Type-Based Derivational Morphology

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Abstract.

Approaches to morphology typically account for regular, completely productive affixation, while ignoring subregular and semiproductive schemata. The alternative approach to derivational morphology presented here relates exceptions and subregularities to productive rules. It accounts for the contribution lexicalized words make to the rule, and for the fact that not all new formations follow the 'rules'. It also captures linguistically relevant generalizations that cannot be expressed in other theories. The approach is formalized in terms of complex recursive schemata structured in a multiple inheritance hierarchy, without positing lexical rules or lexical entries for affixes. These schemata structure the existing lexicon, reducing redundancy, and at the same time serve as the basis for productive word formation. The approach handles zero-derivation and other nonconcatenative morphology straightforwardly.

1. Introduction

Morphological data are characterized by strong regularities as well as subregularities and exceptions. Because of the ubiquity of complex words with meanings that are not fully predictable from their parts, the matter of how these should be treated is important.

In this paper it will be argued that these cases should not be viewed as completely separate from the fully transparent words. If they were, linguistically significant generalizations would be lost, partial similarities between exceptional and non-exceptional patterns would not be expressed, and these words could not be seen as contributing to the determination of the rule.

The paper concentrates on morphological derivation, as contrasted with inflection or compounding, and examples are mainly from German *bar*-adjectives (= English -*able*), which are analyzed in detail in previous work (Riehemann 1993). Further data comes from *able*-adjectives in English and a less regular, more analogical suffix—German -*ig*.

It is traditional to suppose that the suffix -*bar* can be attached to the stem of any transitive verb (e.g. *lesen* 'read' → *lesbar* 'readable'). This rule of -*bar* suffixation is also assumed to be fully productive. Transitive verbs which do not allow -*bar* suffixation and non-transitive verbs that do allow such suffixation would constitute counterexamples to this rule. Such data does indeed exist. Not only are there additional constraints on which verbs this suffix can be attached to, but there are lexicalized exceptions which do not conform to this productive rule. And most importantly, there are new formations which are not captured by the rule.

This data is a problem for most traditional approaches to morphology, namely those which assume *one* affix -*bar* and those which posit *one* lexical rule for forming *bar*-adjectives. These approaches have no mechanisms for dealing with the counterexamples. One might think it possible to refine the rule in such a way that it would describe all and only the correct cases. But the data below suggests that this cannot be done—there does not seem to be a single generalization that is general enough to encompass all existing and possible *bar*-adjectives and at the same time specific enough to exclude impossible examples. It might be possible to construct a complex and highly arbitrary 'rule' that lists all the lexicalized exceptions in its definition. But that would be very unintuitive, and furthermore would not be able to account for productive exceptions. Therefore I will continue to assume as it has been assumed in the literature that 'the rule' is that -*bar* attaches to transitive verbs, and develop an approach in which this regularity is expressed while the exceptions can be handled as well.

In the approach presented here, which I will call TYPE-BASED DERIVATIONAL MORPHOLOGY or TBDM for ease of reference, -*bar* is neither a suffix with its own lexical entry and strict subcategorization information, nor is it just phonological material added by lexical rule. Instead it is seen in terms of a schema, arising as a generalization about existing *bar*-adjectives in the lexicon. The schema says that there is a class of adjectives ending in -*bar* which have transitive verb stems as their first part. It also states various semantic and syntactic properties and relations to the verbal stem. Some of these adjectives are lexicalized subtypes of the pattern, but more can be formed productively according to the constraints embodied in the schema. The system allows for complex and recursive derivation because the transitive verb stems can be complex themselves, and because the resulting adjectives are of the appropriate type to undergo further derivation.

The main *bar*-pattern is seen as a generalization about existing words, just as a subregular one is. These patterns are hierarchically structured with respect to each other, which expresses their relationship. The approach not only accounts for more of the data, but also captures more generalizations, and could be the beginning of a theory of how regular affixations develop and are acquired.

The data will be treated using lexical multiple-inheritance hierarchies as used in HPSG (Head-Driven Phrase Structure Grammar, Pollard & Sag 1987 & 1994). This framework is particularly well suited for expressing these generalizations because it is directly concerned with cross-classifying relations among linguistic types. Also, the rich lexical representations that are motivated by the data can be expressed clearly in HPSG, and fit well with its general assumptions.

Many linguists and psycholinguists, for example Jackendoff (1975), assume that many complex derived words are stored individually in the (mental) lexicon. This means that word formation differs from syntax in that frequent words are not derived 'on-the-fly' every time they are produced, but are stored as units even if they have an internal structure and are predictable from those parts. Evidence for this view comes e.g. from Rainer (1988) and Becker (1990), who observe that even frequent words which are the predictable output of a productive rule can block other words in some cases. So in principle lexicalization is independent of idiosyncrasy, although in most cases some unpredictable aspect is involved as well. Once a word is lexicalized it can undergo semantic drift, and acquire idiosyncrasies of all kinds. So the phenomenon of semantic drift also shows that lexicalization has taken place.

The TBDM approach presupposes this view because the existence of the entries for these lexicalized words, which correspond to the types at the bottom of the hierarchy, is necessary to explain which schemata for word-formation exist. But in the TBDM approach only the idiosyncratic information about these complex words has to be listed, with the remaining information being filled in by inheritance. So unlike the analysis in Jackendoff (1975), this analysis does not require a separate evaluation measure for determining the contribution of lexical rules to reducing the information content of the lexicon. Another difference between Jackendoff's redundancy rules and the TBDM approach is that the latter is able to express not only relationships between words but also the relationships between rules. However, the TBDM approach is similar enough to Jackendoff's ideas to think of it as an incorporation of those insights into an HPSG architecture with the above-mentioned improvements.

Any adequate theory should provide a means of stating the idiosyncratic information in lexical entries, and at the same time it should make precise which parts are predictable and correspond to aspects of a productive rule. This is desirable on a descriptive level, where information would otherwise have to be repeated redundantly. While it could be argued that the partial regularities have historical reasons and do not need to be taken into account by synchronic grammar, that view becomes implausible when considering how large a number of 'regular' complex words need to be listed because of some slight specialization of meaning or other unpredictable properties. Approaches that do not relate lexicalized words to rules in any way also do not predict that existing words in the language will have an effect on what the rules of morphology are, and do not have anything to say about how they could be acquired.

The strongest evidence for the relevance of the existing lexicon is that it is possible to form new words on the basis of existing 'subregular' patterns wherever it is sufficiently clear how the new word would relate to its stem, and how it would be interpreted. This kind of word formation according to patterns determined by a small set of existing words, and sometimes even by analogy to only one word, is needed for a full account of *bar*-derivation. It is widely acknowledged that such a process is the basis of some other kinds of word formation processes (see e.g. Motsch 1988 or Plank (1981) for more examples of semiproductive morphology). Since it is shown that even the highly regular *bar*-derivation cannot be described adequately by a single rule, it will be argued that such a rule is best seen as a special case of word formation on the basis of existing patterns, a very general regularity among existing words.

2. The Morphological Data

2.1. German *bar*-Adjectives

The *bar*-adjective data comes mostly from various corpora of German. The main corpus consists of newspaper texts sampled between 1985 and 1988 (10 million words, 17,292 *bar*-adjective tokens, 836 types). I also looked at other newspaper and more general corpora, and the language used in contributions to electronic newsgroups. For details see Appendix A. This resulted in a total of 1226 different types of *bar*-adjectives, most of which occur only once or twice. Many of these low-frequency words seem to have been productively formed.[1]

The use of corpora was important because it provided the subregularities and exceptions that I probably would not have found through intuition alone. I also used native speakers' judgments to confirm the acceptability of the examples from the corpora[2] and the unacceptability of the examples needed for the argumentation.

