Borrower: GDC
IN PROCESS: 20051207
Lending String: *INT,ORU,MNN,MUB,PAU

Patron: ;dept; ;type; Amith, Jonathan

Journal Title: Written language and literacy.

Volume: 7 **Issue:** 2
Month/Year: 2004 **Pages:** 305-31

Article Author:

Article Title: Wiese, Richard; How to optimize orthography

Imprint: Amsterdam ; Philadelphia ; John Benjamin

ILL Number: 15030736

Call #:

Location: RR

ARIEL
Charge
Maxcost: $25IFM

Shipping Address:
Gettysburg College
Library
Interlibrary Loan
Gettysburg, PA 17325-1493

Fax:
Ariel: 138.234.4.47

Author's address:

Alexandra Wiebelt
Universität Mainz
Deutsches Institut
Jakob-Welderweg 18
55218 Mainz
Germany

e-mail: wiebelt@mail.uni-mainz.de

How to optimize orthography*

Richard Wiese
University of Marburg

The basic goal of this paper is to provide a formal treatment of "orthographic principles" in terms of optimization. Starting from a discussion of a preference-oriented vs. a rule-oriented systematic theory of orthography, the paper explores an explicit description of orthographic regularities in terms of Optimality Theory, that is, in terms of a theory of constraints and their interaction. The empirical focus of this paper is on German orthography, in particular on sound–letter correspondences, on morphological constancy in the light of phonological alternations, and on the (non-)doubling of graphemes. Interactions of various constraints to specify the relationship between regular and irregular spellings involving these domains on the one hand and phonological forms on the other hand are presented.

1. Introduction — frameworks

Optimization in a very general and somewhat vague sense plays a prominent role in many discussions of writing systems and orthography. In theoretically oriented research, writing systems, that is, fundamental systematic properties of the written modality in a language, and orthographies, that is, the explicitly regulated details within a writing system, are often supposed to follow general preferences, though exceptions to these obviously exist, and the principles are often in conflict with each other; see (Rahnenführer, 1980), (Nerius et al., 2000), inter alia. Furthermore, there is often an obvious functional motivation for these rules/preferences (see examples below). But optimization is only poorly understood, first because formal descriptions of orthographic regularities as developed within structural or generative graphemics do not normally include a concept of optimization, and second because, in preference-based descriptions, there is usually no proper characterization how the interaction of the preferences assumed to be operative is possible at all.

Optimality Theory (OT) promises a better understanding of the role of optimization in orthography; first, because the notion of optimization is built into the theory itself; second, because OT by its basic mechanism of evaluating the correspondences between parallel structures (instead of deriving one structure from another), seems particularly fit to deal with orthography; and third, because OT is able to deal with conflicts between preferences in a direct way.

However, very few contributions to the analysis of writing systems and orthography within the OT framework exist to date (for references to the existing work see below). In this paper, some proposals towards an optimality-theoretic approach to the orthographic system of present-day German are offered. In this first section, I will outline basic properties of two different theoretical approaches to orthography, one based on formal rewriting rules, and one based on preferences. In the following sections of this paper, some empirical domains and detailed solutions within such an approach are discussed. The focus of this paper is on sound–letter correspondences and on the (non-)doubling of graphemes in present-day German.

1.1 A rule-based description of orthography

Perhaps the most ambitious project for the explicit integration of orthography into a theory of grammar is that proposed by (Bierwisch, 1975, original publication in 1972). In this work, he presupposes a Generative Grammar of the type developed by (Chomsky, 1965) and (Chomsky and Halle, 1968). In consequence, the model assumes that graphemes should be derived from syntactic surface representations, the feature matrices derived by the insertion of lexical items into syntactic structures. Phonological rules apply to these forms as well as the rules for deriving orthographic representations. The latter are called grapheme–phoneme correspondence rules, taking bundles of phonological features as input and delivering graphemes as output. Finally, the existence of exceptions relative to general rules is recognized by means of exception features which restrict the application of rules to forms marked with this feature. In (1), three rules from this proposal are given, all involved in the spellings of the consonant sequence /ks/ in word-final position (Bierwisch, 1975: 25ff., my translation).

(1) Three rules for the spellings of /ks/ sequences

a. $\begin{pmatrix} +\text{ obstruent} \\ -\text{ continuant} \\ +\text{ back} \\ -\text{ voiced} \end{pmatrix} \rightarrow \langle ch \rangle \,/\, \_\_\_\_ \begin{pmatrix} +\text{ obstruent} \\ +\text{ continuant} \\ +\text{ coronal} \end{pmatrix}$

b. $\begin{pmatrix} +\text{ obstruent} \\ +\text{ continuant} \\ +\text{ coronal} \end{pmatrix} \rightarrow \langle s \rangle$

c. $\begin{pmatrix} +\text{ obstruent} \\ -\text{ continuant} \\ +\text{ back} \\ -\text{ voiced} \end{pmatrix} \begin{pmatrix} +\text{ obstruent} \\ +\text{ continuant} \\ +\text{ coronal} \end{pmatrix} \rightarrow \langle x \rangle \,/\, M.$

Rule (1a) gives the output ⟨ch⟩ for a feature bundle representing /k/, if the segment in the right-hand context is a (voiced or voiceless) /s/, while rule (1b) gives the grapheme ⟨s⟩ for the set of phonemes /s, z/. (A rule not mentioned here will of course give ⟨k⟩ for /k/ in the general case.) Rule (1c) is an exception rule (note that it has the same input condition as rule (1a)): it gives ⟨x⟩ for all those morphemes which are marked with the exception feature M. pointing to the relevant rule.[1] Formally, the rules are context-sensitive rewriting rules. Others have proposed either context-free rules (Eisenberg 1998) or context-sensitive rules plus the possibility of inherently ordered rules, see (Neef, 2003: ch. 4), (Neef, this volume).

The rules given in (1) allow for the derivation of a set of relevant final consonant graphemes in German words. In (2), three such derivations are given as examples; see (Bierwisch, 1975: 33ff.). Each line specifies the result of applying one of the rules in (1). Here as in the remainder of this paper, I follow the often used convention of enclosing underlying phonological forms by "|", while graphemes are signalled by "⟨⟩", and phonemes in general by "/".

(2) A derivation of *Fuchs* 'fox', *Jux* 'joke', *flugs* 'swiftly'

Input:	| f u k s |	| j u k s | [+ R c.]	| f l u: g s |
Rule 1c:		⟨x⟩	
Rule 1a:	⟨c h⟩		
Rule 1b:	⟨c h s⟩		⟨s⟩
Other rules:	⟨F u c h s⟩	⟨J u x⟩	⟨flugs⟩

For *Fuchs* 'fox', rules (1a,b) straightforwardly derive the grapheme sequence ⟨chs⟩. Rule (1a) cannot apply to *flugs* 'swiftly' (though it is pronounced [flu:ks] with voiceless [k]!), because rules operate on the underlying phonological forms. For *Jux* 'joke', the exception feature [+R. c] makes sure that this rule applies, yielding ⟨x⟩. Rule (1a) is blocked by the application of rule (1c). This latter rule necessarily has priority over the competing rule (1a). Otherwise, the

exceptional form ⟨Jux⟩ would never have the chance of being derived. This relationship between two rules, a specific one and a general one, has been stated as the Elsewhere Condition; see (Kiparsky, 1973). Application of rule (1c) to ⟨Jux⟩ also blocks rule (1b); otherwise, the result would be *⟨Juxs⟩. Thus, a special property of grapheme–phoneme correspondence rules is that they apply to each phonological item only once.

