

# Stress perception and production in German Stress Clash Environments

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## Abstract

Several production and perception experiments have been carried out in order to investigate, whether stress clash environments in A(BC)-compounds really trigger a stress shift or a destressing of the secondary stress or not. The results indicate that stress shifting is rather rare than common in German. If it occurs, it manifests itself both on a production and perception level. This situation remains stable, no matter if listeners are presented the full acoustic signal or only delexicalised stimuli. The only environment where stress shift tends to take place more often are words consisting of four syllables. These allow for placement of an additional foot. Stress clashes in trisyllabic compounds are often handled by a destressing of the secondary accent as an alternative to stress shift. However, in the majority of stress clash environments, listeners did perceive the primary and secondary stress in the immediate neighbourhood. Obviously, a stress clash creates less of a problem in German than it does in other Germanic languages.

## 1. Introduction

According to phonological theory, in contexts where two stressed syllables have to be produced consecutively, a so-called “stress clash” occurs. The question whether a syllable counts as phonologically stressed, is defined on the metrical grid. According to [7], stress clash environments need to be defined language dependently. For German, Polish, English, Catalan, it is assumed that stress clashes need a metrical column height of three (lexical stress level). In German, stress clashes can occur after prefixation (a), composition (b) and phrasing (c).

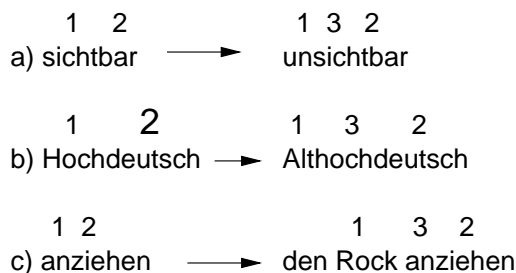


Figure 1: German stress clash environments

According to work in metrical phonology, speakers tend to prevent such stress clashes by either destressing one of the clashing syllables (cf. [7, 4]) or shifting the stress further away from the locus of clash [9]. Introspective phonological analyses for German would predict a stress shift, which ought to manifest itself at least on the perceptual level. This paper investigates whether this hypothesis can be experimentally supported.

## 2. Previous Studies

Earlier studies on English [1, 10, 3] imply that a stress shift, even if perceived as such, cannot be characterised by an actual “shifting” of the prosodic characteristics onto a neighbouring syllable. Even if this syllable is perceived as more prominent, it does not exhibit any significant differences compared to a syllable which has not been the landing site for a shifted stress. However, the work of [12] showed acoustic effects on the syllable the stress has been moved away from. This syllable was shorter in duration and lower in  $F_0$ . [5] also suggests that the acoustic data imply a stress reduction rather than a stress shift. It could be shown for Dutch [11] and English [3] that the stress shift is perceived less clearly if the stress clash triggering context is removed.

Results on German confirm the perceptual nature of the phenomenon: In his study on stress clash, [6] used trisyllabic synthetic, monotonic and delexicalised stimuli which were perceived as carrying primary stress on the first syllable. He found that a majority of subjects perceived a secondary accent on the third syllable even though this did not manifest itself in the acoustic data. Thus, native speakers of German obviously tend to prefer alternating stress patterns on a perceptual level. However, it is still unclear how naturally occurring stress clash environments are perceived and produced in German.

## 3. Choice of Stimuli

As stimuli triggering stress shift, 35 (A(BC))-compounds were chosen from a large newspaper corpus [8]. In all compounds, constituents A and B are monosyllabic, some of the C-constituents are bisyllabic, but ending in an unaccentable schwa-syllable (e.g. *Fach-hoch-schule*: /fax.hox.fu:lə/). Thus, each of these stimuli exhibits a stress clash situation between A and B, provided that A carries the primary stress of the entire compound, and B carries the primary stress of the BC-compound and would thus be the potential location of the secondary stress within the (A(BC))-compound. The phonological prediction for such a constellation is a shift of the secondary stress from the B- onto the C-constituent:

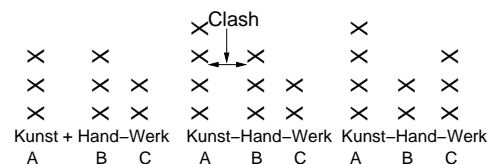


Figure 2: Hypothesised stress shift in one of the stimulus words

## 4. Experiment 1: Secondary Stress Location

In a first experiment, 21 subjects were asked to judge the location of the secondary stress for each stimulus word in a forced choice test.

### 4.1. Setting

The stimuli were read by a female professional speaker and integrated into the carrier sentence “*Er sagte, ... sei das richtige Lösungswort*” in order to guarantee a stable prosodic context. The 21 subjects participating in the experiment were phonetically naïve as well as phonetically trained listeners.

