Universität Potsdam



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Evidence for a lexical entry complexity account

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Abbreviations

AAM	Augmented Addressed Model (Caramazza et al., 1988)
DRM	Dual Route Model
ERP	Event Related Potential
Gr.	Greek
hyb	hybrid
IA Model	Interactive Activation Model (Dell, 1986)
IN Model	Independent Network Model (Caramazza, 1997)
irr	irregular
LD	Lexical Decision
ms	milliseconds
nreg	non-regular
PET	Positron Emission Tomography
PWI	Picture-Word Interference
reg	regular
RT	Reaction Time
SMA	Supplementary motor area
SOA	Stimulus Onset Asynchrony
WR	Words and Rules Theory (Pinker, 1999)

0 Introduction

The incredible productivity and creativity of language depends on two fundamental resources: a *mental lexicon* and a *mental grammar* (Chomsky, 1995; Pinker, 1994). The mental lexicon stores information and masters the arbitrariness of the language. It is a repository of idiosyncratic and word specific, i.e. atomic non-decomposable information. For example, the mental lexicon contains the arbitrary sound-meaning pair for *dog* and the information that it is a noun. The mental lexicon also comprises complex idiosyncratic phrases such as *It rains cats and dogs*, the meaning of which cannot be derived transparently from the constituents (Swinney & Cutler, 1979; Gibbs, 1980).

In addition to the mental lexicon, language is also made up of rules of grammar constraining the computation of complex expressions. These rules of grammar enable human speakers to produce and understand sentences that they have not encountered before. The meaning, then, can be derived from the constituents and knowledge about rules. Not only do these determine sequential ordering of constituents but also hierarchical relations. The recipient of the message *The dog tammed the crig* knows that the dog is the actor of a past action and that the dog did something to the entity *crig*. To compute an infinite number of new structures from stored elements and to derive their meaning is an enormous grammatical ability and the source of productivity and creativity of human language (Chomsky, 1995).

The computational component of the language faculty can be found at various levels in natural languages: e.g. at the sentence level (syntax) and the level of complex words (morphology). Rules manipulate meaning and structure of symbolic representations. Applying recursively, a limited set of units and rules is the core for combinations of unlimited number and unlimited length.

Moreover, rules apply on abstract symbolic categories rather than on particular words. They can generate unusual combinations (*colourless green ideas*) and nonsense sentences (*The dog tammed the crig*).

This dichotomy of the mental lexicon on the one hand and the mental grammar on the other hand can help us to better understand the brain mechanisms we employ to process language. Symbol manipulation underlies classification and identification of classes of symbols suppressing irrelevant information and drawing inferences that are likely to be true of every member of the class, even individual members that have not previously been encountered. The ability to handle an unfamiliar symbol as a member of a class is central to cognition. Hence, the resolution of this dichotomy in mental lexicon and mental grammar is not only of interest to psycholinguistics but to psychology, neurosciences, linguistics and artificial intelligence as well. Ullman (2001a; 2001b) generalises that the distinction between stored and computed representations in language is tied to two distinct brain memory systems: declarative and procedural memory. The declarative memory system is devoted to learning and remembering facts and events, whereas the procedural system is responsible for sequencing of representations or motor actions.

The concepts of mental lexicon and mental grammar have been thoroughly tested in the context of the use of regular versus non-regular inflectional morphology. Inflection is one way languages express grammatical relations by changing the form of a word to give it extra meaning. The inflection of verbs encapsulates the issues of lexicon and grammar. Regular verbs (walk-walked; lachen-lachte [to laugh-laughed]) are computed by a suffixation rule in a neural system for grammatical processing; irregular verbs (run-ran) are retrieved from an associative memory. A heated and polarizing, though fruitful, debate concerns the processing and representation of regular and non-regular verb forms (Marcus, Brinkmann, Clahsen, Wiese & Pinker, 1995; Pinker, 1997; Clahsen, 1999).

„Perhaps regular verbs can become the fruit flies of the neuroscience of language – their recombining units are easy to extract and visualize and they are well studied, small and easy to breed.“ (Pinker, 1997)

The comparison by Steven Pinker of regular verbs being the *fruit flies of neuroscience of language* highlights their importance and potential. Their nature is as fascinating as the genome of those little flies with their protuberant eyes, certain to appear every summer. The study of regular verbs is supposed to uncover meaningful evidence about human cognition like drosophila did for genetics.

Out of the above mentioned debate two approaches have emerged: one camp assumes associative memory mechanisms (Rumelhart, McClelland & the PDP research group, 1986; Ramscar, 2002; MacWhinney & Leinbach, 1991; Daugherty & Seidenberg, 1994), while the other camp presumes the existence of linguistic rules (Berko, 1958; Heidolph, Fläming & Motsch, 1981; Eisenberg, 1994). Pinker (1991; 1999) finally combined both approaches to the *Dual Route Model*.

However, little research has been devoted to the *production* of regular and non-regular verbs and even less to aspects of tense. The aims of this thesis are to explore the cognitive reality of regularity[1], its representation and inflectional processes involved in the production of regular and non-regular verbs in unimpaired speakers. Chapters 1-5 provide the theoretical background (empirical findings and psycholinguistic models) as well as morphological concepts of linguistic theory. Linguistic factors play a crucial role in psycholinguistic processing and must be closely considered in motivating hypotheses and modelling. Chapter 6 and 7 summarize and discuss data of four picture-word-interference experiments exploring the cognitive status of regularity as well as a picture naming experiment which validates

1 The term regularity includes non-regularity. It is a superordinate concept and refers to the general property of items to be regular or not. The non-existence of the concept/term indicates that it has not been analysed as general feature before but only with its specific values regular/non-regular/irregular. Regularity means more or less “regularity status”.

the different morphological inflectional processes assumed and devoted to lexicon and grammar. The discussion in chapter 8 is a re-consideration and evaluation of the current models on verb processing in the light of the experimental data.

1 Regular and non-regular inflection

Theories of language processing often draw upon the accounts made by theoretical linguistics. Theoretical linguistics seeks to *describe* mental representations. The linguist's morphological decomposition of words has often been examined by psycholinguists asking whether there is any correspondence between linguistic theory and the way morphologically complex words are segmented by the speaker or hearer during online production and comprehension. The first chapter aims at anchoring the psycholinguistic question studied in linguistic theory.

Like in most Germanic languages, German verbs can be classified into two fundamentally different classes: regular (weak) and non-regular (strong) verbs. The crucial difference between these classes lies in the formation of their past tense stem. Historically, non-regular verbs are the base stock of all Germanic verbs. Nowadays, non-regular verbs constitute a minority of all verbs as many were regularised with language change.

1.1 Inflectional categories

Inflection is one way languages express grammatical relations. Inflectional processes are specific for certain parts of speech. For German verbs, inherent[2] inflectional categories include *person, tense, number, voice and mood* (cf. Spencer & Zwicky, 1998; Bickel &

2 A non-inherent inflectional category of verbal inflection is for example subject-verb-agreement.

Nichols, 2007). Typologically, different languages may also specify *gender, honorificity, animacy* or *definiteness* on the verb. German nouns are inflected for number and case. Inflectional operations often are systematic and exceptionless.

Regularity is a crucial property to create a tense marked stem of a verb. Regularity, however, is inherent to a verb's grammatical properties because it is arbitrary. The verbs of Indo-European languages generally have distinct suffixes to specify present and past tenses. Verb inflection in German is usually divided into two parts: *regular* (*weak*) and *non-regular* (*strong*) inflection (conjugation). Regular verbs (e.g. (1) *spielen* [to play]) have only one stem and take regular affixes in both past (*–te*) and present (–*t*). Non-regular verbs like (2) *blasen* [to blow] have alternating stems.

(1) ich spiel-*e*, er spiel –*t*, er spiel-<u>*te*</u> [I play, he play-s, he play-ed]
(2) ich blas-*e*, er bl**ä**s-*t*, er bl**ie**s- [I blow, he blow-s, he blew]

The preparation of the stem and the inflection of the verb form for person and number are two distinct processes. Person and number agreement is formed independently of the verb's regularity without any exceptions (disregarding suppletives). This means that person suffixes (e.g. *–st* for second person singular) are added to the tense marked stem, be it regular (du *lachte-st)* or non-regular (du *trank-st)* (Clahsen, 1996; Clahsen, Eisenbeiss, Hadler & Sonnenstuhl, 2001). The primary mechanism in verb production is the generation of the stem, person and number inflection follows only if the stem is completed.

Most inflectional categories fulfil requirements of syntax. Inflection can be governed syntactically realising, for instance, agreement relations. Then inflection is occasioned by a governing head in a sentence and is highly productive. (cf. *he* and *-s* in (3a)). Also determiners and adjectives in many languages agree with the head noun as in the German example in (3b).

(3) a. *he sing-s/we sing*
b. *ein knusprig-es Brot*
a-NOM.SG.NEUTR *crispy*-NOM.SG.NEUTR *bread*-NOM.SG.NEUTR

However, Bickel and Nichols (2007) point out that the sentence level is not the only dimension that conditions inflectional processes:

> *"The relevant grammatical environment can be either syntactic or morphological."* (Bickel & Nichols, 2007)

By contrast to syntactically driven inflectional processes, the inflection can be determined by lexical entries' inherent properties, i.e. morphological properties like aspect in Russian. Aspect in Russian classifies verbal bases into perfective and imperfective in a highly non-regular manner. The future tense of imperfective verbs is formed analytically (periphrastically), but synthetically (by means of a morphological process) if the verb is perfective. Here, inflection is determined by lexical aspect. Also the inflection of verbs in German depends on the inherent regularity status of the verbs.

1.2 Paradigms and classes

The term *paradigm* is derived from the Greek word for *pattern* (Gr. παράδειγμα *parádeigma*). It contains the full set of inflectional endings a stem can have. With respect to verbal inflection, it provides the material to instantiate all possible word forms of the verb and serves as a model or example for all others. Paradigms are often set out as a learning tool in language teaching. By knowing the pattern a new word belongs to, one can easily inflect the new word by generalising on the basis of known words of the same paradigm - usually by adding a suffix to indicate a change in its grammatical function. For German, see example (4) for paradigmatic relations with respect to inflection of verbs for person in present tense (a+b) and past tense (c+d).

(4) a. ich lach-*e*, du lach-*st*, er lach-*t*…
[I laugh, you laugh, he laugh-s…]
b. ich geh-*e*, du geh-*st*, er geh-*t*…
[I go, you go, he go-(e)s…]
c. ich lach-*te*-ø, du lach-*te*-st, er lach-*te*-ø…
[I laughed, you laughed, he laughed…]
d. ich ging-ø, du ging-st, er ging-ø…
[I went, you went, he went…]

The person/number suffixes for conjugating *lachen* and *gehen* are identical but the behaviour of the stem renders them distinct. A multi-paradigm analysis is necessary as there is no way to predict whether a verb employs allomorphic stems or not. The term *paradigm* is used in various senses (for a review see Carstairs-McCarthy, 2000). I adhere to the most common usage of the term paradigm according to which paradigms correspond to the taxonomy of *regular* and *non-regular* verbs (cf. (Carstairs, 1987). Hence, *geben* (to *give)* and *singen [to sing]* belong to the same paradigm; *gehen (to go)* and *lachen [to laugh]* belong to two different paradigms: the latter forms its past tense by adding *–te* to the stem and the former has a special past tense stem.

Recurring regularities within the German non-regular verbs are *conjugation* or *inflectional classes* (Ablautreihen). Ablaut refers to an internal modification involving vowel change. For instance, *s**i**ngen - s**a**ng - ges**u**ngen* [sing – sang – sung] is a case of Ablaut. Inflectional classes stand out due to phonological predictability (Wurzel, 1984). The verb *trinken* [to drink] belongs to the same Ablaut pattern as *singen* (to sing) above as it is inflected alike: trinken - trank – getrunken [drink - drank - drunk] (Wiese, in prep.). Hence, conjugation classes are subclasses of the non-regular paradigm like *s**i**ngen - s**a**ng - ges**u**ngen* and tr**i**nken - tr**a**nk – getr**u**nken, which have the same vowel sequences. *geben* [to *give*] and *singen* [*to sing*] belong to the non-regular paradigm but to different *conjugation classes*.

Conjugation classes reflect regularities among non-regular verbs. However, the empirical motivation of conjugation classes is not without counter examples. The same phonological environment is not necessarily a reliable predictor of the correct past tense forms, e.g. the inflections of *sink* and *think* follow different ablaut patterns (*sank*, *sunk* versus *thought, thought*) and therefore belong to different phonological classes.

Conjugation classes are much more present in Romance languages like French or Italian. Here, verbs which are phonologically alike, i.e. having the same vowel pattern and/or ending, belong to the same type of conjugation. Normatively and for first (L1) and second language (L2) learning they are defined as *classes*.

1.3 Language typology

Anglo-American research constitutes a large part of the psycholinguistic scientific work. Hence, English is studied in much more detail than any other language. This section serves to highlight the structural similarities of Indo-European languages but also their differences. Of most interest here, and therefore in the spotlight, are English and German.

The Indo-European languages comprise a family of several hundred related languages. *Indo* refers to the Indian subcontinent, since geographically the language group extends from Europe in the west to India in the east. German and English are the most widely spoken languages of the branch of *Germanic languages* (Gordon, 2005). They belong to one family and are genetically related.

Germanic languages share several attributes compared to other families. The verbal system of tense and aspect has undergone syncretism and has reduced to the present tense and the past tense (the preterite). In English and German, a large set of verbs uses a dental suffix ([d] or [t] in English and [tə] in German) instead of vowel alternation to indicate past tense. These are known as *Germanic weak verbs* and the remaining as *Germanic strong verbs*[3].

1.3.1 German verbal inflectional system

The German verb system is indeed organised in a greater diversity than shown so far and greater than for example the English one. It is set up by *three* basic paradigms. The *non-regular* paradigm is comprised of *hybrid* and *irregular* verbs. In addition to regular verbs (e.g. (5) *spielen* [to play]), German has a second and third type of verb which most authors group as *irregular* verbs disregarding possible dissociations. *Hybrid* verbs are completely regularly inflected in the present tense but employ irregular stems in the past tense. Hence, they have also more than one stem (e.g. (7) *singen* [to sing] – sang [sang]). *Irregular* verbs have irregular forms in both the present and the past tense (e.g. (6) *blasen* [to blow])[4]

(5) ich spiel-*e*, er spiel –*t*, er spiel-<u>*te*</u> [I play, he play-s, he play-ed]
(6) ich blas-*e*, er bl**ä**s-*t*, er bl**ie**s- [I blow, he blow-s, he blew]
(7) ich sing-*e*, er sing-*t*, er s**a**ng- [I sing, he sing-s, he sang]

Hybrid verbs unify regular and irregular forms in one paradigm. The crux of the matter: their typical and common characteristic are stem vowels like /ei/ in *beißen* and /i:/ in *biegen* which do not have fronted counterparts and therefore cannot mutate to umlaut. As in the previous research, I will use the term *non-regular* to refer to both hybrid and irregular verbs as opposed to regular verbs. The whole picture is exemplified in Figure 1.

3 Weak and strong is a synonym terminology for regular and non-regular. Regarding processing aspects, regular and non-regular obviously describe the assumed cognitive processes more accurately.
4 In the DUDEN grammar (Kunkel-Razum, 2006) another term "Mischverben" is introduced which defines verbs with participles irregularly ending in -n, e.g. mahlen: er mahlt, er mahlte, er hat gemahlen [to mill] although their past tense is regular. Those are another potential object of investigation.

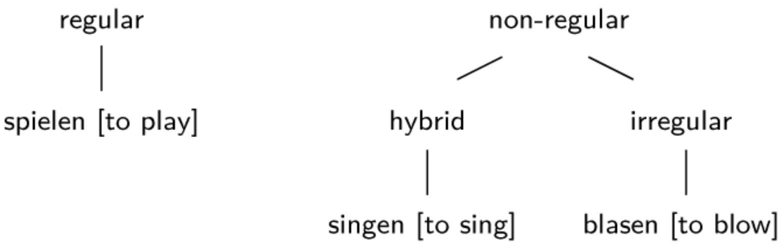

Figure 1. Classification of German verbs

1.3.2 Comparison of English and German inflectional system

The following section discusses two reasons why English is not the most appropriate language (at least not the only one) to test morphological dissociations between regular and non-regular verbs in different tenses. Of particular relevance to the following empirical work, three dimensions will be discussed in order to compare the inflectional systems of English and German: Agreement, regularity and tense. In Figure 2, “x” indicates overt phonological marking for person/number agreement and regularity depending on tense as tense is in the focus of the current study.

	German		English	
	Agreement	Regularity	Agreement	Regularity
Present	x	x	x	–
Past	x	x	–	x

Figure 2. Agreement and Regularity as factors for inflection in German and English.

It can be seen that in German, agreement is potentially visible on word forms in both tenses (du geh**st** [you go] – du ging**st** [you went]). English also inflects in the present tense for person and number, although in a rather rudimentary way. Its overt inflection occurs only for the third person singular. Person and number agreement in the English past tense can only be derived from the context. Verbs are not overtly marked for this feature (exception: to *be*).

Consider the German Regularity column in Figure 2 above. The crosses indicate overtly visible, regularity dependent inflectional processes in the present tense as well as in the past tense. Verbs like *brechen* [to break] are responsible for the cross in the Regularity by Present cell. Some German verbs show non-regularities in the present tense (*ich breche* [I break] – *er bricht* [he breaks]). However, the dissociation between regular and non-regular verb inflection in English targets only past tense generation[5]. Regular verbs concatenate the stem and the suffix *–ed* (*laugh – laughed*) – very similar to German (*lachen – lachte*). This is a productive process which can be applied to novel verbs. The past forms of the *non-regular* English verbs are morphologically simple and correspond to past stems (*take – took*) - insufficient, however, to study the interplay of agreement and regularity. According to most accounts, to produce non-regular past tense verbs, English speakers just have to retrieve the particular form from the mental lexicon. On the contrary, the past tense forms of the German verbs are morphologically complex. They consist of the past stem and an inflectional suffix expressing person.

Languages tend to regularise inflection. The German verb *fragen* [to ask] for example, was inflected non-regularly in the past, cf. *er frug* [he asked.IRR], which is out of use today. Nowadays, the widely used form is *er fragte* [he asked.REG]. Non-regular inflection is not productive. New (i.e. loan) words in German and other languages as well as novel words are conjugated regularly (like *chatten* [to chat] *er chattete*, *tammen* [to tam] *er tammte*). The same observations hold for participle constructions (Clahsen, 1996; Clahsen, Hadler & Weyerts, 2004). In English, there are also doublets like *to dream* whose past tense can either be regular *dreamed*, *dreamed* or non-regular *dreamt, dreamt*.

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5 Due to the suppletive forms of the English 'to be' and 'to have' these verbs are sometimes also considered as showing "non-regular" inflection in present tense. However, the more general observation is that English verbs show no non-regular forms in present tense at all.

Finally, although German and English belong to the West Germanic language family, differences in representation and processing of verbs between English and German could result from the agreement asymmetry with regularity in English. Language-specific processing of regular and non-regular verbs has been shown by Meunier & Marslen-Wilson (2004). They have examined word-level regular - non-regular verb contrasts in French, a Romance language. In cross-modal priming experiments, effects seemed not to be a function of verb type: regular and non-regular verbs yielded the same amount of priming in French whereas English non-regular verbs showed reduced priming in the same task as opposed to regular verbs. French regular and irregular inflected forms do not show different priming patterns. The facilitatory effects of morphologically related primes are equally strong whether they involve the same or different underlying stem as their targets. Pairs like *buvons/boire* [we drink/to drink] prime just as well as pairs like *aimons/aimer* [we love/to love]. This pattern of results was confirmed with the masked priming technique ruling out the influence of semantic factors.

Though the French and English data were in contrast, French and Italian results were compatible (for experiments on Italian see Orsolini & Marslen-Wilson, 1997). Compared to English, French and Italian are Romance languages with richer inflection for different types of tense, aspect and person suffixes. Irregular past-tense forms occur in a morphologically more structured and phonologically more predictable linguistic environment than in English. In connection with these and the upcoming experimental findings it is important to point out once more that English and German belong to the same, i.e. West Germanic, language family.

1.4 Aspects of regular and non-regular nominal inflection

Although the focus of this study is on cognitive mechanisms of regular and non-regular verb processing, regularity is associated with noun processing as well. This section will give a brief introduction and comparison between regularity of nouns and verbs. The comparison of nominal and verbal inflection can shed light on the discussion of the morphological structure of verbs. Nouns have been more extensively studied than verbs. A study by Tylor, Bright, Fletcher and Stamatakis, (2004) suggests that noun and verb stems do not differ regarding their representation, but to generate morphologically complex verbs mostly those neural systems are engaged which are involved in processes of morpho-phonology and syntax.