Three general points are noteworthy in the present context: first, the rules are directional, in that they invariably lead from phonological inputs to orthographic outputs (in contradiction to the characterization of the rules as 'grapheme–phoneme correspondence'). There is no sense at all in this framework for looking at generalizations "from letter to sound" (as in the concept of recoding proposed by (Neef, 2003)). Second, the rules are sensitive to phonological information alone. More generally, they are designed to apply to exactly one level of representation. Finally, the orthographic forms are derived by rule in every single case; that is, the mechanism of a context-sensitive grapheme–phoneme-correspondence rule is the only device available in this framework.

1.2 Preference-based descriptions of orthography

The notion that each orthography is a particular system of representing language in the visual domain quickly leads to the proposal that there exist options, alternative pathways, for such representations. Each of these implements different preferences, or modes of representing language in the visual domain, where following one specific preference possibly implies the negation of another such preference. The existing literature on orthographic systems is replete with discussions of such preferences. In (3), a list of such preferences is presented. The list was compiled from a number of sources, including (Eisenberg, 1996), (Maas, 1992), (Maas, 1997: 2–7), (Nerius et al., 2000), (Rahnenführer, 1980). (Venezky, this volume) presents a good survey on such preferences from a cross-linguistic perspective.

(3) Preferences in orthography, examples
   a. One letter — one phoneme/sound.
   b. Write as you speak.
   c. Write as you would like to be read.
   d. One morpheme — one spelling (stem constancy).
   e. Mark boundaries (word, sentence, etc.).
   f. Do not change a spelling.
   g. Do not change an orthography.
   h. Do not change the inventory of letters.

   i. Make the orthography easy to learn.
   j. Make the orthography hard to learn.[2]
   k. Make the orthography easy to read.
   l. Make the orthography easy to write.

As the above list demonstrates, the preferences are diverse, as they relate aspects of an orthography to different levels of language, or items of language (phonemes, morphemes, words, etc.), or to language use (reading, writing) or learning (reading, writing). The list could be extended easily, and some of the preferences on the list could be differentiated into distinct sub-preferences.

The existence of such principles appears to be well-founded on the grounds of various lines of evidence. But the rule-based approach has no direct way of integrating such principles in its mechanisms. A rule violating principles as those above is just as easy to state as one obeying these principles, and whether the outcome of rule application is such that preferences are obeyed or not is an accidental by-product of rules. In an rule-based approach such as that of (Bierwisch, 1975), there is no possible place for principles as those mentioned in (3). The reason is, first, that the principles are "wishes" or "preferences" with many exceptions or even counter-examples.

This observation relates to the fact that the principles pose conflicting demands upon writing systems and upon the other domains of a grammar with which writing interacts (phonology and morphology, among others). Preferences are not necessarily compatible with each other: ease in writing (3l) may be in direct conflict with ease in reading (3k), for example, and "Write as you speak" (3b) clashes with the plea not to change a spelling (3f) in the case of pronunciation changes over time. The preference to give each sound a letter-size symbol (3a), in turn, is seriously curbed by the ban against the addition of new letter symbols into an alphabet (3h). Such conflicting demands have often been identified and discussed; (Munske, 1984) discusses conflicts between phonematic and morphematic principles, and between phonematic and historical principles. Other examples can be found in the work of (Maas, 1997), (Nerius et al., 2000), and (Venezky, this volume).

For these reasons, the preferences are rarely, if ever, true in an absolute sense. This again may be the reason that none of the preferences are accepted in the literature without controversy, and that systematic descriptions of orthographic systems normally do not make use of preferences as those listed in (3). It has been close to impossible to integrate the principles into a coherent, let alone, formal framework for the description of writing systems and orthographies.

It would be possible to use preferences of the kind presented in (3) as guiding principles underlying orthographic rules. But in such a move, much information would be doubled: preferences would exist as such, and as encoded in the individual rules. Furthermore, the problem of conflicting preferences would still remain an unsolved issue. Before I discuss some of the preferences in more detail, a theory with a focus on the interaction of preferences (in a specific sense), Optimality Theory, will be introduced.

2. Optimality Theory in the description of orthography

2.1 Principles of Optimality Theory

Optimality Theory (OT) was developed in response to the growing unease in theoretical linguistics about the derivational machinery in Generative Grammar, and because of the indirect role played by markedness considerations. In the work by (McCarthy and Prince, 1993) and (Prince and Smolensky, 1993) especially, these concerns led to a conception of a formal grammar which takes the notions of constraints (expressions of preferences), constraint interactions (hierarchies of such constraints), and violability of constraints as core ideas. This is not the place for an introduction to OT; for these see (Archangeli and Langendoen, 1997) and (Kager, 1999). Instead, I briefly mention crucial claims and properties of OT here, and present an introductory example in 2.3.2 below.

The basic claim of OT is that grammar is based not on the application of rules, but on constraint interaction. Constraints come in two types: some of them evaluate surface forms with respect to wellformedness (i.e., markedness), and others with respect to faithfulness, which basically means that the input (the underlying form of lexical entries) should be identical to the output (the surface form) of the respective input. Constraint interaction consists in the parallel application of all constraints, which are put into an order of domination (the constraint hierarchy), to the inputs. The fact that constraints put potentially conflicting demands to a form is recognized by making constraints violable. But they can be violated only if this leads to the non-violation of a higher-ranking constraint.

Furthermore, constraints are assumed to be universal. In order to account for the fact that languages are different, the constraint hiearchies (and not the constraints themselves) differ from language to language. In the pure form of the theory, grammars of different languages differ by constraint ranking alone.

In sum, grammaticality results from satisfaction of higher-ranking constraints with respect to lower-ranking constraints. In the evaluation of candidates, a procedure which leads to the choice of the correct output given an input, "the correct output is the candidate whose complete structure best satisfies the constraint hierarchy." (Prince and Smolensky, 1993: 19).

2.2 Inputs and outputs

We now turn towards the integration of orthography into a grammar in the sense of OT, a largely neglected topic. As any other part of grammar, the orthography part must take an input (from the lexicon) and specify the output which is optimal according to the hierarchy of orthographically relevant constraints. It is the task of the linguist to find a constraint hierarchy which leads, within the formal structure of an OT evaluation, to the choice of the orthographic output which is correct in the language under consideration.

In the present work, I take the inputs to be the non-predictable elements of an orthographic form plus the phonological input of the respective forms. Outputs, in the present work, are orthographic word-forms. No attention is paid here to aspects such as capitalization, punctuation, etc. Alternative conceptions for the input are possible; in the study of (Geilfuß-Wolfgang, 2002), for example, inputs are fully specified strings of graphemes. The present view assumes that predictable vs. non-predictable features of writing can be learned from exposure to the surface forms and is illustrated by the examples in (4). For a few words from English and German, the assumed inputs and outputs are given here. Empty orthographic input information is denoted by "Ø". *Bus* 'bus' and *Kuss* 'kiss, n.' are near-minimal pairs with respect to the doubling of the final letter (to be discussed as "geminates" in Section 3.3 below). In accord with the standard analyses, I take the doubled letter to be the regular case here; accordingly, *Bus* is marked with an underlying grapheme ⟨s⟩ in the input in order to express this lexical exception; see also Section 3.3 below. A more principled alternative to this marking of exceptional spelling might be to mark this lexical item by the violation of the constraint requiring final doubling (the constraint PARADIGM introduced in (16) below). This would be a solution in the spirit of Direct OT (Golston, 1996).