The prototypical *bar*-adjective is derived from a transitive[3] verb. An example is *bemerkbar* 'noticeable':

(1) *Sie bemerken die Veränderung. Die Veränderung ist bemerkbar.*
They notice the change. The change is noticeable.

As in passives, the accusative object of the verb becomes the subject of the adjective. But the dropped subject normally cannot be expressed in *by*-phrases. Semantically a notion of possibility is added—something that is *lesbar can* be read.

It is traditionally assumed that the suffix *-bar* is fully productive and can attach to all transitive verbs. While it is true that it can attach to many transitive verbs to form new *bar*-adjectives, there seem to be additional semantic constraints.

Toman (1987) proposed that the verbs have to be (weakly) intentional, which includes not only verbs in which the subject is an intentionally acting agent but also those where at least 'an effort can be made'. As examples of the latter he gives *erkennen* ('recognize'), *bemerken* ('notice') and *erraten* ('guess'). This constraint is intended to exclude examples such as ?*verbitterbar* ('embitterable'), ?*enttäuschbar* ('disappointable') and ?*überraschbar* ('surprisable'). While it is disputable whether these really should be excluded, it is clear that restrictions in addition to transitivity are needed to exclude **wiegbar* ('weighable') or **dauerbar* ('lastable'), as in examples like (2):

(2) * *1 Kilogramm ist (von dem Buch) wiegbar.*
1 kilogram is (by the book) weighable.

But an absolute intentionality constraint would also wrongly exclude possible examples like *abbaubar* ('decomposable'), *resorbierbar* ('absorbable'), *regenerierbar* ('regenerable'), and *verformbar* ('deformable'):

[1] Of course I do not claim that all words that happen to be occur only once in my corpora are productively formed, or even that it is possible to determine this for any particular example—what is productive for one speaker may be lexicalized for another. But most of these infrequent words are completely regular and predictable, and according to speakers' intuitions they are not established as lexicalized words of German. And on a more general level, affixes with large numbers of infrequent types are probably more productive than affixes with few infrequent types.

[2] Examples from corpora need some verification since they may be typos etc. But the occurrence in a corpus plus verification is much stronger evidence than mere acceptance by a native speaker, since many speakers, especially non-linguists, tend to accept examples that they would never produce, as long as they are comprehensible and 'make sense'. And the researchers' intuitions may have been affected by studying a phenomenon for too long. Corpora can also provide the right data to present to one's informants, examples that might otherwise have escaped attention.

[3] 'Transitive' is here and throughout to be understood as referring to verbs which have an object bearing accusative case.

(3) *biologisch leicht abbaubare Stoffe*
biologically easily decomposable substances
'easily biodegradable substances'

For more details about the nonmorphological properties of *bar*-adjectives see Riehemann 1993.

Still -*bar* affixation is a highly productive process. In the main corpus more than half the types (435) occur only once or twice, accounting for only 3.15% of the tokens. Most of these are not listed in any dictionary, and people use them even if they do not remember having heard them before. This suggests that they have formed these words productively. This becomes even more obvious from the fact that the suffix can be attached to verbs that have newly entered the language—*faxbar* 'faxable' used to be such a word, and currently *ftpbar* 'ftpable' is beginning to appear on a few web pages.

The corpora also show that there are a number of frequent, lexicalized *bar*-adjectives. In fact, 7% of the types account for 70% of the tokens. These words have exceptional properties of all kinds:

- phonological:
  - dropping of '-ig' in the stem
    (*entschuldigen* 'excuse' ⇒ *entschuldbar* 'excusable')
- semantic:
  - additional aspect of meaning
    (*essen* 'eat' ⇒ *eßbar* 'safely edible')
  - obligation instead of possibility
    (*zahlen* 'pay' ⇒ *zahlbar* 'payable' ('payable by the 15th' = 'has to be paid by the 15th'))
  - lexicalized in one particular sense
    (*halten* 'hold, keep' ⇒ *haltbar* 'non-perishable' ('keep-able'))
- syntactic:
  - from verbs with dative objects
    (*entrinnen* (+ Dat) 'escape' ⇒ *unentrinnbar* 'inescapable')
  - from verbs with prepositional objects
    (*verfügen über* 'have at one's disposal' ⇒ *verfügbar* 'available')
  - from reflexive verbs
    (*sich regenerieren* 'regenerate' ⇒ *regenerierbar* 'regenerable')
  - from intransitive verbs
    (*brennen* 'burn' ⇒ *brennbar* 'inflammable')
- really exceptional
  - no verbal stem (*sichtbar* 'visible')
  - no notion of possibility (*fruchtbar* 'fruitful')

These examples illustrate the well-known fact that complex words cannot always be interpreted in a completely compositional fashion and that lexicalization can result in semantic drift and the development of idiosyncrasies of various kinds. But most of these words are also still clearly related to the 'rule', i.e. they have some properties in common with the completely regular *bar*-adjectives. For example, most of them share the notion of possibility in their semantics and the fact that the verb's object becomes the adjective's 'subject'. Listing them with full specifications would mean having to repeat predictable, transparent information.

Also—unexpectedly and more importantly—there are *new* formations which do not conform to the pattern of the fully 'regular' ones. The assumption is that infrequent words which one has not consciously heard before and which are not listed in dictionaries are too rare to have been learned as exceptions.

- from verbs with dative objects:
  - *unausweichbar* 'inescapable'
  - *unentfliehbar* 'un-flee-from-able'
  - *unentziehbar* 'unwithdrawable'
  - *unwiderstehbar* 'irresistible'
- from verbs with prepositional objects:
  - *quantifizierbar* 'quantifiable'
  - *unzweifelbar* 'undoubtable'
  - *verzichtbar* 'abstainable'
  - *zugreifbar* 'accessible'
- from reflexive verbs:
  - *deformierbar* 'deformable'
  - *erneuerbar* 'renewable'
  - *verflüchtigbar* 'evaporatable'
  - *zersetzbar* 'decomposable'
- from intransitive verbs:
  - *unausbleibbar* 'inevitable'
  - *ungerinnbar* 'uncoagulatable'
  - *verrottbar* 'decayable'
  - *verheilbar* 'healable'

These adjectives are formed from verbs which do not have an object in accusative case[4], thereby violating what is seen in traditional word-syntactic approaches as the 'subcategorization requirements' of the affix.[5] But because these words do have parallels among the lexicalized subregularities,

[4] It is impossible to know whether the people who used these words shared the intuition that the reflexive verbs above do not have transitive counterparts from which the adjectives could have been formed. But it is likely that they do because there are no transitive uses like *die Natur erneuert diese Energiequelle* corresponding to examples like *erneuerbare Energiequellen* 'renewable sources of energy'.

[5] If exceptions could be explained semantically, then there would be no exceptions, and everything could be done by one rule. Thematic aspects certainly play a role in determining which of the exceptional words get produced, but it is not a hard and fast constraint, i.e. not everything that is a theme can be used. This can be seen for example with intransitive *fallen* 'fall' (**fallbar*), or when the object is in dative case (**helfbar* 'helpable').

there are generalizations present in Type-Based Derivational Morphology that serve to structure the existing lexicon. These can be used as a basis for semiproductive word formation.

2.2. English *able*-Adjectives

The same kinds of observations can be made for English *able*-adjectives, although it is much harder to find examples that are unquestionably derived from intransitive verbs, since unlike in German it is often possible to use even the underlying verbs transitively (with a causative meaning). Examples of this kind are *detonable*, *lapsable*, *rottable*, *unwiltable*, or *burstable*. These are found in the corpora, but could arguably have been derived from the respective transitivized forms of the verbs.