In English and German, nouns can show regularities in their plural formation. In English, plural is mostly built by affixing –s to the stem (8a), apart from exceptions like (8b). Exceptions unpredictably employ allomorphs in the plural that have to be learnt during language acquisition.

(8) a. *chair – chairs* [reg]
b. *foot – feet* [nreg]

In contrast to English, the German plural system is highly diverse. Noun inflection in highly inflecting languages like German is organised in declensional classes like verbs in conjugational classes (Bordag & Pechmann, 2009, for Czech). German has five plural affixes, *-(e)n*, *-s*, *-e*, *-er* and *-∅* (see 9 (a-e)). Example (9f) additionally involves umlauting of the back stem vowel - a frequent and unpredictable phenomenon in German[6].

(9)	a. *Frau – Frauen* [nreg]	[woman - women]
	b. *Auto – Autos* [reg]	[car - cars]
	c. *Hund – Hunde* [nreg]	[dog - dogs]
	d. *Kind – Kinder* [nreg]	[child - children]
	e. *Daumen - Daumen* [nreg][7]	[thumb - thumbs]
	f. *Haus - Häuser* [nreg]	[house - houses]

6 In fact, some researchers (e.g. Penke, 2006) assume umlauting to be rule-driven and therefore not to be an unpredictable process. Another argument pro unpredictability is considered in example (10).

7 Non-regularity of Daumen is questionable, because Computer as a loan word exhibits the same null-inflection [*Computer-s].

g. *Erbse* - *Erbsen* [reg] [pea - peas]
(cf. Clahsen, Rothweiler, Woest & Marcus, 1992)

Plural formation with *–s* (9b) is a productive process although *–s* is a very infrequent marker. Marcus (1995), Marcus et al. (1995) and Clahsen et al. (Clahsen, Eisenbeiss & Sonnenstuhl, 1997) argue for s-plurals to be a regular default process. –s plurals meet the criterion of productivity in German and English as the plural suffix –s is generalised to new and pseudowords as well as acronyms etc., hence, probably by rule application (for a detailed review see Clahsen, 1999). All other noun plurals are assumed to be irregular and stored as fully inflected forms in the mental lexicon in this Dual Route account.

However, there is a controversy according to the default inflectional process of nouns. Penke & Krause (2002) investigated whether other classes of noun plural formation can also be regarded as regular. The most frequent plural marker is *–n* (Sonnenstuhl & Huth, 2002). *-n* is completely predictable for feminine nouns that end in schwa in the singular (9e) while *–n* is not predictable for masculine or neuter nouns. Penke and Krause (2002) presented data on German *-n* plurals that suggested that feminine noun plurals on *–n* —although clearly not the German default plural— result from a process of regular affixation. Agrammatic aphasic patients were instructed to transform a given singular noun into the respective plural form. These data provided evidence that non-feminine *–n* plurals and feminine *–n* plurals can be affected differently in agrammatism. Moreover, this dissociation is supported by a word form frequency effect for non-feminine n-plural nouns. Further evidence comes from a lexical decision (LD) experiment with unimpaired participants whose performance showed a qualitative distinction between these two types of *-n* plurals. Altogether, Penke & Krause (2002) concluded that *–n* plurals cannot be uniformly treated. They proposed that feminine nouns ending in schwa are built by regular affixation like *–s* plural and others are stored as full forms.

It is of importance for correct morphological processing how the word is inflected – either regularly or non-regularly. In

German, the crucial point that causes unpredictability and non-regularity is not only the suffix but also the umlaut which may co-occur with *-e*, *-er* and *-∅*. Compare (10a) and (b):

(10) a. *Hund – Hunde*
b. *Kuh – Kühe*

Both are e-plurals but *Kühe* employs a new stem and that class therefore bears characteristics of non-regular inflection. The examples in (10) also demonstrate that it is not clearly predictable whether the inflectional suffix or the stem itself is non-regular. This confound complicates the study of regularity of nouns.

The two systems – verb inflection and noun inflection – are not strictly comparable anyway and neither are transferable principles, because the types of inflectional processes are different. Due to theoretical and formal differences between nouns and verbs, it is widely assumed that both word classes have different demands on cognitive processing (Kauschke, 2007; Druks, 2002; Davidoff & Masterson, 1996).

Word classes can be dissociated by distinct connected properties. Kauschke (2007) discusses criteria of several linguistic areas. Basically, conceptual representations of nouns[8] denote objects and verbs denote actions. Clearly, verbs and nouns differ in their inflectional categories. For most Indo-European languages, verbal inflection includes tense, mood, aspect and congruency with the subject of a sentence. Critical for nominal inflection are, however, definiteness, number and case. But there are not only morphological criteria to mention; syntactically, verbs and nouns vary in distribution, position, function and argument structure.

These descriptive analyses have often been confronted with the cognitive dimensions. There is a consensus that verbs and nouns differ in their cortical representations (Sahin, Pinker & Halgren, 2006). Many researchers (e.g. Laiacona & Caramazza, 2004) argue for a double dissociation between the availability of nouns and verbs in aphasia. There are brain damaged patients who show a

8 Except nominalisations like *the destruction*.

selective difficulty in producing nouns in the context of a relatively spared ability to produce verbs, while other patients show the opposite pattern (Caramazza & Hillis, 1991).

In speech production, verbs are retrieved and articulated more slowly than nouns (Szekely, D`Amico, Devescovi, Federmeier, Herron, Iyer, Jacobsen & Bates, 2005). Szekely and colleagues examined factors influencing noun and verb production in a timed picture naming paradigm. Despite careful control of multiple factors like age of acquisition, length, naming agreement and complexity etc., *massive differences* [p.7] in noun and verb production persisted. Action naming was shown to take significantly longer than object naming and can then only be attributed to word class.

All in all, it is debatable whether differences stem from grammatical categories per se or from related and confounding properties. But in most studies, the theoretical and the cognitive view do not dissect. An exception is Siri et al. (2008).

1.5 Summary

This dissertation investigates the inflectional processes involved in the production of regular and non-regular German verbs, in particular the generation of past and present tense stems. In German, three types of verbs are known, namely regular, irregular and hybrid verbs. In the literature, this distinction has not yet been made because present tense conjugation has not been essential, as only past tense and mostly non-German languages were studied. In the following, like in former studies, hybrid and irregular verbs will be considered as the *non-regular* class. Hybrid verbs are supposedly irregular verbs, only their stem vowel ([ei] or [ie]) is not mutable to umlaut. The subsumption of irregular and hybrid verbs is a simplification. The renaming of the irregular class to *non-regular* should foster awareness for the simplification. However, it is necessary to take up again with the finer grained distinction in regular, hybrid and irregular verbs later on.

The next two chapters address issues concerning the cognitive mechanisms of mental lexicon and mental grammar, i.e. the dissociation of regular and non-regular verbs. Chapter 2 provides empirical evidence for the distinction and discusses models attempting to account for these findings.

2 Approaches to regular and non-regular inflection

2.1 Articulation latencies of regular and non-regular verbs

This section presents a summary of previous studies demonstrating that two types of knowledge entail two types of cognitive processes. The first study using a speeded production task on adult native speakers was presented by Prasada et al. (1990, as cited in Seidenberg, 1992 and Pinker & Prince, 1994)[9]. In the past-tense naming task, participants generated past tense forms of English verbs aloud and articulation latencies were measured. Regular verbs were produced faster than non-regular ones, indicating a dissociation of cognitive processes. All experimental items were visually presented as base forms. One point of criticism against this outcome was put forward by Pinker & Prince (1994) and targets the ratio of regulars and non-regulars, which was not balanced.

Similar results are reported by Seidenberg & Bruck (1990, as cited in Seidenberg, 1992)[10] who examined regular and non-regular verbs in a production task. Participants were randomly presented with frequency-matched regular and non-regular present tense verb stems, i.e. forms that are, in English, identical to present tense inflected forms except in the third person singular.

9 Prasada et al. (1990) is a conference paper that, unfortunately, is not available anymore.
10 The materials from the original conference presentation (Seidenberg & Bruck, 1990) proved unobtainable.

Participants first read the base form aloud and then generated the corresponding past tense form. They were considerably faster producing regular verbs than non-regular verbs. Even after subtracting the base-form reading time from the past-tense generation time, it took participants significantly longer to produce non-regular verbs.[11]

Clahsen et al. (2004) modified the design of Prasada et al. (1990) to study frequency effects on morphology in children. Of interest here are the results from the adult control group: The adults' production latencies revealed a main effect for verb type – a difference between regularly and non-regularly formed participles. As in previous studies, participles of regular verbs were produced faster than non-regular ones. Participants were asked to inflect auditory stimuli (verb stems) into participles in sentential context (e.g. *Der Gitarrist hat die Gitarre *nehm-** ***genommen***. [The guitarist has *take* taken the guitar]). As a qualification, it must be mentioned that the effect did not surface in the item analysis. Though the phonological similarity (even identity) of all item onsets (*ge-*) constitutes an advantage for accuracy of measurement, a preparation effect could have inhibited full development of the verb type difference. Still, the latency difference was only about 20 ms – less than half of what Prasada et al. (1990) and Seidenberg and Bruck (1990) had observed. The main findings of the study indicated that the mental mechanisms and representations for processing morphologically complex words are the same in children and adults. It was suggested that the production of non-regular participles may be slowed down by the retrieval of stored participle forms from the mental lexicon.

In sum, all these studies employ similar experimental techniques, and all report significantly longer reaction times for non-regular verbs. This result is unexpected assuming that non-regular verbs are stored as full forms in the mental lexicon. Lexical

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11 Seidenberg & Bruck (1990) interpret the results as support for connectionist models (see 2.4.1), although the pattern is no less compatible with Prasada et al.'s (1990) study strengthening Dual Route processing (see 2.2).

look up, or the retrieval of full forms from memory, is supposed to be faster than generating word forms by rule. In the following section 2.2, the quality of psycholinguistic models on representation and processing of verbs is measured by their consistency with these empirical findings.

2.2 Dual Route models of language production

In research on monolingual speech processing, the models that incorporate the idea of mental lexicon and mental grammar are Dual Route Models (DRM). They have formed the basis for several theories on verb production. The characteristic property of Dual Route Models is the existence of two independent routes working in parallel to attain a single outcome[12]. In the last decades, a number of Dual Route Models have been proposed for both production (e.g. the Words and Rules Theory; Pinker, 1999) and comprehension (e.g. the Augmented Addressed Model (AAM); Caramazza, Laudanna & Romani, 1988) of morphologically simple and complex words. As the present discussion will be limited to language production, the following review will focus on the well-known Words and Rules Theory by Pinker (1999).

The background of the Dual Route Models of verb production is generative grammar. Early generative phonology (Chomsky & Halle, 1968) tried to explain every linguistic expression through rule-based computation of symbols, except for totally intractable forms like suppletives (e.g. (*I*) *am*). Dual Route Models of verb production follow the traditional distinction between grammar and lexicon: They combine the rule-based single mechanism model (e.g. Halle & Mohanan, 1985) and the associative single

12 Some Dual Route models do not broach the issues of morphology but other cognitive processes like reading (see Coltheart, Curtis, Atkins & Haller, 1993). In these models, learnt, familiar words which have a lexical entry are processed via the lexical route. The lexical entry contains the phonological structure of these known words. A non-lexical route applies for reading of new or non-words. Any pronounceable letter string can be converted into sounds by using grapheme-phoneme conversion. Reading is a race between both routes.

mechanism model (e.g. McClelland & Rumelhart, 1986). Hence, the crucial assumption in Dual Route Models is that there are two routes reflecting different linguistic processes. Foremost, the authors distinguish regular and non-regular processing. Regular forms are composed of stem and suffix by a rule-governed process. Non-regular forms, however, are not derived by rule; rather, they are stored in an associative memory system as ready made lexical units.

The structural differences between regular and non-regular inflectional patterns reflect the very general characteristic of the human language faculty: the division into lexicon and grammar (Pinker, 1999; Pinker & Ullman, 2002; Clahsen, 1999). Irregular verbs have signatures of lexical memory and regular verbs have signatures of computational processes (Pinker & Ullman, 2002). Phenomena like inflecting neologisms or overgeneralisations etc. are empirical tests for the division of human language faculty and will be discussed in detail as along with their neuropsychological underpinnings in section 2.3.2. Several terms exist in the literature for the regular/non-regular[13] dichotomy: Clahsen (1999) refers to the distinction as *lexically based inflection* vs. *inflection based on combinatorial rules*. Zwitserlood and colleagues (2002) use *full listing* vs. *decomposition approaches*. Ullman (2001b) distinguishes between *declarative* and *procedural knowledge.* His work is in fact an implementation of the Dual Route Model in a broader theory of language and memory. These models are grounded in psycholinguistic data indicating two different cognitive processing mechanisms.

2.3 The Words and Rules Theory

In *Words and Rules* (WR; Pinker, 1999), Pinker describes the representation and processing of regular and non-regular

13 The terms "regular" and "irregular inflection" (Pinker, 1991) are adapted to the concept of regularity used in this work. "Irregular" denotes a subgroup of non-regular inflection.

morphology in English. He had already devised a hybrid model for this in the early 80s, asserting that two different mechanisms apply. In his description, he employs elements of associative models as well as elements of strictly rule-based accounts. For the first of the two routes, the lexical route, Pinker claims that a lexicon exists and that fixed words and forms are retrieved without any opportunity to combine them in an unprecedented way. This route is strictly limited to lexical look-up of ready-made entries. The other route operates by applying a rule that concatenates, for example, verb stems and affixes and will, henceforth, be referred to as the rule-based route. Both routes activate lexical entries, but regular stems require the combination of more than one element to form a complex word, and this combination is achieved by means of grammar. The scope of the rules is restricted to the inner construction of words (morphology) and does not account for the serial order of words within sentences[14].

According to WR, humans do not possess a discrete rule for the past tense generation. All the WR theory postulates is "a general operation for merging or unifying constituents" (Pinker & Ullman, 2002). The "operation" is so "general" that it can also apply for plural inflection of nouns where, like for past tense generation, an affix is added to a stem. Actually, pluralisation and past tense generation differ in input and output, but to concatenate constituents the same rule applies. The great advantage of the general merging operation becomes evident if the lexical route breaks down. Then, the rule-based route comes to the rescue. Humans are able to apply the rule whenever memory fails, be it due to aphasia or imperfect acquisition of the lexicon, and unimpaired adults easily generalise rule-driven processes to form novel words.

In spite of the strict distinction of the lexical and rule-based route, the WR theory allows frequently used regular words to be

14 The output of both the lexical and the morphological route is input for syntactic rules but it is beyond the scope of WR and this thesis.

stored in the lexicon, too, and to treat and access them as full forms just like non-regular words.

There can be no doubt that WR has been an influential work in the field of human language processing; yet, it only makes explicit predictions with respect to regular and non-regular past tense production. Obviously, the restriction to past tense does not allow drawing generalisations to other tenses. German, to mention just one inflectional language, possesses a much richer morphology and regularity plays a role in suffixation of number/person marking in present tense as well. Pinker's discussion does not extend to present tense. Therefore, the relation between present and past tense still remains an underinvestigated issue.

2.3.1 The blocking mechanism

So far, a model containing a lexical route and a rule-based route would predict that non-regular verbs are produced in a shorter time than regulars because look-up is faster than generating words by rules. But empirical findings paint just the opposite picture. Pinker & Prince (1994) and Pinker (1999) respond to the observation that it takes longer to produce non-regular verbs than regular verbs (Prasada et al., 1990; Seidenberg, 1992) by introducing a mechanism of *blocking*: A non-regular form (e.g. *came*) prohibits application of the rule in order to avoid ungrammatical forms (e.g. *comed*) (also Pinker, 1999:130). Blocking the regular route is costly and time-consuming. The production of irregular forms takes longer because blocking demands additional cognitive resources.

The term *blocking* was coined by Aronoff (1976), originally denoting a semantic principle that serves to avoid synonymy. If a society has a viable expression for a particular concept, there is no need to invent a new expression for the exact same concept. For example, it is perfectly fine to say *this morning*, but **this night* is not, because there exists the expression *tonight* which refers to the intended concept. In this context, blocking is conceived both as a synchronic theoretical principle and as a diachronic tendency. Likewise, availability of a viable non-regular verb form which predates a regular verb form expressing the same concept will block regularisation (e.g. *ran* blocks *runned*). Furthermore, blocking is not restricted to inflection: Aronoff discusses the term in the context of derivation as well, for cases where the same base is involved (*brevity* blocks *brevitude*). The role of frequency in blocking is crucial: the more frequent item blocks the less frequent one (Aronoff, 2000).

Psycholinguistics essentially uses a variant of the blocking principle. Analogously, the blocking principle in morphological processing dictates that a non-regular form listed in the mental lexicon blocks the application of the corresponding general rule, i.e. the generation of a new word. The non-regular form *broke* prevents adults to add the regular suffix *–ed* to *break* saying *breaked*. In the WR framework, the regular and non-regular routes are initiated by default for *all* verbs and operate in parallel (*parallel race model*). If the lexical route yields a successful result prior to the rule-based route – look-up is a faster process than composition at any rate –, retrieval of the pre-stored inflected form blocks ("pre-empts") the concatenating rule-based route. However, because of higher cognitive processing load, blocking the rule-based route is time-consuming. Therefore, the production of non-regular forms takes longer. Should the lexical route not lead to a suitable form, the rule-based route wins and applies by default.

Sahin et al. (2006) claim that they have found a neural correlate for blocking in an fMRI study. They made English native speakers inflect or read words sub-vocally. The experiment had a 2 × 2 × 3 factorial design, manipulating Grammatical Category (Noun/Verb), Regularity (Regular/Non-regular) and Task (Overt-Inflect/Zero-Inflect/Read). The participants' responses were cued by sentence fragments, like *Yesterday they* __ calling for past tense and, hence, overt inflection as opposed to zero inflection with a null morpheme. Utterances in the reading condition were elicited by *Read word:* ___.

For the purposes of the present work, comparisons subtracting regular from non-regular overt inflection of nouns and especially verbs are of primary interest. The fMRI-activation patterns of this particular comparison were not conforming to the well-known anterior (non-regular) / posterior (regular) dissociation (see next section 2.3.2). Although the experiment failed to exhibit the typical dissociation, non-regular processing increased activation markedly in the supplementary motor area (SMA) in both hemispheres. Sahin et al. (2006) report that this region is associated with conflict resolution or inhibition of habitual processes. Therefore, they attribute the region's activity to suppression of a morphological rule, which means the area is activated either for blocking processes or for competition between similar non-regular forms. The latter alternative is more likely, and it supports the assumption that this correlate for blocking is not as pronounced for nouns as it is for verbs because the number of competitors is lower.

Recordings of participants' fixations during inter-trial intervals were intended to serve as a baseline, but in their data analysis the authors opted for subtraction of conditions from each other, such that, for example, overt inflection (plural or past tense) was contrasted with zero inflection. Sahin and colleagues (2006) argue that the difference in activation between both conditions reflects the retrieval of phonological content of the suffix, plus concatenation of stem and suffix, plus phonological adjustments.

Still, once the study is more carefully examined, it becomes disputable whether the correlate really reflects blocking. Methodological objections concerning subtraction include that any analysis by subtraction faces the challenge of establishing valid minimal pairs *baseline* vs. *baseline* + *task*. It is very difficult to meet this challenge in practice, and even then, the interpretation of the results remains full of uncertainties. In Sahin et al. (2006), the authors did not subtract a condition from a baseline but two conditions from each other. Obviously, different conditions employ non-identical tasks and to date we have only vague ideas about the exact processing mechanisms behind each task. It is well possible that overt inflection and zero inflection differ in more than what we associate with suffixation (as explained above).

Therefore, it remains an open question what really is reflected by the activation pattern in Sahin et al. (2006)[15].

Separate comparisons of zero inflection and overt inflection for nouns and verbs would have been of highest importance to the current study. As Sahin et al. (2006) studied English, a comparison between zero inflection and overt inflection of verbs would have been equivalent to a present and past tense contrast. This interaction between word class and inflection is not resolved, or at least not reported, even though the authors themselves reported differences in the processing of nouns and verbs.

The reader should keep these objections in mind. Arguments against blocking will be given in section 2.3.4.

