Schwa deletion in German read and spontaneous speech

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1 Introduction

1.1 Schwa deletion as a Connected Speech phenomenon

Vowel reduction and deletion, and in particular deletion of schwa, play a pivotal role in other reduction phenomena. Kohler (1990) points out that in a series of processes that derive reduced realizations from canonical forms, it is either a precondition or intermediate stage, and he provides Generative Phonology-type rewrite-rules (Chomsky and Halle 1968) to specify processes such as /r/-vocalization, weak forms, elisions and assimilations.

Our study of schwa deletion in spontaneous and read speech complements the examination of vowel deletions in spontaneous speech by Helgason and Kohler (1996), which largely excluded schwa. They focused on vowels other than schwa for quantitative and qualitative reasons: schwa is deleted far more frequently than other vowels, but at the same time the reductions in which schwa deletion is a part rarely retain the residual articulations (captured by the **-MA** label) that characterize many other vowel deletions (Helgason and Kohler 1996:121). The overview offered in that study is brought up to date and expanded to include read speech and a greater body of spontaneous speech data.

1.2 Previous studies of schwa deletion

The present study aims to address deficiencies of previous accounts of schwa deletion, specifically those offered in *Siebs* (de Boor et al. 1969:58–63), in the *Großes Wörterbuch der deutschen Aussprache* (hereafter *WdA*, Krech et al. 1982:35–36), and in *Duden* (Mangold 1990:32–34). Only one of these, the *WdA*, is based on the phonetic investigation of a corpus, and all three pronunciation dictionaries limit themselves to realizations before sonorants. This study aims to ascertain the accuracy of the dictionaries' observations, and to expand the understanding of realization of schwa to other phonetic contexts.

The accounts offered by the dictionaries are summarized in Table 1.

1.2.1 *(Großes) Wörterbuch der deutschen Aussprache*

The prescriptions in the *WdA* are based on research reported in Meinhold (1962). The investigation is also the basis for Meinhold (1973) and Meinhold and Stock (1980), which offer less phonetic and methodological de-

Table 1: Comparison of schwa realizations prescribed by three pronunciation dictionaries. + means the schwa is present, − that schwa is absent, n/a means that no advice is offered. In the final category of assimilation of place, realizations featuring schwa deletion and place assimilation are approved (+) or condemned (−).

Environment	***WdA***	***Siebs***	***Duden***
preceding a stressed syllable	+	n/a	n/a
word-finally	+	+	n/a
in 1st syllable of *-enen*	n/a	−	n/a
in 2nd syllable of *-enen*	+	+	+
after plosives	−	−	− in /ən əl/ + in /əm/
after fricatives	−	−	−
after affricates	−	−	−
after nasals	+	+	+ in /əm ən/ − in /əl/
after approximants	+	+	+
after vowels	+	+	+
assimilation of place	+	−	+

tail, but even the more phonetically relevant examination from 1962 has its limitations. Meinhold's research is carried out in the prescriptivist framework of the Krech group, a collective collaborating on the *Wörterbuch der deutschen Aussprache* (Krech et al. 1964, 1969) revised as the *Großes Wörterbuch der deutschen Aussprache* (Krech et al. 1982), with the primary aim being didactic, aimed at learners of German *Hochlautung* (standard pronunciation)[4]. Although he is not one of the editors of the *WdA*, Meinhold is cited as having worked on the issue of final schwa realization, called here "die Endsilbe *e*", or "schwachtoniges *e* [ə]", and which is one of a dozen aspects of pronunciation, such as glottal stop in vowel onsets, vowel nasalization and plosive aspiration, that have been singled out for examination. The form of the rules in Krech et al. (1969) and Krech et

[4]The normative view inherent in the *WdA* is made concrete in the two later papers: Meinhold (1973) retains little phonetic detail, while the aim of Meinhold and Stock (1980) is not phonetic; they seek to elaborate a Trubetzkoyan phonological system for German which is very much based on the *Standardsprache*. As a phonological rather than phonetic investigation, they are vague about the data forming the basis for their statements, indeed their section *Das Untersuchungsmaterial* does not address what a phonetician might consider materials at all.

al. (1982) is almost identical, apart from certain examples, and that occasionally the later version suggests that forms *are* realized as described, whereas the earlier says that they *may be*. Meinhold's prescriptions for schwa realization are summarized under three headings:

- environments where schwa must be pronounced;
- realization of schwa in the ending *-en*;
- realization of schwa in the ending *-el*.

1.2.2 *Siebs*

The norms advocated by Boor et al. (1969) in the authoritative *Siebs* are if anything even more severe than those in the *WdA*. *Siebs* has two levels of correctness, pure ("rein") and moderate ("gemäßigt"), and in the pure form of pronunciation all schwas are pronounced, whereas in the moderate form, [ə] may be dropped except in cases which are then exhaustively listed.

1.2.3 *Duden*

Duden, like the *WdA* and *Siebs*, describes only schwa before /m n l r/, but is less conservative: it states that the vowel is pronounced only in slow and clear speech, and its detailed description of environments is more sophisticated and realistic than either other work. In particular, *Duden* offers different rules according to the following, as well as the preceding consonant.

From Table 1 it is clear that the prescriptions of the three dictionaries are largely similar, with the following differences:

1. Only the *WdA* addresses schwa preceding a stressed syllable.
2. *Duden* does not address word-final schwa.
3. *Duden* has a more exhaustive set of rules after nasals.
4. *Siebs* condemns forms featuring assimilation of place.