### 4.2. Results

In 66% of the cases, listeners identified the B-constituent as carrying secondary stress (no stress shift), whereas in the remaining 34%, the C-constituent was judged as more prominent (stress shift). The results show significantly, that the phonological hypothesis of a stress shift in this particular environment has to be rejected. Instead, the secondary stress is rather perceived next to the primary one. The results are even more convincing for trisyllabic compounds (preception of stress shift in 28%). In four-syllabic compounds, no significant preference for either configuration is detectable (perception of stress shift in 54%). The results also show, that the naïve listeners are much less consistent in their judgements. Phonetic experts agreed in 80% between first and second judgement of identical stimuli, whereas naïve listeners agreed only in 50%. Since naïve listeners reported difficulties with the task, it was decided to carry out all further experiments with phonetic experts. An overview of the results is shown in Table 1.

	Stress Shift	No Stress Shift
all	34%	66%
three-syll.	28%	72%
four-syll.	46%	54%

Table 1: Judgements for Experiment 1

## 5. Experiment 2: Prominence Perception

In experiment 1, the use of an identical carrier sentence appears to have triggered a contrastive accentuation of the primarily stressed syllable. This strong primary stress apparently disturbed the impression of the secondary stresses. Therefore, for a follow-up experiment, the stimuli were recorded again using their original newspaper contexts as carrier sentences.

### 5.1. Setting

The sentences were read by two non-professional male speakers who were not familiar with the purpose of the experiment. It was checked that none of the stimuli were produced in the immediate vicinity to a prosodic phrase boundary, which may have influenced the perceptual impression by the presence of a boundary tone. Since listeners had reported problems with the forced choice task in experiment 1, they were allowed to judge the perceptual prominence of each syllable independently on a continuous scale they could set in a GUI (cf. Figure 3). Internally, the listeners’ judgements were mapped on a 0-30 scale similar to the one used by [2]. The upper boundary of the scale

was supposed to be used as an orientation line for perceived lexical stress, the lower boundary was supposed to reflect a completely destressed syllable. Listeners were allowed to judge syllables as equally prominent. This enabled listeners to mark subtle differences in prominence as well as the impression of absolute destressing. 19 subjects participated in the experiment, all of them phonetically trained. In order to make sure that the listeners judged both speakers’ productions independently, the test was carried out in two separate sessions on different days.

### 5.2. Results

In three stimuli, the speakers clearly (100% inter-subject agreement) realised the primary stress on the second syllable instead of the first. These examples were not taken into account in the subsequent evaluation. Again, the majority of the listeners did not perceive a stress shift of the B- onto the C-constituent (only 29%). Also, a destressing of the B-constituent, where second and third syllable are perceived as almost equally weak in prominence, did not take place very often (11.5%). The preferred pattern remained the impression of a secondary stress on the B-constituent (43%). In the remaining cases (16.3%), listeners located the primary stress on the second or third syllable making these cases obsolete for the aim of this study. An overview of the results is given in Table 2.

Stress Shift	No Stress Shift	Destressing	Other
28.9%	43.3%	11.5%	16.3%

Table 2: Judgements for Experiment 2

On average, subjects correlate substantially, but not highly. The fact, that some subjects correlate highly or very highly (Spearman-Rho,  $\rho$  ranging between 0.7 and 0.9), but others only poorly (Spearman-Rho,  $\rho < 0.5$ ), indicates different listener strategies in the location of lexical stress. Five subjects correlate poorly with all other participants, whereas 5 others correlate very often highly with the others. This indicates a different degree of reliability of the different participants. 8 words proved to be difficult concerning the location of primary stress and were left out in the further examination. 10 of the 68 compounds significantly show ( $\chi^2, p < 0.01$ ) a stress pattern **1 2 3** with a secondary stress on the second syllable and neither a stress shift nor a destressing. For 33 compounds, no significant tendency for either pattern could be found, but the majority of the judgements indicates the pattern **1 2 3** as well. In the compounds consisting of four syllables and three other words, subjects perceived the pattern **1 3 2** (stress shift) in the majority of cases. However, this tendency was only significant ( $\chi^2, p < 0.01$ ) for one speaker. This speaker produced three trisyllabic words with a perceptually clear stress shift as well.