2.3.2 Psycholinguistic evidence for a regular/non-regular dissociation of verbs

A large body of research supports the lexicon vs. grammar dissociation of regular and non-regular verbs, including findings drawn from:

(a) past-tense acquisition in children (Marcus, Pinker, Ullman, Hollander, Rosen & Xu, 1992)
(b) normal adult processing (Stanners, Neiser, Hernon & Hall, 1979; Alegre & Gordon, 1999; Prasada et al., 1990)
(c) breakdown of speech production in aphasic patients (Marslen-Wilson & Tyler, 1997; Ullman, Corkin, Coppola & Hickok, 1997) and

15 During the last years, a debate arose whether neuroimaging studies contribute to the development of theories and whether they enhance our understanding of cognitive process at all. Neuroimaging studies use the blood-oxygen-level dependent (BOLD) signal as dependent variable but it is not entirely clear what an increase in the BOLD signal reflects and means (Logothetis, 2008). Coltheart (2005) and Page (2006) doubt any substantial contribution of neuroimaging techniques because the data provide no evidence to differentiate between possible models. Cognitive models cannot be tested using neuroimaging data because the functional role of parts of the brain is as yet not sufficiently understood (Page, 2006). Pure localisation of cognitive processes is not what cognitive scientists are interested in. They want to know *how* the brain works.

(d) neuroimaging and electrophysiology (Jaeger, Lockwood, Kemmerer, van Valin, Murphy & Khalak, 1996; Beretta, Campbell, Carr, Huang, Schmitt, Christianson & Cao, 2003; Newman, Ullman, Pancheva, Waligura & Neville, 2007).

2.3.2.1 Past-tense acquisition

The acquisition of non-regular words follows a U-shaped learning curve that plots the percentage of correctly produced past tense non-regular words: correct production is followed by a phase of incorrectly regularised non-regulars. After a while, children make fewer mistakes, until they eventually produce nearly all regulars and non-regulars correctly (Marcus et al., 1992).

The proportion of those over-regularisations is relatively small, but the existence of the phenomenon confirms the assumption of a symbolic rule-based mechanism: children extract the rule for past tense formation from their language input ("append *-ed*") and tend to over-apply it to other forms. This happens only when the children have not yet acquired the non-regular form that could block the application of the rule. This period of over-regularisation requires recognition and awareness of rules in the language. Therefore, incorrect realisation is not a step backwards after children have already produced correct past tense forms: initially, they had stored all forms in the lexicon. Later, with temporarily increasing error rates, they apply rules.

2.3.2.2 Normal adult processing

Priming

Many behavioural studies in the large body of literature have employed priming tasks. If a target word is preceded by a prime, reaction times to the target stimulus are demonstrably affected by the type of relation that holds between prime and target. These relations are then manipulated experimentally. Influential priming-based work related to the issue at hand has been undertaken by Stanners et al. (1979). In a lexical decision task, regularly inflected words primed (facilitated) their stem[16] to the same extent as stems primed themselves (full-priming). The priming effect on words such as *walk* was as large when it was preceded by *walked* as when it was preceded by *walk*. The prime *walked* and the target word *walk* are morphologically related. With such pairs, reaction times for lexical decision about the target are faster than for pairs where prime and target are not related. Overall, studies have shown that facilitatory priming effects for regular verbs are consistent (e.g. Stanners et al., 1979; Sonnenstuhl, Eisenbeiss & Clahsen, 1999). According to Dual Route theories, they are decomposable and are in fact decomposed during processing (*walked = walk + ed*). The prime *walked* activates the lexical entry for the stem *walk*, so the target is activated and retrieved more easily. More precisely, for regular verbs, the stem primes itself (Pinker, 1997). However, non-regular verbs primed by their past tense forms did not produce an equivalent degree of facilitation.

Inflected regular past tense forms are orthographically and phonologically more similar to their stem than non-regular past tense forms are (see, for example, *walked - walk* versus *taught - teach*) and it might be these different form properties that account for full priming of regular past tense forms. However, facilitation cannot be explained by effects of orthographic priming (Stanners et al., 1979; Rastle, Davis, Marslen-Wilson & Tyler, 2000).

In a control experiment, Stanners et al. (1979) investigated the effects of orthographic similarity of irregular past tense forms on morphological priming. In one of their experiments (Experiment 2), prime and target differed in the amount of similarity: prime and target differed either by one letter (the similar condition; e.g., *hang–hung*) or by more than one letter (the dissimilar condition; e.g., *shake–shook*). As the priming effect persisted, it can be concluded that the difference in reaction time does not stem from orthographic overlap – at least not entirely. Under the Dual Route account, regular verbs have to be assumed to have only one lexical

16 In English, the stem of verbs is identical to the infinitive.

entry. By contrast, non-regular verbs showed only reduced priming effects. They seem to be not morphologically related to their base form.

However, results are inconsistent concerning the question of priming effects for non-regular verbs; for these, researchers found either reduced/partial (Stanners et al., 1979; Clahsen, 1999) or no priming (Kempley & Morton, 1982). The inconsistencies might be due to partial regularities of non-regular verbs. In general, non-regular verbs do not exhibit full priming because they are not stored in a decomposed fashion, but have a special past tense form. Hence, the mental representations of the two verb types must be distinct.

Frequency effects

Generally speaking, reactions to more frequently used words are easier and faster performed (Whaley, 1978, in lexical decision tasks; Forster & Chambers, 1973, in naming tasks). Still, such frequency effects are only observed with processing of non-regular word forms. It is known from Clahsen (1996) that word-form frequency matters, such that non-regular processing is faster for high-frequent words than for low-frequent words. In a visual lexical decision task, the stem frequency was held constant. However, word form frequency effects were observed for non-regular German participles (e.g. *ge-sung-en* [sung]) but not for regular ones (e.g. ge-lach-t [laughed]). The frequency effect for non-regular participles has been interpreted as evidence for distinct allomorphic stems of non-regular verbs. Regular participles did not exhibit such a frequency effect in Clahsen's (1996) study and thus are assumed to be represented as single stem from which word forms are computed by rule.

Meanwhile, multiple studies support a *reverse* (or *anti-*) frequency effect for visual processing of regular words (Alegre & Gordon, 1999; Clahsen et al., 2004), where LD-responses to high-frequency regulars are slower than to low-frequent ones. Beck (1997) had previously reported this finding, but had presumed it to be an artefact resulting from the experimental design. Clahsen et al. (2004) explain the results with the Words and Rules Theory by Pinker (1999): Because of their widespread use, high-frequent regular word forms might be stored in the mental lexicon as well. For reasons of economy, they are not computed with every lexical access. Thus, the system avoids the generation of identical items. High-frequent regular verb forms share their representational status with non-regular forms in the Dual Route Mechanism. Stored forms block the application of the rule and slow down reaction times.

Similar to visual LD experiments, experiments of speeded production of inflected word forms revealed dissociating frequency effects. In a past tense naming task by Prasada et al. (1990, cited after Seidenberg, 1992, and Pinker & Prince, 1994), the frequency of the base form influenced both regular and non-regular past tense generation, while the frequency of the past tense form affected generation of non-regulars only. The frequency effect with longer latencies for low-frequent words for non-regulars (but not for regulars) has since been replicated for example by Seidenberg & Bruck (1990, as cited in Seidenberg, 1992). With respect to the representation of regular and non-regular verbs, similar conclusions are drawn from production as from reception. Reaction times favor a Dual Route representation.

2.3.2.3 Breakdown of speech production in aphasic patients

Agrammatism is a common symptom in the course of brain damage to Broca's area. Agrammatic speech is difficult to initiate and lacks fluency. While comprehension in agrammatic patients is generally preserved[17], Broca's aphasia affects production of words and sentences. Agrammatic Broca's aphasics exhibit a deviant pattern of verb production. The first thing to notice in their spontaneous speech is the absence of verbs and second, that the verbs produced lack inflection.

In a cross-modal priming task (Marslen-Wilson & Tyler, 1997), English native patients with agrammatism as a result of Broca's

17 although there are also aphasics with receptive agrammatism

aphasia were selectively impaired in their performance on English past-tense lexical decision. Some showed partial priming for non-regular verbs while priming of regular verbs was absent; one patient displayed the reverse priming pattern. The authors of the study took this as evidence for a regular/non-regular double dissociation indicating different neural structures involved in verb processing. Complementary data revealed that anterior lesions are often accompanied by impairments of regular inflection, posterior lesions by impairments of non-regular inflection (Ullman et al., 1997).[18]

In a study of patient AW, Miozzo (2003) attributed the dissociation to a more general principle. AW's deficit did not affect regular verbs (*walked*) or nouns (*gloves*), but her performance with respect to non-regular forms (*found* as well as *children*). Morphological rules seemed to be spared because AW's impairments were not restricted to one single word class, but rather affected particular types of inflection. Dual Route Mechanisms can be generalised over word classes, though properties of word classes vary in several respects. In general, processing of regular inflection may remain normal, while processing of non-regular inflection may be selectively damaged and vice versa.

Researchers have different opinions as to whether the existing neuropsychological and neuroanatomic data are convincing. In a meta-analysis of 75 individuals with Broca's aphasia by Faroqi-Shah (2007), performance of regular/non-regular verb production is characterised by heavy inter- and intra-individual differences. The meta-analysis shows that the dissociation between regular and non-regular verbs is not robust and lesion patterns are not consistent. The great variation in the data is rooted in the variety of methods, statistical analyses, concepts, operational definitions, and most importantly, handling of control subjects.[19] Furthermore,

18 past tense generation task: Patients were presented with a sentence like "Every day I dig a hole. Just like every day, yesterday I ____ a hole" and asked to complete the sentence by providing the past tense form of the verb (here: "dug").
19 Ceiling effects for control subjects present statistical problems.

two objections to the meta-analysis can be made: First, Faroqi-Shah (2007) analysed more than 100 data sets without disentangling the locus and type of impairment carefully enough. Indeed, difficulties in retrieving the stem of regular verbs is also a memory-dependent capacity like the retrieval of non-regular verbs. In this regard, it actually appears reasonable not to expect dissociations between regular and non-regular inflection. Why then should the lesion sites of regular and non-regular verbs dissociate? Second, patients' improvements over time are often disregarded. Simmons-Mackie & Damico (1997) have shown that aphasic patients often develop compensation strategies for lesioned parts of the processing system, so data from their processing performance may not be as convincing as it seems at first glance.

Single brain areas indexed by lesion studies are necessary, but at the same time not sufficient for particular operations. In any case, this section shows that regular and non-regular verbs *can* be selectively impaired. Thus, there seems to be a double dissociation between regular and non-regular past tense forms in these patients, which indicates that the processes underlying regular and non-regular inflection can be selectively impaired and therefore belong to different cognitive systems (Marslen-Wilson & Tyler, 1997).

2.3.2.4 Neuroimaging and electrophysiology

If the production of regular and non-regular verbs follows different principles, it is plausible that the relevant processes take place in different brain areas (Marslen-Wilson & Tyler, 1998). Indeed, imaging studies show different patterns of activation for processing of regular and non-regular forms. Basically, non-regular verbs activate larger brain regions than regular verbs (Jaeger et al., 1996; Beretta et al., 2003, among others); in particular, activation occurs in distinct, partially overlapping areas: while the processing of regular forms is more left-lateralised, non-regular processing exhibits a tendency towards bilateral activation.

Across studies focusing on the cortical regions for processing regular and non-regular verbs, the two major regions involved in differential activation are the temporal and frontal areas (see a review in Beretta et al., 2003). More precisely, it is the left inferior frontal cortex, Broca's area, which shows activation for processing and production of regular verbs. In contrast, abstracting over the multitude of studies, posterior areas (left tempo-parietal cortex) subserve the processing and production of non-regulars (Jaeger et al., 1996). This strongly supports the Dual Route hypothesis and is consistent with neuropsychological evidence (Ullman et al., 1997).

However, exact activation patterns do not match across studies. There are no two studies with comparable results. The numerous studies form a heterogeneous picture with respect to specific areas associated with either type of inflection. It may well be because methodologies varied from PET to fMRI and languages from morphologically rich to poor. Further, experiments presented stimuli either in a blocked or mixed design, or tested only very few participants and, finally, experiments employed various different tasks (silent naming, repetition, inflection) and data analyses (comparison of conditions or subtracting out activity from neutral condition).

Neuroanatomical correlates spread over a wide range, and therefore are inconclusive. The advantage of the imaging technique is its high spatial resolution, but due to its low temporal resolution, the method cannot tap the time course of inflection processing. In fact, reconsidering the aforementioned findings, they are suited to arouse the suspicion of a paradox: greater activation reflects and implies higher processing load. Despite regular verbs being morphologically complex and non-regular verbs morphologically simple, the evidence suggests that it is more demanding to produce or retrieve non-regular verbs, even though the processing of regulars must proceed in at least two steps, that is, one more than what is necessary for non-regulars.

Support for the frontal/temporal distinction also comes from event-related brain potential (ERP) studies recording electric potentials from the scalp (cf. Newman et al., 2007, and Ullman, 2001a, for a review of several studies). Violations of regular suffixation rules (omission or misapplication) elicited a *Left Anterior*[20] Negativity (LAN), and in some studies triggered the P600 component (Lück, Hahne & Clahsen, 2006). Roughly, both are associated with syntactic processing. In most studies, the LAN reflects an early, purely syntactic process (Friederici, 1995). The P600 component is a positive voltage deflection 600 ms after stimulus onset. The amplitude increases in response to verb agreement violations (Osterhout & Mobley, 1995) or phrase structure violations (Hahne & Friederici, 1999). For morphological violations, the same components manifest themselves as for syntactic ones. Manipulations of non-regular morphology elicited an N400 in a classical bilateral fashion, distributed *temporally* (Penke, Weyerts, Gross, Zander, Münte & Clahsen, 1997). Grossly simplified, the N400 reflects lexical-semantic integration and processing. Hence, the ERP-patterns of incorrectly inflected verbs support the distinction between mental lexicon and mental grammar of morphologically complex words.

2.3.3 Representation of regularity in the Words and Rules Theory

So far, WR states that regularity does not have a representational counterpart but emerges from the architecture of the Dual Route Mechanism. Regular forms are produced if no non-regular form has been found after an exhaustive search (Pinker & Ullman, 2002). There is no need to postulate an explicit feature representing the regularity status of words.

> *"From our brain's point of view no verb is either regular or irregular until it has been looked up in memory and discovered to have, or to lack, a special past tense form"* (Pinker, 1999:131)

20 The regions correspond to the imaging studies. There is mutual support between ERP and imaging studies.

Verb production is governed by two distinct subsystems that allow a binary choice and no deviations. This is the foundation for the generalisation that regular and non-regular verbs *"should be dissociable from virtually every point of view"* (Pinker, 1991:532). The independence of these two systems can be confirmed by the observation that they may be selectively affected by language disorders (Miozzo, 2003).

In 2002, Steven Pinker elucidates his ideas concerning the nature of morphological features. He claims that non-regular verbs are stored with a past tense feature in their lexical entry, which specifies non-regular forms as non-regular:

> *"Irregular forms are just words, acquired and stored like other words, but with a grammatical feature like 'past tense' incorporated into their lexical entries"* (Pinker & Ullman, 2002:456).

However, he is not very explicit and specific about this point. Usually, grammatical information is represented as abstract generic nodes. Schriefers (1993) and Jescheniak and Levelt (1994) addressed the same question exploring the representation of grammatical gender. The idea of generic nodes is that each item with a particular property is connected to the same node. In fact, Pinker's suggestion is restricted to irregular verbs.

Still vaguely, WR (see Pinker & Ullman, 2002) predicts that all words are connected in such a way that, in case of impairment, *all* regularly inflected words will show a deficit, i.e. nouns and present tense verbs alike. This would imply a specific superordinate feature that is stored in the mental lexicon and for which every lexical entry must be specified. One possibility to achieve this is the idea of generic nodes, such as for gender or grammatical class. All words, i.e. their corresponding lemmas, are supposed to be linked to that particular feature. In favour of a generic regularity feature, patient AW – suffering from a left temporal lesion (Miozzo, 2003) – responded less accurately to non-regular forms of both verbs (e.g. *found*) and nouns (e.g. *children*). In her case, the deficit in producing non-regular inflection clearly set apart regularly from non-regularly inflected words. Her impairment affected past tense, past participles and plural formation. All mechanisms associated with regular processing were seemingly intact, since they yielded the same (appropriate) kind of responses as controls.

Miozzo suggested AW's deficit to be one of retrieving the word phonology from the lexicon. AW did not pursue the strategy *add – ed to a verb to form its past tense* because she also guessed non-regular verb forms by changing the vowel (see also Patterson, Lambon Ralph, Hodges & McClelland, 2001). Hence, she *knew* whether a verb takes a non-regular form or not but non-regular phonological forms were inaccessible. This fact could lead one to conclude that the information about a verbs' regularity status is stored separately from its phonological form. In reference to Pinker (1991), Miozzo (2003) envisions a representation of a regularity feature and ascribes it the important function *"to block the suffixation process and to trigger the retrieval of the irregular* [non-regular, H.T.] *form from stored phonology."* (Miozzo, 2003:124). There has repeatedly been evidence that regular and non-regular inflection actually behave differently, but the mechanism behind them has not been addressed carefully. It will be tested here whether the notion of a regularity feature could help to clarify empirical findings related to the regular/non-regular distinction.

2.3.4 The Words-and-Rules-Theory's difficulties

WR has two central limitations: first, it makes explicit predictions only in relation to regular and non-regular *past* tense production. Hence, tense is a non-considered factor. Second, the model is limited, as it concentrates solely on English as the language of interest. Research on the interaction of inflection (person/number) and present tense would be illuminating in itself, and it would also help to disentangle the confound resulting from the formal overlap of person/number/tense inflectional endings in English verb inflection.

One source of evidence for WR was a pronounced frequency effect for non-regular forms as opposed to an absent frequency effect for regular verbs (Prasada et al., 1990). However, frequency effects should be observable for regular inflection as well: the stems of regularly inflected verbs also have to be retrieved from the lexicon and underlie the same psycholinguistic mechanisms for lexical access. Consequently, a valid position could be to expect frequency effects within paradigms in non-regular verbs and between paradigms of regular verbs, as they employ the same stem within a paradigm.

The following problems arise out of the limitations: first, blocking is a promising attempt by Pinker & Prince (1994) and Pinker (1999) to explain empirical data. However, according to the WR blocking is kind of waiting of a non-regular form for spell out: a quite unintuitive and uneconomic mechanism. The blocking of the rule-based route can hardly be a general cognitive principle. It is like abandoning the mental grammar and this would at the same time put the creativity of the language at risk. An example should demonstrate that blocking can be bypassed: humans are able to modify idiosyncratic expressions on the level of both morphology and syntax. For example, although (er) **geh-te* [he go-ed] even (er) **ging-te* [he went-ed] are ungrammatical, they are possible to produce and are even interpretable correctly. No rule-based route is blocked despite the existence of the non-regular form (er) *ging* [he went]. The neural correlate for blocking found by Sahin et al. (2006) is not considered striking evidence due to the methodological problems discussed above.

Secondly, the model is not precise about the representation of regularity (see section 2.3.3): It stores regular verbs and non-regular verbs in a shared lexicon. Whenever stems are retrieved from the lexicon, both routes are active and run in parallel. It is not clear from the model *how* the appropriate route is triggered, i.e. where the information comes from whether the rule-based route has to be blocked or not.

2.4 Connectionist accounts

During the 80s, some researchers dismissed symbols and rules and put forward single-route models and explanations.

Connectionist models are the most widely discussed single-route models (e.g. McClelland & Rumelhart, 1986; Plunkett & Marchman, 1993). Others are the full-listing theory by Butterworth (1983) and Bybee (1988) or the Analogy proposal by Skousen (1992). Representing other single-route accounts, connectionist models shall now be introduced in more detail. The original rule-less model is the Pattern Associator, a Parallel Distributed Processing model by Rumelhart & McClelland (1986)[21].

Connectionism denotes a school of thought within cognitive science, in the field of artificial intelligence. It focuses on the development of cognitive skills such as language acquisition. Researchers study the self-organising learning process the final state of which is the object of empirical investigation. Connectionist networks constrain learning algorithms and simulate humanlike neural processes with the help of computers.

Advocates of connectionism assert that behind knowledge and cognitive skills (such as language) stand associative networks rather than symbols, rules and combinatorial operations. They follow the basic principle of describing mental processes through interconnected networks of simple units. Multiple sources of knowledge and interacting mechanisms are assumed. Networks can structurally resemble neurons and synapses, or words with their manifold relations. The system provides an environment and resources from which (grammatical and lexical) knowledge can emerge.