It is worth recalling that of the three dictionaries, the *WdA* is the only one explicitly to adduce detailed phonetic research, that of Meinhold. However, even that research addresses only schwas preceding sonorants, but

does not have the detail of *Duden*, which offers different rules according to the following consonant.

As the only phonetically grounded account, Meinhold (1962) is the main point of reference for our study. The methodology of his study is made clearer in Krech et al. (1969) than in Meinhold (1962) itself: the same materials were used for the examination of specific phenomena seen as problematic in the *WdA*. Auditory phonetic analysis is made of studio quality tape recordings. The emphasis is on professional speakers from the stage (*cf. Siebs*) as well as radio, and the materials are exclusively read speech with a preponderance of classical texts (detailed in Krech 1968 and Meinhold 1973). The nature of the materials makes it possible for Meinhold to separate his findings into prose ("ungebundene Rede") and verse ("gebundene Rede"): in all cases, Meinhold found schwa to be deleted more frequently in prose than in verse. In the comparison of our findings with Meinhold's, we present only his results for prose, as being closest to our category of read speech. Furthermore, the emphasis in our study is on deletion, and in Meinhold on preservation of schwa, so in the presentation of results his findings have been transformed for ease of comparison with ours.

1.3 Advantages of the present study

As well as having a technological advantage over Meinhold – in addition to auditory phonetics, labellers have the waveform and spectrogram information inherent in *xassp* (IPDS 1997b) – the current study is greater in size and scope. The CD-ROMs of the Kiel Corpora allow an unprecedentedly large amount of data to be examined – over 92,000 words of running speech, both read and unscripted. Read speech is arguably untypical of genuine speaker behaviour, whereas unscripted speech offers more realistic data. The disadvantage of an unscripted corpus is the lack of control over the material recorded, although the elicitation of the *Verbmobil* database by the appointment-making task is relatively structured by comparison with the *Daily Soap Scenario* (Benno Peters, personal communication), in which pairs of speakers discuss an excerpt from the popular soap opera *Lindenstraße*, of which they have seen slightly different versions. The advantage of corpus research is that generalizations made about the material are legitimate generalizations about spoken language, precisely because observations are based on heterogenous material. The database

therefore provides material varying in speech style, but for both styles the "full" form from which a "reduced" form is derived descriptively is made available, as canonical representation, together with, and incorporated into, the variant record.

The existence of a canonical and variant transcription does not imply the espousal of any particular model of speech production: the aim of the labelling is to capture a broad range of factors that may be at play in running speech. For pragmatic convenience in this paper it is assumed (i) that each word can be described as a sequence of time-slots, being a phoneme-sized acoustic segment as it appears in the citation form, e.g. *vielleicht* has six such slots [f ɪ l aɪ ç t], *ich* has two [ɪ ç]; (ii) that these segments have features that can be dissociated. It is clear that there are also non-linear aspects of speech production that such a labelling cannot entirely capture, and such labels as **-q** for glottalization, and **-MA** for residual articulations point to this property of speech.

2 Method

2.1 Materials

KielDat databases (Pätzold 1997) were generated containing all data made available so far on CD-ROM (IPDS 1994, 1995, 1996, 1997a) and detailed in Table 2 (p.105). The spontaneous speech dialogues are listed separately according to whether or not they have been prosodically labelled. In searches of the database where prosodic information is relevant, it must be borne in mind whether prosodic labelling is available or not. For example, in prosodically labelled data, phrase boundaries are marked by the label **PG**, whereas in unlabelled data they must be inferred from punctuation and markers indicating breath and pause.

2.2 Procedure

As for the investigation of phonatory correlates of juncture (Rodgers 1999), the intermediate device of a lexicon is used, to allow for simplified searches according to the question under investigation. A structured list of `awk` (Aho, Kernighan, and Weinberger 1988) search-scripts generates a lexicon containing only items of interest, with one field containing information relevant to hypotheses about the item: presence or absence of schwa, word

class, position relative to stress, accent, position in the phrase and word, and segmental context. This information can then be processed with further scripts and one-liners to generate descriptive statistics and focus on certain label combinations.

3 Findings

3.1 Overview

A total of 69231 words is examined, 31378 in read speech, 37853 in spontaneous (of which 25488 in prosodically labelled, 12365 in unlabelled speech).

The first statistic offered is an update of the overview given by Helgason and Kohler (1996:120) of vowel deletion in the Kiel corpus overall. The 69231 words contain 50894 vowels in read speech, and 60057 in spontaneous. Schwa is the most common vowel in both speech styles, representing 21% (10483/50894) of vowels in read speech, and 17% (10250/""60057) in spontaneous. It is also the most frequently deleted: in read speech 44% (4627/10483) of schwas are deleted, as opposed to only 0.6% (236/40411) of all other vowels; for spontaneous speech 64% (6581/10250) of schwas, and 2.7% (1339/49807) of all other vowels are deleted. Deletion of schwa represents the overwhelming majority of all vowel deletions: for read speech 95% (4627/4863), and for spontaneous speech 83% (6581/7920) of all vowels deleted are schwa. Not only is schwa more frequently deleted in spontaneous than read speech, but deletions of all other vowels are also more numerous.