The following *able*-adjectives, mainly taken from corpora of written English, were judged acceptable but not common words of English by the majority of native speakers I asked, while the same speakers thought that their verbal stems could not be used transitively.[6]

- from intransitive verbs:
  decayable, *demurrable*, *expirable*, *materializable*, *mutatable*
- from verbs with prepositional objects:
  abstainable, *adherable*, *compliable*, *consentable*, *listenable*, *unagreeable*, *votable*

These are arguably too rare to have been learned as exceptions by native speakers, and they do not conform to the 'rule' of -*able* affixation but appear to have been productively formed.

Even clearer evidence comes from recent computer terminology. I found several occurrences each of *grepable/greppable*, *lynxable* and *telnetable/telnettable* on the WWW, while the corresponding verbs never seem to be used transitively. These words must have been productively formed in recent history by at least one individual, probably by several people independently.

2.3. German *ig*-Adjectives

German *ig*-adjectives are a good example of two things: how one affix can have various specialized subpatterns, and how the formation of new words follows these patterns. It is not sufficient to encode only the information they share at a higher level.

The suffix -*ig* can be used to form adjectives from a wide variety of categories: nouns (*Staub, staubig* 'Dust, dusty'), verbs (*zappeln, zappelig* 'fidget, fidgety'), adverbs (*sofort, sofortig* 'immediately, immediate'), and nonproductively, adjectives (*voll, völlig* 'full, fully') (Fleischer & Barz 1992).

[6] The judgments about the substantially longer list of adjectives varied greatly among speakers, with some accepting almost none of the words, while most others thought almost all were acceptable and some even common. This is not surprising if word formation is indeed based on the existing lexicon in the way proposed here, since the possibility of forming (and accepting) new instances should depend on the number of words of this kind someone has come across previously, and whether a generalization has been formed.

But there are fine semantic restrictions even within the productive categories. For example the *ig*-adjectives formed from nouns all mean something like 'characterized by' (*Rost, rostig* 'rust, rusty'). But it is not possible to form new *ig*-adjectives from just any noun—for example *knopfig* (as in **knopfiger Anzug* 'buttony suit') is not a possible word (Motsch 1977), although it would seem to make sense semantically if a suit is characterized by having a large number of, or otherwise very noticeable, buttons.

This fact seems puzzling, but on further examination of the data it turns out that the existing *ig*-adjectives fall into various subgroups semantically. Some have a meaning of 'like (an) X' (*Kalk, kalkig* 'lime, limy'), others combine with nouns denoting concrete physical objects and mean 'characterized by the presence of substances (on the object)': *fleckig* 'spotted', *schmutzig* 'dirty', *ölig* 'oily', *dreckig* 'dirty', *staubig* 'dusty', *fettig* 'fatty'. Motsch actually argues that the meaning has to involve 'impurities', and it is true that new formations of this kind tend to have this kind of negative meaning (*Siff, siffig* 'filth, filthy'). The acceptability of new formations is inversely proportional to the distance from existing patterns. ??*Politurig* 'polishy' would be an example of 'characterized by the presence of non-negative substance (on object)', and does not seem acceptable. We have already seen an unacceptable example of a non-substance on an object (**knopfig*). And it is impossible to form words just on the higher level meaning 'characterized by' that all the various patterns seem to have in common **pausige Konferenz* 'pausy conference', **buchiges Zimmer* 'booky room'.

New formations in analogy to the existing semantic groups, on the other hand, are common. *Deppig* 'foolish' is an example with a 'like' meaning, *fusselig* 'linty' one of the 'characterized by contaminating substance (on object)' type.

This shows that *-ig* is not simply productive with nouns, but it is necessary to look at more detail and determine what kinds of nouns it is found with, since the possibilities for new formations mirror the existing data.

2.4. Semi-Affixes

In the morphology of German, there are entities that are traditionally called 'Affixoide' that are said to have a status that is intermediate between an affix and part of a compound. Examples of these are *-voll* 'full', *-frei* 'free', *-arm* 'poor', *-zeug* 'stuff', *-wesen* 'being', and *-gut* 'property'[7], (Olsen 1988). Each of these is an existing word of German, and has a meaning related to that word when it occurs in a complex morphological structure. But these words have also developed specialized functions within such structures, which needs to be captured. Their meaning is usually more general and abstract than that of the corresponding simplex words. For example, *Zeug* means 'stuff' (usually pejoratively), and the words *Strickzeug* (stuff needed for knitting), *Schulzeug* (stuff needed for school), and *Putzzeug* (stuff needed for cleaning) are clearly related to that meaning, but do not have the pejorative aspect, and all share a semantic 'purpose' relation. Although this relation is frequently found in other compounds, too, it is especially relevant here, because the fact that there is such a group of words ending in *-zeug* with that meaning is the basis for forming new ones. So, even if one treats them as compounds formally (as Olsen suggests) it is necessary to pay attention to the existing lexical items and the patterns among them, since it is not sufficient to

[7] These are glosses for the independent words.

assume that the lexical entry for *Zeug* together with the rules of compounding will give the right results. One does not find compounds with *-zeug* involving a 'belong to' or 'part of' relation, for example.

3. Previous Approaches and Problems

In this section previous suggestions for dealing with derivation in theories of morphology are summarized briefly, and some of the problems they run into are pointed out.

Two major approaches to an account for the regular aspects of word formation have been suggested in the linguistic literature: one is based on the arrangement of items, i.e. a WORD-SYNTAX; the other on processes, i.e. LEXICAL RULES.

The first approach could be called phrase-structural, and, for a complex word like *lesbar*, would posit the internal structure shown in (4):

(4) $[[\mathrm{les}]_{\mathrm{V}}[\mathrm{bar}]_{\mathrm{A^{af}}}]_{\mathrm{A}}$

Here the first part is the stem of the verb *lesen* ('read'), and the second the affix *-bar*, with a phrase structure rule allowing the two to combine to yield a complex adjective, where the category is determined by the suffix. An approach of this kind was proposed for example by Selkirk (1982). See Spencer 1991 for references to related work, and an overview of the item-and-arrangement tradition in morphology.

The second approach is exemplified for instance by Aronoff (1976) or Jackendoff (1975) (following Chomsky 1970), who assume lexical rules or lexical redundancy rules. Here the affix is introduced syncategorematically in the rule, so in the corresponding figure (5), representing information about the word's derivation, the first part is still a verb, but the affix is added by the rule and is not itself marked for category.

(5) $[[\mathrm{les}]_{\mathrm{V}}\,\mathrm{bar}]_{\mathrm{A}}$

In both these approaches subregularities and exceptions are a problem, since in the first, a clear subcategorization requirement needs to be stated for the affix, and in the second, one has to state which class of words the rule applies to.

Therefore it seems best to see affixes as generalizations about classes of words. What is proposed here is neither word syntax nor lexical rules, though closer to lexical rules, since it does not give the suffix an independent existence. One could of course think of an entire TBDM schema as being a unusual kind of 'lexical entry' for the suffix. But the proposed analysis has the advantage of generalizing readily to non-affixal morphology.

I assume an internal morphological structure for derived words similar to that in (5). But unlike in lexical rule approaches this structure is explicitly represented as part of the information about a complex word, similar to the coding of phrase structure, although in contrast to (4) the affix does not have its own lexical entry and is not marked for category.

In TBDM, there is a schema expressing the fact that there is a class of words, ending in the suffix *-bar*, that have transitive verbs as their morphological basis. It also states how the syntax and semantics of the verb relates to that of the adjective. For example, the accusative object of the verb is linked with the subject of the adjective, and the semantics of the verb reappears within the scope of the possibility operator in the semantics of the adjective.