Single-route models have in common that they treat both regular and non-regular verbs in the same way. Words are stored associatively in one single memory system, none are decomposed. Even regular past tense verbs are represented as full forms, without using explicit (i.e. symbolic) rules.[22] Regular stems are

21 Single-route models must not be put on a level and associated with connectionism. Nothing speaks against a connectionist model that explicitly consists of two routes or that develops two routes automatically during training and learning.

22 However, connectionist models can indeed employ explicit rules. Rodriguez et al. (1999) demonstrate a neural net which has learnt how to count. Its acquired knowledge can be described and represented by rules. However, it is often not

mapped directly onto their past tense form through generalisation procedures. Generalisations of mapping are mainly driven by the frequency of co-occurrences and similarity between items. Connectionist models challenged the classical theory of mind, according to which cognition relies on symbol manipulation by formal rule application. Critical remarks followed by Levelt (1991). He compared the two approaches to the theory of mind at hand: the symbolic and connectionist one. Connectionist models are finite state machines with a predefined finite number of states (see Levelt, 1991). On the downside, current connectionist models cannot handle the symbolic aspects of language. They do not represent adequately how a finite number of elements of a particular language can be used infinitely. Therefore, the connectionist account has its limits e.g. in recursion. This makes connectionist models intolerant towards expansion of knowledge and can only represent a well defined section of human cognition.

2.4.1 The Pattern Associator

The most popular associative single-route model is the *Pattern Associator* conceived by Rumelhart & McClelland (1986) for English past tense inflection. A pattern associator learns associations between input patterns and output patterns, e.g. in case of the *Pattern Associator* between past tense forms and infinitives. Most appealing, it can generate what it learns about one pattern to similar input patterns.

The network consists of nodes and connections. Nodes process incoming activation and, depending on their own activation, nodes influence connected nodes. They do not pass symbolic information but deliver numeric activation values which are a result of computations.

A neural network consists of many simple processing units each of which is connected to many other units. Basically, the Pattern Associator is a two-layer network: it consists of input

easy to reveal the rules because they are intertwined with weights and activation values in the network.

nodes and output nodes. Each node in a layer is connected to all of the other nodes in its layer, and all of the nodes in each adjacent layer, e.g. past tense forms are connected to infinitives. Each unit has a numerical activation level (analogous to the firing rate of real neurons). Input units in a network receive information, while output units send information. The activation of an output unit is determined by the product of the input activation and the specific weight associated with that connection. The connections are uniform and not labelled. However, connections differ in their strengths. The relations between nodes emerge through statistical computations: Training, i.e. increasing input, means adjusting and modifying connection weights and finally learning. With every usage, connections become stronger, while unused ones remain weak. The strength of connections arises and increases also by similarities (e.g. semantic, orthographic or phonological) to neighbouring nodes. The Pattern Associator can be trained to respond with a certain output to a presented input. Adjusting connection weights changes input/output behaviour.

The Pattern Associator strives after a direct mapping from the phonetic representation of the stem to the phonetic representation of the past tense form. It works as follows: first, an input-encoding network takes a phonological representation of a stem and converts it into *Wickelfeature* format. To model the linear order of phonemes within verb stems, for example, Rumelhart & McClelland (1986) introduced so called *Wickelphones*, which are trigrams of phonemes. The verb *walk* is for example represented by the four *Wickelphones* #wa, wal, alk, lk#. This way, the order of phonemes in a word is coded unambiguously. The Wickelphones themselves consist of Wickelfeatures which combine the distinctive phonetic features of the Wickelphones reducing the number of nodes. Then, verb stems are paired with the Wickelfeature representation of past tense in the Perceptron Pattern Associator. An output-decoding network decodes the structure back into phonological representations. By the Wickelfeature format, the model uses *distributed representations*. Words are represented by several nodes and each node is involved in the representation of several words.

The phonological relationship between present and past tense of non-regular forms is arbitrary. Although rhyming schemes of phonologically related non-regular verbs do exist by similarity (e.g. *sink - sank, drink - drank*), these relationships between past and present tense stem are not reliably predictive. There are many exceptions and counterexamples (e.g. *think - thought, link - linked*, not *thank* or *lank*). However, the existence of these conjugation classes is in perfect accordance with connectionist views of the Pattern Associator.[23] Even for processing non-words, the Pattern Associator has learnt what the most suitable form would be. It works with abstract strings rather than words.[24]

One of the goals of Rumelhart & McClelland (1986) was to model the acquisition of the English past tense. The Pattern Associator indeed captures lots of the intricacies of this process without rules but only by retrieval of full-listed forms. The output converges well with acquisition data of children. Errors made by the model do not only resemble errors made by children, they even follow the U-shaped learning curve of non-regular verbs.

The outcome of the experiments introduced in 2.1 above was that regular verbs are responded to faster than non-regular verbs. The explanation provided within the connectionist framework for the naming latency difference between regular and non-regular verb production does not only depend on properties of the words itself, e.g. its frequency, but also on its neighbourhood, i.e. the similarity between patterns of spelling of connected words. Greater phonological similarity of a novel or a real verb stem to other real non-regular verb stems increases likelihood and acceptability of non-regular past tense forms. In contrast, phonological similarity to regular verbs does not have any effect (Bybee & Moder, 1983). Furthermore, regular and non-regular verbs' neighbourhood differ in their consistency, i.e. non-regular verbs are surrounded by more exceptions ("enemies" in

23 Not all connectionist accounts are based on phonological information. Instead, the relationship between present and past tense non-regulars tends to rely more heavily on semantic information (e.g. Joanisse & Seidenberg, 1999).

24 Therefore, it is not sensitive to word frequency.

Seidenberg, 1992) than regular verbs are and therefore yield longer reaction times. Why does the Pattern Associator perform like it does? Weights of connections between nodes encode facts about frequency and consistency of correspondences. The more frequent a verb is, the stronger the weights become. The more similarities two words have, the stronger their connection. Connections in the network are weighted and are a product of learning algorithms. As regular verbs have many friends (moderately deviating neighbours) and less enemies (strongly deviating neighbours) connections between regular verbs are stronger and therefore the nodes have more activation. These words can be spelled out very easily. Non-regular words have only few friends and many enemies. The neighbourhood of non-regular verbs is diverse and inconsistent. Thus, because of less pre-activation, non-regular verbs yield lower reaction times (cf. Seidenberg, 1992).

However, none of the current connectionist models is entirely psychologically realistic (cf. Ling & Marinov, 1993, for a critical review). In the Pattern Associator, homophones cannot be processed accurately because the model relies on phonology. How does the system know which form to select or produce? Let us consider the English example *to lie.* Its past tense can be either regular (*lied, lied*) meaning “make false statements” or non-regular (*lay, lain*) to express “place oneself in a flat position”. MacWhinney & Leinbach (1991) made an attempt to distinguish past tense forms of homophones like *ring* and *wring*. The model used a new architecture and learning algorithm as well as a larger input corpus, a fuller paradigm, and a new phonological representation. Learning the past tense was more realistic. MacWhinney and Leinbach (1991) solved the homophony problem by including semantic features that allowed the system to differentiate between homophones.

2.4.2 Strengths and weaknesses of connectionist models

Connectionist accounts have often been criticised, and were continuously optimised in reaction to criticisms (cf. Pinker & Prince (1988) and Marcus et al. (1992), evaluating McClelland & Rumelhart, 1986). Their strong point is trying to explain how the brain processes information. Neural networks represent the brain and cognitive processing reliably and incorporate the flexibility demanded by the complexity of the real world. Learning algorithms are robust, i.e. they can tolerate minimal deviations from materials on which they were trained. Connectionists argue that neural networks can handle phenomena naturally and they provide ample simulations for cognitive tasks like object recognition, action planning, and coordinated motion. Neural networks are a good basis for operations that require parallel processing. They retrieve information quickly and process it effectively.[25]

Irrespective of the achievements of current connectionist models, connectionists are continuously faced with substantial problems. As the neural networks function on the basis of resemblance and similarity, it is difficult for them to abstract from learnt criteria the model is based on. Thus, concepts are handled with only limited flexibility: according to a neural net, a tiger could be defined as a black-and-orange feline. Albino tigers, however, would not be recognised as tigers under such a definition, as they do not meet the criteria for "tiger". Furthermore, the models simplify biological diversity like physiological differences between different types of neurons, or between neurochemical processes. The models are not suitable for yet higher cognitive processes like emotions and reasoning thus far (cf. Levelt, 1991).

25 However, parallelism could be captured by symbols-and-rules models as well.

2.5 Summary

From the above review of empirical data and models of past tense generation, it becomes evident that the past tense debate has reached stalemate. Dual Route Models are built on the assumption that regular and non-regular verbs behave differently. Indeed, the studies reviewed imply that two qualitatively different systems are involved in verb processing. Likewise, connectionists do not claim that verbs must necessarily behave alike just because they are stored in a single network. Münte and colleagues (Münte, Rodriguez-Fornells & Kutas, 1999) pointed out that also the neuroscientific fMRI and ERP data support neither a single nor a Dual Route Model. They believe the issue to be more complex than "one or two computations". Both classes of models leave an incomplete picture.

The emphasis in this work is not on contributing to that controversy by finding empirical evidence for or against either single or Dual Route Models. Instead, the important conclusion to be drawn from criticisms against the blocking mechanism is that German provides a test case for the blocking mechanism if one is to consider not only past tense, but also present tense. In German present tense, (er) *beiß-t* [he bite-s] versus (er) *lach-t* [he laugh-s] are both built regularly. However, *beißen* [to bite] is non-regular in the past tense and *lachen* [to laugh] is regular in the past tense. WR claims that individual forms are regular or non-regular and therefore would not predict the classic regular-non-regular distinction in present tense where both forms can be inflected regularly.

This thesis deals with these problems of WR and tries to intervene through looking at German and the present tense. Previous studies did not consider whether regularity is represented as a property of individual forms (implicit assumption of DRM) or of whole inflectional paradigms. The following experiments investigated hybrid verbs to test these two hypotheses. The representation of regularity is explored in Experiments 1-4 and the blocking mechanism is tested in Experiment 5. This raises a more complete picture of German verbal inflection and sheds light on the mental lexicon and grammar more broadly.

3 Psycholinguistic models of language production

This chapter covers aspects of speech production that are relevant to the discussion of the empirical data in subsequent chapters. The theoretical background will be set by reviewing the **Levelt Model** of speech production. It refines several former models (e.g. Garrett, 1975; Shattuck-Hufnagel, 1979) and provides, amongst others, explanations for the preparation and production of morphologically complex words. By being very explicit, it can account for plenty of the phenomena reported in the literature – so the hypotheses of the present dissertation are established within this framework. Furthermore, the **Interactive Activation (IA) Model** by Dell and the **Independent Network (IN) Model** by Caramazza will be introduced and compared, focussing on the representation of verb features and morphological processes. The emphasis in discussing these models is placed on their coverage of morphological complex words in the mental lexicon.

3.1 Lexical access and lexical selection

The language production process consists of composing a preverbal message, coding it verbally, and articulating it. Thus, Levelt (1989) suggests dividing speech production into three levels: *conceptualisation*, *formulation,* and *articulation*. In the literature, there is a broad consensus on the division into these three general processing steps (cf. Levelt, 1989; Levelt, Roelofs & Meyer, 1999; Dell, 1986; Caramazza, 1997). The process progresses from concepts to perceivable code via word forms. The verbal output can then be decoded again by a listener. Among other issues, psycholinguistics is primarily concerned with the level of formulation, i.e., of transforming conceptual into linguistic structures.

The core process of language production is the *lexical access*. This denotes the retrieval of lemmas and the corresponding word forms from the mental lexicon that express the activated concept (cf. Levelt, Schriefers, Vorberg, Meyer, Pechmann & Having, 1991). The division of lexical entries into lemma and word form is an essential property of lexical access according to Levelt's model (but see Caramazza (1997) refuting such a bifurcation). The division into these two stages has already been motivated in Kempen & Huijbers (1983). Lemmas are linked to and activated by concepts. A *lemma* (e.g. 'sing-') is semantically specified and makes syntactic information available (Levelt et al., 1999). Roughly, it has a particular meaning and belongs to a syntactic category, depending on which it is associated with further syntactic information (e.g. gender for nouns, subcategorisation for verbs); still, they are abstract entities because they do not contain morphophonological information, which is stored on the word form level. Crucially, a lemma can be realised in different *word forms* which are instantiations systematically varying according to their syntactic context. Lemmas "point" to word forms (Levelt et al., 1999:187). Word forms are either auditory or written realisations of lemmas. Some lemmas have alternating word forms. This will play a crucial role in the course of this thesis. While lemmas provide syntactic information, word forms carry morphophonological properties (but see Caramazza, 1997). Nothing is said about the representation of regularity of verbs.

In the 1990s, the idea of split lexical entries led to a debate about whether lexical access proceeds in discrete or overlapping stages, respectively. A lemma may either be selected *prior* to morphophonological encoding (e.g. Levelt et al., 1999), i.e. morphophonological information is activated only after the selection of the correct lemma, or lexical selection and morphophonological encoding proceed in parallel. This debate affected the architecture of the models discussed below.

Based on speech error data, Garrett (1975) proposed one of the pioneering models – besides Fromkin (1973). He already suggested two discrete stages of processing. Analyses of speech error data revealed regularities and dissociations between word and sound substitution errors. Corresponding to the distinction between meaning (lemma) and form, word exchanges occur between phrases and within the same word class, whereas sound exchanges occur within a phrase and involve adjacent words in the same phrase, i.e., sound exchanges often involve words belonging to different word classes. Garrett attributed these findings to two discrete serial stages which are not overlapping but incremental (although multiple words for one phrase may be processed in parallel on different levels). In competing models, different types of information can be accessed simultaneously (e.g. Dell, 1986). The selection of a lemma and its word form is interactive. Hence, processing on both levels is overlapping. Caramazza (1997) maintains that there is no separate lemma level, and disputes successive retrieval of lemma and word form. He argues for a simultaneous but also independent activation of semantic, syntactic and phonological information (see 3.4 for a discussion of the IN).

Selection of the lemma is preceded by a parallel check for the fit between lemmas and the intended concept. There is consensus about the initial activation of semantic alternatives on the lemma level. With a combined picture naming and auditory lexical decision task, Levelt et al. (1991) substantiate the view assuming activation of multiple lemmas, i.e. co-activation of lemmas belonging to the same semantic field. Semantically neighbouring words elicit robust priming effects as opposed to unrelated words. Eventually, the target item receives most activation, and its lemma is selected. This process is often labelled *lexical selection*.

However, there is a controversy regarding the number of lemmas that become input for phonological encoding. Levelt (1989) and Levelt and colleagues (1991) emphasise in an early version of the model that lexical selection must *converge* on a single lemma after *parallel processing*. Critical targets in the experiment just mentioned (Levelt et al., 1991) were those items phonologically related to semantic alternatives (like e.g. *sheep* – (goat) - *goal*). Compared to unrelated ones, they revealed no effect, in accordance with the assumption of convergence on a single lemma. This would support that only the selected lemma is processed phonologically.

Yet, parallel activation of lemmas *and word forms* can easily be witnessed in speech errors called *blends*. A blend is a merge of two semantically related word forms like *stummy* for *stomach* and *tummy* (from Fromkin, 1973). Roelofs (1992) noticed that most blends involve near-synonyms. If lemmas of two near-synonyms are equally active, both word forms would indeed be activated as well.

While Levelt et al. (1991) could not demonstrate mediated priming, Peterson & Savoy (1998) found phonological activation of semantic alternatives (*sheep* primes *goal* via *goat*). These findings were restricted to near-synonyms. In more recent proposals (e.g. Levelt et al., 1999), the authors take that special case of mediated priming as support for a *cascading* model. Phonological properties of a semantically processed but unselected item influence lexical access. The assumption that only the selected lemma becomes phonologically encoded remains held up. Near synonyms turn out to be an exception, i.e. out of several activated lemmas, some become phonologically prepared. The word form encoded first will attain articulation. As the IA Model (Dell, 1986) is based on compelling speech error data such as blends, it can naturally be concluded that even slightly activated lemmas initiate phonological encoding.

Two-stage processing, as advocated by Levelt (Levelt, 1989; Levelt et al., 1999), is implemented by the WEAVER++ model, a comprehensive model of word form encoding (Roelofs, 1997). The model can successfully produce words and even blends when erroneously retrieving two lemmas.

All three language production models – the Levelt model, the IA Model and the IN Model – conceive the *mental lexicon* as a network that contains nodes on several levels. Nodes are connected to each other both on their own level as well as across levels. Selection of a target node depends on its activation, which varies gradually. The most activated lemma is selected. Selection is more difficult in the presence of highly activated competing nodes.

Activation processes are characterised by *spreading activation*, another key concept in language production theories introduced by Dell (1986). Every node with an activation higher than zero immediately passes on (a portion of) activation to all connected nodes (*spreading*). The activation of nodes increases with new activation (*summation*) and *decay*s over time if it does not receive new activation. The activation of a selected node drops to zero immediately after selection to avoid repeated selection of the same node.

The time required to retrieve lexical items is a function of the frequency of the item and of morphological processes on higher levels. Frequently used words are produced faster than less frequently used words (Oldfield & Wingfield, 1965), as their activation threshold is lower. In addition, Jescheniak & Levelt (1994) specify that the frequency effect occurs on the word form level. Jescheniak and Levelt had participants name pictures and found that the frequency effects observed in picture naming disappeared in a delayed cued-naming paradigm. Because the picture naming paradigm – with a sufficient delay – only measures post-lexical processes, they concluded that frequency effects have their origin at the word form level. Otherwise, the effects would not have vanished.

The ease of lexical access also depends on semantic factors. For a long time, lexical access in the mental lexicon was seen as a process of lexical competition because of the Stroop-like interference effects (cf. Schriefers, Meyer & Levelt, 1990; Levelt et al., 1999): Naming of pictures is slower in the presence of semantically related distractors (e.g. *sheep - goat*) compared to unrelated words (e.g. *sheep - tree*). The idea of the *lexical selection by competition* hypothesis is that activation percolates to semantically related competitors, as the mental lexicon is conceived as a network of nodes. Selection of the target is more difficult in the presence of highly activated competing non-target nodes. Any semantically related distractor receives activation both from the picture and from the distractor word. In contrast, unrelated words are not affected by activation of the target, and therefore the target itself is selected more easily.

Recently, a new perspective on semantic interference has arisen: some studies showed semantic *facilitation* for semantically related words.[26] In carefully designed picture-word interference experiments, Mahon and colleagues (Mahon, Costa, Peterson, Vargas & Caramazza, 2007) manipulated semantic distance between target and distractor according to a standard graded measure of semantic distance. The closer within-category target-distractor pairs, the faster the target was produced. For example, the picture of a *horse* has been named reliably faster with *zebra* than with *whale* (Mahon et al., 2007). Consequently, the facilitation effect cannot be lexical, and is not in accordance with the *lexical selection by competition* hypothesis (for a review, see Mahon et al., 2007). The data demand a reinterpretation of semantic interference in lexical selection. The authors propose an explanation in terms of increasing priming as the semantic distance decreases.

The second crucial finding by Mahon and colleagues on the way to an alternative hypothesis was that articulation latencies depended on criteria of the distractor relevant to the response, i.e. semantic as well as syntactic information about the target was helpful to exclude non-target words from the response set. Therefore, verbs did not interfere semantically with nouns, as they were no potential targets.[27] Participants were faster naming *bed*

26 The first discovery leading to a rethink was that low-frequent distractors are not facilitating, unlike high-frequent ones (Miozzo & Caramazza, 2003). According to the lexical selection by competition hypothesis, one would expect this because the activation threshold of low-frequent items is assumed to be higher, and they thus should not interfere with the target as much as high-frequent (almost pre-activated) distractors do.

27 In 2006, Finkbeiner and Caramazza attributed semantic facilitation effects to response selection. In a picture-word-distractor experiment participants were presented with semantically related/unrelated distractors that were either forward- or backward-masked. Although unmasked distractors yielded semantic interference, they showed reliable semantic facilitation under masked conditions, i.e. facilitation due to semantic overlap of target and distractor, such as for the pair car – truck as opposed to car – table. Masking prevents phonological activation, as no competing responses need to be blocked. Together with semantic priming, it results in facilitatory effects.

with the distractor *sleep* than with *shoot*. Ultimately, Finkbeiner and Caramazza (2006) and Mahon et al. (2007) propose the *response exclusion hypothesis*, stating that unrelated distractors can be suppressed sooner than items sharing the relevant properties.