(4) Input and output in predictable and unpredictable spellings

Word	*Input*	*Output*
German *Fisch*	⟨Ø⟩; |fɪʃ|	⟨fisch⟩
German *Photo*	⟨ph Ø⟩; |'fo:to|	⟨photo⟩

English *fish*	⟨Ø⟩; |fɪʃ|	⟨fish⟩
English *enough*	⟨Ø o u g h⟩; |ɪ'nʌf|	⟨enough⟩
German *Kuss*	⟨Ø⟩; |kʊs|	⟨kuss⟩
German *Bus*	⟨Ø s⟩; |bʊs|	⟨bus⟩

The input representations in (4) are insufficient insofar as they contain no information about the precise correspondence between individual units on the phonological and orthographic level. Following (Prinz and Wiese, 1990), I assume that a phonological representation contains abstract positions (often called CV-positions following (Clements and Keyser, 1983)), and that graphemes as well as phonological segments are linked to these positions. Positions thus provide the necessary meeting points between phonemes/segments and graphemes/letters and specify unambiguously which segment/grapheme corresponds to which other unit. The representations allow for one-to-many linkings between phonemes and graphemes, and vice versa. These representations are not drawn explicitly in the following.

Note further that the orthographic parts of inputs in (4) are sometimes completely unspecified (as for German *Fisch* or English *fish*) or partly specified, as most obviously for English *enough*. This represents linguistic judgments as to the predictability or unpredictability of particular spellings.[3] As in the case of the rule-based framework sketched in Section 1.1, some of the specific decisions made in (4) may have to be revised.

A further principled question which arises here is the nature of the regularity which specifies the correspondence between particular underlying segments and particular graphemes. It would not make sense and be against the OT claim for the universality of constraints, to argue that there are constraints saying, for example, that the grapheme ⟨f⟩ corresponds to phoneme /f/. There is nothing inherently universal in this correspondence, however regular it is in a particular language or even in a whole set of alphabetic systems. Regular sound–letter correspondences such as ⟨f⟩ ⟷ /f/ must be part of the structural description of a specific language, just as the set of phonemes, the set of morphemes (sound–meaning correspondences), etc. In other words, pairings such as ⟨a⟩ ⟷ /a/ or ⟨f⟩ ⟷ /f/ are as arbitrary as are the form-meaning pairings of the Saussurean linguistic sign, and a pairing ⟨b⟩ ⟷ /f/ or ⟨e⟩ ⟷ /a/ would be just as good as the ones cited before.

The picture is drastically different if looked at historically. Here we note that there are principles among the preferences listed above (3f–h) which disfavor changes in spellings, orthography, and alphabets. These preferences provide good reason not to change the sound–letter correspondences which are

part of an orthography. For orthographies based on the Roman alphabet, this means that the correspondences established in Latin writing provide a role-model which was changed remarkably little over the more than 2,000 years to follow. Most basic sound–letter correspondences are still the same; very few letters were added.

In the following analyses, I will take these individual letter–sound correspondences for granted. Deviations from the sound–letter correspondences are taken care of by enriching input forms in the manner proposed in (4) above. This will allow for all kinds of deviations, such as writing ⟨ph⟩ for /f/, so-called silent letters, etc.

The correspondence between phonological and orthographic units in the present work is not restricted to a particular level of representation. Rather, I assume that at least the levels given in (5) need to be recognized for a principled account of the sound–letter correspondences. This view departs from that of (Bierwisch, 1975) (see Section 1.1), as well as that of (Neef, 2003) who operates on the two output levels alone, or from the view presented in (Wiese, 1989), where a model is proposed in which grapheme–phoneme correspondence rules take the intermediate output of the Lexical Phonology as the only orthographically relevant phonological level.[4] In the present model, there is no need for absolute restrictions of this sort. Orthographic input and output are conceptualized as introduced in (4). In (5), abbreviations for the four relevant levels are introduced as well.

(5) Levels and notation

phonological input:	**P-Input**
phonological output:	**P-Output**
orthographic input:	**O-Input**
orthographic output:	**O-Output**

2.3 Constraints

In this paper, I reanalyze and reformulate some so-called principles which have been identified in earlier work on orthographic systems, especially that of present-day German. Among such principles, at least the ones listed in (3) should be mentioned. However, there is no general one-to-one relationship between such preferences and the constraints as used in OT work.

Up to now, very few studies of writing systems and orthography within the OT framework have surfaced. I am aware of only three studies, that of (Sternefeld, 2000), (Geilfuß-Wolfgang, 2002) and (Primus, this volume). All of

these studies deal with present-day German, in particular with orthographic geminates and hyphenation.

2.3.1 *Correspondence theory*

A central part of current Optimality Theory is a theory of *correspondence*, the relation between different units on different levels of representation to each other; see (McCarthy and Prince, 1995) and others. In the following, correspondence-related constraints are argued to be central for an OT-approach to orthography. Given that the relationship between phonological and orthographic word forms is central to any account of alphabetic orthography, this is no surprise. Generally, correspondence theory in OT can be summarized as in (6).

(6) The notion of correspondence
   a. There is a correspondence relation between elements of each input and output level.
   b. Mismatches between corresponding elements in different levels are to be avoided; i.e., count as constraint violations.
   c. Such mismatches are found, but only if enforced by higher-ranking constraints.
   d. Mismatches consist in omissions and/or additions of elements on one level, but not the other.

Note that the wording in (6) is very general with respect to the units supposed to stand in the correspondence relation. Indeed, all types of linguistic units must be involved. One type of correspondence therefore involves boundaries between units, a correspondence called 'alignment' in recent OT. Alignment is the co-occurrence of (left or right) edges of distinct categories, where the categories (such as graphemes, syllables, or morphemes) can be drawn from the categorial inventories of distinct linguistic levels. The general format of alignment is given in (7), following (McCarthy and Prince, 1994: 80); we will come across instances of this below.

(7) Alignment
   ALIGN(CAT1, EDGE1, CAT2, EDGE2) =def
   For all Cat1, there is a Cat2 such that Edge1 of Cat1 and Edge2 of Cat2 coincide.

In applying this framework to orthography, it is immediately obvious that correspondence is a key concept in generalizations on orthography. Several types of both input and output correspondence must be distinguished. A large

number of principles such as those mentioned in (3) above (recast here in OT terms) will be shown to contain statements on various correspondence relations. Different rankings of the constraints proposed, especially those which are in conflict with each other, will then deliver various types of writing systems (for example, so-called deep vs. shallow systems of orthography, that is, those which refer to surface-phonemic patterns vs. those which refer to morphophonemic or even lexical identities).