## 6. Experiment 3: Validation of stress shift

Since previous studies have shown a less clear impression of stress shift once the triggering context is removed, this was tested for those stimuli where a shift has been perceived in a significant number of cases. The stimulus words were the following ones:

- Hauptfahrrinne (*A* Haupt(*B* fahr-*C* rin-ne))
- Geldbriefträger (*A* Geld(*B* brief-*C* trä-ger))
- Hilfsbuchhalter (*A* Hilfs(*B* buch-*C* hal-ter))
- Fachhochschule (*A* Fach(*B* hoch-*C* schu-le))

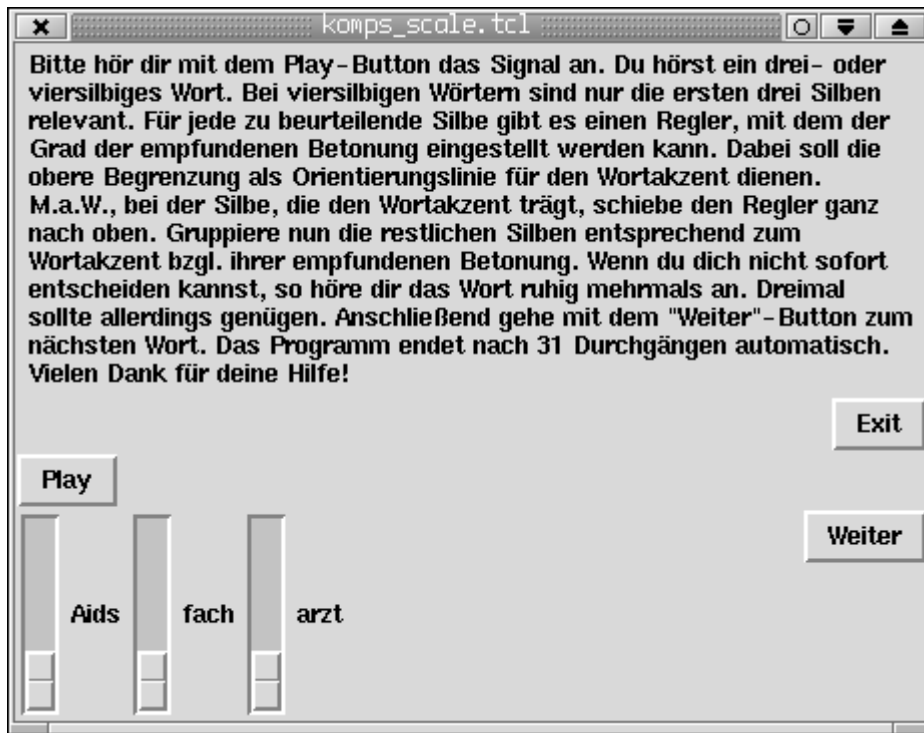


Figure 3: GUI for the perception experiment

- Heizkraftwerk (<sub>A</sub> Heiz(<sub>B</sub> kraft-<sub>C</sub> werk))

### 6.1. Setting

The A-constituent of the stimuli is the part which ought to trigger the stress shift away from the B-constituent onto the C-constituent (cf. Figure 2). Thus, the A-constituent was deleted and 10 phonetic experts had to decide about the location of the primary stress in the remaining BC-compound.

### 6.2. Results

Except for the compound *Heiz-kraft-werk*, the results indicate a clear preference of perceiving the primary stress on the second syllable (cf. Table 3). Here, the stress shift clearly manifests itself so strongly, that it remains perceptible even if the stress shifting context is deleted. The only stimulus that proved difficult to judge was the only remaining trisyllabic one.

	Syll 1 prominent	Syll 2 prominent
Buch-hal-(ter)	30%	70%
Fahr-rin-(ne)	30%	70%
Brief-trä-(ger)	20%	80%
Hoch-schu-(le)	0%	100%
Kraft-werk	50%	50%

Table 3: Judgements for Experiment 3

## 7. Experiment 4: Perception of delexicalised stimuli

In order to check whether the perceptual impression was somehow influenced by the lexical structure of the compounds, a last

perception experiment was carried out, this time using delexicalised versions of the stimuli.

### 7.1. Setting

The stimuli of one speaker were delexicalised using the PRAAT software. The resulting stimuli were again judged by 11 phonetic experts. The conditions were otherwise identical to experiment 2 (cf. Section 5). In order to be reliably able to identify the influence of the lexical representation, the stimuli were first judged together with an orthographical representation or the stimulus words and 2 weeks later without it.

### 7.2. Results

Listeners' judgements were certainly influenced by the lexical structure of the stimuli, since the judgements differed greatly between those where an orthographical representation was present and others where it was not. Subjects reported difficulties given no orthographical representation. Given access to orthography, the only stimulus clearly showing a stress shift remained the one that had been also identified as having stress shift in the prior experiment for this speaker *Wind-schutz-scheibe*. Without orthographical representation, the impression of a stress shift became more frequent, for some listeners much more than for others. Also, many listeners placed the primary stress on the second syllable, which often contained the (late)  $F_0$  peak. Others often perceived two primary stresses on first and second syllable, but no stress shift. A destressing was not perceived more frequently without the orthographical representation. In the previous tests, people were probably influenced by the lexical structure and much more willing to perceive the primary stress on the first syllable. The predominant impression remained the stress pattern **1 2 3** or **1 1 2**. The minor number

of cases showed a speaker strategy to avoid the stress clash by either destressing or shifting the secondary stress. Again, four-syllabic words were perceived as exhibiting a stress shift or a destressing more often—however not significantly—than others. Table 4 shows the results of Experiment 4