Because TBDM schemata contain this additional information, they are not just phonological like those in Bybee & Slobin 1982. These authors give evidence that children form product-oriented phonological schemata of complex words, and for example do not try to add an affix to a word that already appears to contain that affix. Only later do they 'learn the rules' of affixation.

Perhaps one can link up the two views. It is not implausible that children, when learning complex morphology, should first form phonological generalizations, since these are most directly available. The more complex schemata, as used in TBDM, could then be formed later. Once children realize that the class is not merely defined by its characteristic ending, but also that the first part has to be a stem of a certain kind, they can go on to discover the systematic syntactic and semantic relationships of the complex words to those stems.

This may be part of the explanation of how 'rules' are acquired. They could start out as generalizations about rote-learned examples and gradually become more complex, while remaining of the same kind and never losing their connection to existing words of the language.

In TBDM there are also generalizations for the other (subregular) patterns. These analyze far fewer existing words, which is part of the explanation of why they cannot be used unconditionally in productive word formation.[8]

All generalizations serve primarily to organize the existing lexicon, and are only secondarily used to form new words. It is important to realize that the 'organizing function' is not just a question of parsimony, but that it is important to explain morphological facts: word formation is based on generalizations in the existing lexicon.[9]

Under this view it is to be expected that morphological productivity is not a question of 'all or nothing'. Patterns can be more or less evident, depending on how many types of words they

[8] There is some independent evidence for the psychological reality of such patterns. Berko (1958) asked English speaking adults to form the past tense of nonsense words whose stems ended in the sequence *-ing*. 50% of them said **bang* or **bung* for the past tense of **bing*, and 75% made **gling* into **glang* or **glung*. This shows that adults do not necessarily use the most productive rule of their language and affix *-ed*, but instead may form the past tense in in analogy with existing irregular forms: most English verbs with stems ending in *-ing* have past tenses in *-ang* or *-ung*.

[9] This general conception of morphology is also advocated by Bybee (1988, 1994), who does not use a symbolic rule mechanism either. Salmons 1993 shows that such lexicon internal structure is relevant for at least one other aspect of synchronic grammar—gender assignment.

generalize over, how frequently those occur in the language, how noticeable the morphological effects are, and how uniform the semantic changes are that go along with them.

It is important to realize that productivity is not just a question of the generality of the 'input' class. An affix can be restricted to attach only to a narrowly defined kind of stem of which there are not many instances, but still be completely productive within that domain.

To sum up, in order to deal with subregularities and exceptions in a principled way, it seems necessary to have a hierarchical model of some sort, because fine-grained distinctions about semantic and other word classes need to be made to capture the data. A traditional approach formulated in terms of word syntax or lexical rules is not sufficient. Both these approaches could be extended in the right direction by introducing hierarchies of affixes or lexical rules making the right fine-grained distinctions. But this would amount to a duplication of the hierarchy of words, which is independently needed to structure the lexicon, and which seems to be the primary level of classification, and probably the most natural starting point for children noting similarities among words.

For example, as we have seen, in the case of *ig*-adjectives there are many cases of lexicalized words where the suffix *-ig* is combined with nouns denoting potentially contaminating substances. These adjectives modify nouns denoting concrete physical objects, and they mean something like 'characterized by the presence of the contaminating substance (on the object)'. It is desirable to express the generalizations about this class of adjectives to structure the lexicon and in order to avoid having to repeat redundant information. Productive formation of *ig*-adjectives is crucially dependent on these existing word classes, and since the generalizations have already been expressed, it is easy to use them as schemata for productive word formation.

It would also be possible to express these fine-grained distinctions in a separate affix hierarchy. But this would result in an entry for *-ig* (among others) which says that it combines only with nouns denoting potentially contaminating substances and results in adjectives which are able to modify nouns denoting concrete physical objects, and which mean 'characterized by the presence of the contaminating substance (on the object)', *in addition to* the already existing word class of adjectives ending in *ig* able to modify nouns denoting concrete physical objects and meaning 'characterized by the presence of the contaminating substance (on the object)'. This is redundant, and it does not capture the fact that this affix entry exists and is productive precisely because the corresponding word class exists.

4. HPSG and the Hierarchical Lexicon

In this paper, an account for some of the empirical observations from the previous sections is developed within an HPSG framework. In this section a very brief overview of HPSG is given, and some notation is explained. More details can be found in chapter 1 of Pollard & Sag 1994, and the typed feature formalism is described in Carpenter 1992.

HPSG is a linguistic theory that emphasizes the need for integration of partial information from various linguistic (and in principle also nonlinguistic) sources in an order-independent way: the grammar is formulated as a declarative system of constraints.

4.1. Typed Feature Structures

The fundamental objects of linguistic analysis in HPSG are signs, modelled by feature structures. This allows for the parallel representation of phonological, syntactic, semantic, and other information. Feature structures can be described by AVMs (attribute-value-matrices), sets of pairs of attributes and their values. The values can themselves be complex.

The feature structures employed in HPSG are TYPED. The type indicates what kind of object is being described, with the types being partially ordered by subsumption. This allows generalizations to be expressed elegantly. In the hierarchies in this paper, more inclusive types will be higher in the ordering, i.e., will be supertypes of others which contain more information. When they are mentioned, types are shown in italics in the top left corner of the AVM.

Two paths in a feature structure can lead to the same node. This is called structure sharing, is indicated by boxed numerals in AVMs, and involves TOKEN IDENTITY. TAGS with colons before them (such as $:\boxed{2}$ in figure 10) refer to the whole CONTENT. Lists are enclosed in angle brackets.

4.2. The Lexicon

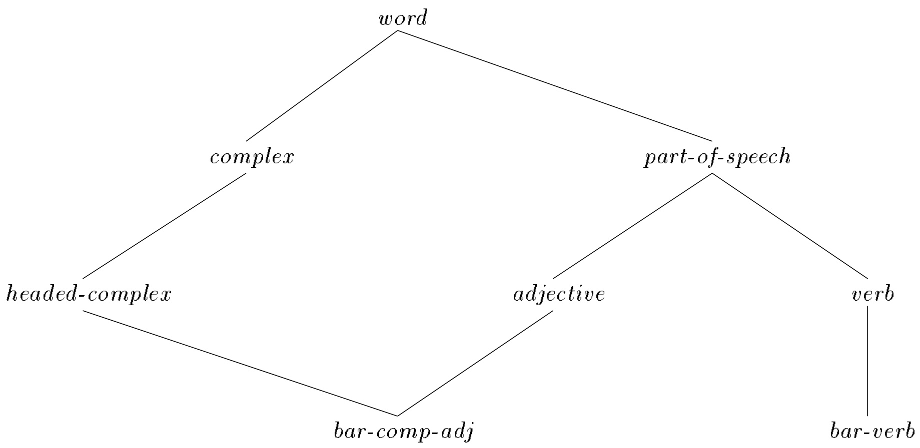
Type-Based Derivational Morphology makes crucial use of the hierarchical structure of the lexicon which is supported by HPSG. This idea was developed in Flickinger, Pollard, & Wasow 1985, in Chapter 8 of Pollard & Sag 1987, and in more detail in Flickinger 1987. In these approaches, inflectional and derivational morphology is assumed to be dealt with by lexical rules.

The status and interpretation of lexical rules has been discussed extensively in the literature. Copestake (1992) has integrated them into the hierarchical structure of the lexicon, so that subsumption relationships between lexical rules can be expressed. Krieger & Nerbonne (1993), Riehemann (1993), Koenig & Jurafsky (1994), and Kathol (in press) have proposed various ways of eliminating the need for a lexical rule mechanism.