2.3.2 *A first example*

One obvious, though often ignored, generalization on sound–letter correspondences is that the linear order between corresponding elements in phonological and orthographic representations is the same.[5] An example would be the word "Fisch" /fɪʃ/ which cannot be written **Schif* nor in any other order of either the letters or graphemes. Borrowing from a discussion of a constraint called LINEARITY, (McCarthy and Prince, 1994: 7), I propose the following constraint:

(8) LINEARITY
   Corresponding elements in P-Output and O-Output have identical linear order.

This constraint may be used as introducing the basic system of analysis in OT, that of presenting the evaluation of an input by a constraint tableau. The tableau contains possible outputs given an input, and indicates how these outputs fare with respect to certain constraints. In (9) the graphemes are exactly the ones required for the word. Only candidates with permutation in linear order of graphemes are considered. Constraint violations are noted in the cells of the tables by asterisks; candidates are written below the input which is displayed in the first cell of the table; and the winning candidate is singled out by the pointing finger.[6]

(9) A simple evaluation involving linear correspondence

⟨Ø⟩; |fɪʃ|	LINEARITY
☞ ⟨fisch⟩	
⟨schif⟩	*
⟨ifsch⟩	*

While both ⟨schif⟩ and ⟨ifsch⟩ are phonotactically and graphotactically possible in German, they violate LINEARITY and therefore are not possible graphemic outputs for the form in question.

3. Application to German orthography

The preceding example is trivial in the sense that it does not display conflicting constraints. Such conflicts are now studied by looking at a few richer areas of German orthography, and introducing constraint interaction in several areas. These areas are those in (10). For each of these areas, I will propose and discuss constraints or constraint families in subsequent Section 3.1 to 3.4.

(10) Constraint areas covered
  a. correspondence between orthographic and phonological forms
  b. correspondence within stems (stem constancy)
  c. ban on gemination
  d. treatment of phonological alternations

3.1 The phonological principle: one letter — one sound

Correspondence between phonological and orthographic forms comes in several different shapes. It relates to either graphemes or letters on the orthographic side; and it takes inputs and/or outputs on both sides as relevant levels. Therefore, the constraint requiring correspondence between units on the two levels is in fact not a single constraint, but a constraint family. Furthermore, a constraint is violated both by the presence of some unit on an output level with no counter-part on an input level, and by the reverse. The former (output, but without input) is addition (schematically displayed in (11a)); the latter (input, but without output) is omission (see 11b).[7] Note that the constraints (11a, b) just ask for *some* element to correspond to another; constraint (11c), an identity constraint goes one step further and demands identical elements to correspond; see below for elaboration.

(11) Constraint family sound–letter correspondence
  a. DEP(P-INPUT/P-OUTPUT, O-OUTPUT) — No addition!
  b. MAX(P-INPUT/P-OUTPUT, O-OUTPUT) — No deletion!
  c. IDENT(P-INPUT/P-OUTPUT, O-OUTPUT) — Corresponding elements must be identical!

On the basis of these schemata, a number of constraints can be formulated which express some of the preferences in (3) rather directly. The bidirectional nature of the correspondence relation allows for constraints looking into both directions (cf. (12a) and (12b)). At least the constraints in (12) are empirically well-founded and will be discussed briefly.[8]

(12) A collection of correspondence constraints
  a. Phonemes correspond to graphemes.
  (For every phoneme, there is one grapheme.)
  b. Graphemes correspond to phonemes.
  (For every grapheme, there is one phoneme.)
  c. Distinctive information corresponds to something in the orthography.
  (Phonemic length, tone, stress, etc. is expressed orthographically.)
  d. Non-distinctive information corresponds to graphemes.
  (Predictable schwa, phonetic vowel length, assimilated nasals, etc. is expressed orthographically)

The first two constraints conjunctively require a one-to-one relationship between graphemes and phonemes. (12c) relates to distinctive features other than segments. Given that those features are less often present in orthographic forms, it seems advisable to set separate constraints here. Finally, it is generally true that non-distinctive information is even less often represented orthographically. Very little allophonic or other phonetic detail is expressed in German orthography, for example; in other words, the principle of "Write as you speak" is a very low-ranking constraint. Looking over the set of constraints in (12), there seems to be an inherent constraint ranking here: a, b >> c >> d, with ">>" denoting a domination relation between the constraints in (12).[9]

Violations of the constraints in (12) are found, but not at will; an elementary prediction of the present work is that violations can occur only if caused by other constraints, through the force of their higher ranking.

Here are some examples of violations of constraints (12a-d) from German orthography. Geminates (see above and below) contain a consonant grapheme not corresponding to a phoneme; stress (even if distinctive) is not represented; the glottal stop or the various degrees of voicing and aspiration are never represented; some orthographic words represent phonemic length in a redundant (double) fashion; and the graphemic sequence ⟨ng⟩ usually (though not always) corresponds to a surface phonemic sequence without /g/. But inspite of these clear cases of orthographic blindness for non-phonemic information, it is not the case that non-distinctive features are never represented orthographically. Examples are mentioned in (12d) above.

A further correspondence constraint within the group of grapheme–phoneme correspondence relates to graphemic input and output in a different way. It is relevant both for forms displaying unpredictable correspondences (as those in (4) above), as well as for consonantal alternations such as the results of

Final Devoicing and g-Spirantization. These phonological alternations lead to a change in the nature of some consonants, so that they are different phonemes. But the spelling of these consonants does not change (cf. *Tag* ([ta:k]) 'day' with *Tage* ([ta:gə]) 'days'). In these cases, there is a phoneme for each grapheme (and vice versa), but it is not the "correct" one, the one specified by the individual correspondences discussed in Section 2.2 above. In addition to constraints disallowing deletion and addition, there must be constraints demanding identity of graphemes and phonemes, with respect to the individual sound–letter correspondences such as ⟨f⟩ ⟷ /f/, which are, as outlined above, "presupposed" in the present system. Such identity can exist between input consonants and graphemic output, but also between output consonants and graphemic output.[10] I take these observations to constitute evidence that all of the levels given in (5) are needed for a systematic descriptions of letter–sound-correspondence. The necessary constraints can be formulated as in (13).

(13) Identity constraints
   a. IDENT(P-INPUT, O-OUTPUT)
      For all phonemes in the input, the grapheme is the one specified in regular sound–letter correspondence.
   b. IDENT(P-OUTPUT, O-OUTPUT)
      For all phonemes in the output, the grapheme is the one specified in regular sound–letter correspondence.

Constraint tableaux displaying the forms and the necessary constraint rankings are given in (14), for the singular form (14a) and the plural form (14b). For simplicity's sake, I assume that the input to the plural suffix in *Tage* 'days' is schwa. This is questionable, but of no consequence in the present context. One alternative, proposed by (Primus, this volume: ch. 5.2), is to make use of a constraint demanding a vowel grapheme (surfacing as ⟨e⟩) for each syllable in the spelling. Only with the ranking order IDENT(P-INPUT, O-OUTPUT) >> IDENT(P-OUTPUT, O-OUTPUT) can the correct spellings for both *Tag* and *Tage* be derived. Other spellings, such as ⟨taf⟩, will violate both of the constraints.