	Stress Shift	No Stress Shift	Destress.
orth. shown	3%	69%	28%
no orth.	22%	59%	19%

Table 4: Judgements for delexicalised stimuli

## 8. Discussion

The results clearly show that stress shift may occur in German stress clash environments but it is far away from being the regular variant. If it does occur, though, it apparently has an articulatory and acoustic manifestation and is not only a perceptual phenomenon. This becomes evident because the impression of a stress shift remained stable even if the stress shifting environment was deleted. If the syllabic structure allows the insertion of an additional foot, as it is the case in four-syllabic compounds, a stress shift becomes much more likely than in trisyllabic ones. If the stimuli are delexicalised and thus the semantic and lexical representation is inaccessible to the listeners, a perception of stress shift is more likely but not predominant.

Unfortunately, the few stimuli do not allow any conclusive acoustic investigation. Especially an analysis of the duration patterns is difficult without any comparative material of identical speakers. Also, the analysis of  $F_0$  is difficult for the stimulus material, because it contains large amounts of unvoiced segments mainly due to German final devoicing at syllable boundaries. However, an analysis of the  $F_0$  patterns shows a presence of a late peak on the primary stress syllable in those cases where no stress shift was perceptible. The stimuli where listeners perceived a destressing often showed a flat  $F_0$  contour after the pitch accent staying at a relatively high level. It appears to be the case, however, that a close analysis of the duration patterns is necessary to find out more about the phonetic basis of the prosodic realisations in stress clash environments. Also, listener and speaker strategies appear to play a role.

## 9. Conclusions

It has been shown that despite it being assumed a typical phenomenon of German, stress shift or even destressing in stress clash contexts appears to be a variant rather than a regular phenomenon. The only stimuli where a stress shift was perceived more reliably were words, where an additional foot could be placed after the syllable the stress was shifted onto. However, if a stress shift takes place, it is not only a perceptual phenomenon but remains perceptible even if the context causing the clash is removed. A destressing of the secondary stress appears to be an alternative production strategy speakers use in order to handle stress clash environments. A more detailed analysis of the acoustic realisation of stress clash environments remains future work.

## 10. References

- [1] Cooper, W.E.; Eady, S.J., 1986. Metrical Phonology in speech production. *Journal of Memory and Language*, 25(3),369-384.
- [2] Fant, G.; Kruckenberg, A., 1989. Preliminaries to the study of Swedish prose reading and reading style. *STL-QPSR* 2/1989, 1-68.
- [3] Grabe, E.; Warren, P., 1995. Stress Shift: Do speakers do it or listeners hear it? In: Cornell, B.; Arvaniti, A. (eds.), *Papers in Laboratory Phonology IV. Phonology and Phonetic Evidence*, Cambridge: Cambridge University Press, 95-109.
- [4] Gussenhoven, C., 1991. The English rhythm rule as an accent deletion rule. *Phonology*, 8, 1-35.
- [5] Horne, M., 1990. Empirical evidence for a deletion formulation of the rhythm rule in English. *Linguistics*, 28, 959-981.
- [6] Mengel, A. 1998. *Deutscher Wortakzent. Symbole, Signale* Phorm Verlag: München.
- [7] Nespor, M.; Vogel, I., 1986. *Prosodic Phonology*, Foris: Dordrecht.
- [8] Quasthoff, U., 1998. Deutscher Wortschatz im Internet. *LDV Forum. Zeitschrift für Computerlinguistic und Sprachtechnologie*, 15(2), 4-23.
- [9] Selkirk, E. (1984). *Phonology and Syntax. The relation between sound and structure*, Cambridge University Press: Cambridge.
- [10] Shattuck-Hufnagel, S., 1995. The importance of phonological transcription in empirical approaches to “stress shift” vs. “early accent”: comments on Grabe and Warren, and Vogel, Bunnell and Hoskins. In Cornell, B.; Arvaniti, A. (eds.), *Papers in Laboratory Phonology IV. Phonology and Phonetic Evidence*, Cambridge University Press: Cambridge, 128-140.
- [11] van Heuven, V., 1991. Stress clash avoidance in Dutch: Inversion of stress patterns in complex nouns? In: *Proceedings of ICPHS '91*, Aix en Provence, France, vol. 3, 226-229.
- [12] Vogel, I; Bunnell, H.T.; Hoskins, S., 1995. the phonology and phonetics of the rhythm rule. In Cornell, B.; Arvaniti, A. (eds.), *Papers in Laboratory Phonology IV. Phonology and Phonetic Evidence*, Cambridge University Press: Cambridge, 111-127.