Table 2: Materials constituting read and spontaneous speech databases. Read speech is segmentally and prosodically labelled, spontaneous speech differs according to level of labelling available. State of labelling: 3rd March 2000.

Session	**Materials**	**Size**
PHONDAT90	Berlin sentences	1200 sentences
PHONDAT90	Marburg sentences	1200 sentences
PHONDAT90	*Die Buttergeschichte*	3 passages
PHONDAT90	*Der Nordwind und die Sonne*	2 passages
PHONDAT90	Restkorpus	396 sentences
PHONDAT92	Erlangen sentences	500 sentences
PHONDAT92	Siemens sentences	500 sentences

(a) Read

Session	n **dialogues**	n **turns**	**Pros label**
g07a	7	115	yes
g08a	7	109	yes
g09a	7	159	yes
g14a	7	77	yes
g19a	7	151	yes
g202a	1	12	yes
g21a	7	87	yes
g25a	7	107	yes
g274a	1	13	yes
g287a	1	13	yes
g297a	1	11	yes
g306a	1	25	yes
g31a	7	102	yes
subtotal	**61**	**981**	
g10a	7	141	no
g11a	7	116	no
g12a	7	149	no
g36a	7	119	no
g37a	7	140	no
g38a	7	110	no
g41a	7	112	no
g42a	7	116	no
subtotal	**56**	**1003**	
Total	**117**	**1984**	

(b) Spontaneous

Table 3: Overview of deletion of schwa and other vowels in read and spontaneous speech. Vowels are in descending order of their relative frequency of deletion.

Vowel	**deleted**	**present**	**total**	**% deleted**
Read				
ə	4627	5856	10483	44.1
ɪ	125	5136	5261	2.4
ʊ	33	2367	2400	1.4
eː	17	1776	1793	0.9
oː	7	940	947	0.7
ɐ	18	2669	2687	0.7
ɔ	8	1497	1505	0.5
ɛ	11	2076	2087	0.5
iː	11	2365	2376	0.5
iːɐ	2	532	534	0.4
ɔɐ	1	540	541	0.2
yː	1	619	620	0.2
aɪ	1	2987	2988	0.0
a	1	4241	4242	0.0
other	0	12430	12430	0.0
Total of non-schwa	236	40175	40411	0.6
Total of all vowels	4863	46031	50894	9.6
Spontaneous				
ə	6581	3669	10250	64.2
ʊ	283	2210	2493	11.4
ɛ	202	2896	3098	6.5
ɪ	371	6204	6575	5.6
uː	45	1039	1084	4.2
aɪ	148	3864	4012	3.7
ʏ	20	557	577	3.5
eː	72	2654	2726	2.6
oː	45	1682	1727	2.6
yːɐ	5	198	203	2.5
ɐ	43	2200	2243	1.9
iː	35	2838	2873	1.2
iːɐ	18	1721	1739	1.0
aːɐ	3	402	405	0.7
ø	1	196	197	0.5
yː	1	219	220	0.5
ɛː	2	463	465	0.4
a	24	6806	6830	0.4
ɔ	7	2220	2227	0.3
aː	12	4920	4932	0.2
ɛɐ	1	577	578	0.2
aʊ	1	1132	1133	0.1
other	0	3470	3470	0.0
Total of non-schwa	1339	48468	49807	2.7
Total of all vowels	7920	52137	60057	13.2

The patterns of deletion in vowels other than schwa bear consideration, and are presented in Table 3. We see that high and open-mid vowels are more likely to be deleted, although there may be some lexical effects here, as noted by Helgason and Kohler (1996): the high incidence of /ɛ ɪ ʊ/ is an artefact of the high incidence of *es*, *vielleicht*, *ich*, *in*, and ordinals including *und*.

Of the 31378 words in read speech, and 37853 in spontaneous, a schwa occurs in 10012 and 9735 words respectively. Yet there are 10483 schwas in read speech, and 10250 in spontaneous speech, indicating that in some words schwa occurs more than once. Table 4 provides an overview of schwa distribution in the words of the *Kiel Corpus*, including position relative to the stressed syllable. The prosodic and rhythmic context of multiple schwas may be quite different: e.g., of the three schwas in the word *gebetene* (/gəˈbeːtənə/), the first, preceding a stressed syllable, is likely to be present, as is the schwa occurring word-finally, whereas the medial schwa may be deleted. Such cases are examined in detail in Section 3.3 (p.111).

Table 4: Overview of size of corpus, and frequency of schwa according to position relative to stressed syllable, and whether schwa is a singleton or adjacent to other schwas, for the *Kiel Corpus*.

	Read	Spont
Words in corpus	31378	37853
Schwa in corpus	10483	10250
of which *n* precede a stressed syllable, see Table 8, p.113	723	642
of which *n* follow a stressed syllable see Section 3.5, p.113 ff.	9760	9608
Words containing schwa	10012	9735
of which *n* have one schwa following a stressed syllable, see Section 3.5, p.113 ff.	9935	9681
(corresponding to *n* schwa)	(10327)	(10130)
of which *n* have >1 schwa following a stressed syllable, see Table 7, p.111	77	54
(corresponding to *n* schwa)	(156)	(120)

3.2 Influence of preceding consonant on schwas preceding a sonorant

Meinhold limits his observations to schwas preceding /m n l/, but only offers figures for schwa preceding /n/, separating his findings according to the preceding context. Table 5 gives the absolute and relative frequencies of schwa deletion and preservation in [ən] syllables according to preceding context in the *Kiel Corpus of Read/Spontaneous Speech*, following Meinhold's pattern selection. Figure 1 presents the absolute frequencies graphically. It shows that in this subset of schwa syllables (which the categorization in Section 3.5 (p.113) establishes as that most likely to have schwa deleted) preceding context plays an important role, although it does not provide an exhaustive account of deletions. Table 6 compares the relative frequencies of schwa deletion found in these contexts for Meinhold's and the Kiel data. The same data are represented graphically in Figure 2 (p.110).