In the field of lexical access, Finkbeiner and Caramazza (2006) and Mahon et al. (2007) provide a new interesting empirical fact. The new explanation licences the tentative conclusion that semantic interference is not a lexical but rather a post–lexical process.

3.2 The Levelt Model (Levelt, 1999)

3.2.1 Architecture

Levelt et al. (1999) designed a model of the production of single-word utterances. The production process of a single word is assumed to consist of five levels (strata): (1) the lexical concept, (2) the lemma, (3) the morpheme, (4) the phonological word and (5) the phonetic-gestural code. (2) and (3) are referred to as *grammatical encoding*. Activation spreads from concepts to articulation (unidirectionally), and there are no inhibitory connections (see Figure 3). The following descriptive overview of the model focuses on the stages and their output.

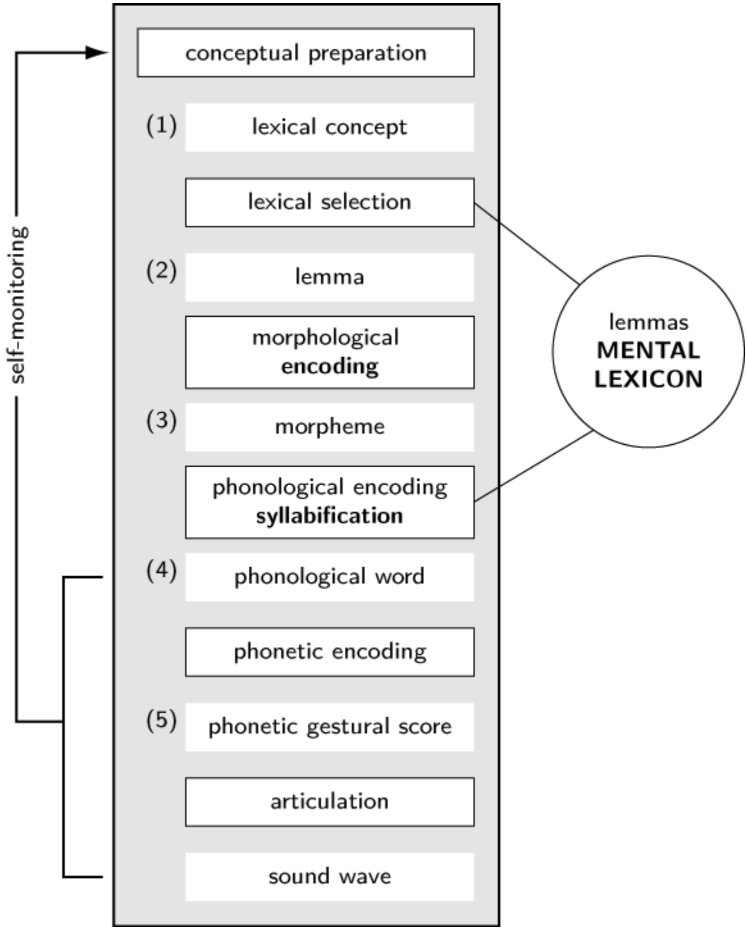

Figure 3. Levelt et al.'s (1999) Language Production Model.

In a first step, the content of the intended utterance is created. The idea of the intended speech act is pre-linguistically, conceptually prepared by activating sensory specific mental representations. By specifying semantics, lexical concepts (1) mediate between the communicative goal and language-specific words. Lexical concepts are "concepts flagged by way of a verbal label." (Levelt et al., 1999:1). They constitute the output of the first stage. Because of the organisation of mental representations in a network-like structure, lexical concepts of semantic associates become active simultaneously. With CAT as target, ANIMAL and MOUSE will be concurrently activated (see discussion above).

Levelt et al. (1999:4) argued that lexical concepts must be represented holistically instead of being decomposed into features. This organisation is necessary to avoid the *hyperonym problem* (Levelt, 1989), i.e. automatic co-activation of a superordinate concept (e.g. *animal*) by the features of the concept (e.g. *dog*) itself. If this was disregarded, the selection of a target would be beyond the intention of the speaker, which is obviously not the case.

From given lexical concepts, activation spreads to the lemma level (2), where *formulation* of the message begins. The activation spreads not only to the target lemma but also to the cohort of semantically related lemmas. On the lemma level, grammatical information is supposed to be stored in separate generic nodes linked to the lemma, like for word category (Pechmann & Zerbst, 2002) and, with respect to verbs, subcategorisation information (Branigan, Pickering, Liversedge, Stewart & Urbach, 1995) or auxiliary type (Tabossi, Collina & Sanz, 2002). *Generic* means that every entity with that particular attribute is linked to the corresponding abstract feature representation.

The level of formulation is divided into two stages. The first is grammatical encoding, comprising the retrieval of lemmas (2) and the generation of a syntactic structure (Kempen & Hoenkamp, 1987). Lemmas are fully specified grammatically, but not yet inflected. To retrieve grammatical properties, lemmas *point* to their grammatical features. For morphologically complex words, all properties are activated on the lemma level, but still as abstract features (3). Having completed the retrieval of conceptual-semantic and syntactic information, the speaker has to bring all morphemes into the correct order and find the appropriate phonological word form (4) fitting the lemma (see the two-stage model discussion in section 3.1). Only selected lemmas activate their phonological forms (Levelt et al., 1999:15). As with grammatical features, lemmas also have pointers to word forms.

This second stage for retrieving the lemma's word form is called *phonological encoding*. Lemmas become phonologically specified, implying the creation of a phonetic plan. For this purpose, the ordered set of pointers brings phonemes into the correct serial order, and phrases (utterances longer than one single word) are structured and specified prosodically and metrically as well. Thus, any successful outcome of the phonological encoding requires (a) morphological, (b) phonological and (c) segmental processing (cf. Levelt, 1999:5). Finally, the production process is completed with the articulation (5) of the intended utterance. A self-monitoring mechanism applies from phonological words onwards and ensures error-free production. It observes internal speech during the generation of words and utterances, and adjusts and corrects the internal representations before articulation.

Chapters 6-8 make use of the theoretical framework provided by the revised Levelt Model. The model makes assumptions about the representation and instantiation of tense, which serves as an example for illustrating the processes involved in producing inflectional categories here. Tense (event time) is in fact a conceptual category (Levelt et al., 1999), but it has grammatical reflexes in inflectional languages like German. It cannot be realised by changing a single conceptual feature (e.g. ± past). Rather, tense is expressed by complex words. Its instantiation in inflectional languages has implications for the processes on the formulation level, i.e. diacritic parameters need to be set to trigger the appropriate morphological processes.

3.2.2 Diacritic parameters

Essential entities underlying production of complex words are *diacritics*. Diacritics are connected to lemma nodes and can be conceptualized as slots for specification of free parameters, such as person, number, mood, or tense, which receive a value during the process of grammatical encoding (Levelt et al., 1999:6). Setting diacritics at the lemma level is necessary for the encoding of appropriately inflected word forms.

As Levelt et al. (1999) is primarily a theory about very simple word naming, there is only some hand waving about tense and its information flow from conceptualization to setting the diacritics. However, Janssen (1999:46) assumes a distinction between concept nodes and concept classification nodes at the conceptual level, where the message is created. Lexical concept nodes point and refer to objects or actions. Conceptual processing of inflectional categories like tense or number is separated from the lexical content and represented by concept classification nodes. Concept classification nodes carry variable information that cannot be stored fixed to lexical concepts. For instance, *TABLE* can be modified by PLURAL to *TABLES*. Hence, *concept classification nodes* modify and extend the meaning of *lexical concept nodes,* and are not interpretable in isolation.

The division into *concept nodes* and *concept classification nodes* ensures independence of lexical processing from inflectional processing. Inflectional morphemes are indeed separable from lexical content, as is known from speech errors like morpheme stranding, extensively studied by Garrett (1982).

The information on the conceptual level is transferred to the formulation level through spreading activation. The lemmas then contain the current value of the inflectional categories in the form of diacritics, i.e. the diacritics temporarily store a word's variable information like e.g. *present* or *plural*. The values depend on the context and concept of the utterance and have their origin at the conceptual level. Further processing of inflectional morphemes is set and determined by diacritics. Later in processing, diacritics are represented by inflectional affixes.

The diacritic feature of tense involves conceptualization of temporal reference, such as *+past* or *+present*. It is noteworthy that tense diacritic parameters are essentially identical for morphologically regular and non-regular verbs. Other diacritic parameters, such as verb number for subject–verb agreement (Bock, 2004) need not be specified during formulation. They are assumed to operate only during syntactic encoding. Diacritics differ from syntactic properties in the latter's permanent link to the lemma via generic nodes. Diacritics carry information that is copied prior to the lemma retrieval from the *concept classification nodes* to the diacritics of the currently activated lemma.

Faroqi-Shah & Thompson (2007) provide evidence for diacritic encoding from neuropsychological data. Agrammatic patients exhibited verb inflection difficulties. Their encoding of verb inflection was examined with a multiple-choice sentence completion task. Faroqi-Shah & Thompson (2007) report that errors in the production of verbs were likely to occur when temporal reference was involved. Agrammatic aphasic patients may have had difficulties with diacritic encoding and retrieval of tense features rather than with inflection per se, i.e., their errors were not the direct result of morphological complexity but of impaired setting of diacritics. A temporal context was provided for all trials. However, it cannot be excluded that the deficit in tensed verbs is due to a failure in conceptualisation of tense.

The Levelt Model's three most important characteristics are (1) seriality, (2) modularity and (3) feed-forward activation. The levels function autonomously in a hierarchical order and pass down their output to the lower levels (see Figure 3), but not until all processing is completed. There is no feedback between the levels as in former models (e.g. Fromkin, 1973; Garrett, 1975; Shattuck-Hufnagel, 1979). Modularity calls for an additional assumption: incrementality. Longer utterances are not prepared as a whole but are split up into shorter units so that some parts can be processed on a higher level while subsequent parts are already simultaneously processed on lower levels. Yet, internally, each processing step is still serial. This ensures fluency, especially for longer utterances.

3.3 The Interactive Activation Model

The Interactive Activation Model is a theory of sentence production, as explicitly stated in the introduction to Dell (1986). The fundamental difference between the Levelt Model and the Interactive Activation (IA) Model is the activation flow. While the Levelt Model is organised into strictly serial modules, the IA

Model is highly interactive, i.e., activation spreads not only unidirectionally *top-down* but also *bottom-up*. This is a prerequisite for feedback processes, although the feedback is restricted to adjacent levels (*local*). Another basic assumption of the IA Model by Dell (1986) is that connections are excitatory rather than inhibitory.

Most of Dell's processing hypotheses stem from speech error analyses. He observed that speech errors result in real words of the language more frequently than random chance would predict (*lexical bias effect,* Dell & Reich, 1981). Dell interprets this finding as a consequence of feedback from activated word forms to the lemmas via *backward spreading*. This entails that lemma selection and phonological encoding are interrelated through bidirectional connections. Crucially, semantic alternatives of a target become phonologically activated as well. If errors in phonological encoding activate existing word forms (like *rude lip* / *lewd rip*), erroneously activated word forms induce activation in their corresponding lemmas, which in turn add to the activation of the word form again. Consequently, such non-target word forms reach the activation threshold quickly enough to be selected. It has also been shown in experiments[28] that errors occur less often if the resulting form is not a real word (like *luke risk* / *ruke lisk*).

Dell's (Dell & Reich, 1981) second observation is the relatively frequent occurrence of *mixed errors,* that is, the production of linguistic items which are both semantically and phonologically misguided, e.g. producing *rat* instead of *cat,* which is semantically and phonologically related. For reasons of logical consistency, these can only arise from simultaneous activation of semantic and phonological information in parallel. With this in mind, it appears implausible to opt for a model consisting of two discrete stages. Hence, Dell & Reich (1981) take this finding as evidence for

28 Speech error induction techniques include, for example, exposing participants to an auditory distractor word immediately before the utterance of a target word, or increasing the speech rate. Elicited slips of the tongue can be caused by phoneme exchanges resulting in anticipations, and perseverations.

upward feedback processes from phonological encoding to the lemma level.

Last but not least, and in a similar line of thought, interactivity is the explanation for the *word superiority effect* (Dell & Reich, 1981). Readers recognise letters in the context of a word better than when the same letters are presented in pseudowords or in isolation (Reicher, 1969). The word superiority effect shows that speech processing does not only involve bottom-up but also top-down processes.

Dell emphasises that errors are not faults of the cognitive system, but must be expected and accommodated by the theory's assumptions. The architecture of the IA Model can successfully simulate production processes, but it can equally model performance leading to speech errors. Inappropriate items are selected simply because of their higher activation. Therefore, errors are a product of random noise, the emergence of which is integral to the model and presumably also to the brain.

Having outlined the general principles of the Interactive Activation Model, it is necessary to say a few words about its architecture, as it will prove relevant to the subsequent more detailed discussion of individual processing steps, especially morphological encoding. The lexicon is organised as a structured network. It consists of nodes on the conceptual, lexical (i.e. lemma) and phonological levels. Concepts are represented feature by feature in a decomposed form with all concept nodes interconnected.

If a node on the conceptual level is activated, it activates all connected lexical nodes on the lemma level. *Every* activated lexical node spreads activation to the phonological level (in contrast to Levelt, 1989; Levelt et al., 1999, where phonological activation is strictly limited to the selected lemma). The lemma with the highest activation will finally be phonologically represented and articulated. But in the IA Model, activation spreads back to upper levels, reflecting its interactive character.

The levels mentioned above contain declarative knowledge about:

(1) concepts
(2) words/morphemes
(3) syllables
(4) phonemes
(5) phonetic features

Word nodes are marked for syntactic and morphological category.

Representations are constructed by generative rules stored on each level, i.e. by combinatorial knowledge for *syntactic, morphological and phonological encoding*. The interplay between lexicon and rules follows the slots-and-fillers-principle: rules specify the item for the appropriate slot and thus compose the constituent lemmas, morphemes and phonemes into a coherent sequence.

The combination of rules and lexicon creates an opportunity for modelling the production of regular and non-regular verbs, in that morphological frames may include slots for verb stems and affixes.

To sum up, the main difference between the Interactive Activation Model and the Levelt Model is the feedback, and thereby the spreading of information and activation from lower-level to higher-level processes. As Dell's model is not a serial model, it is possible that the phonological form influences the selection of the lemma. Phonological encoding begins before the final selection of the lemma. Hence, it allows for a short period of time in which both lemma and word form are activated. Furthermore, all activated lemmas (semantic competitors) become phonologically encoded.

3.4 The Independent Network Model

The models introduced in the preceding sections have in common that they represent lexical information in the form of networks, and that processes are described as spreading activation between nodes. These characteristics are no less essential for the third model – the Independent Network Model. Nevertheless, it presents a challenging alternative to the two-stage theory with respect to activation of syntactic features. Strikingly, Caramazza & Miozzo (1997) and Miozzo & Caramazza (1997) have found that Italian speakers can retrieve partial phonological information about the target without knowing its grammatical gender.

Levelt constructed his model mainly based on reaction time data, while Dell's model is based on speech error analyses. For his Independent Network Model, Caramazza (1997) used empirical data gathered from cognitive neuropsychology and linguistic performance of aphasic patients. He discovered that some anomic patients can provide information about grammatical properties of words even if they cannot produce the word itself. Conversely, there are also patients who are able to produce the phonological form but do not have access to grammatical information about the words they are producing – an observation akin to the dissociations between semantic and syntactic information found by Caramazza & Miozzo (1997) and Miozzo & Caramazza (1997). For these reasons, Caramazza (1997) addresses the relationship between semantics, syntax and word form in a novel way. He proposes that information is stored in three independent networks – representing semantic, phonological, and syntactic knowledge, respectively.

1. The lexical-semantic network stores the meaning of words, represented as features.
2. The lexical-syntactic network contains grammatical information (e.g. gender).
3. The phonological network stores phonological output representations (lexemes).

The networks of the IN Model are autonomous. Information from each network can be retrieved independently; phonological lexemes, for instance, can be accessed without prior retrieval of syntactic information.

The IN Model also has a network containing orthographic output lexemes for written language production. Caramazza considered the modality of production to be essential because the architecture of the IN Model is based on data from patients with modality-specific impairments: having observed patients like SJD and HW (Caramazza & Hillis, 1991), who exhibited selective grammatical deficits in written and oral production, respectively, Caramazza and colleagues concluded that phonological and orthographic word forms must be stored separately. The output network has to be modality-specific. All word forms are, however, connected to the same semantic network, where concepts are stored in a decomposed way. Both orthographic and phonological word forms are connected to the syntactic network, where grammatical properties such as word class,[29] gender, and tense are represented. Grammatical features are organised into subnetworks; a German subnetwork for gender would, for example, consist of nodes for masculine, feminine and neuter. Links between nodes of a subnetwork are inhibitory because no more than one can be demanded at a time.

In the IN Model, the modality-specific word forms can either be accessed via activation of grammatical features or without prior activation of the syntactic network (e.g. tip-of-the-tongue (TOT-) states[30]), since the networks are independent. Unlike in the previous models (the Levelt Model and the Interactive Activation Model), activation is passed on instantaneously from the lexical-semantic network to the word form networks, with feed-forward activation only. The IN Model does not feature a modality-independent lemma level.[31] Links between lexical-semantic representations and phonological/orthographic word forms are direct and require no intermediary. Consequently, all word forms sharing semantic features become activated simultaneously, similar to the Interactive Activation Model. Caramazza arrived at

29 Word class might be represented in the lexical semantic network because it has a "semantic reflex", i.e. semantic attributes can determine word class like for example "objecthood" (Caramazza & Miozzo, 1997: 340).

30 Tip-of-the-tongue phenomena are states in which the phonological form of target words is temporarily not or only partially available, while syntactic information is preserved and can be accessed. This has often been taken as evidence for the lemma-word form distinction.

31 Caramazza considers lemma selection and activation of grammatical features as one single process and therefore proposes to fuse the two in the model.

this assumption after he observed patients producing different semantic errors in naming and writing for the same target. Orally, patient PW produced *pliers* instead of *tweezers* and wrote *needle* in response to the same picture of tweezers. He then named it *pliers* again (cf. Caramazza, 1997). The explanation for these contrasting error patterns in both output modalities successfully avoids reference to abstract lemma nodes and instead rests solely upon activation spreading between lexical representations and word forms (forward spreading only). Nonetheless, this argument, which relies solely on patient performance, is not incontrovertible, since the data might as well be explained in a model *assuming* lemma nodes.

Despite this objection, dispensability of the lemma level is not in conflict with Levelt (1989) and Levelt et al. (1999). Caramazza's data rather confirm the two-stage theory, as Levelt et al. have never claimed that the grammatical features must necessarily be selected and accessed with each lexical access. Activation without selection typically has different consequences than activation with selection. If grammatical features need not be retrieved in a syntactic context, selection may easily be skipped.

In Caramazza's model, tense is represented as a subnetwork of the grammatical network. The theory is not very explicit about this, except for stating that tense nodes receive activation from the lexical-semantic network. Caramazza explicates that tense is an extrinsic feature opposed to intrinsic features like gender (cf. Bordag & Pechmann, 2009). Extrinsic features are derived from the conceptual level. The value for tense (e.g. present or past) is determined by its use depending on the context (Caramazza, 1997:186; footnote 4). Unfortunately, the IN Model does not make any claims about morphological processing at all. Hence, the processing of tensed verbs which are morphologically complex cannot be modelled. Existing data and discussion concerning this issue are neglected by the author.

3.5 Discrete versus cascaded processing

An issue that is a matter of debate among theories of word production is how activation flows between the two levels of lexical representation. Discrete *serial* models of lexical access (e.g. Levelt, 1989; Levelt et al., 1999) advocate activation flow strictly from layer to layer. Although multiple lexical nodes become activated, only one node (the selected one) will spread activation from the semantic to the phonological layer. Phonological encoding starts only after the lexical selection is completed. In contrast, some activation spreading theories of lexical access, such as Humphreys, Riddock, and Quinlan's (1988), propose that activation flows continuously from layer to layer in a *cascaded* fashion. Activated nodes spread some proportional activation regardless of which node will eventually be selected. Phonological information will not only be activated for the selected node. Earlier experimental studies spoke for discrete processing (Schriefers et al., 1990; Levelt et al., 1991). More recent studies supported cascading models (Peterson & Savoy, 1998).

Humphreys et al. (1988) is a cascade model assuming only forward spreading of activation. Activation does not spread from the phonological level back to lexical levels. This is an important difference to cascading interactive models which also allow backward spreading (e.g. Dell, 1986). Models with backward spreading can account for mixed errors and the lexical bias effect.