(14) Tag vs. Tage('day — days')
   a. Tag

⟨Ø⟩; |ta:g|	IDENT(P-INPUT, O-OUTPUT)	IDENT(P-OUTPUT, O-OUTPUT)
☞ ⟨tag⟩		*
⟨tak⟩	*!	
⟨taf⟩	*!	*

   b. Tage

⟨Ø⟩; |ta:gə|	IDENT(P-INPUT, O-OUTPUT)	IDENT(P-OUTPUT, O-OUTPUT)
☞ ⟨tage⟩		
⟨take⟩	*!	*
⟨tafe⟩	*!	*

3.2 The morphological principle

The morphological principle or "stem constancy" is the preference of keeping the spelling of a stem the same for all its word forms. That is, a stem will appear with exactly one orthographic form even if the phonological forms are different. (Ramers, 2002) notes that stem constancy is relevant in at least the following five domains of German orthography: Umlaut, double graphemes, ⟨h⟩ as a length marker (lengthening-⟨h⟩, "Dehnungs-h"), Final Devoicing, and spirantization of /g/ after /ɪ/. This observation constitutes the case for another set of correspondence constraints, in this case one between different orthographic outputs, independent of their relevant phonological forms. The tendency of orthographic word forms to conform to one single shape is well-known and has been discussed under different names (such as "Morphematisches Prinzip", (Nerius et al., 2000: ch. 5.1)). In terms of correspondence-based OT, it appears as the constraint family given in (15), restricted here to stems:

(15) Stem constancy
   a. MAX(O-OUTPUT, O-OUTPUT)
      'No deletion between orthographic forms of stems'
   b. DEP(O-OUTPUT, O-OUTPUT)
      'No addition between orthographic forms of stems'

At further investigation, it becomes clear that there are two variants of these constraints: either the form of a basic stem is kept in all derived or inflected word forms, or the preference is for all stem forms in a paradigm to be alike — with no reference to a basic form. The two variants (which are not always easy to distinguish empirically) are presented in (16).

(16) Two types of stem constancy
   a. STEM: Keep the basic form in all outputs.
      MAX/DEP (O-OUTPUT(STEM), O-OUTPUT)
   b. PARADIGM: Keep the forms in a paradigm alike.
      MAX/DEP (O-OUTPUT, O-OUTPUT)

The presence of lengthening-⟨h⟩ presents one example for these constraints.[11] The context conditions for this letter include the condition that ⟨h⟩ can either be stem-final (17a) or only be followed by a consonant letter corresponding to a sonorant (i.e., a liquid or nasal). In (17b), some examples are given. Letters corresponding to non-sonorant consonants are not found after lengthening-⟨h⟩. A few counter-examples exist (as in *Draht* 'wire'), but can be regarded as fossilized historical remnants. But this almost unviolated condition is regularly put to rest in those inflected forms in which a non-sonorant letter is affixed to an h-final stem; see examples in (17c). The letter ⟨h⟩, if present in the stem, is not deleted in any of these critical cases.

(17) Lengthening-⟨h⟩
   a. Zeh, sah, roh, Stroh 'tent, saw, raw, straw'
   b. Wahl, Wahn, Bahn, Wehr, fahr, Lehm, ihn 'forest, delusion, track, dam, drive, clay, him'
   c. dreh-t, sieh-t, droh-t, zieh-t, Stroh-s 'turns, sees, threatens, pulls, straw (gen.)'

The configuration which would lead to stem constancy in this case needs to recognize a constraint disallowing ⟨h⟩ as a length marker before non-sonorant letters. The logic behind such a constraint is not known; I will therefore simply assume an ad-hoc constraint *h-OBSTRUENT. This constraint needs to be dominated by a stem constancy constraint, STEM for the time being. The resulting analysis is given in (18) for the inflected form *dreht* 'turns, v.'.[12]

(18) Lengthening-⟨h⟩ in non-sonorant context

⟨Ø h⟩; |dreːt|	STEM	*h-OBSTRUENT
☞ ⟨dreht⟩		*
⟨dret⟩	*!	

Stem constancy also relates, in a similar fashion, to the topic of the following section, that of gemination and its avoidance. The spelling of double consonants demonstrates the role of stem constancy by the fact that double consonant letters normally do not appear in a word-final consonant letter cluster. However, if the stem is spelt (for reasons discusssed in the following section) with a geminate, then this geminate is kept under inflection, even if no new syllable results. (19) shows a few relevant examples. The tableau would be analogous to that in (18).

(19) Geminates in final context
   stellen – stellte 'put – put, past 1st ps., sg.'

   wollen – willst 'will – will, pres. 2nd ps., sg.'
   rennen – rennt 'run – run, pres. 3rd ps., sg.'
   schaffen – geschafft 'achieve – achieve, perf. partic.'

3.3 Gemination avoidance

One prominent feature of German orthography is the use of double consonant letters, here called geminates, under specific conditions.[13] Such geminates do not occur freely, providing a first indication that they are restricted systematically, and must fall under the control of constraints. To see this, it is sufficient to note that idiosyncratic spellings with arbitrary gemination do not exist. Spellings such as **Ffoto* do not occur, no matter how irregular the spellings are. Instead, geminates are found under specific circumstances, where their presence can be demonstrated to follow from the requirements of other — higher-ranking — constraints.

Gemination and non-gemination on the whole is once again subject to a whole family of constraints. Some examples are given in (20).

(20) "Once is enough" — NOGEM
   a. No gemination of morpheme-internal graphemes
   b. No gemination across morphemes
   c. No gemination of complex graphemes

The first of these is a constraint with many obvious violations. The analysis below will explore some of the constraints which dominate constraint (20a) such that geminates can be found. The second constraint (20b) is of a different nature: it is relevant for spellings such as *Seeen* 'seas'; *Zooorchester* 'zoo orchestra', or *Teeei* 'tea egg'. Here, two identical letters morpheme-finally are followed by an identical letter from the subsequent morpheme within the same word or compound. Such three-fold occurrence of letters (related to consonants and vowels!) is not ruled out strictly, but regarded as perceptually difficult or odd. The new official orthography therefore as an option allows these words to be spelt with a hyphen: *See-en, Zoo-Orchester, Tee-Ei* (Duden 2004: 1128 (§45)).[14] The result is that there are two optimal outputs in these cases, a configuration explored in other applications of OT as well; see (Anttila and Cho, 1998) and (McCarthy, 2002: ch. 4.5). I do not discuss this further in the present context.

The constraint against gemination of complex graphemes (20c) is very different again: morpheme-internally, it is unviolated in German (and not restricted to consonant letters). As shown in (21), no grapheme which can be regarded as complex undergoes gemination.

(21) Simple and complex graphemes

Ok	not ok
zz	schsch
ff	chch
aa	ää
ee	ii

Interestingly, any addition to a basic letter form (including trema for ⟨i⟩) makes a grapheme complex. This constraint is never violated and completely independent of any phonology; it refers to the complexity of a grapheme alone. (Primus, this volume) presents a more comprehensive analysis of the constraints involved here. The three anti-gemination constraints in (20) need to be treated as different constraints because, as just shown, they follow different patterns of (non-)violability.