There has also been an implementation in HPSG of a word-syntactic approach. Krieger & Nerbonne (1993) and Krieger (1994) use a phrase structural approach to morphology to illustrate their inheritance lexicon. They assume that derivational affixes have category marked lexical entries and that they combine with other material, subject to various morphological principles.

This approach avoids the exception problem to a certain extent by having a hierarchical lexicon with multiple inheritance; and it was the source of inspiration for my own ideas. Words are classified both according to their category and their morphological properties, as can be seen in figure (6), part of the hierarchy from Krieger & Nerbonne 1993.

(6)



Headed-complex words are taken to be subject to various principles, e.g. the MORPHOLOGICAL HEAD FEATURE PRINCIPLE (see below).

bar-adjectives are represented as a word class under which the exceptional lexicalized instances are nonmonotonically grouped. This means that irregular forms can have properties that override the more general regular information given in the class definition. The definition states that a *bar*-adjective has two parts, a *bar-suffix* and a *bar-verb*, as can be seen in (7).

(7)
$$\begin{bmatrix} \textit{bar-comp-adj} & \\ \textsc{morphs} & \begin{bmatrix} \textsc{head-morph} & \textit{bar-suffix} \\ \textsc{comp-morph} & \textit{bar-verb} \end{bmatrix} \end{bmatrix}$$

The lexical entry for -*bar* which Krieger 1994 assumes is given in somewhat abbreviated form in (8):

(8)
$$\begin{bmatrix} \textit{bar-suffix} & \\ \textsc{morph} & \begin{bmatrix} \textsc{form} & \textit{bar} \\ \textsc{subcat} & \begin{bmatrix} \textit{bar-verb} & \\ \textsc{syn}\,|\,\textsc{loc}\,|\,\textsc{subcat} & \begin{bmatrix} \textsc{obj} & \boxed{1} \\ \textsc{comps} & \boxed{2} \end{bmatrix} \\ \textsc{sem} & \boxed{3} \end{bmatrix} \end{bmatrix} \\ \textsc{syn}\,|\,\textsc{loc} & \begin{bmatrix} \textsc{head}\,|\,\textsc{maj} & A \\ \textsc{subcat} & \begin{bmatrix} \textsc{subj} & \boxed{1} \\ \textsc{obj} & \textit{NIL} \\ \textsc{comps} & \boxed{2} \end{bmatrix} \end{bmatrix} \\ \textsc{sem} & \begin{bmatrix} \textsc{operator} & \Diamond \\ \textsc{scope} & \boxed{3} \end{bmatrix} \end{bmatrix}$$

It turns out that having both this classificatory approach to morphology *and* a word-syntactic treatment at the same time leads to several redundancies. One of these is that the category is multiply determined—once by inheritance, since *bar-comp-adjectives* are a subtype of adjectives, and once by the MORPHOLOGICAL HEAD FEATURE PRINCIPLE, which states that the category of the complex word is the same as that of the affix. Also, the information as to which verbs the affix can combine with is given twice: in the class definition, and also in the subcategorization requirements within the lexical entry of the affix. Finally, for lexicalized instances which are of type *bar-comp-adjective*, one still needs to make sure that the first part is appropriately marked as a *bar-verb*. All this indicates that the hierarchical approach alone, if properly extended, should be able to capture the facts.

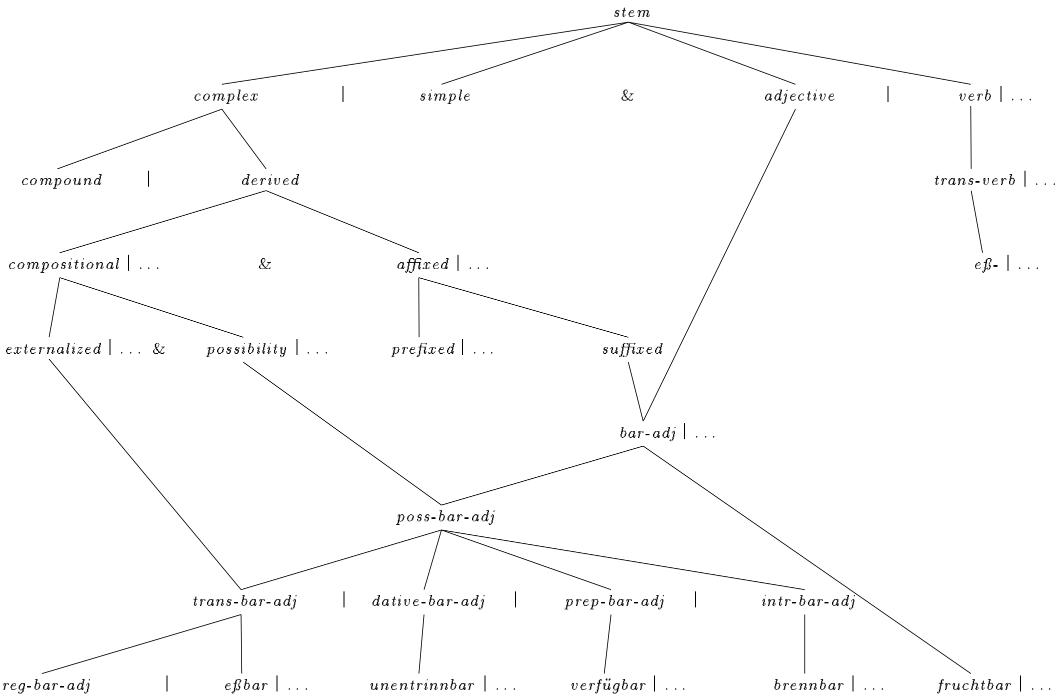
Furthermore, for less regular suffixes such as *-ig*, one would need 'lexical entries' for all the various subcases occurring with different noun-classes. This would be a little less troublesome if they were organized into a hierarchy, but still it seems to be the the case that the more complicated this gets, the more sense it makes to organize the *words* into the hierarchy, rather than the affixes. Such a hierarchy of words is needed in any case, for the lexicalized forms, and it would have to be duplicated in the affix hierarchy. Also, once it becomes necessary to refer to arbitrary semantic information in the 'subcategorization' information for the affix, it becomes much less similar to syntactic subcategorization, and it is questionable whether it should still be analyzed that way. It seems more natural to have a class of words having these semantic properties, and to say that new ones can be formed precisely because of the existence of that pattern.

5. An Approach to Morphology Based on Monotonic Multiple Inheritance

5.1. A HIERARCHY OF *bar*-ADJECTIVES

Figure (9) shows what a hierarchy could look like that addresses some of the problems mentioned above. It illustrates a simplified analysis of German *bar*-adjectives:

(9)



In this hierarchy stems are cross-classified according to various properties. It is assumed that stems in turn are parts of inflected words along the lines suggested in Kathol (in press), but the precise means of dealing with inflection is irrelevant for the treatment of derivation proposed here.

Since it is impossible to give a complete picture of such a hierarchy, some new notation has been introduced to mark where information is left out. This is especially important since I am assuming a closed-world interpretation, i.e. a given type does not have any more subtypes than the ones that are explicitly mentioned. Every linguistic object that is of a particular type has to be of one of the subtypes of that type, and every object has to belong to a maximal type at the bottom of the hierarchy.

Explanation of the notation: '|' stands for disjunction (exclusive or), where either all disjuncts are specified, or it is indicated (by the dots) that there are (finitely many) more; '&' marks the boundaries between different dimensions of classification and always has wide scope over '|'. So, for example, what is said at the top of the hierarchy is that every stem must be either complex or simple, *and* either an adjective, or a verb, or belong to another of a finite number of categories which are not all listed here.

