 | 20.6 | 2.5 | 37.2 | 27.6 |
| fw | 3 | 11 | 1 | 5 | 333 | 247 |
| % | 2.9 | 13.9 | 3.1 | 1.6 | 53.5 | 43.0 |
| cw | 19 | 7 | 218 | 43 | 115 | 195 |
| % | 3.0 | 2.3 | 21.2 | 2.7 | 19.8 | 19.0 |
| **nas** | 0 | - | 1 | 0 | 0 | 0 |
| % | 0 | - | 0.1 | 0 | 0 | 0 |
| fw | 0 | - | 0 | 0 | 0 | 0 |
| % | 0 | - | 0 | 0 | 0 | 0 |
| cw | 0 | - | 1 | 0 | 0 | 0 |
| % | 0 | - | 0.1 | 0 | 0 | 0 |
| **plos** | 720 | 361 | 841 | 1882 | 755 | 1161 |
| % | 97.0 | 95.2 | 79.2 | 97.5 | 62.8 | 72.4 |
| fw | 102 | 68 | 31 | 308 | 289 | 327 |
| % | 97.1 | 86.1 | 96.9 | 98.4 | 46.4 | 57.0 |
| cw | 618 | 293 | 810 | 1574 | 466 | 834 |
| **%** | 97.0 | 97.6 | **7**8.7 | 97.3 | 80.2 | 81.1 |

### 3.3.3 Summarizing the gestural interpretation of German plosives

Taking all the statistical data together we arrive at the following coherent picture of trends in the reduction of opening and closing gestures involving plosives in German:

- The word-initial position is least affected, the poststress 'plosive+schwa+nasal' syllable most affected, i.e. the start of a speech gesture at the beginning of a linguistic unit has a higher value for message transmission than other positions and is more likely to keep specific characteristics, whereas its final course is more subject to levelling and integration.
- Ceteris paribus, unstressed function words show greater reduction than content words.
- Ceteris paribus, the less formal dialogue style shows more reduction than the more formal reading style.
- Thus these three external factors control the phonetic manifestation of plosives in their phonetic contexts in such a way that gesture levelling is the more extreme the lower the signalling value of words in speech communication, be it related to word boundaries, to word class or to speaking style; i.e. at this point articulatory economy must be checked by the hearer's variable demands for distinctiveness.
- Fortis plosives are more resistant to reduction, except for deletion in word-medial position after nasal and before fricative or lateral as well as word-final after nasal or fricative.
- In postnasal context as well as in 'plosive+schwa+nasal' syllables, lenis plosives tend to be nasalised, in both cases combining an oral occlusion with only one velic position, viz. the default, lowered one, also found in breathing.

### 3.4 Vowel nasalization combined with nasal consonant elision

A nasal consonant leads to a long articulatory component of nasalization across neighbouring sonorants, and its oral occlusion may be weakened resulting in turn in nasalised vocoids contrasting with oral ones**.** Table 4 provides the statistics of such gestural levelling in the German data bases.

Table 4
Absolute frequencies of nasal consonant deletions, total and syllable-final, and of syllable-final nasal consonant structures in German c(ontent)w(ords) and f(unction)w(ords) of spontaneous and read speech

| | **Spontaneous** | | **Read** | |
|---|---|---|---|---|
| | **fw** | **cw** | **fw** | **cw** |
| total of deletions | 130 | 198 | 38 | 26 |
| syllable-final deletions | 122 | 179 | 29 | 23 |
| total of syllable-final nasals | 7414 | 8336 | 4722 | 8104 |

Nasal consonant deletion, in conjunction with vocoid nasalization becoming distinstive, is almost entirely limited to coda position and occurs with much greater frequency in spontaneous than in read speech, and it is also proportionally more frequent in function than in content words. Cases include *uns* (us), *dann* ('then'), *schon* ('already'), *in* ('in'), *vom* ('of'), *kann* ('can'), *eine* ('a'), *Montag* ('Monday'), and, as an extreme reduction of a 'plosive+schwa+nasal' syllable, *morgen (vormittag)* ('tomorrow (morning))' [mɔ̃] in the read corpus.