To return to the violable constraint (20a), we need to identify conditions under which geminates do occur. In the literature, there is some debate about these conditions, with the presupposition that one single cause can be made responsible for the existence of these geminates. One causal factor proposed is ambisyllabicity of the corresponding consonant: geminates are found when this consonant is part of two syllables, closing off the first syllable and starting the following syllable, see (Ramers, 1992) and (Wiese, 2000: ch. 3.2). A variant of this view is that of signalling two types of syllable closures, close syllable cut and open syllable cut (see (Vennemann, 1991), (Maas, 1999)). One other factor is the marking of the preceding vowel as a short one (see (Augst, 1985) and (Sternefeld, 2000) for this view). Yet another cause for a geminate may be the tendency to give morphemes (stems) equal length or weight in terms of number of letters.[15] As a stem with a short vowel (one grapheme) and a single consonant will have a small number of letters, gemination makes the number of letters or graphemes approach the number of stems with more phonological material. Functionally, the advantage of giving stems roughly the same length in terms of their number of graphemes consists in the greater ease in predicting morpheme and word boundaries.

In the analysis to follow, the focus is on double *consonant* letters as geminates. Double vowel letters have a different status in the orthography (as we have seen above) and in the relationship to phonology. With respect to the phonology, they correspond to phonemically distinctive length (two postions, of whatever kind) of the respective vowel, that is, to representations in P-INPUT, while consonant doubling is related to P-OUTPUT. According to most authors' view, German consonants corresponding to an orthographic geminate are not phonemically distinct from other consonants. As for the debate on the funcational motivation for gemination, there is no reason, in the present framework, to reduce the existence of geminates to a single causing factor alone. It is perfectly reasonable to assume that geminates serve several functions. It is crucial however, that some independently motivated constraint dominates the NoGem constraint. I will arbitrarily assume that a constraint SYLLABLE-CONTACT represents the preference in German orthography to signal the prosody of a specific syllable contact within a prosodic foot (the prosody involving vowel length, heaviness of the first/stressed syllable and the preference for an onset consonant for the second syllable). This constraint will operate in conjunction with lower-ranking NoGem as in (22). For the example of *Butter* 'butter', the result will be a geminate.

(22) Geminates or not

⟨Ø⟩; |butʀ|	SYLLABLE-CONTACT	NoGem
☞ ⟨butter⟩		*
⟨buter⟩	*!	

There is one class of words in which a geminate is found although the relevant prosodic condition is not present. The words include the ones in (23a). Here it is not possible to relate the presence of the geminates to the prosodic conditions covered by SYLLABLE-CONTACT. There is no second syllable, and there cannot be one, because of the the fact that these words are never inflected. (23b) presents non-geminated words from the same lexical categories.

(23) Other geminates and non-geminates
  a. denn, dass, statt, wann 'since, that, instead, when'
  b. ob, was, an, mit 'whether, what, at, with'

The solution for such words (so-called 'closed class' words) is to provide them with lexical entries which specify their geminates, following the principle introduced above according to which all unpredictable orthographic information is lexically specified. The alternative would be to rely on a constraint requiring an adjustment in length between orthographic forms (see discussion above), making geminated words "longer". Following this view, the non-geminated, otherwise similar, words in (23b) would be the exceptional forms, and not the words in (23a).

The final important class with respect to gemination are those in which geminates are found either in the expected position, the one asked for by SYL-

LABLE-CONTACT, but also in other positions, especially word-finally. Examples are given in (24); the class of relevant words is large and includes nouns, verbs and adjectives.

(24) More geminates[17]
   a. Fall – Fälle, Herr – Herren, Schiff – Schiffe, Blatt – Blätter
      'fall – falls, lord – lords, ship – ships, leaf – leaves'
   b. renn – rennen, scharr – scharren, pack – packen, fass – fassen
      'run – run (inf.), scrape – scrape, (inf.), seize – seize (inf.), catch – catch (inf.)'
   c. satt – satte, dünn – dünne, matt – matte, schroff – schroffe
      'full – full, infl., thin – thin, infl., dull – dull, infl., gruff – gruff, infl.'

The interaction of PARADIGM (16b) and NOGEM (24) will give the right result in this case. The inflected (right-hand) forms in the pairs in (24) are just an indication that the (left-hand) stem is part of a larger paradigm. What the analysis in (25) says is that *Kuss* is spelt with a geminate because of *Küsse* and all other word forms in the paradigm of this stem.

(25) The role of paradigms

⟨Ø⟩; |kus|	PARADIGM	NOGEM
☞ ⟨kuss⟩		*
⟨kus⟩	*!	

A word such as *Bus* is slightly more complicated because it is, as introduced in (4), exceptionally (lexically) marked not to display a geminate in the base form. This input marking needs to be adhered to; the constraint responsible is DEP-O-OUTPUT/O-INPUT, and it must be ranked higher than PARADIGM. Otherwise, the result would be as for *Kuss*. The complete ranking and the evaluation is presented in (26).

(26) Domination by lexical input marking

⟨Ø s⟩; |bus|	DEP-O-OUTPUT/O-INPUT	PARADIGM	NOGEM
☞ ⟨bus⟩		*	
⟨buss⟩	*!		*

The over-all result of this section is a preliminary ranking order of constraints as such: DEP-O-OUTPUT/O-INPUT >> PARADIGM, SYLLABLE-CONTACT >> NOGEM. As in other standard implementations of OT, this is a language-specific ranking, in this case for present-day Standard German.

3.4 More alternations — treatment of Umlaut

One particular instance of the identity constraint discussed above is involved in the spelling of the phonemes /ɛ, ɛː/. These vowels are either just full vowels in a stem, or are related by umlaut to the vowels /a, aː/. A well-known generalization on the spellings of these vowels is that the vowels /ɛ, ɛː/ are normally spelt ⟨e⟩ if they are non-alternating vowels as in the words given in (26a), while the same vowels are spelt ⟨ä⟩, if they relate to a vowel /a/ by the rule known as umlaut; see (27b). Note that the quality of the two types of vowels is the same; again, we are dealing with comparisons which range purely over the set of orthographic forms.

(27) Umlauted and non-umlauted vowels
   a. Becken, Echo, wecken, Ende 'basin, echo, wake, end'
   b. Bach – Bäche, nah – Nähe, fangen – Fänger, Wand – Wände
      'brook – brooks, close – closeness, catch – catcher, wall – walls'

The intuitive notion to be captured here is that *Bach – Bäche* are closer to each other than *Bach – *Beche* would be. That is, this pattern suggests that the grapheme ⟨ä⟩ is closer to ⟨a⟩ than ⟨a⟩ is to ⟨e⟩. In other words, the identity constraint introduced above needs further differentiation in order to account for the subtle differences. I will assume that the difference between ⟨a⟩ and ⟨e⟩ is singled out by a violation of IDENT-GRAPHEME, a constraint comparing two graphemes for forms which are related within a paradigm (as is the case for each grapheme in *Bach – Bäche* 'brook, sg., pl.'). The difference between ⟨a⟩ and ⟨ä⟩, in contrast, is one picked up by IDENT-DIACRITIC, a constraint sensitive to the addition of the diacritic added to the letter. That German orthography is indeed sensitive to diacritics was already noted in relation to the ban on doubling (see Section 3.3): letters furnished with a diacritic cannot be geminated. The constraint IDENT-DIACRITIC is inherently ranked below the constraint IDENT-GRAPHEME. For the word *Bäche* 'brooks' related to *Bach* 'brook', the evaluation will be as in (28).