The specific stems at the bottom of the hierarchy are the lexicalized ones that need to be listed because of irregular properties or simply because they are conventionally known words (see section 1). But they can be subsumed under the more general patterns one level above and only their idiosyncratic aspects need to be mentioned.

For the *bar*-adjectives from transitive verbs, there are so many lexicalized examples (which are, of course, not all shown here), and this pattern (*trans-bar-adj*) is so general and salient, that it is perceived as a productive rule. Because of the closed-world interpretation of the hierarchy, it is necessary to introduce a new type (*reg-bar-adj*) on the lowest level that inherits all the constraints from *trans-bar-adj*, and functions as the schema for productive word formation. This says in effect that such a *bar*-adjective is either one of the lexicalized ones, or any word that meets the constraints on the type *reg-bar-adj*, i.e. any word fitting this schema. Every appropriate stem of type *trans-verb* can be 'filled in' via unification, resulting in a new word with predictable properties.[10] The approach can handle complex derivation because the stem itself can be complex, e.g. the verbal stem *werf* 'throw' can be prefixed by *ab-* 'off' to make the transitive verb stem *abwerf*, which is of the appropriate type to fit this schema, so the adjective *abwerfbar* 'throw-off-able' can be formed. This adjective is in turn of the appropriate type for *keit*-suffixation, so the noun *Abwerfbarkeit* can be formed. Recursive type constraints are formally explained in Carpenter (1992), chapter 15.[11] Their morphological use here is parallel to their use for phrasal construction in HPSG—see e.g. Zajac (1992). One difference is that derivational schemata represent words, not phrases, and that many derived words are lexicalized whereas most phrases have to be constructed, although of course the derivational schemata can be used productively and there are lexicalized idiomatic phrases. A more significant difference is that *all* derivational affixes are introduced syncategorematically, whereas this is the exception for syntactic rules in most grammatical frameworks.[12]

Note also the introduction of a schematic subtype for *trans-bar-adj* provides a way of describing that this is a fully productive schema (of course not explaining why—for that one would need a theory of productivity, and access to frequency information).[13] There is no schema for *bar*-adjectives from intransitive verbs on the lowest level. But the generalization *is* available, and one could imagine that various factors such as the degree of productivity of the class and the urgency of the need for a word could be the reason for making these subregular classes available as schemata for productive use.[14]

Let me explain the various functions of lexical type hierarchies. First of all, they structure the lexicon, by representing linguistically relevant subclasses of words explicitly. They thereby reduce redundancy in the representations for lexicalized (idiosyncratic or exceptional) words, and relate them to the rule, rather than just listing them. This seems desirable, because generalizations are expressed that would otherwise be lost, e.g. the relationship to passives and the semantic notion of possibility shared with other derived words. But it does not seem strictly necessary from a logical

[10] So, formally a schema is just an ordinary complex type constraint, but in this paper the term 'schema' is used to refer to those type constraints at the bottom of the hierarchy that can be used for productive word formation because they have an underspecified morphological base that can be 'filled in'.

[11] It would not be possible to implement this approach using standard macros or templates as e.g. in Shieber (1986), because these do not allow recursion.

[12] The analogy to syntax also makes it clear why it would be spurious to have an independent entry for the syncategorematically introduced material.

[13] It is hard to formalize what defines productivity. Semantic coherence, number of types and frequency of tokens, and predictability of properties all play a role. In some cases an affix might appear not to be fully productive only because very few lexical items match the constraints imposed on the stem, and those constraints may be hard to determine. These issues, in particular the role of frequency information, have been debated by Baayen 1992, van Marle 1992, Frauenfelder & Schreuder 1992, Clark 1993, and Bybee 1994. It remains to be seen how well their insights can be captured by the hierarchical approach. Type frequency, one of the most important factors, is available as the number of subtypes (corresponding to the lexicalized instances) a pattern has.

[14] As a first approximation for increasing robustness in a computational system one could say that if word cannot be found in the lexicon or analyzed by the productive schemata, all word-formation patterns with more than a certain number of subtypes can be tried. This would result in the system's ability to parse but not generate new formations like *verrottbar* 'rottable'.

point of view, since there can only be a finite number of lexicalized words in a given language, which could in principle be listed. But simple listing would not only miss generalizations, e.g. the fact that all these words are adjectives and have similar semantics. It would also make it unnecessarily complicated to see these words as morphologically complex. It amounts to saying that the tiniest idiosyncrasy[15] in a word has as a consequence that it is listed without any connection to its stem, that none of its properties are predictable, and that the existence of this lexical item does not affect which morphological rules there are in the language.

The patterns that arise by virtue of this structuring function can then be used to account for productive word formation: speakers use their knowledge of learned patterns to form new exemplars. It is not necessary to have a separate lexical rule mechanism for this purpose or use a word-syntactic approach.

And finally, these hierarchies can be used to describe word-formation that is analogical and not strictly rule governed. This is not yet fully worked out formally, but it is fairly straightforward to see what a processing regime might look like that uses existing (subregular) patterns to analyze unfamiliar words, and to produce new words when there is good motivation.[16] Ideally this would be based on a good theory of productivity, taking into account not only the number of lexicalized types and frequency information but also factors like the semantic coherence of the class.

5.2. The Productive Schema

This is the schema for the fully productive, regular *bar*-adjectives:

[15] An example of this would be the word *einsetzbar* 'usable', which is transparently related to the transitive verb stem *einsetz* 'use'. The adjective nevertheless needs to be listed so it can be expressed that it means 'usable' while the verbal stem has many meanings, including the basic meaning 'put in' or 'insert', and more specialized meanings like 'apply' (force) and 'bet' (money), and 'risk' (one's life). Some of these senses could be made into *bar*-adjectives productively, but it is a fact about German that *einsetzbar* is normally used to mean 'usable'. In the Mannheim Corpus there are 38 occurrences of *einsetzbar*, all of which have this meaning—they are about the usability of medical substances, new technology, weapons, sources of energy, and personnel.

[16] For example, it is conceivable that people become more likely to form a slightly funny sounding *bar*-adjective if it is needed for coordination with other adjectives, or just because expressing the desired meaning with an adjectival semantics is important. E.g. when *breathable* bags have just been invented, or *renewable* sources of energy discovered, it is preferable to be able to express these new concepts concisely, especially if the syntactic alternatives are long and not very appealing. See also Clark & Clark 1979.

(10)
$$\begin{bmatrix} \textit{reg-bar-adj} & \\ \text{PHONOLOGY} & \boxed{1} + \textit{bar} \\ \text{MORPH-B} & \left\langle \begin{bmatrix} \textit{trans-verb} & \\ \text{PHON} & \boxed{1} \\ \text{SYNSEM} \mid \text{LOC} & \begin{bmatrix} \text{CAT} \mid \text{VAL} \mid \text{COMPS} & \langle \textbf{NP[acc]}:\boxed{2}\rangle \oplus \boxed{3} \\ \text{CONT} \mid \text{NUC} & \boxed{4}\begin{bmatrix}\text{ACT} & \\ \text{UND} & \boxed{2}\end{bmatrix}\end{bmatrix}\end{bmatrix}\right\rangle \\ \text{SYNSEM} \mid \text{LOCAL} & \begin{bmatrix} \text{CATEGORY} & \begin{bmatrix}\text{HEAD} & \textit{adj} \\ \text{VALENCE} & \begin{bmatrix}\text{SUBJ} & \langle \textbf{NP}:\boxed{2}\rangle \\ \text{COMPS} & \boxed{3}\end{bmatrix}\end{bmatrix} \\ \text{CONTENT} \mid \text{NUCLEUS} & \begin{bmatrix}\text{RELN} & \Diamond \\ \text{ARG1} & \boxed{2} \\ \text{ARG2} & \boxed{4}\end{bmatrix}\end{bmatrix}\end{bmatrix}$$

Through the various structure-sharings it specifies the relationships between the stem, which is the value of MORPH-B (morphological bases), and the whole complex word. For example, the semantics of the verb ($\boxed{4}$) is put into the scope of the possibility operator in the semantics of the adjective. $\boxed{2}$ is the UNDERGOER from the semantics of the verb (ACTOR and UNDERGOER are developed by Davis (1996) as part of his linking theory). This is to emphasize that the meaning of *bar*-adjectives is something like 'noun is capable of being verb-ed'—it is a notion of possibility qualified with respect to properties of the adjective's subject. Additional thematic restrictions on the UNDERGOER may be necessary, as discussed above. It is unclear how to write these down formally, but they are already part of the generalization over the lexicalized *bar*-adjectives from transitive verbs.