3.6 Remarks on diversity of models

All three models – the Levelt Model, the Interactive Activation Model and the Independent Network Model - essentially capture the lexical retrieval process in the form of spreading activation, but they make different claims about the relationships between the activation of syntactic, semantic and phonological information. The models reviewed above are still under evaluation and, of course, find themselves in a process of constant re-consideration. As of yet, there has neither been conclusive empirical evidence nor a conclusive argument in exclusive favour of either of the models. Cascade models, however, are more difficult to test because when faced with the potentially problematic finding of a lack of phonological activation of unselected items, they could hypothesize that the activation exists but is too weak to be detected.

While the Interactive Activation Model above constitutes a more comprehensive model of speaking, including both word and sentential utterances, the present study will focus on aspects of single word production. Specifically, the Levelt model's postulations about word-form encoding processes are scrutinised in order to determine whether they remain viable when producing regular and non-regular verbs. Moreover, Levelt et al. (1999) present the most explicit model of production of morphologically complex words.

3.7 Producing morphologically complex words

The beginning of this chapter introduced the Levelt model as one example of speech production models. This chapter will address the Levelt Model from a procedural perspective. How can the generation of complex words, especially of tensed verbs, be explained in the architecture of the Levelt model? I will adhere to the description of generating the verb form *escorting* - a morphologically complex verb – as provided in Levelt et al. (1999), and primarily focus on grammatical encoding.

Let us take the lemma *escort* with the corresponding set of pointers on the lemma level (Levelt et al., 1999) as a starting point. First, the lemma is activated, and its diacritic parameters are set for progressive. Subsequently, Levelt postulates that the corresponding morphemes are retrieved from the form lexicon. The lemma points and spreads activation to the morphemes *escort* and *-ing* on the form level. They are then brought into the correct serial order and concatenated.

As has already been noted in 3.2, word form generation requires the retrieval of the lexical stem plus three types of information:

morphological, phonological, and segmental details of the intended word form. Every required morpheme is immediately retrieved from the mental lexicon. Word forms for activated morphemes contain metrical and segmental information. Metrical information about morphemes includes whether morphemes are free or bound: *-ing* for example, cannot stand alone. Morphemes contain a specification of whether they are phonological heads (like *escort*) or not (like *-ing*). In addition, they are numbered for ordering, so that concatenation can proceed successfully. Afterwards, activated phonological plans can be modified by syllabificational processes to ensure correct pronunciation: *es.cor.ting* (instead of *e.scort.ing*, for instance). Syllabification varies depending on the phonological environment and results in different phonological words. Phonological words, in Levelt's understanding (Levelt et al., 1999), are a prosodic unit defined in terms of syllabification prior to articulation. They differ from the phonological plans for targets because they are adapted to the context like in *es.cor.ting* where /t/ becomes onset of the third syllable. Differently with *popart* which consists of two phonological words: *pop.art.* Finally, phonological words will be encoded phonetically, and incrementally converted into muscle contractions and sound waves.

For complex as well as for mono-morphemic words, diacritics have to be set at the early stage of conceptualisation, i.e. independently of the complexity of the target. The encoding process then proceeds with selecting or generating that word form which corresponds to these diacritics. Diacritics for person and number agreement between subject and verb are extrinsic features that can be set prior to grammatical encoding. This information is available upon encountering the subject, and does not depend on verb lemma retrieval.

Furthermore, setting diacritic parameters for tense is independent of the regularity status of the verb. The difference between regular and non-regular inflection arises only in later processing stages: In the case of non-regular inflection, there is no one-to-one mapping between diacritics and affixes. Non-regular verbs select an allomorph of the stem. Selection of an inflectional affix is determined by the inherent grammatical properties of a lemma and by variable diacritic parameters.

To retrieve regular words, Levelt et al. (1999:12) point out that *two* nodes are involved only at the word form level, one for *escort* and the other one for *-ing*. "Regular inflections are probably all of this type, but non-regular verb inflections are not, usually. The lemma *go*-past will activate the *one* [emph. HT] morpheme *went*." For both types of inflection, the first step is selecting and setting diacritics. Production then proceeds with selecting or generating the word form that corresponds to the diacritics.

For concatenation of morphemes to fully inflected word forms, Levelt et al. (1999) assume rules to apply. That is, rules definitely apply for processing regular words, and apply occasionally if required for non-regulars. These rules are implicit in the Levelt model. They are more explicit in the Words and Rules Theory by Pinker (1999) and Clahsen (1999).

3.8 Morphological processing in comprehension

Comprehension is the other side of the coin when investigating the processing of morphologically complex words. Although there are fundamental differences between comprehending and producing language, research from both modalities addresses the organisation of the mental lexicon (for a study on the regular/non-regular distinction in comprehension see Baayen, Dijkstra & Schreuder (1997)). Both modalities use different representations of word forms (Zwitserlood, 1994), but it is likely that they share conceptual representations – everything else would be computationally inefficient (Cutting, 1998).

One of the first and most influencing models of word recognition has been provided by Taft and Forster (1975). Morphological analysis and segmentation are integral parts of lexical storage and retrieval of prefixed words respectively, together with separate representations of base morphemes (i.e. stems) and affixes. According to Taft and Forster (1975), lexical access of morphologically complex words means *stripping affixes* and accessing constituent morphemes individually even in the case of bound morphemes (for example, *-juvenate* in *rejuvenate*). Thus when a prefixed word is to be recognised, it is first decomposed into its prefix and stem, and lexical access then proceeds on the basis of the stem only. The authors present evidence from a lexical decision task, where reaction times to items with bound morphemes were longer than for pseudo-bound control words (like *-pertoire* in *repertoire*). Therefore, it was suggested that affix stripping is a highly automatic process, and the delayed reactions with bound morphemes indicate the need for reanalysis if no matching stem can be found in the lexicon.

The model Taft and Forster put forward concerns both the processing of visually recognised prefixed words and their storage in the mental lexicon. A prefixed word is stored in the lexicon as a representation of its stem. The lexical entry includes information about which prefixes can combine with the stem to form a word. For example, Taft and Forster interpret lexical entries as having an internal structure like RE(JUVENATE), hence, complexity is represented in lexical entries. Prefix information is stored within this lexical entry. The authors exemplify this point themselves:

> *"the theory that states that the entry for rejuvenate is re(juvenate) would claim that admit, remit, and so on, all have separate lexical entries."* (Taft & Forster, 1975:645)

The ideas of Taft and Forster (1975) were revised by Caramazza and colleagues, who developed another model of word recognition: The Augmented Addressed Morphology Model (AAM) (Caramazza, Miceli, Silveri & Laudanna, 1985; Caramazza et al., 1988) presents an elaborate model of the lexicon which clearly incorporates the morphological structure of lexical items and morphological procedures for lexical access. Taft and Forster (1975) did not assume holistic processing of words at all. The AAM, however, unifies decomposition and full-listing.

Word form representations and processing, according to AAM, are modality specific. Basically, processing of written words relies on what the stimulus carries in its surface: orthographic information.

Moreover, word recognition follows the principle of similarity: The incoming stimulus is checked against stored word forms. A letter string activates its whole word representation (if there is any) as well as its morphemes. For example *walked* activates *walked* + *walk-* + *-ed*. Also word forms of similar words will be activated, e.g. *walks* or *walking*. The orthographic representation which gains the most activation and therefore reaches a threshold first will activate its lexical entry. The two processing mechanisms – full-listing and decomposition - work in parallel. However, it is assumed that full-listing delivers the output more rapidly than the activation of several constituting morphemes. A stimulus is represented as a full form if it has been learnt by prior exposure. Otherwise the word is accessed by the lexical representations of its morphemes.

In Caramazza et al.'s (1988) empirical work, reactions to non-decomposable non-words (*canzovi*) were fastest, followed by reactions to non-words with partial morphological structure (*canzevi*). Most difficulties and longest reactions times arose with morphologically legitimate non-words (*cantevi*) because they were parsed as if they were morphologically complex. The parser was slowed down by the identified constituent morphemes. Therefore, non-words with suffixes were read using a morphological parsing address procedure. Materials of the lexical decision experiment in their study of Italian were controlled for frequency and similarity, and they tested different types of non-words.

Summing up, the lexicon contains full-form representations of word forms and decomposed word forms of roots and affixes. Whole word processing is assumed for known words and decomposed processing for unknown and regular words. As a consequence of orthographic forms guiding processing, all irregular words must be stored because they do not have a trigger for decomposition on their surface. Roots and affixes are independently represented but regular ("major") roots linked to corresponding suffixes. For the Italian verb *correre* [to run], *corr-* is a major stem linked to all suffixes (of which some are linked through inhibitory connections), and *cors-* is linked only to suffixes it can co-occur with.

4 Representation and processing of grammatical features

In investigating verb and noun inflection, linguistic units are divided into smaller units, i.e. the noun or verb stem and grammatical features such as gender, number, person or tense. These grammatical features provide valuable clues for structural processes in language comprehension as well as production. Most production models agree upon abstract representation of grammatical features on the lemma level (e.g. Levelt, 1989; Levelt et al., 1999; Dell, 1986). This information is assumed to be generic, i.e. all lexical items sharing a particular property are linked to the same abstract feature. In the following, the structure of the mental lexicon as well as of lexical entries is outlined before theoretical approaches on the classification of grammatical features are discussed. Finally, the processing of two types of grammatical features, namely gender and declension/conjugation class, is reviewed in more detail.

4.1 Representation of lexical information in the mental lexicon

Theories of language production (and comprehension) typically propose that word retrieval involves the selection of lexical information. The mental lexicon is the repository which is assumed to represent lexical information and is part of the human long-term memory. In which form linguistic information is stored is a question of the configuration of the mental lexicon. The proposals vary to a great extent for particular requirements of semantic, syntactic, morphological and phonological information (for a review see Rapp & Golrick, 2006). Conventionally, the mental lexicon organises speakers' vocabulary in the mind like in a dictionary. It is conceived of as a list of words, the *lexical entries* (cf. Pustejovsky, 1996). There is controversy about the content of lexical entries. Agreement has been reached regarding information about (a) the pronunciation, (b) the meaning, (c) morphological properties, and (d) syntactic properties of its entries[32] (Levelt, 1989:182). Keeping as close as possible to the definition given by Levelt et al. (1999),

> *"…a lexical entry is an item in the mental lexicon, consisting of a lemma, its lexical concept (if any), and its morphemes (one or more) with their segmental and metrical properties." (Levelt, 1989:182)*

Several recent directions in research are pointing to a view of the mental lexicon that is not that of the classical dictionary (e.g. Elman, 2004). Rather, the lexicon is viewed as a complex, dynamic system of knowledge in which information is not stored passively but actively directs on mental states.

4.1.1 Structure of the mental lexicon

The fundamental question about the organisation of the mental lexicon is: What is the primary unit of representation? The answer concerning the exact type of linguistic representations is an issue of the linguistic level addressed. Theories about for example semantic representations and morphological processing provide conflicting answers to this question.

How semantic knowledge is organized is still an unresolved issue (cf. Aitchison, 1997). In the literature are two main accounts that specify how semantic knowledge is represented and retrieved. The Feature Comparison Model (Smith, Shoben & Rips, 1974) assumes semantic knowledge to be decomposed in features. Concepts share features and their meaning is computed during

32 Idiosyncratic information alike

processing. The more features two concepts have in common the more similar are the concepts. On the other hand, the Hierarchical Network Model (Collins & Loftus, 1975) describes semantic knowledge as categorical, associative relations among concepts in a network-like structure. The closer and the stronger the connections are between two items the more similar are the two concepts. This structure reflects hierarchies and hyperonyms inherit their properties to hyponyms.

Of more interest for the current study are theories about representation and processing of morphologically complex and simple words. Aspects of morphology in the mental lexicon could enable us to examine the roles and interplay of storage and computation in the mind. Representation of language is an important component of a theory of language processing. It is not easy to distinguish representation and rules and to keep them apart.

Mainly two ideas about the representation of morphologically complex words are pitted against each other in the literature. First, Butterworth (1983) claims non-compositional full listing of all words in the lexicon. There are lexical entries for each word forms like for *kiss*, *kissed*, *kissing* etc. However, all the entries include a representation of their morphological structure. A variant of the full listing assumption was proposed by Lukatela and colleagues (Lukatela, Gligorijevic, Kostic & Turvey, 1980) arguing for a *satellites entries* model. The lexical organization of the inflected nouns is assumed with the nominative singular as base form in the centre (*nucleus*) connected to all possible inflected forms as satellites grouped around it. In a lexical decision task, participants' reaction times were fastest in response to the nominative singular and did not differ for genitive and instrumental. Lukatela et al. (1980) argue against morphological decomposition.

Secondly, the competing position reckons representation of separated constituting morphemes in the lexicon, i.e. only stems like *kiss-* plus representations for exceptions (e.g. *sheep*) are listed (Taft, 1981; Taft & Forster, 1975). In these models, the basic operation is affix-stripping and the remaining root is looked up in the lexicon. Facilitation effects by morphologically related distractors in picture naming tasks are a good argument for decomposed storage in the mental lexicon (Dohmes, Zwitserlood & Bölte, 2004, among others). Intermediate positions between full listing and decomposition by Pinker (1999) for production and Caramazza et al. (1988) for comprehension have already been described in sections 2.3 and 3.7. These conflicting proposals still form an inconclusive picture, especially for the representation of non-regular forms.

4.1.2 Underspecified lexical entries

After the overview of accounts about the structure of the mental lexicon regarding semantic and morphological information this section continues with an approach about the structure of lexical entries as parts of the mental lexicon by Clahsen (1999) who argues for underspecified lexical entries.

Arguing persuasively for Dual Route processing, Clahsen (1999) and Clahsen et al. (2001, 2002) propose structured, underspecified lexical entries for non-regular participles such as (*ge*)*trunken* [drunk]. The lexical entry of non-regular verbs has two layers: the verb stem on top of the lexical entry is an unmarked mother node. Information about the ending and about ablaut is coded by subnodes spreading from each corresponding unmarked mother node. Subnodes are feature pairs formed upon the pattern <phonological string, morphological feature value>. Non-regular forms conceived of as subnodes of lexical entries get features from the mother node by inheritance (Clahsen, 1999). The concept of underspecified lexical entries is based on Minimalist Morphology (Wunderlich, 1996). The past tense and participle forms of non-regular verbs are pretty similar to their stems. Often they differ only in length and vowel quality. Underspecified lexical entries are an economic way of representation and can account for the high degree of similarities of non-regular verbs (see Figure 4).

Lexical entries of non-regular verbs are schemes that restrict the possible non-regularities. In contrast, entries for regular verbs consist only of the mother node. Participles are built by regular affixation of the affix -*t* to the mother.

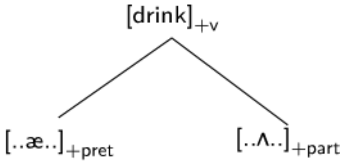

Figure 4. Clahsen's (1999) structured lexical entry for the non-regular verb *to drink*.

4.2 Internal and external features

Turning back to language production, retrieving word forms entails also the retrieval of grammatical features. On the level of grammatical features the discussion is very close to the primary unit of representation in the mental lexicon. In most production models, grammatical information is stored on the lemma level in form of generic nodes.

The grammatical features can be classified as *internal* or *external* (Bordag & Pechmann, 2009). The lexical information of internal features only becomes available with the activation of a specific lemma (e.g. grammatical gender). External features, however, are conceptually determined by the context and therefore are available before any lemma is activated. Their value is variable and lemma-independent (e.g. number or tense). A similar distinction between *extrinsic* (contextually determined) and *intrinsic* (inherently associated) features was made first by Caramazza (1997) and Schiller & Caramazza (2002). The definition of *internal* and *external* by Bordag and Pechmann (2009) displays a strong dependency on the notion of the lemma and its activation – a concept not found in Caramazza's model. According to Bordag and Pechmann, external features are obligatorily activated and specified as diacritic parameters during grammatical encoding in the Levelt Model. If external values specify the output sufficiently and internal feature values are not distinctive for inflectional processes, internal features can be bypassed[33].

With regard to the grammatical features, gender and declension/conjugation class, their values remain unaffected by agreement or government relations. They are both internal features and stated arbitrarily in the form of generic features which has been revealed by several picture-word interference (PWI) studies on grammatical feature activation (Schriefers, 1993; Bordag & Pechmann, 2009; see below).

In PWI studies, a presented picture (target) has to be named whereby the articulation latency is measured. The picture ("target") emerges either simultaneously, or somewhat earlier or later (different *stimulus onset asynchronies* (SOAs)) than an auditory or written distractor[34]. Although participants are asked to ignore them, distractors are processed unconsciously and the type of distractor has an impact on the picture naming. Usually, semantically related distractors cause interference while phonologically related ones lead to facilitation (Schriefers et al., 1990). Moreover, variation of SOAs is an important variable for obtaining picture-word interference effects and studying the time course of encoding. Schriefers et al. (1990) presented auditory distractors at varying SOAs. If lexicalization proceeds in two distinct stages such that lexical selection precedes phonological encoding, one would predict semantic interference and phonological facilitation to occur at distinct SOAs. The results supported the idea of two distinct stages, because the time to name target pictures was affected by the semantic distractors at short SOAs only. In contrast, an influence of the phonological distractors was only present at long SOAs.

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33 An exception is the gender congruency effect that is observable for bare noun naming. Other accounts considering the bypassing of feature selection are Schriefers (1993) and Levelt et al. (1999).

34 Following conventions in the literature, "targets" and "utterances of participants" are quoted, distractor words are underlined, everything else (morphemes, lemmas…) is written in italics.

4.3 Processing grammatical gender

The PWI paradigm was used first by Schriefers (1993) for examining the selection of grammatical gender in language production. In this study Dutch participants were asked to name depicted coloured objects that were paired either with gender *congruent* or gender *incongruent* distractor words. Note that in Dutch *common* gender (*de groene stoel* [the green chair]) is distinguished from *neutral* gender (*het groene bed* [the green bed]). The stimuli should be named with noun phrases consisting either of determiner + adjective + noun (e.g. *het groene bed* [the green bed]) or adjective + noun (e.g. *groen bed* [green bed]). Dutch is a gender-marked language in which adjectives are gender-inflected only when determiners are absent. The study showed that pictures were named faster when the name of the target picture and a distractor noun were gender *congruent*. According to Schriefers (1993), delayed reaction times in *in*congruent conditions reflect a competition of two different gender feature values for the final selection. The distractor word automatically activates its corresponding gender value and distracts the gender selection for the target. Usually, gender is proposed to be represented as abstract generic nodes independently of semantics (Jescheniak & Levelt, 1994; among many others; see Figure 5).

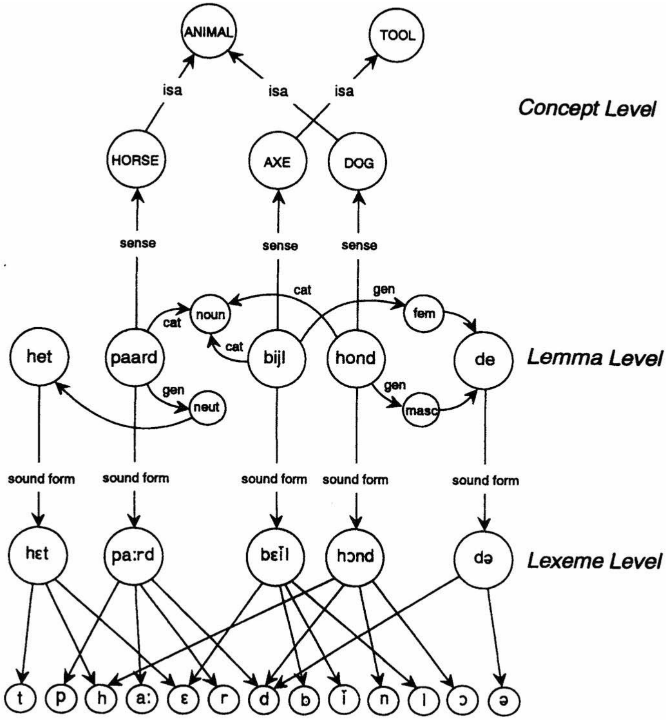

Figure 5. Lexical information on the lemma level is represented as generic nodes. paard and hond are linked to the single noun-node (taken from Jescheniak & Levelt, 1994).