Table 5: Schwa deletion in word-internal [ən] in the *Kiel Corpus* according to preceding segmental context.

Preceding context	**deleted**	**present**	**total**	**deleted as % of total**
Read				
fortis plosive	707	42	749	94.4
lenis plosive	1571	75	1646	95.4
fortis fricative	901	199	1100	81.9
lenis fricative	142	20	162	87.7
liquid	461	230	691	66.7
nasal	442	273	715	61.8
vowel	106	96	202	52.5
Spontaneous				
fortis plosive	2004	32	2036	98.4
lenis plosive	1302	21	1323	98.4
fortis fricative	1030	240	1270	81.1
lenis fricative	26	8	34	76.5
liquid	256	26	282	90.8
nasal	995	46	1041	95.6
vowel	122	38	160	76.3

In the Kiel data a pattern is clear in both speech styles, although deletion is higher in spontaneous than read speech overall. The highest rate

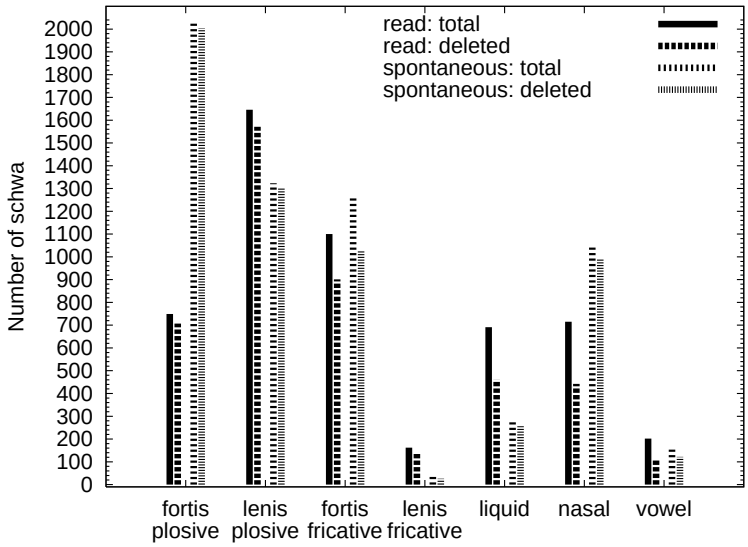

Figure 1: Graphical representation of data shown in Table 5 (p.108), showing schwa deletion in word-internal [ən] according to preceding segmental context.

Table 6: Summary of findings reported for prose ("ungebundene Rede") in Meinhold (1962), compared with read and spontaneous speech in Kiel corpora for schwa preceding /n/ after the different obstruent and sonorant contexts. n/p = not provided.

		% schwa deleted			
Preceded by	**Meinhold**	**Kiel read**	**∆Meinh**	**Kiel spont**	**∆Meinh**
Fricative	94,9	82,6	−12,3	81	−13,9
Fortis plosive	89,7	94,4	+4,7	98,4	+8,7
Lenis plosive	81,9	95,4	+13,5	98,4	+16,5
Nasal	24,3	61,8	+37,5	95,6	+71,3
Liquid	31,7	66,7	+35	90,8	+59,1
Vowel	n/p	52,5	n/p	76,3	n/p

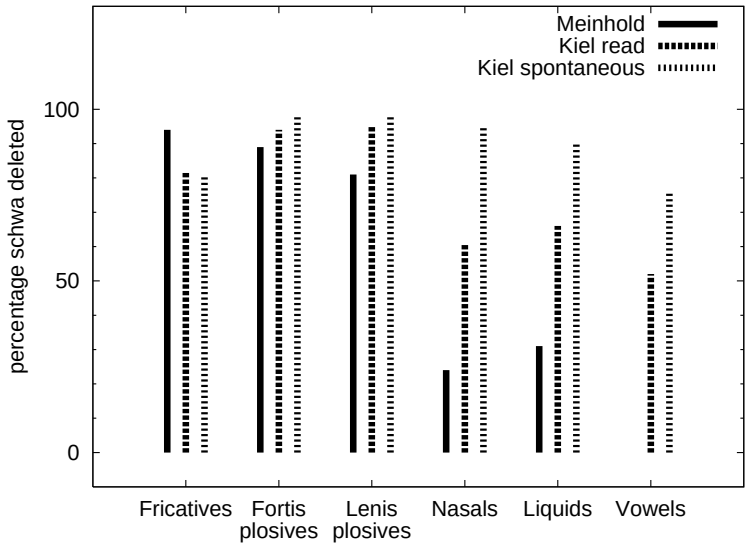

Figure 2: Graphical representation of data in Table 6 (p.109), summarizing findings reported for prose ("ungebundene Rede") in Meinhold (1962), compared with read and speech in Kiel corpora.

of deletion is following plosives whether fortis or lenis; deletions after fricatives represent just above 80% in both styles. Frequency effects explain the particularly high incidence of deletion in plosives in spontaneous speech: ordinals ending in *-sten* (fortis plosives) are common, as are the verbs *haben* and *sagen* (lenis plosives). Similarly in spontaneous speech, schwa deletion is especially common after nasals due to high incidence of *Ihnen*, *können*, *einen* and *nehmen*; and of liquids due to high incidence of *wollen*, *sollen* and *vielen*. These words certainly occur in read speech as well, but less frequently. In both speech styles the least conducive preceding context for schwa deletion is a vowel: in both, *gehen* and *stehen* feature by far the highest number of deletions.