Syntactically, the schema states that the verb's accusative object is the same as the subject of the adjective. It also specifies that further complements can be inherited, although it is debatable whether this should be dealt with syntactically (see Riehemann 1993).

Phonologically, the affix is added to the phonology of the verbal stem. This does not always have to be simple concatenation as in the case of German -*bar*. The phonological constraints apply for each derivational step, automatically giving the effect of cyclic phonology.[17]

5.3. The Higher Level Generalizations

Not all of the information in the schema in figure 10 has to be given at this point in the hierarchy. This is because it makes sense to isolate the various parts of this constraint, to make it possible to express generalizations in the lexicon.

For example, it is true for all suffixed words that the suffix comes after the stem, as expressed in (11). The hierarchical lexicon enables us to express this kind of generalization. Therefore Selkirk's (1982) argument against 'introducing affixes in the rules' as missing these generalizations does not apply.

[17] See Orgun 1994 for data that cannot be handled by noncyclic approaches, and for an approach to phonology that seems compatible with the view of morphology expressed in this paper.

(11) $\begin{bmatrix} \textit{suffixed} & \\ \text{PHONOLOGY} & \boxed{1} + \textit{suffix} \\ \text{MORPH-B} & \left\langle \begin{bmatrix} \text{PHON} & \boxed{1} \end{bmatrix} \right\rangle \end{bmatrix}$

Note that the affix lives only in the phonology. It is not a sign and therefore not on the list of morphological bases. MORPH-B is a list because that is necessary for compounds.[18]

This appears to bring with it a locality effect: the information about previous affixes is not available to further affixations, or to phonology or syntax. But reference to the internal structure is needed in some kinds of word formation, as some affixes combine only with morphologically simple stems (*entflecken* ('de-stain'), **entfettflecken* ('de-grease-stain')) and others only with complex stems, sometimes even requiring a particular other suffix in their base (Hoeksema 1988). Where a limited amount of information about internal structure is needed (for example to make sure the *-ate* sequence that is truncated in English *-able* affixation is a formative (c.f. **debable*))[19], it is available via the types. In most cases it is sufficient to know that a word has undergone affixation. But even more complex information, for example about the specific affixes required, can be made available in this way. Although affixes are not explicitly represented as part of the structure, the stems are, which makes the internal structure of complex words recoverable (in contrast to Anderson 1992). But this information is not automatically available, which might explain why these phenomena are not common.

It seems independently necessary to allow words to be parts of other words for compounding, so there is nothing particularly strange about viewing the stem of a derived word as an independent word that forms part of the complex one. On the other hand, there is no need to view the affix as being a sign of its own.[20]

Semantically, *bar*-adjectives share the possibility aspect with other derived words ending in *-lich*.

(12) $\begin{bmatrix} \textit{possibility} & \\ \text{SYNSEM} \mid \text{LOCAL} \mid \text{CONTENT} \mid \text{NUCLEUS} \mid \text{RELN} & \Diamond \end{bmatrix}$

This is not an uncommon situation: there are, for example, many affixes for agent nominalization, all of which have a related meaning (Beard 1990).

Syntactically, *bar*-adjectives have quite a lot in common with passives, in particular the fact that the object of the verb corresponds to the subject of the adjective (or passive):

[18] One can imagine that what happens when compounds develop into affixes is that the second element of the list 'drops out' of that list and only its phonology survives, since the word's semantic relationship to the complex word is no longer transparent.

[19] Carstairs-McCarthy 1992 has argued that the alternative phonological account offered by Anderson 1992 does not work for all cases.

[20] For an analysis of coordination involving affixes (e.g. *kostenlos oder -günstig*) consistent with this approach see Wiese (1995).

(13)
$$\left[\begin{array}{ll} \textit{externalized} & \\ \text{MORPH-B} & \left\langle \left[\begin{array}{ll} \textit{trans-verb} & \\ \text{SYNSEM}\,|\,\text{LOC}\,|\,\text{CAT}\,|\,\text{VAL}\,|\,\text{COMPS} & \langle \textbf{NP[acc]}:\boxed{1} \ldots \rangle \end{array}\right] \right\rangle \\ \text{SYNSEM}\,|\,\text{LOCAL}\,|\,\text{CATEGORY}\,|\,\text{VALENCE}\,|\,\text{SUBJ} & \langle \textbf{NP}: \boxed{1} \rangle \end{array}\right]$$

The constraint on the subregular *prep-bar-adj* is that the semantics of the adjective's subject corresponds to the semantics of the verb's PP complement.

(14)
$$\left[\begin{array}{ll} \textit{prep-bar-adj} & \\ \text{MORPH-B} & \left\langle \left[\begin{array}{ll} \text{SYNSEM}\,|\,\text{LOC}\,|\,\text{CAT}\,|\,\text{VAL}\,|\,\text{COMPS} & \langle \textbf{PP}:\boxed{1} \ldots \rangle \end{array}\right] \right\rangle \\ \text{SYNSEM}\,|\,\text{LOCAL}\,|\,\text{CATEGORY}\,|\,\text{VALENCE}\,|\,\text{SUBJ} & \langle \textbf{NP}: \boxed{1} \rangle \end{array}\right]$$

Because of all the information available in the type *trans-bar-adj*, the lexical entries for lexicalized *bar*-adjectives can be minimal, and look like the one for *vergleichbar* in (15):

(15)
$$\left[\begin{array}{ll} \textit{vergleichbar} & \\ \text{MORPH-B} & \left\langle \left[\textit{vergleich}\right] \right\rangle \end{array}\right]$$

Together with the inherited information, all the necessary phonological, syntactic, and semantic information about this complex word is available without stipulation:

(16)
$$\left[\begin{array}{ll} \textit{vergleichbar} & \\ \text{PHONOLOGY} & \textit{vergleichbar} \\ \text{MORPH-B} & \left\langle \left[\begin{array}{ll} \textit{vergleich} & \\ \text{PHON} & \textit{vergleich} \\ \text{SYNSEM}\,|\,\text{LOCAL} & \left[\begin{array}{ll} \text{CAT}\,|\,\text{VAL}\,|\,\text{COMPS} & \langle \textbf{NP[acc]}:\boxed{2} \rangle \oplus \boxed{3} > \\ \text{CONT}\,|\,\text{NUC} & \boxed{4} \left[\begin{array}{ll} \text{RELN} & \textit{compare}' \\ \text{ACT} & \\ \text{UND} & \boxed{2} \end{array}\right] \end{array}\right] \end{array}\right] \right\rangle \\ \text{SYNSEM}\,|\,\text{LOCAL} & \left[\begin{array}{ll} \text{CATEGORY} & \left[\begin{array}{ll} \text{HEAD} & \textit{adj} \\ \text{VALENCE} & \left[\begin{array}{ll} \text{SUBJ} & \langle \textbf{NP}:\boxed{2} \rangle \\ \text{COMPS} & \boxed{3} \end{array}\right] \end{array}\right] \\ \text{CONTENT}\,|\,\text{NUCLEUS} & \left[\begin{array}{ll} \text{RELN} & \Diamond \\ \text{ARG1} & \boxed{2} \\ \text{ARG2} & \boxed{4} \end{array}\right] \end{array}\right] \end{array}\right]$$

Note that such an entry does not exist for non-lexicalized *bar*-adjectives such as *ziehbar*. But that word can be productively formed by unifying in the first part of the *reg-bar-adj* schema with the transitive verb stem *zieh*.