The *gender congruency effect* has been replicated by Van Berkum (1997), La Heij and colleagues (La Heij, Mak, Sander & Willeboordse, 1998) and, for German, by Schriefers and Teruel (2000). However, it could not be verified for French and Italian (Miozzo & Caramazza, 1999; Alario & Caramazza, 2002). Hence, this effect seems to be language-specific. In Romance languages, the selection of the determiner often does not only depend on the gender of the noun phrase (i.e. grammatical features) but also on the phonological context (i.e. the onset of the word following the determiner). The Italian definite determiner *il* (masculine singular, e.g. *il tavolo* [the table]) is replaced by *lo* if the following word begins with a vowel, an affricate, or consonant clusters with /*s*/ or /*gn*/ (e.g. *lo strano tavolo* [the strange table]). While classically, the gender congruency effect was attributed to the lemma level, Caramazza and his colleagues (Miozzo & Caramazza, 1999; Alario & Caramazza, 2002; Schiller & Caramazza, 2003) instead perceive it as a competition of determiners instead of abstract gender nodes. The determiner cannot be selected until sufficient phonological context is available. Effects resting on grammatical feature selection would not be detectable during later processing stages. Caramazza and colleagues conclude that the observed congruency effect is a determiner effect rather than a lemma effect.

4.4 Processing declension and conjugation classes

Research on language production has mainly focused on noun and gender processing, so that only little is known about the processing of verbs. This is because most of the psycholinguistic research so far has focused on Germanic and Romance languages, which are less inflecting than, for example, Slavic languages. An exception is the study by Bordag & Pechmann (2009), which explores declension and conjugation classes in Czech. In the following section, this study is discussed in more detail as it provides evidence for the cognitive reality of conjugational class as internal feature for verb processing in Czech.

Like most Slavic languages, Czech has a pronounced inflectional system. Syntactic functions are expressed by inflectional suffixes on nouns, verbs and adjectives. Czech nouns are declined according to case, number and declension class (DC); gender has syntactic implications. Most grammarians agree upon 14 DCs, with each class denoting a specific set of inflectional endings (see Bordag & Pechmann (2009) for an overview). Verbs are inflected for person, number, mood, tense, voice aspect and conjugational class (CC). There are five main classes; items belonging to the same class share their inflectional suffixes.

Bordag & Pechmann (2009) explored the declension classes of nouns and the conjugation classes of verbs in Czech. Both are assumed to be lexically specified grammatical features, i.e. internal features stored at the lemma level which have morphological implications.

Three experiments investigated a DC/CC congruency effect using the PWI paradigm. Participants named pictures of objects in dative singular while they were presented with DC-congruent or DC-incongruent distractors in Experiment 1, and they were asked to name depicted actions in third person singular present tense while they were presented with CC-congruent or CC-incongruent distractors in Experiment 2. Noun stimuli were chosen from six DCs and distractors were presented in citation form (nominative). Verb targets and distractors came from three CCs and distractors appeared in the infinitive. All targets were also paired with identical and neutral (xxxxx) distractors as control conditions. There was no interval between the presentation of the target and the distractor (SOA = 0 ms).

As expected, incongruent distractors (DC and CC) delayed articulation latencies and error rates were higher than in congruent conditions. The configuration of the results resembled the gender congruency effect. Bordag and Pechmann stipulated generic DC/CC nodes on the lemma level which are linking ("mediating") elements to the inflectional endings on the word form level. Incongruently related picture-distractor pairs activated two different class nodes at the same time, which strove for activation and final selection. The competition delayed the formulation processes. A congruently activated node, however, bundled the whole activation and was therefore faster and more easily selected.

Their Experiment 3, in which only DC was under investigation, explored whether the competitive process observed resulted from competition between abstract feature representations during the grammatical encoding or between inflectional endings, during phonological encoding. In the experiment, Czech participants were now instructed to produce nouns in the genitive and instrumental, respectively. Inflectional endings for the selected

DCs in the genitive were formally distinct; in the instrumental they were identical. The congruency effect showing up in both case naming conditions (genitive and instrumental) was interpreted as competition on the abstract DC level; it could not have its origin on the word form level because, in the instrumental, there was overtly no mismatch and therefore no source for any competitive process.

However, the authors interpret the effect with caution. It was a null result (no difference between genitive and instrumental case) and effects of grammatical and phonological encoding do not necessarily have to be additive. It is possible that a phonological component in the genitive singular was present, but not statistically detectable.

With this congruency effect, the study demonstrated that DC and CC have psychological reality and that the features are stored generically, otherwise no competition could have been observed.

5 Tense

Tense is a grammatical category of verbs expressing the time at, during, or over which a state or action denoted by a verb occurs. In most languages tense is conveyed by inflectional morphemes. This thesis focuses on tense because tense in German is intertwined with the inflectional processes triggered by person and number agreement between verb and subject as demonstrated in Figure 2.

The first paragraph of this section is about the deictic character of tense (Reichenbach, 1947; Levelt, 1989). Then the basic ideas about linguistic (typological) placement and the formal variations in expressing the concepts of *time* are discussed. The next part provides observations about the usage (pragmatic status) of present and past tense - the two tenses under investigation.

Many theories about tense are based on the ideas of Reichenbach (1947), a German philosopher of science. Tense is the time an action or state happens as denoted by the verb. Reichenbach (1947) formalised tense as a relation between **S** (speaking time) and **E** (event time). E can also be an interval (Comrie, 1987). These two parameters describe the three absolute tenses:

(11) a. S = E, present [S *with* E]
b. S > E, past [S *after* E]
c. S < E, future [S *before* E]

Thus, in a. both the event and the report occur simultaneously. Events in the past tense precede the moment of speaking, while those in the future have not yet taken place.

In order to analyse complex, relative tenses (e.g. past perfect), Reichenbach (1947) introduced a *reference point* - another event or fixed time. The reference point in (12)

(12) *I called John, but he had left.*

is the main clause *I called John*. It is distinct from the event point (John's leaving) and S, the moment of speaking. That elucidates the *deictic* character of tense (Levelt, 1989). Tense expressions are understood relative to the moment of speaking and *deictic* means relating entities to a reference point. We can visualise tense by locating situations on a timeline relative to the present moment or to each other (Comrie, 1987). According to Comrie (1987), communicating in the present tense sets *"the present moment as the deictic center"*.

Closely connected with the question of the semantics of time reference are formal factors. Not all languages have grammaticalised tenses (Comrie, 1987; 1989). For example. the isolating language Chinese refers to the past with adverbials. Present and past tense in German are *synthetically* formed tenses expressed by the verb (i.e. one word). The verb is composed of several bound morphemes. Furthermore, it is necessary to differentiate synthetically formed tense expressions from periphrastic ones such as the past perfect, which consists of an auxiliary and the participle form of the main verb.[35] Synthetically formed tenses may differ in the degree of tightness of the bond between the inflectional morphemes and the verb stem. Bickel & Nichols (2007) differentiate constructions along a *scale of fusion* (isolating>concatenating>non-linear). German tense morphology comprises both morphemes that can be separated from their host in a linear fashion (in the present and regular past) as well as morphemes which defy linear segmentation from the verb stem. The latter belong to the non-regular past and consist of Ablaut or Umlaut (cf. Bickel & Nichols, 2007).

35 These distinctions apply to individual constructions, like the formation of a particular tense, rather than to whole languages.

Present tense is formally unmarked in most languages (Bybee, 1985) and thus not expressed by a separate morpheme. Pragmatically, the present tense can also be found with generic or future meaning. Take habitual actions like (13) as an example:

(13) *I call John for lunch (at 1 o'clock).*

The act of *calling John* must not be taken literally at the moment of speaking. Only very rarely the time of speaking (S) and the event time (E) occur really simultaneously. A real coincidence (see (6.a) exists only with performative acts (cf. Comrie, 1987). A similar divergence between formal tense marking and expressed meaning exists for past tense as well: past forms can also be found in conditional clauses with non-past meaning.

According to Dudengrammatik (1998), present (52%) and past tense (38%) are the most frequently used tenses in German and together account for 90% of all occurrences of tensed verbs. However, DUDEN uses written corpora, in which the past tense is relatively frequent. In Henning's (2000) analysis of spoken language, the percentage of past tense immediately plunged to a mere 15% of all sentences.

The German past tense – which formally corresponds most closely to the English simple past – has a different pragmatic status in German than simple past has in English. In German, and especially in spoken language, the past tense is much less frequent than the simple past is in English, due to the commonly used past perfect (e.g. du hast ge-*spiel*-t [you have-2.sg.PRES *play*-PART, you played]) referring to completed actions. Careful disentanglement of the factors of frequency and regularity is necessary when addressing issues of verb inflection. Consequently, assumptions about the mechanisms governing regular vs. non-regular inflection in English cannot be transferred to German immediately, without further consideration.

6 The empirical stance

6.1 Why and how regularity might be represented

The previous theoretical section was devoted to elaborate a wide-coverage framework of producing regular and non-regular verbs also reviewing research on the activation of grammatical features during lexical access. Based on the theoretical framework and the results from Bordag & Pechmann (2009), it is hypothesized that regularity is mentally represented and initiates Dual Route processing as claimed by several authors (Pinker, 1999; Clahsen, 1999; Jaeger et al., 1996). The goal of the proposed study is to further examine the mechanism responsible for lexical selection of verbs and to provide an initial attempt to look at the way in which lexical representations may act as a cue for morphological processing in one way or another.

Regularity is – like DC/CC in Czech - an internal and invariable, indispensable grammatical property with morphological implications. Pinker & Ullman (2002) already suggested a stored past tense feature associated with non-regular verbs' lexical entries (see section 2.3.3). Three reasons support the representation of regularity as part of the lexical information stored in the mental lexicon connected to the appropriate lemma.

First, there are patients with neurological disorders like AW (a patient with acquired word-finding difficulties caused by a left-temporal lesion; Miozzo, 2003) showing a clear dissection of non-regular forms of both verbs (e.g. *found*) and nouns (e.g. *children*). One possible explanation is that the rule-based system is still intact, while the non-regular forms, however, cannot be retrieved anymore. Then, it would be quite a coincidence that nouns as well as verbs were affected by AW's lesion. It is even more surprising that while the retrieval of non-regular word forms from the lexicon is so severely impaired the retrieval of regular stems *from the lexicon* is not affected by the damage. Although neuropsychological association data are not the most meaningful source of evidence, AW's performance data might also tell that there is a superordinate feature with two values: *regular* and *non-regular* (cf. chapter 2.3.2.3). From theoretical considerations and empirical data, several researchers, including Ullman et al. (1997), Patterson et al. (2001) and Miozzo (2003), drew the following conclusion: Patients *know* that a verb is non-regular

> *"…and hence do not append the suffix -ed to its stem. But because phonology remains inaccessible, they can only guess the verb form; so, for example, they change a vowel or a consonant to produce verbs that resemble existing non-regular verb forms. In other words, it seems that the regular/irregular [non-regular, HT] status of the verb is information that is stored separately from the form of the irregular verb [non-regular, HT]."* (Miozzo, 2003:124)

The article continues with a proposal similar to Pinker's (1991):

> *"Perhaps the function of the information about the regular/irregular* [non-regular, HT] *status of the verb is to block the suffixation process and to trigger the retrieval of the irregular* [non-regular, HT] *form from stored phonology."*

Second, it is not inherent to verbs' meaning or form (i.e. infinitive, compare *geben* [irregular, to give] and *leben* [regular, to live]) whether they follow regular or non-regular inflection. Regularity is an arbitrary characteristic that needs to be inherent to the lexical entry.

Third, in addition to the theoretical considerations, Bordag and Pechmann (2009) gave evidence for the cognitive reality of a similar internal feature of verbs in Czech, namely conjugational class. Understanding the regularity encoding of CC might be helpful. CC and regularity of verbs have several things in common. CC is also assumed to be represented at the lemma level and to classify verbs. CC, like regularity most probably too, has to be set before further processing. Both differ from gender as they have morphological implications on verbs.

Summing up, the assumption of a psychologically real regularity feature rests on the observed *full* loss of producing non-regular forms of the agrammatic patients like AW, the arbitrariness of a verb's regularity and the DC/CC congruency effect (mainly CC) in Czech. The question emerges of *how* regularity is represented. One possibility is the idea of generic nodes, like the assumed representation for gender (cf. Schriefers & Jescheniak, 1999, for grammatical gender) or grammatical class in the most famous model of speech production (Levelt et al., 1999) or DC/CC (Bordag & Pechmann, 2009). In this case, each lemma would be connected to one fixed value for its regularity. Therefore, the production of regular and non-regular forms can proceed very fast and is not prone to errors. This feature can be assumed to be binary, with the two observable values being regular and non-regular.[36].

The hypotheses in the following section are derived from the DC/CC congruency effect in Czech, while being aware that a priori functional and descriptive similarity does not necessarily demand the same processing principles.

6.2 The regularity congruency effect

The experiments described in chapter 7 address the representation and processing of regular and non-regular verbs. The experimental question is whether verb lemmas are stored together with a feature that specifies their regularity status. The PWI paradigm is used to reveal and to study the activation and encoding of this status. The same technique already revealed congruency effects for gender (Schriefers, 1993) and conjugational

36 It might turn out that regularity is a ternary feature if hybrid verbs are an autonomous verb type besides regular and irregular verbs.

class in Czech (Bordag & Pechmann, 2009). With the hypotheses established in this thesis, Experiments 1-4 of the current study search for a *regularity* congruency effect. The relations between target and distractor were manipulated with respect to the regularity of verbs: picture and distractor were either *congruent* (both regular or non-regular) or *incongruent* (they differed in regularity). If interference occurs, it is supposed to reflect competition for selection among regularity features of lemmas – though this reasoning can only be analogue to Schriefers (1993) and Bordag & Pechmann (2009). Gender and regularity are not directly comparable because the former is a syntactic property. Most inflecting word classes (e.g. adjectives, pronouns, numerals) require agreement in gender (and number and case) with the head noun. DC/CC and regularity are more closely related. CC is comparable with regularity as both are morphological properties of verbs.

Temporal changes in the mapping of pictures onto their respective phonological forms may in effect provide insight into encoding processes during lexical access. For production in general, comparing naming latencies gathered with the PWI paradigm, different naming conditions can be placed along a latency scale (cf. the scale in (14)). Naming without distractors is fastest (cf. Schriefers et al., 1990) and can serve as a baseline for other conditions. The mere presence of a string of characters increases articulation latencies. Even a neutral distractor like a row of 'x' (xxxxx) delays naming. This condition measures the interference of *any* stimulus. Identical distractors lead to an increase in reaction time, but not as much as critical distractors which embody the experimental manipulation. Their placement on the scale depends on their nature.

(14) without < xxxxx < identical < critical distractors

Specifically, the most interesting relation is the one between the critical conditions. The hypotheses are based on the CC-congruency effect (Bordag & Pechmann, 2009) because of the striking resemblance between CC in Czech and regularity in

German. It is expected that naming in incongruent conditions is slower than in congruent conditions because of a Stroop-like interference effect. Competition between different regularity values should prolong reaction times to the target. That is, if participants consistently name pictures in incongruent trials more slowly than in congruent trials, this reflects additional effort to activate the target including its grammatical features. Conflicting information activated through the distractor must be suppressed. It takes time to resolve the conflict[37]. Further, it is predicted that naming is fastest in control conditions (xxxxx and identical) for which I expect no interference due to the regularity status of the target. Effects shown experimentally may hint at the mechanisms of language production in an actual discourse context – here, various other interference phenomena would have to be assumed.

In addition to the predicted regularity *congruency* effect, it is of interest to look for a pure *regularity* effect in present tense, like the one found for past tense naming by Seidenberg & Bruck (1990, as cited in Seidenberg, 1992). In their study, regularity clearly affected articulation latencies. The authors had participants inflect regular and non-regular verbs in past tense from written present tense stems and measured onset latencies. Though the materials were matched for present tense stem frequency, it took participants significantly longer to generate non-regular past tense forms. On average 100 ms deviation between regular and non-regular verbs' articulation latencies were reported and this result equals Prasada et al.'s (1990). The Words and Rules Theory (Pinker, 1999) and the theory about internally structured lexical entries (Clahsen, 1999) assume that regular as well as non-regular verbs are inflected regularly in present tense. Pinker (1999) does not deal with this issue explicitly, but the theory implies that verbs which can be built regularly are computed regularly. Therefore,

37 Things are reverse regarding word class. Competing word class information facilitates naming, because words of different grammatical categories do not fight for the same syntactic slot (Pechmann & Zerbst, 2002; Pechmann & Garrett, 2004) but words of the same grammatical category do. Regularity, however, has more similarities with CC and therefore hypotheses are derived from Bordag & Pechmann (2009).

only past tense non-regular verbs are assumed to be fully listed. Similarly, present tense regular status of verbs is implied, though not expressed explicitly by Clahsen (1999): here, the present tense word forms are the top nodes of the underspecified lexical entries (cf. Figure 4, section 4.1.2). Non-regular word forms are embodied by sub-nodes which are limited to past tense. Contrary to these two theories, Janssen (1999) found signs of non-regular processing of Dutch verbs also in present tense. He investigated inflection frames of verbs which were specific for verb type (regular or non-regular verbs) independent of the tense produced. Janssen (1999) concluded that the inflectional frame of non-regular verbs does not have a specific slot for the tense suffix (e.g. *–te* for German past tense) because their past tense is lexically coded, i.e. idiosyncratic. As an effect of regularity it is expected that it takes less time to produce regular verbs:

(15) regular < non-regular

If verbs maintain their regularity status across tenses, the regularity effect is hypothesised to appear also across tenses. Hence, if this regularity effect can be replicated in present tense, where regularity for most German verbs is not overtly visible, verbs are likely to be stored and represented as *classes,* i.e. regularity is then represented as an abstract generic feature. Those verbs connected to the same feature are inflected alike. Alternatively, one might argue that word forms are marked for regularity *individually*, i.e. only by means of their past tense form. Under the assumption of individually marked word forms, the regularity effect is not assumed to arise in present tense because regular and non-regular verbs do not belong to the same morphosyntactic category. In this case, regular and non-regular verbs are expected to be superficially regular and therefore to be equally fast.

Intimately connected with the question of how regularity might be represented is the question on the structure of lexical entries of verbs. In particular, the retrieval of non-regular word forms might be more difficult because the lexical entry contains several word forms from which a single one must be selected. If the regularity effect hypothesis in the present tense proves true, an explanation different from both the blocking mechanism (Pinker, 1999) and the assumption of internally structured lexical entries (Clahsen, 1999) is more likely – relying more on the structure of lexical entries – for example its complexity.

As this is, to my knowledge, the first time the present tense production of verbs is studied, predictions for the factor TENSE are drawn from pragmatic factors: German past tense is used less frequently than present tense (cf. section 5) Therefore, naming of actions in present tense is expected to proceed faster than naming in past tense.

(16) present tense < past tense

It will be examined whether the tense of the utterance affects regular and non-regular verbs in a similar manner. Presumably, a *tense effect* (the past tense is produced more slowly than the present tense) occurs only for non-regular verbs, since they utilise different word forms in either tense and past tense word forms are less frequent than present tense word forms. Regular verbs, however, are assumed to employ the same stem, so the discourse frequency of the tense should not matter.

In summary, the hypotheses tested in Experiments 1 to 5 are the following:

(1) The articulation process is delayed by neutral distractors (xxxxx), identical distractors, congruent and incongruent distractors listed in order of increasing interference
(2) Regular verbs are produced faster than non-regular verbs in past and present tense
(3) Verb naming of non-regular verbs in the present tense is faster than verb naming in the past tense. Regular verbs are produced equally fast in both tenses

However, the first hypothesis cannot be examined in Experiment 5 using the modified experimental paradigm, namely simple picture naming without distractors.

Depending on the results and the interaction between Type of distractor, Regularity and Tense, conclusions can be drawn about:

(1) whether verbs are stored in classes.
(2) whether regularity is represented as a generic feature.
(3) whether tense contributes to Dual Route processing.
(4) which mechanism can explain present tense performance.
(5) inflectional encoding with underspecified lexical entries.

Previous studies investigated either past tense or participle formation of regular and non-regular verbs. With the hypotheses sketched, the current study aimed at the production of present and past tense. The focus in the following empirical investigation is on whether there is a dissociation between construction or retrieval of tense marked verb stems and to explore whether tense affects the production processes. The hypotheses implicate the presupposition that German verbs behave in the same way as the English verbs, even though German has a richer morphology. Still, this difference is only crucial for person/number marking and should not affect the regular/non-regular distinction with regard to the generation of tensed stems. In both languages, the tense-marked stem is assumed to be generated first and then inflected for person and number.