Comparing the Kiel findings with Meinhold's figures, there is a clear discrepancy. Meinhold finds greater rates of deletion in fricatives than we

find in either speech style, but for every other category, we find greater rates of deletion than he, the difference being most dramatic in nasals and liquids, where within the Kiel data there are furthermore great differences between spontaneous and read speech. Meinhold does not include vowels in his survey, although the *WdA*, like *Duden* and *Siebs*, claims deletion cannot occur after vowels. The Kiel data show that this is not the case.

3.3 Adjacent schwas

Some words contain more than one schwa, and of special interest are those where the vowels are in adjacent syllables, as in words like *spätestens*, *siebenten*. In read speech there are 77 such cases, in spontaneous speech 54.

Table 7: Overview of frequency of adjacent schwas

	Read	Spontaneous
Words with adjacent schwa	77	54
in *n* of which 2nd schwa is word-final	62	41
in *n* of which 2nd schwa is word-internal	15	13

3.3.1 Word-final final schwa

Let us turn first to the 15 (out of 77) cases in read speech, and 13 (out of 54) in spontaneous, where the final schwa is word final, as in *ankommende*, *geebnete*, *hervorragende* and *verschiedene*.

In these cases, the final schwa is never deleted. Furthermore, in all four cases in read speech where the first schwa is followed by a nonsonorant (words like *arbeitete*, *geebnete*), that schwa is also present; this is also the case for two of the three comparable cases in spontaneous speech. Only in one case is the first schwa deleted but the second present, in the word *allerneueste*. In this case, the deletion of the schwa can be regarded as an artefact of the labelling: the schwa following the diphthong /ɔɪ/ is derived by rule, but in such forms *Duden Rechtschreibung* (Drosdowski et al. 1991) has *neu[e]ste*, meaning the schwa is optional; the *Duden Aussprachewörterbuch* (Mangold 1990) features a schwa where there is

schwa in the orthography, but clearly not where it is absent. If the alternative transcription without schwa had been chosen, there would be no schwa to be marked as deleted or present.

In words where the second schwa is word-final (and never deleted), but the first schwa is followed by a sonorant, as in *folgende* and *ankommende*, the first schwa is deleted in all cases (10/10) in spontaneous speech, and in seven out of eleven cases in read speech. In the remaining four cases in read speech both schwas are present: the words are *erschienene* (twice) and *entwickelte*, and *ankommende*, in other realizations of which the first schwa is deleted.

These figures suggest that phonetic factors alone do not condition presence or absence of the schwa: morphological factors as well as preceding and following consonant are important. In items like *arbeitete* it is important for the word to retain its quadrisyllabicity – i.e. that the two final schwas *-tete* should be perceived as two syllables – to distinguish it from *arbeite*, the present tense form: in a realization like [ɑːbaɪtʰə̥tə], the frication and aspiration elicit a percept of disyllabicity. This is further addressed in the Discussion (p.118).

3.3.2 Both schwas are word-internal

There are 62 (out of 77) cases in read speech, and 41 (out of 54) in spontaneous, where both schwas are word-internal.

Where the second schwa is followed by a nonsonorant it is never deleted. Such a constellation accounts for two of the 41 cases in spontaneous speech, the words *folgendes* and *Spannendes*, where the first schwa is followed by a sonorant and deleted. In read speech there are twelve such cases, all in the word *trockenes*: in nine cases the first schwa is deleted, in the other three both schwas are present. In this case, by contrast with the example of *arbeitete* above, the first schwa syllable can be reduced or even deleted without compromising intelligibility.

This leaves cases where the final schwa is followed by a sonorant. The first schwa is also followed by a sonorant in 20 words out 50 in read speech, and in 33 out of 39 in spontaneous.

In the 20 cases in read speech, the second schwa is deleted only twice, in the word *röchelnden*, where the first schwa is present in both cases. In the remaining 18 where the second schwa is present, the first schwa is present in four realizations of *wartenden*, and deleted in 14 cases, twelve

times also *wartenden*, and twice *entsprechenden*.

In spontaneous speech, the 33 cases are evenly split between deletion of both schwas (16/33) and deletion of the first schwa with the second retained (17/33). Most cases where both schwas are deleted are realizations of *siebenten* (12/16), which is a special case of an ordinal with the schwa deletion co-occurring with other reduction phenomena, and three realizations of *bedeutendsten*, which is an [n]-cluster-[n] sequence. Where the first schwa is deleted but the second present, the constellation is typically [əndən] in *folgenden* or [ənən] in *offenen*.