5.4. Zero-Derivation

In Type-Based Derivational Morphology zero-derivation can be dealt with in a much nicer way than in word-syntactic systems. Because affixes do not have lexical entries, it is not necessary to assume lexical entries for suffixes without phonology. The only difference between a derived and a zero-derived form is that in the latter there is no effect of the derivation in the phonology.

5.5. Properties of the Approach

TBDM expresses the relationship of subregularities and exceptions to the 'rule' and makes precise exactly which properties are shared in each case. Semiproductive patterns are available, along with information about the number of subtypes they have. This can be seen as the beginning of an account of degrees of productivity. Statistical information cannot be exploited in the standard HPSG formalism, but there is work on integrating probabilistic information with a typed feature structure system—see e.g. Brew (1995). So this kind of information could eventually be available for use in computational systems as well.

Affixes are not treated as signs, and they have no syntax and semantics; that is, they do not mediate syntactic and semantic properties between the 'input' and the 'output' category by first making them their own. From this, it also follows that affixes are not heads. But the fact that most suffixes are category specific does not need to be expressed explicitly—it is hard to imagine a word formation schema which is general enough to match more than one major part of speech, yet specific enough to include a predictable syntax and semantics. Furthermore, all that is 'determined' by morphological heads is category (Zwicky 1985, Bauer 1990), which is easy to figure out even without any affixes (e.g. in zero-derivation). Also, affixes with a very specific semantics will be compatible only with one category—and the ones that are more flexible (e.g. diminutives) seem to be exceptions anyway.

The information embodied in the schemata is split up at one level into syntactic, semantic, and morphological information, and even further within that. This captures generalizations at higher levels which would otherwise be lost—some of the generalizations are useful for some other morphological phenomena.[21] For example, the syntactic generalizations could be used for the passive construction and the semantic ones for *lich*-adjectives. In this case the morphological properties are not needed elsewhere, but for other affixes there are phonological effects that are independent of the semantics. Hence this approach expresses modular generalizations lost in rule approaches.

Inheritance is monotonic; that is, no information specified at a higher level can be overridden by more specific information lower in the hierarchy. This seems desirable from an acquisition point of view: if all information were defeasible it would be unclear how the schemata would be formed.

[21] This should be constrained by a general theory of what a linguistically relevant generalization/class of words is. It is not quite as unrestricted as it may seem, since not all generalizations that are logically possible contribute to a simplification of the lexicon. Forming a class of words beginning in the letter 'a' for example would not reduce the amount of information that needs to be listed. But not all generalizations that reduce redundancy may be linguistically relevant, and further criteria need to be developed, taking into account significant clusterings of information, and whether a generalization is required in more than one place in the grammar.

Further potential problems with default systems have been discussed in Calder 1991 and Kilbury 1993. The price that has to be paid is a larger number of types in the hierarchy. It remains to be seen whether recent nonmonotonic logics that can distinguish between strict and defeasible information might be able to deal with the acquisition problem and avoid wrong classifications of new items to be entered into the hierarchy, by making clear what the defining characteristics are. An example of a potential problem for classification are the *bar*-adjectives from intransitive verbs—these have more features in common with the *lich*-adjectives than with the regular *bar*-adjectives. Meanwhile, it makes sense to pursue the monotonic approach further because it is actually more constrained, since none of the generalizations emerging from the data can be dropped or changed for the productive rule.

Pinker (1997 and earlier work) argues that there is neurological evidence for a distinction between regular and irregular past-tense. There are patients who are able to process irregular past-tense forms but not regular ones, and there is also imaging data showing that different regions of the brain are active for these tasks.

If this turned out to be true for productively formed vs. irregular *derived* words as well,[22] that would be consistent with the proposed theory. Productively forming a word involves additional mechanisms not needed for the retrieval of lexicalized word forms, so whatever brain functions are used for locating the stem in memory and unifying it into the schema could be those that are impaired.

6. Conclusions

In Type-Based Derivational Morphology, generalizations from existing words are expressed as explicit schemata, which primarily reflect how the lexicon is organized, and only secondarily account for productive word formation.

This approach can do everything word syntax can, and more—it can handle exceptions, and productive rules, but also existing partially regular words and new subregular cases. This avoids redundancy in lexical specifications by making explicit the partial relationships that exist to the productive rule. And it becomes possible to exploit existing subregular patterns for semiproductive word formation. In addition TBDM is capable of capturing generalizations that are lost in other approaches, e.g. the syntactic properties shared with passives. Furthermore, it can deal with zero-derivation and other nonconcatenative morphology.

The approach is even more important for other affixes, such as the German *ig*-adjectives discussed in section 2.3, which exhibit more irregularity and analogy. It is also needed for the semi-affixes discussed in section 2.4 and it can express the generalizations at various levels of generality needed for compounding.

[22] This is hard to assess experimentally since many frequent words are lexicalized even though all their properties are predictable from their parts and the relevant schema, and it varies from speaker to speaker for which words this is the case.

Berko's (1958) data about past tense formation by analogy (see section 3) suggests that an approach which is able to handle subregularities might also be needed for inflection, although this is not as crucial as for derivation. The proposed approach should generalize to inflection with some appropriate modifications.

It remains to be seen how much sense the approach makes for other languages. Some related work has been done already on Sierra Miwok morphophonology (Bird & Klein 1994), Korean inflection (Kim 1994), and Mohawk noun incorporation (Malouf 1994). Also, Bybee (1994) has shown that a lexicon based view of morphology is appropriate for various languages, and is in fact needed to explain some of the data.

TBDM seems to be a natural way in which to make precise the old idea of 'redundancy rules', which goes back to at least Jackendoff (1975) for morphology and Stanley (1967) for phonology.[23] The idea behind redundancy rules is that their primary role is to give structure to the existing lexicon, and only secondarily to provide a means for word formation. Precisely this idea is captured by TBDM, which in addition can relate lexical rules to each other and account for subregularities.

The approach is a natural extension of the same formalism HPSG uses in its syntactic and lexical analyses in general, while it is not clear that a similar incorporation of the idea of 'redundancy rules' into other theories, such as the Minimalist Program, is possible.

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[23] Anderson 1992 has argued for this view of lexical rules. Bochner 1988 has given it an alternative formalization, which has recently been taken up again by Ackerman 1995.

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Appendix A: List of the Corpora used

1. **Mannheim Newspaper Corpus**, 1985-1988; 10,766,759 Words, 17,297 Tokens, 836 Types
2. **Rosengren Newspaper Corpus** (Rosengren 1977), 1966/67; 2,976,894 Words, 4346 Tokens, 343 Types (no context)
3. **Gelhaus Mannheim Corpus** (Gelhaus 1977), 1206 Tokens, 313 Types (no context)
4. **Wendekorpus** (mostly Newspapers), 1989/90; 488,563 Words, 661 Tokens, 152 Types
5. **Journal 'Germanistik'** 1991; 385,531 Words, 343 Tokens, 119 Types
6. **Electronic Newsgroups**, collected by the ELWIS project, University of Tübingen, 1992/93; roughly 20 Million Words