(28) Umlauted vowel letters

⟨Ø⟩; |bɛχə|	IDENT(P-INPUT, O-OUTPUT)	IDENT-GRAPHEME	NOGEM	IDENT-DIACRITIC
☞ ⟨bäche⟩				*
⟨beche⟩		*!		
⟨bache⟩	*!			

Some constraints from the previous discussions are added here. The result is a more complete constraint ranking for some of the constraints introduced in the present paper. A survey glance at the constraints used in the present paper leads to a final point: the constraints proposed here are quite plausible as constraints applicable to many, if not all, spelling systems.[17] As in applications of OT to other domains of grammar, it is exclusively the ranking order of the constraints which leads to differences in grammars. Even in debates about correct spellings as in the recent spelling reform in German-speaking countries, it is generally the emphasis on the relative importance of principles which is at stake. I return to this issue below.

4. Summary

From the collected observations and analyses above, it becomes obvious that the framework of Optimality Theory, a theory of the interaction of violable constraints, is a promising approach to the study of writing systems and orthography.[18] The parallels between the previous work on preferences in orthography and the fundamental assumptions in OT can be summarized as follows:

1. 'Orthographic principles' are often in conflict.
2. Such conflicts between 'principles' are what OT is about.
3. Correspondences between levels or components are expressed naturally.
4. There is no commitment to a derivational or autonomous treatment.
5. Applying OT to orthography allows for seamless integration with current theoretical work in phonology and morphology.

I conclude with a more general remark. Work in theoretical linguistics in general avoids, with the few exceptions noted above, the study of orthography in terms of formal grammar. One reason may be the wide-spread feeling that orthography is an area shaped not so much by "natural language" and its underlying forces, but by cultural norms and its vagaries. The present paper attempts to correct this impression by pointing out that there are very similar forces operative in orthography as in other parts of grammar. These forces are the constraints of different types and their inherent and contingent (language-specific) rankings. As a second general result, I have attempted to demonstrate that it is possible in orthography as well as in the rest of grammar to separate well-formedness constraints from "processes" in the sense of derivational rules.

The application of OT to orthography may even be helpful towards a better understanding of orthography reforms, as the one implemented recently in German-speaking countries. The authors of this reform as laid down in the official document (cf. Duden 2004: 1113–1152) explicitly followed some of the orthographic principles presented in (3), but failed to understand the existence of conflicts between some of the principles. For example, in the interest of consistent sound–letter correspondence, voiceless /s/ is ruled to be written ⟨ß⟩ only after long vowels and diphthongs; while it is spelt ⟨ss⟩ after short vowels. But this move immediately leads to a violation of stem constancy (a principle also emphatically proposed in the reform) in cases such as *gießen* 'pour, inf.' vs. *goss* 'pour, pret., 1./3. sg.' (cf. the old spelling *goß*). While proponents of the reform welcome the increase in sound–letter correspondence for ⟨ß⟩ and ⟨ss⟩, opponents of the reform point out the newly coined violation for stem constancy. Linguistic analysis can possibly help to rationalize the debate by presenting the logic of the conflicting demands perspicuously.

Notes

* The content of this paper has been discussed with the participants at the Cologne workshop "From letter to sound", at the "Germanic Linguistics Annual Conference", Buffalo, New York, and at the Linguistics Colloquium of the University of Marburg. I thank many colleagues for providing me with helpful questions and suggestions, especially the editors of this volume, Beatrice Primus and Martin Neef, and two anonymous reviewers. All of these helped me to clarify many of the ideas in this paper.

1. The decision to make ⟨x⟩ exceptional with respect to ⟨chs⟩ (see also (Eisenberg, 1998: 291) and (Neef, 2002: 177)) is most likely wrong. While it is true that a number of words ending in /ks/ is spelt ⟨chs⟩ (see *Lachs* 'salmon', *Wachs* 'wax', *Luchs* 'lynx', and about eight others), the spelling ⟨x⟩ is much more productive, and not restricted to recent loan words: *Hexe* 'witch', *fix* 'fast', *Nixe* 'mermaid'. The point of the present example is to illustrate a reasonably complex rule-based approach, not to argue for its linguistic adequacy in detail.

2. This preference seems absurd only at first sight. In a society in which knowledge of writing means power, it may be in the interest of scribes to actively pursue this preference for their writing system; see (Sampson, 1985). Some properties of so-called secret scripts are discussed by (Wiebelt, this volume).

3. The issue of how the *phonological* input should be specified in an OT framework is a separate issue, ignored here. It is often discussed under the topic of "lexicon optimization" ((Prince and Smolensky, 1993: ch. 9.3), (Inkelas et al., 1997), (McCarthy, 2002: ch. 3.1.2.4)).

4. The present model allows multiple correspondences between phonological and orthographic levels. This is also different from the autonomous graphematic view proposed by (Eisenberg, 1996) and (Primus, 2000). Some evidence against a purely autonomous view of orthography is presented in (Wiese, 2002).

5. I am not aware of a violation of this constraint for word-internal spellings in German. In English, however, there are well-known variant spellings between (Amer. English) *center* and (Brit. English) *centre*, which would provide interesting material for study in this respect. For a discussion of LINEARITY ("If unit A precedes unit B in pronunciation, then the spelling for unit A should precede that for unit B in writing.") see (Venezky, this volume), who also mentions violations of this principle from English.

6. For the present example, it may be more adequate to count each single violation of LINEARITY as one violation of the constraint.

7. DEP and MAX are commonly used abbreviations ("depends on the input" and "maximally expresses") for the constraints banning addition and deletion in correspondence theory.

8. Note that, in theories separating underlying and surface representation, the term "phoneme" is commonly used to refer to both underlying segments and surface phonemes. I follow that usage here.

9. Primus (2000: 12) also notes the strong, but not complete, neglect of non-distinctive information in German orthography.

10. A high ranking identity constraint of type (13b) will make the orthography of that language a "shallow" orthography. In contrast, so-called "deep" orthographies have high ranking constraints of type (13a).

11. Lengthening-⟨h⟩ is another case for debate in German orthography; see (Ossner, 2001) and (Neef and Primus, 2001).

12. Lengthening-⟨h⟩ is probably, although relatively frequent in the native vocabulary, an irregular spelling. It is therefore represented in the orthographic part of the input for *dreh*.

13. There is a large body of discussion on these geminates in German, see (Eisenberg and Günther, 1989), (Maas, 1992), (Sternefeld, 2000), (Ramers, 2002), (Neef, 2003), and many others.

14. Word-internal hyphenation at line ends provides another example. According to the reformed orthography two hyphenations are sometimes possible, as in *Ta-blett* or *Tab-lett* 'tray'. These cases are discussed by (Geilfuß-Wolfgang, 2002) and (Primus, this volume).

15. This tendency certainly exists; it may also be responsible for the ban against the gemination of complex graphemes (20c).

16. Note that ⟨ck⟩ has a distribution equivalent to all other geminates and therefore stands in for ⟨kk⟩ (except that is not treated like a geminate in the reformed orthography).

17. Of course, writing systems choose particular types of categories, such as alphabetic graphemes, syllabic signs or morphemic signs. Constraints referring to units not chosen in a particular writing system apply only vacuously.