Where the first schwa is followed by a nonsonorant, there is a clear pattern: in read speech 28 words out of 30, and in spontaneous speech six out of six have the first schwa present and the second deleted. The constellation is [ə]-fricative-plosive-[ən] in *mindestens*, *frühestens*, and *spätestens*. The two remaining cases in read speech show both schwa present once, and both schwa deleted once, each time in realizations of the word *spätestens*.

3.4 Schwa preceding stressed syllables

The majority of schwas follows the stressed syllable in a word, but a sizable minority remains to be examined. These number 723 items in read speech, and 642 in spontaneous. Deletion of schwas in either speech style is negligible, however, occurring twice in 723 cases, in *gewinnt* and *gehört*. In spontaneous speech, there are 22 cases, out of 642; these are in the word *gerade*, which alternates with the form *grade*, in which the syncopated form has been lexicalized, and before sonorants, or obstruents, when schwa is often realized as a voiceless vowel, as in Figure 3 (p.114).

Table 8: Overview of frequency of schwas preceding a stressed syllable

	Read	Spontaneous
Schwas preceding a stressed syllable	723	642
of which *n* are deleted	2	22

3.5 Schwa following stressed syllables

A small subset of schwas following stressed syllables has already been examined in the investigation of adjacent schwas above. There remains the

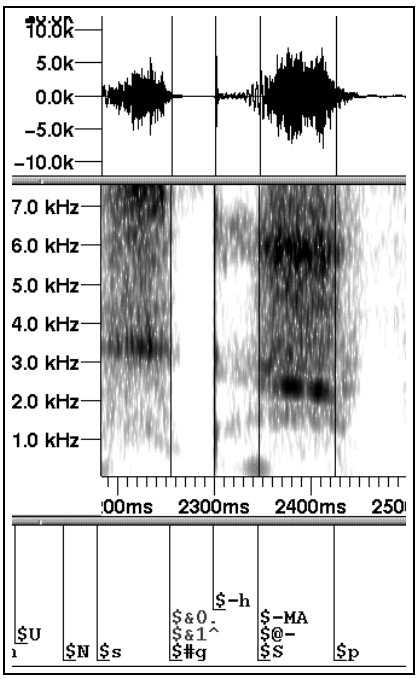

Figure 3: Schwa deletion manifested as a voiceless vowel in *[Vorbereitung]sgesp[räch]* in `g124a007`.

bulk of singleton (i.e. non-adjacent) schwas following stressed syllables, to be examined, i.e. 9606 in read speech and 9499 in spontaneous, which is in fact 9500 including the first schwa in the word *zusammenhängenden*.

Let us turn first to word-final schwas. In read speech there are 3727 items, of which 96 are deleted, that is 2.6%. The rate of deletion is higher in spontaneous speech at 23%, with 726 of 3140 schwas deleted. The deleted items in both speech styles are typically in verbs, especially function words: the dozen most frequent items in spontaneous speech, and those in double figures, are *habe* (168), *würde* (116), *wäre* (115), *sehe* (30), *könnte* (25), *hätte* (24), *glaube* (23), *denke* (23), *komme* (16), *finde* (13), *wollte* (12) and *schlage* (12), which together make up three-quarters

Table 9: Overview of frequency of singleton schwas following a stressed syllable

	Read	Spont
Singleton schwas following a stressed syllable	9606	9500
in *n* of which schwa is word-final	3727	3140
of which *n* are deleted	96	726
in *n* of which schwa is word-internal before a nonsonorant	342	173
of which *n* are deleted	5	8
in *n* of which schwa is word-internal before a sonorant	5537	6187
of which *n* are deleted	4426	5757

(76%) of all deletions. In many cases the following word begins with a vowel, canonically marked with **Q** – 62 words out of 96 in read speech and 491 out of 726 in spontaneous – which is realized as **Q-** in almost all cases: 61 out of 62 in read speech, and 483 out of 491 in spontaneous. It is worth noting that for many of these items an orthographically lexicalized form co-exists in which apocope has taken place, e.g. *hab', wär', seh', hätt', find'*.

A further insight into word-final schwa deletion is offered by taking word class into account. A higher proportion of the deletions in each speech style is in function words than in content words: in read speech 60% (58/96), in spontaneous 68% (490/726). Furthermore, of the remaining deletions that occur in content words, only a few are not in verbs: in read speech 95% (224/236) are in first person singular verb forms, 88% in spontaneous (207/236).

Word-internally, the behaviour of schwas can be separated according to the consonant that follows. Deletion before a nonsonorant is rare, representing only five out of 342 cases in read speech, and seven out of 172 in spontaneous. There is no particular pattern to these few deletions, although the (first) schwa in the word *meinetwegen* is deleted in both speech styles. By contrast, deletion of schwas before a sonorant is common in both speech styles. In read speech, 81% (4462/5537) of schwas are deleted, in spontaneous speech 93% (5757/6187) are affected.