### 3.5 Nasalization and lenition in other languages

Since the nasalization and lenition phenomena discussed for German are seen as reorganizations of opening and closing gestures in a generalisable simplification of human speech production under phonetic and communicative constraints, the German phrase-level tendencies may be expected in other languages as well, and this hypothesis should be checked against relevant data in a wide variety of languages. There are very few languages for which these data are sufficiently available today. However, we may refer to a number of connected phenomena known from historical sound change and from less comprehensive reports on other languages. We can, for instance, illustrate lenition by the chain of Italian *madre* [madre], Spanish *madre* [maðɾe] and French *mère* [mɛːʁ] from Latin *matrem*. In nasal consonant environment this lenition results in the nasalization of plosives, as in the English and German endings *-ing* (historically [ɪŋg]), or in French *maintenant* [mɛ̃nnã]. As regards vowel nasalization linked to elimination of oral occlusion in nasal consonants, we can quote French *fin* from Latin *finem*. The processes of lenition and nasalization are not limited to this historical dimension, but continue in the modern Romance languages. So in the Italian AVIP corpus from Napoli we find [soβra] by the side of [sopra] for *sopra*, about 50% of the time in the limited data I have looked at, and one instance of *(arriva) praticamente* has an accumulation of lenition and nasalization [βraðʲiɣãṽɛ̃ntɛ]. Examples of nasalization and lenition of lenis plosives from English are *Wednesday* [wɛnzdɪ], *ordinary* [ɔːnrɪ] , and *father*, *mother*, *gather*, *together*, *weather*, which had /d/ in Old and Middle English.

## 4. Conclusion

A large part of present-day phonetic analysis has to do with phonetic substantiation of phonological structures, especially those represented by linear segmental phonemes in word citation forms. This means that word phonology and its phonetic exponents are the focus of attention, and the analyis of lab speech in the form of words in isolation or embedded in metalinguistic sentences or even of nonsense words is the dominant research paradigm.

The investigation of the phonetics in real acts of speech communication is still very much on the periphery of phonetic research activity and goals. When connected speech in text reading and, more rarely, in spontaneous dialogue is tackled, the phonetic word forms recorded are projected onto the phonemic representations of canonical forms and interpreted with reference to them. The data description then produces classifications of discrete linear phoneme changes, deletions and insertions, and of similar segment-related allophonic modifications.

In this paper I have followed a paradigm that takes symbolic representations of a segmental phonemic nature only as a heuristic tool for processing and systematically accessing large data bases (Kohler 1996). When variant word forms are thus grouped round canonical lexical entries the relationship of these satellites is no longer seen in terms of individual phonemic and allophonic correspondences, but as more global and more extended articulatory patterns in which the specific phonemes and allophones are closely integrated. These patterns are motivated by general hypotheses about the production of words in utterances under the control of global articulatory settings, rather than by hypotheses about the production of sounds in words. These hypotheses subsume assumptions about speech production and perception in human speech communication generally, and specific assumptions about speech in individual languages. Lenition and nasalization tendencies

of plosives can be assumed to be general features of human speech communication, controlled by the speaker's drive to reduce effort and by the listener's variable demands on signal distinctiveness for message transmission in different communicative situations; their language-related statistical manifestation is governed by specific reduction coefficients that are set by the particular linguistic community, in relation to such factors as word boundaries, word class, prosodic, syntactic and semantic structures, and speaking style.

An important distinction is maintained between phonetic lexicalization, on the one hand, and phrase-level phonetic variation under contextual and situational conditions as well as through statistical degrees of freedom, on the other. In this phrase-level variation, articulatory economy in homogeneous patterns plays a large role. What is phonetic lexicalization today is the result of phrase-level processes from a historical perspective (Passy 1890, Rousselot 1891). In this way synchronic variation enters into diachronic change, and both are related to the same phonetic driving forces. Synchronic and diachronic studies thus reinforce each other and reciprocally and collectively increase our insight into how speech and language work in everyday communication. What we need in future research is the analysis of phrase-level phonetics for a great spread of diverse languages in order to empirically support or refute the claims made about the general dynamic patterns of human sound production in speech communication. In the spirit of the Neogrammarians, and against structuralist overemphasis of language-specific phonemic systems, we can then reinstate cross-language analyses of phonetic parameters as primary elements of speech communication in synchrony and diachrony (Ohala 1993).

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