18. For this view see also (Sternefeld, 2000: 35): "... die Graphematik [ist] ein prototypisches Anwendungsgebiet für die OT". It is surprising, in the light of this, how little work has been done on writing systems in the OT framework.

References

Anttila, A., & Cho, Y.-M. Y. 1998. Variation and change in optimality theory. Lingua 104:31–56.

Archangeli, D., & Langendoen, D. T. (eds.). 1997. Optimality theory: An overview. Oxford: Blackwell.

Augst, G. 1985. Regeln zur deutschen Rechtschreibung vom 1. Januar 2001. Entwurf einer neuen Verordnung zur Bereinigung der Laut-Buchstabenbeziehung. Frankfurt: Peter Lang.

Bierwisch, M. 1975. Schriftstruktur und Phonologie. In Phonologie und Generative Grammatik, F. Kiefer (ed.), 11–51. Frankfurt: Athenaion.

Chomsky, N. A. 1965. Aspects of the theory of syntax. Cambridge MA: The MIT Press.

Chomsky, N. A. & Halle, M. 1968. The sound pattern of English. New York: Harper and Row.

Clements, G. N., & Keyser, S. J. 1983. CV-phonology. Cambridge MA: The MIT Press.

Duden. 2004. Die deutsche Rechtschreibung (23rd edition). Mannheim etc.: Dudenverlag.

Eisenberg, P. 1996. Das deutsche Schriftsystem. In Schrift und Schriftlichkeit, H. Günther and O. Ludwig (eds.), 1451–55. Berlin: Walter de Gruyter.

Eisenberg, P. 1998. Grundriss der deutschen Grammatik. Band 1: Das Wort. Stuttgart: Metzler.

Eisenberg, P., & Günther, H. (eds.). 1989. Schriftsystem und Orthographie. Tübingen: Niemeyer.

Geilfuß-Wolfgang, J. 2002. Optimal hyphenation. In The relation of writing to spoken language, M. Neef, A. Neijt and R. Sproat (eds.), 115–30. Tübingen: Niemeyer.

Golston, C. 1996. Direct optimality theory: Representation as pure markedness. Language 72:713–48.

Inkelas, S., Orgun, C. O., & Zoll, C. 1997. The implications of lexical exceptions for the nature of grammar. In Derivations and constraints in phonology, I. Roca (ed.), 393–418. Oxford: Oxford University Press.

Kager, R. 1999. Optimality theory. Cambridge: Cambridge University Press.

Kiparsky, P. 1973. "Elsewhere" in phonology. In A festschrift for Morris Halle, S. R. Anderson and P. Kiparsky (eds.), 93–106. New York: Holt, Rinehart and Winston.

Maas, U. 1992. Grundzüge der deutschen Orthographie. Tübingen: Niemeyer.

Maas, U. 1997. Grundstrukturen der deutschen Orthographie. Osnabrück: Universität Osnabrück.

Maas, U. 1999. Phonologie. Einführung in die funktionale Phonetik des Deutschen. Wiesbaden: Westdeutscher Verlag.
McCarthy, J. J. 2002. A thematic guide to optimality theory. Cambridge: Cambridge University Press.
McCarthy, J. J., & Prince, A. S. 1993. Prosodic morphology I. Constraint interaction and satisfaction. New Brunswick: Rutgers University Center for Cognitive Science.
McCarthy, J. J., & Prince, A. S. 1994. Generalized alignment. In Yearbook of Morphology 1993, G. E. Booij and J. van Marle (eds.), 79–153. Dordrecht: Kluwer.
McCarthy, J. J., & Prince, A. S. 1995. Faithfulness and reduplicative identity. In Papers in Optimality Theory [University of Massachusetts Occasional Papers in Linguistics 18], J. N. Beckman, L. Walsh Dickey and S. Urbanczyk (eds.), 249–384. Amherst MA: Graduate Linguistic Student Association.
Munske, H. H. 1984. Zu den 'Prinzipien' der deutschen Orthographie. In Studia Linguistica et Philologica. Festschrift für Klaus Matzel zum sechzigsten Geburtstag, H. W. Eroms et al (eds.), 235–53. Heidelberg: Carl Winter.
Neef, M. 2002. The reader's view: Sharpening in German. In The relation of writing to spoken language, M. Neef, A. Neijt and R. Sproat (eds.), 169–91. Tübingen: Niemeyer.
Neef, M. 2003. Unterdeminiertheit in der Graphematik des Deutschen. Habilitation thesis, University of Cologne.
Neef, M., & Primus, B. 2001. Stumme Zeugen der Autonomie. Eine Replik auf Ossner. Linguistische Berichte 187: 353–78.
Nerius, D. et al. 2000. Duden — Deutsche Orthographie. Mannheim: Dudenverlag.
Ossner, J. 2001. Das ⟨h⟩-Graphem im Deutschen. Linguistische Berichte 185:369–400.
Primus, B. 2000. Suprasegmentale Graphematik und Phonologie: Die Dehnungzeichen im Deutschen. Linguistische Berichte 181:9–34.
Prince, Alan S., & Smolensky, Paul. 1993. Optimality theory. Constraint interaction in generative grammar. Ms. Rutgers University, New Brunswick; University of Colorado, Boulder.
Prinz, M., & Wiese, R. 1990. Ein nicht-lineares Modell der Graphem–Phonem-Korrespondenz. Folia Linguistica 24:73–103.
Rahnenführer, I. 1980. Zu den Prinzipien der Schreibung des Deutschen. In Theoretische Probleme der deutschen Orthographie, D. Nerius and J. Scharnhorst (eds.), 231–59. Berlin: Akademie Verlag.
Ramers, K. H. 1992. Ambisilbische Konsonanten im Deutschen. In Silbenphonologie des Deutschen, P. Eisenberg, K. H. Ramers and H. Vater (eds.), 246–83. Tübingen: Gunter Narr.
Ramers, K. H. 2002. Prinzipien der Wortschreibung im Deutschen. Deutsche Sprache 30:220–36.
Sampson, G. 1985. Writing Systems. London: Hutchinson.
Sternefeld, W. 2000. Schreibgeminaten im Deutschen: Ein Fall für die Optimalitätstheorie. Linguistische Berichte 181:35–54.
Vennemann, T. 1991. Syllable structure and syllable cut prosodies in modern standard German. In Certamen phonologicum, P. M. Bertinetto, M. Kenstowicz and M. Loporcaro (eds.), 211–43. Torino: Rosenberg & Sellier.

Wiese, R. 1989. Schrift und die Modularität der Grammatik. In Schriftsystem und Orthographie, P. Eisenberg and H. Günther (eds.), 321–39. Tübingen: Niemeyer.
Wiese, R. 2000. The phonology of German. Oxford: Oxford University Press.
Wiese, R. 2002. Vom Laut zum Buchstaben oder zurück? In Sprache als Form. Festschrift für Utz Maas zum 60. Geburtstag, M. Bommes, D. Tophinke and C. Noack (eds.), 151–60. Wiesbaden: Westdeutscher Verlag.

Author's address:

Richard Wiese
Universität Marburg
Institut für Germanistische Sprachwissenschaft
D-35032 Marburg
Germany

e-mail: wiese@mailer.uni-marburg.de