Position in the word and phrase seems to play some role. Regarding position in the word, medial syllables tend to be more frequently deleted (88% (217/246) deleted in read speech, as many as 96% (157/163) in

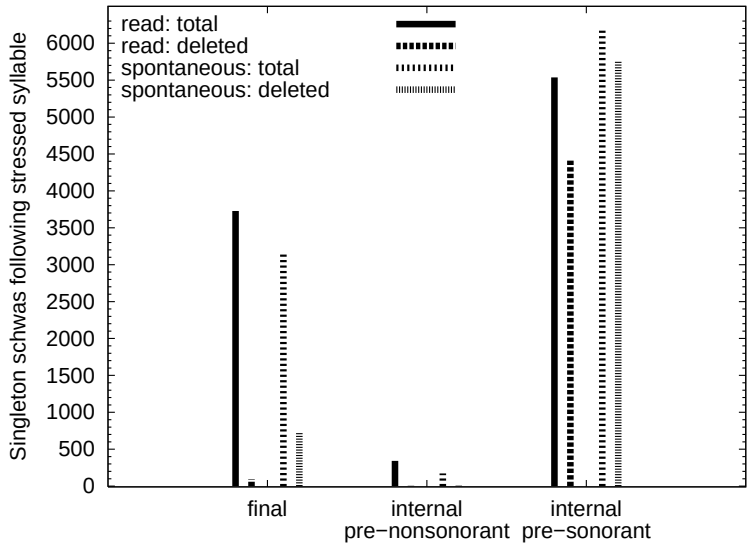

Figure 4: Overview of distribution of deleted and undeleted singleton schwa following a stressed syllable, as in Table 9 (p.115). For read speech, *n* is 9606, for spontaneous *n* is 9500.

spontaneous) than schwas that are in a final syllable (80% (4245/5291) in read speech, 92% (5600/6024) in spontaneous). As for position in the phrase, the pattern is clearer in spontaneous speech than in read. Schwas that are in the final syllable in the word but preceding a phrase boundary are less frequently deleted (79% (1397/1753) in read speech, 91% (1816/1989) in spontaneous) than those where no phrase boundary follows (80% (2681/3347) in read speech, 96% (3623/3794) in spontaneous).

4 Discussion

This paper has examined schwa deletion in an unprecedentedly large database of read and spontaneous speech, and sought to explain the patterns of deletion and preservation of schwa by recourse to a handful of factors.

Statistical support is found for certain givens previously based on intuition, while other insights need to be altered in the light of what has been found.

It is almost a truism to say that schwa is the most frequently occurring vowel, and the most frequently deleted. Summarizing the data in Table 3 (p.106) we can confirm that this is the case: schwas make up almost one fifth of all vowels in the database, and are deleted in 44% and 64% of cases in read and spontaneous speech respectively. Other vowels taken as a whole are deleted in only 0.6% and 2.7% of cases, and even the most frequently deleted non-schwa vowel (ɪ and ʊ in turn) represents only 2.6% of deletions in read speech and 3.6% in spontaneous. We may further note that vowel deletion as a whole, and not just of schwa, is more frequent in spontaneous than read speech.

The comparison with the findings of Meinhold (1962) adopted by the *WdA*, and similar to those of *Siebs* and *Duden*, shows that the standard account of schwa realization needs major revision. Schwa is deleted after nasals, liquids, and vowels, contrary to Meinhold's findings. Further contrary to his findings, but in the other direction, we find a lower rate of deletion after fricatives than he. It must also be borne in mind that Meinhold's study is limited, addressing only the influence of a subset of preceding contexts, and offering statistical findings only preceding /n/, although he claims to address schwa before /m l/ as well.

The data on schwas in adjacent syllables (p.111) suggest that the vowel will be preserved or deleted as a function of following segmental context, and not merely as a function of preceding context, as the pronunciation dictionaries suggest. Word-final schwa is never deleted, regardless of speech style. Similarly, a schwa is preserved in both speech styles when it appears before a nonsonorant, regardless of whether it is the first or second of the two schwas. An exception to this is the realization of *allerneueste*, where the schwa follows a diphthong, but as discussed, this is an artefact of the labelling.

The case of *allerneueste* highlights the issue of appropriateness of canonical forms also raised by Wesener (1999). In certain lexical items, it is inappropriate to suggest that a schwa is present in the canonical form of the word, but that this schwa is not realized. Positing a schwa in the canonical form of function words like *haben, können* arguably inflates the statistics for schwa deletions, as the schwa is not present in the speaker's lexical entry for such items. Lexicalized written forms of *hab', wär'* exist alongside *habe, wäre*, just as *allerneuste* (without e) exists alongside

allerneueste: it seems that lexicalized spoken forms of *wär, hab* also exist. However, it is not suggested that a lexicalized form without schwa exists alongside every single form with schwa; rather, we argue that for certain common words, especially function words, there exist two lexicalized forms with and without schwa, and that in other cases, phonetic, morphological, and syntactic factors condition derivation of schwa-less forms from canonical forms with schwa.

Cases of adjacent schwas also indicate the importance of morphological information. The first schwa was not deleted in *arbeitete* or *geebnete*. In the case of *geebnete* a schwa has already been lost in deriving the verbal from the adjectival form (*eben* (adj.) → *ebnen* (vb.) → *geebnete* (participle), and the syllable cannot be further reduced (*cf. trocken* (adj.), *trocknen* (vb.)). Similarly in *arbeitete*, the schwa must remain to distinguish the tense of the verb (see p.112).

Of the three pronunciation dictionaries surveyed, the *WdA* is the only one to raise morphological factors, pointing out that schwa cannot be deleted in unstressed German suffixes. The examples of words where schwa is pronounced in the later version (Krech et al. 1982) are *leitest, leitet, Atem*: in the earlier version (Krech et al. 1969) *Atem* is not listed: *-tem* here is not a suffix. A realization of *leitest, leitet* in which the schwa is deleted is possible, but frication would offer an alternative cue to the suffix.

The patterns of schwa deletion are somewhat more complex where the schwa precedes a sonorant. When the schwa is the first of two (regardless of what follows the second schwa), it is typically deleted, this pattern being more marked in spontaneous than read speech. Similarly, a schwa preceding a sonorant is also typically deleted when it is in second position and the first schwa precedes a nonsonorant. Where both schwas are followed by a sonorant, the second schwa is almost always preserved in read speech, whereas in spontaneous speech, roughly half of these second schwas are also deleted: in such cases both schwas are in fact deleted.

The pattern for schwas preceding stressed syllables is relatively uncomplex. In both speech styles the vowel is rarely deleted, indeed in read speech almost never so. Where the deletion occurs in spontaneous speech, it often manifests itself as a devoicing, *cf.* Figure 3 (p.114). Several cases of a deleted schwa are in *grade*, which exists as a lexicalized form alongside *gerade*.

The largest category examined is of single schwas following a stressed syllable. When the schwa is word-internal but preceding a nonsonorant

it is typically preserved. In both speech styles the most likely environment for deletion is when the schwa is word-internal preceding a sonorant. The following consonant is not the only important factor: position in the word and phrase also have an effect. Word-internal schwa preceding a sonorant is more frequently preserved in a word-final than word-medial syllable, especially in spontaneous speech. And word-final schwa preceding a phrase-boundary is more frequently preserved than where no phrase-boundary follows, especially in spontaneous speech.

Finally, when the schwa is word-final, its deletion or preservation is strongly influenced by the following word: verbs, especially function words, account for three-quarters of deletions in this category, and when the following word begins with a vowel, that vowel will typically be realized without a glottal stop, indicating that there is a strong connection between the items. A further analysis was made of word class in this subset, and it was clear that function words, and first person singular content word verb inflexions account for the vast majority of such deletions. This word-final schwa deletion (apocope) is lexicalized in certain common words, such that *wär'* and *hab'* exist alongside *wäre* and *habe*.

Lexicalization of certain forms clearly plays an important role in schwa deletion, as in processes of articulatory reduction generally. It is inconceivable, however, that all the variability so fully documented in spontaneous speech is lexicalized, and that listeners somehow map a potentially infinite number of realizations onto stored representations. In this light, phonological rewrite-rules of the kind offered in Kohler (1990), by means of which it is possible to derive a wide variety of realizations, serve only as a descriptive device, and do not offer an explanation of production reality.

This study has found that a schwa preceding a sonorant is most likely to be deleted; this echoes the focus of Meinhold (1962), who limited his study to schwa before /m n l/ (and effectively to schwa before /n/), and the advice of the pronunciation dictionaries. Vowel duration is highly variable, and in stress-timed languages unstressed syllables following stressed syllables in the same foot tend to be compressed in time proportionate to the number of syllables in the foot (Lehiste 1972; Port 1981). As well as temporal compression, there tends to be reduction in gestural magnitude (Browman and Goldstein 1992). In /əm ən əl/ syllables, the entire sonorant is also variable, along a scale that ranges from a full duration and opening movement for the schwa, to imperceptible duration with no opening movement. Realizations featuring assimilation of place of articulation,

e.g. *haben* as [hɑːm], show further reduction resulting in the elimination of an articulatory movement (the apical closure in /n/).

Alongside the possibility that certain forms are lexicalized, parallel to the case in written German where there is *zum, ins* for *zu dem, in das*, Kohler (1991) proposes a "reduction coefficient" to account for the variety of realizations found in real speech. In this scheme, canonical forms exist in the speaker's lexicon, and are the starting point for an utterance, but the form is reduced by different kinds of reduction processes whose ability to take effect is specified by the coefficient. This coefficient therefore triggers general phonetic rules of articulatory reduction and speech economy, to generate an output that represents a trade-off between effort for the speaker and intelligibility for the listener, in line with the H&H theory of Lindblom (1990).

The data presented here offer some support for the idea of a reduction coefficient. It is clear that a blanket rule of schwa deletion is not being applied as a pure function of low-level phonetic properties of the utterance, and that other factors also play a role: word class, morphology, speech style and stress may all be seen to determine whether a schwa may be deleted or not. Furthermore, schwa deletion is just one factor in articulatory reduction, and the reduction coefficient does not simply specify whether or not the schwa can be deleted. Rather, the reduction coefficient has recourse to two distinct levels: global articulatory structures which determine whether, for example, a gesture comprises one movement or two; and local rules and their application, such as vowel reduction, nasalization, assimilation of place of articulation. The coefficient has access to entire holistic complexes of articulation which can be expressed as single rules or processes, such as assimilation of place of articulation, yet these rules are purely descriptive, and their (degree of) application is conditioned at a higher level of planning whose aim is economical production without compromising intelligibility. In this sense such a coefficient affects not simply schwa deletion, or even a more general control area of vowel reduction, but a range of multidimensional scales of reduction and compression. It becomes clear, through investigating the complexities of real speech data, that no process of articulatory reduction is a black-and-white issue, and that the interplay of highly variable scales conditions speech production. In thinking otherwise, pronunciation dictionaries may be the most obvious offenders, but they have the excuse of a didactic need; speech researchers who simplify the picture without also clarifying it are more at fault.

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