7 Experiments

7.1 Experiment 1 – Present tense

To review, the main goal of Experiment 1 was to evaluate the representation of regular and non-regular German verbs in present tense where regularity differences are not apparent. However, Janssen (1999) pointed out that strong verbs of Dutch showed signs of idiosyncrasies in present tense. Exploring present tense allows to draw conclusions as to the way of representation and storage (paradigmatically or individually) of verbs.

For this purpose, a variant of the picture-word interference paradigm was adopted. The gender congruency effect as well as the word class and DC/CC effect have been reliably observed in previous studies involving that paradigm in several languages (German: Pechmann & Zerbst, 2002; Pechmann, Garrett & Zerbst, 2004; Dutch: Schriefers, 1993; Italian: Alario & Caramazza, 2002; Schiller & Caramazza, 2003; Czech: Bordag & Pechmann, 2009). During the presentation of the picture and the distractor, both lemmas and the associated feature nodes become active. If picture and distractor activate two distinct features, more information must be gathered before the competition can be resolved that the correct name for the picture can be selected. To assess this, articulation latencies under both congruent and incongruent conditions will be compared with each other as well as with control conditions. Speech onset latencies are a dependent measure.

The Stroop-like task is only a tool to demonstrate cognitive processes. Normal production processes might proceed mostly without disruptions. The advantage of the picture-word interference paradigm in speech production is that it involves conceptualisation and avoids potential priming between the presented and elicited forms. However, Experiment 5 explores the limit of the methodology of Experiments 1-4 and also serves as a control experiment. It is supposed to demonstrate separable morphological processes during morphological encoding and hence any effects will be located at the word form level (as opposed to the lemma level in Experiments 1-4).

7.1.1 Methods

Participants

Thirty-two native speakers of German participated in Experiment 1. They were all students of the University of Leipzig. All received money for their participation.

Materials

A set of 32 black and white line drawings was selected for the experiment. The pictures depicted the actions of intransitive German verbs (see example Figure 6). Twelve additional pictures served as practice items. The pictures were taken from Masterson & Druks (1998) or were created in comparable style and complexity. Sixteen verbs were classified as regular, the others as non-regular (cf. Appendix) and selected items were controlled for word form and lemma frequency (Baayen, Piepenbrock & van Rijn, 1993).

Each picture was paired with four different distractor words that were either identical, neutral or - with respect to regularity – congruently or incongruently related with the item (see Figure 6). In the identical condition, the distractor was identical with the name of the picture (picture = “singen” [to “sing”] – distractor = singen [to sing]). Identical distractors make congruency effects more likely. Participants seem to pay more attention to the distractors if some are identical (Pechmann & Schriefers, unpublished). In the neutral condition a row of five Xs was used as distractor ("singen" - xxxxx). In the congruent condition the verbs used as pictures and distractors were either both regular or both non-regular. In the incongruent condition they differed in regularity.

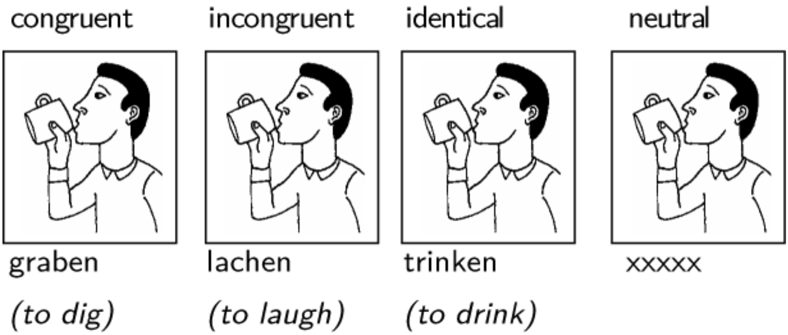

Figure 6. Stimuli examples for the verb *trinken* (to drink).

Combined target verbs and distractors were neither semantically nor phonologically related. Semantic relatedness was judged by two independent native speakers. To avoid phonological facilitation, pairings were restricted not to share initial segments, not to rhyme or not to belong to the same ablaut pattern. These criteria restricted the target pool enormously. Thus, it was not possible to match the groups of regular and non-regular verbs exactly for length and frequency (see section 7.2.3 for a discussion of these issues).

All distractors belonged to the response set, i.e. they were pictures in the experiment. Previous studies demonstrated (Levelt et al., 1999) that competition among lexical items is stronger if distractors are possible responses. They are previously sort of flagged in the familiarisation phase and therefore their activation level is higher (Levelt et al., 1999). This boosts interference[38] (cf. as well Mahon et al. (2007) exploring "response related criteria").

38 However, Caramazza & Costa (2000) did not find support for this assumption studying semantic interference The current study will test morphological

Apparatus

The experiments took place in a dimly lit noise insulation booth at the University of Leipzig. The stimuli were presented as black line drawings on a light grey background of a computer screen using ERTS (Experimental Run Time System, Beringer, 1995).

Distractor words were presented in lowercase black letters in bold font. Response times were measured by a voicekey. The Microphone used was a Sony MS957.

Procedure

Participants were tested individually in a quiet room. They read written instructions requesting that they should name the depicted action as fast and as accurately as possible. They could ask the experimenter to clarify the whole procedure.

The first part of the experiment was designed to familiarise the participants with the stimuli. In a first step they named each picture in the 3rd person singular present tense in a sentence context (*Jemand singt. [Somebody is singing.]*). In that phase, the appropriate verbs were written under the picture in the infinitive, such that participants could read the correct picture names and memorise them. In a second step, all pictures should be named again without the appropriate words written underneath the images. Finally, the participants performed 12 practice trials that were identical to the experimental situation. After the practice set, participants received feedback if necessary (e.g., a remark on their clicking noises).

The second part was the experiment itself. The sequence of events in a trial was as follows: a fixation-asterisk appeared in the centre of the screen for 1000 ms. This indicated that the subject of the sentence „*jemand*" [*someone*] had to be produced. 200 ms after the disappearance of the fixation asterisk, the picture and distractor were shown in the centre of the screen. The depicted

interference. Just to be on the safe side the distractors were taken from the response set.

action was uttered in the 3rd person singular present tense, thus a correct grammatical sentence was produced by the participants. Participants' reaction times were measured from displaying the picture on the screen until the first phoneme of the utterance triggered a voice key. After triggering the voice key, the picture and the distractor disappeared from the screen.

To refrain overlap of inflectional endings, distractors were presented in the infinitive. Furthermore, the distractors were presented with four stimulus onset asynchronies (SOA: -200, -100, 0, 100 ms) randomly below or above the target picture as written words. Participants were instructed to ignore them and to simply name the picture. Every target picture appeared once in each condition and SOA.

The experiment consisted of four blocks – one for each SOA. They alternated across participants. Each target appeared once in each block, four times in the whole experiment. Target-distractor pairs were rotated among the four SOA. For each SOA, the targets were presented once in the congruent condition, once in the incongruent condition, once in the neutral condition and once in the identical condition. The different distractor conditions in each block were randomised across the participants.

Each block started with two warm-up items. Those were excluded from all analyses. The experimenter evaluated each utterance for correctness via keyboard after each trial. The participants did not receive this evaluation as feedback.

The experiment lasted approximately 20 minutes.

7.1.2 Results

Incorrect responses were excluded from all analyses. Reasons for exclusion were wrong namings, hesitations during articulation, technical problems with the measuring and voice key triggering (3.8 % of all data). Reaction times shorter than 200 ms or longer than 1500 ms and those outside of two standard deviations of the subject's mean were identified as missing values. The total of missing values was 8.6 % of all data points randomly distributed across the four distractor types (see Table 1).

Table 1. Percentage of missing values (Experiment 1).

Type	Percentage of missing values
Naming and measurement	3.8
Cut off	4.8
Total of missing values	8.6

Table 2. Mean Response Latencies (RT, in Milliseconds), Accuracy Proportions (PA, in %) and Absolute Errors (Err), Varied by Regularity, SOA and Distractor (Experiment 1).

	Regularity		SOA				Distractor			
	reg	**nreg**	**-200**	**-100**	**0**	**100**	**ident**	**neut**	**incon**	**con**
RT	653	657	658	657	654	652	622	644	672	683
PA	7.6	9.6	8.1	8.3	9.3	8.7	7.0	8.7	8.4	10.3
Err	155	197	83	85	95	89	72	89	86	105

Mean naming latencies per SOA, Distractor type and Regularity of the utterance can be seen in Table 3.

Table 3. Mean Response Latencies (RT, in Milliseconds, standard deviations in parentheses), Varied by Regularity, SOA and Distractor (Experiment 1).

	Stimulus onset asynchrony									
	-200		**-100**		**0**		**100**		**M**	
Distractor	**reg**	**nreg**	**reg**	**nreg**	**reg**	**nreg**	**reg**	**nreg**	**reg**	**nreg**
identical	616	622	621	608	620	638	633	627	622	623
	(94)	(83)	(99)	(84)	(99)	(96)	(99)	(86)	(98)	(88)
neutral	647	645	649	645	642	648	644	623	645	643
	(99)	(92)	(98)	(103)	(103)	(99)	(102)	(104)	(100)	(100)
incongruent	672	677	672	683	655	684	663	669	665	678
	(103)	(104)	(107)	(94)	(108)	(118)	(119)	(116)	(109)	(108)
congruent	688	690	693	694	671	676	672	683	681	686
	(110)	(113)	(99)	(110)	(124)	(126)	(132)	(136)	(117)	(122)
M	655	661	658	656	647	661	653	650	653	657
	(105)	(101)	(104)	(103)	(110)	(111)	(115)	(115)	(109)	(108)

Naming latencies were entered into a within-subjects analysis of variance (ANOVA) with three independent variables: SOA (four levels), DISTRACTOR TYPE (four levels) and REGULARITY of the uttered verb (two levels). In addition to the participant analyses (F1), an item analysis (F2) was conducted. Only significant F-ratios are reported.

A main effect of DISTRACTOR TYPE was found [F1(3,93) = 67.04, MSE = 3001.31, p<.001; F2(3,45) = 66.63, MSE = 1473.33, p < .001] but none for SOA or REGULARITY. The post hoc Scheffé test for the main effect ($diff_{crit;\ p<.05}$. = 17.1) indicated that the two control conditions (identical M=622, SD=93) and neutral (M=644, SD=100) differed significantly from each other and from the two experimental conditions (incongruent (M=672, SD=108) and congruent (M=683, SD=119). However, the Scheffé test showed both critical conditions having the same amount of influence on naming the pictures.

Interactions were found between SOA and DISTRACTOR TYPE [F1(9,279) = 2.40, MSE = 1986.69, p < .05; F2(9,135) =1.41, MSE = 1264.06, p = .19] as well as SOA and REGULARITY [F1(3,93) = 2.86, MSE = 1827.31, $p < .05$; F2(3,45) = 1.51, MSE = 1156.27, p = .22]. However, since they were not even marginally significant in the item analysis, and especially in light of the missing main effects an interpretation without further experiments seems to be too speculative to be seriously discussed.

Analysing the second dependent variable ERROR RATES an ANOVA with the factors DISTRACTOR TYPE, REGULARITY and SOA was performed. A main effect for DISTRACTOR TYPE [F1(3,93) =3.9, MSE = 4.2, $p<.05$; F2(3,45) =3.2, MSE = 2,5, $p < .05$] was found but none for REGULARITY and SOA. The posthoc Scheffé test did not confirm the main effect. The lack of significance shows that the errors made are equally distributed across conditions. None of the conditions is more error prone than the others (see Table 4).

Table 4. Accuracy Proportions (in %, absolute numbers in parentheses), Varied by Regularity and Distractor (Experiment 1).

	Distractor			
Regularity	**inc**	**con**	**id**	**neu**
reg	6.6 (34)	8.8 (45)	5.9 (30)	9.0 (46)
nreg	10.2 (52)	11.7 (60)	8.2 (42)	8.4 (43)

7.1.3 Discussion

In Experiment 1, it was tested whether regularity is represented in form of abstract regularity nodes as assumed for gender, number or conjugational class (Levelt et al., 1999; Bordag & Pechmann, 2009). In a picture-distractor paradigm, participants named pictures of actions with verbs in the 3rd pers.sg. present tense. The analyses showed a main effect of Distractor type on naming latencies, but neither an effect of Regularity nor interactions as had originally been hypothesised. There was no significant difference in accuracy. The main effect of Distractor type revealed no difference between congruent and incongruent distractors, but significant differences to the control distractors (identical, neutral).

In fact, participants did not ignore the distractors, but the congruency of the verbs with respect to regularity did not affect the articulation process. The data do not reflect a competition of different feature values of the presumed abstract regularity feature. Rather, participants seem to be only affected by the mere appearance of a distracting (irrelevant) verb, independently of its regularity. Actually, no conclusion for morphological processing can be drawn based on this null effect.

While regularity is not consistently relevant for present tense inflected verbs, it is consistently crucial information for past tense inflection. In the past tense, verbs are coherently and uniformly clearly identifiable as regular or non-regular. All verbs equal in manifesting their regularity status in past tense. To test this assumption and the regularity congruency effect, the same experiment was run again using past tense inflected verbs, for which the regular/ non-regular distinction has already been shown in former studies (Prasada et al., 1990; Seidenberg & Bruck, 1990, as cited in Seidenberg, 1992) but without addressing its representation.

7.2 Experiment 2 – Past tense

7.2.1 Method

Participants

Thirty-two students of the University of Leipzig participated in the experiment and were paid for their participation. None of them had taken part in Experiment 1.

Materials and Procedure

Methodologically, Experiment 2 was identical to Experiment 1. The only difference was that participants were now instructed to produce sentences in the past tense where regularity is overtly visible for all items, e.g. *Jemand sang. [Somebody was singing.]*.

7.2.2 Results

Naming and measurement errors (6.2 % of the data) were excluded using the same criteria as in the previous experiment. A cutoff discarded extreme articulation latencies shorter than 200 ms and longer than 1500 ms as well as values plus or minus two standard deviations from the subject's mean. They were handled as missing values. The total of missing values was 6.9 %. Mean reaction times and error rates for each of the three involved factors are summarised in Table 6.

Table 5. Percentage of missing values (Experiment 2).

Type	Percentage of missing values
Naming and measurement	6.2
Cut off	0.7
Total of missing values	6.9

Table 6. Mean Response Latencies (RT, in Milliseconds), Accuracy Proportions (PA, in %) and Absolute Errors (Err), Varied by Regularity, SOA and Distractor (Experiment 2).

	Regularity		SOA				Distractor			
	reg	**nreg**	**-200**	**-100**	**0**	**100**	**ident**	**neut**	**incon**	**con**
RT	705	734	721	724	720	714	681	716	746	738
PA	6.6	7.1	6.7	5.9	7.8	7.1	4.2	6.4	7.6	9.3
Err	136	146	69	60	80	73	43	166	78	95

Table 7 summarises the full picture of results of Experiment 2.

Table 7. Mean Response Latencies (RT, in Milliseconds, standard deviations in parentheses), Varied by Regularity, SOA and Distractor (Experiment 2).

	Stimulus onset asynchrony									
	-200		**-100**		**0**		**100**		**M**	
Distractor	**reg**	**nreg**	**reg**	**nreg**	**reg**	**nreg**	**reg**	**nreg**	**reg**	**nreg**
identical	647	689	657	685	689	700	662	713	664	697
	(128)	(145)	(123)	(118)	(159)	(138)	(123)	(133)	(135)	(134)
neutral	709	748	711	734	688	715	695	723	701	730
	(146)	(140)	(137)	(137)	(135)	(118)	(141)	(142)	(140)	(135)
incongruent	724	769	745	766	719	791	725	730	728	764
	(139)	(134)	(146)	(137)	(139)	(167)	(159)	(146)	(146)	(148)
congruent	729	753	743	762	720	741	712	744	726	750
	(135)	(139)	(141)	(120)	(131)	(135)	(139)	(145)	(137)	(135)
M	702	739	713	735	704	736	699	727	705	734
	(141)	(143)	(141)	(132)	(142)	(144)	(143)	(142)	(142)	(140)

For Experiment 2, a three factorial ANOVA was performed again, both by participants (F1) and items (F2). The results revealed significant main effects for DISTRACTOR TYPE [$F1(3,93) = 57.41$, $MSE = 4082.20$, $p < .001$; $F2(3,45) = 41.92$, $MSE = 2799.42$, $p < .001$] and REGULARITY [$F1(1,31) = 34.37$, $MSE = 6407.55$, $p < .001$; $F2(1,15)=5.34$, $MSE = 20689.16$, $p<.05$]. A post hoc Scheffé test for DISTRACTOR TYPE ($diff_{crit;\ p<.05.} = 16.0$) showed that the control conditions (identical and neutral) differ from the experimental conditions (congruent and incongruent), but no effect was found comparing the two critical conditions with each other. Although the interaction SOA by DISTRACTOR TYPE $F1(9,279) = 2.65$, $MSE = 4111.56$, $p < .01$; $F2(9,135) = 2.40$, $MSE = 2333.63$, $p < .05$ reached significance, no significant differences could be observed comparing the critical conditions by a post hoc Scheffé test ($diff_{crit;\ p<.05.}=66.5$). The interaction stems from the longer naming latencies under the critical condition at SOA -200 and -100 compared to the control conditions, which is not of exorbitant interest. Interactions with the factor REGULARITY were not significant.

Table 8 shows error rates by type of distractor and regularity of the utterance (regular or non-regular).

Table 8. Accuracy Proportions (in %, absolute numbers in parentheses), Varied by Regularity and Distractor (Experiment 2).

	Distractor			
Regularity	**inc**	**con**	**id**	**neu**
reg	6.1 (31)	9.4 (48)	5.1 (26)	6.1 (31)
nreg	9.2 (47)	9.2 (47)	3.3 (17)	6.8 (35)

The analysis of errors was also significant. An ANOVA with the Distractor type (four levels) and Regularity (two levels) as variables revealed a significant main effect in the number of errors for Distractor type: $F1(3, 93) = 7.09$, $p < 0.001$, $F2(3, 45) = 6.0$, $p < 0.01$. A paired-samples t-test comparing only the congruent and incongruent conditions showed that this effect was not significant: $t1(126) = -1.29$, $p = .197$, $t2(62) = -1.01$, $p = .317$.

Mean articulation latencies under neutral condition were compared between both tenses. Experiment 1 yielded a present tense mean of 644 ms and Experiment 2 a past tense mean of 715 ms. An independent two-tailed t-test[39] of articulation latencies between present and past tense under neutral condition showed significance, $t_1(1747) = -12.86$, $p < .001$.

7.2.3 Discussion

The picture-word interference paradigm is used in speech production research to show and elicit interference or facilitation effects - depending on the feature studied. It is assumed that target and distractor both compete for selection and activate their grammatical features prior to the final selection of the target. Experiment 2 sought to elicit a regularity congruency effect due to competing abstract regularity nodes in verb naming in past tense.

39 The results are reported despite the fact that the Levene's test for homogeneity was significant, which means that the assumption of homogeneity of variances is violated.

The results indicate that critical distractors (both incongruent and congruent) increase the difficulty to access the correct lexical item. Hence, compared to control conditions the critical distractors are indeed doing their job. The regularity of the distractor, however, does not seem to affect the production, even though being obvious in the past tense. Any word not related in either form or meaning superimposed to the picture would have had the same impact. What we see is an unspecific distraction effect not applicable to the regularity of the verbs. Furthermore, the interaction SOA by Distractor type gives the additional information that distractors affect the target at the two earliest SOAs, namely -200 and -100 ms.

Although the current results do not reveal the predicted congruency effect by Distractor type, they demonstrate a strong Regularity main effect as was also expected. It takes participants longer to produce non-regular verb forms than regular ones (Prasada et al., 1990; Seidenberg & Bruck, 1990, as cited in Seidenberg, 1992). This boosts the assumption that regular and non-regular morphology involve separate morphological processes. Latency differences between regular and non-regular verbs are classically explained with blocking which postulates a specific advantage in producing regular verbs (Pinker, 1999). Using an application of the Dual Route Theory, the Dual Route Mechanism must be triggered as argued in the introduction - at least the blocking procedure itself. The experiments do not give evidence for such a "regularity feature" as of yet because the critical conditions do not reveal an interference effect.

Up to this point the results do not form a unified picture, including some contradicting elements. Since the results of Experiment 1 do not look like regularity is influencing the production latencies in the present tense and the past tense results of Experiment 2, however, do point to an influence of regularity, the factor tense seems worthy of further exploration. A comparison of naming latencies under neutral conditions in Experiment 1 and 2 (taking into account that the participants of the experiments were not identical, thus skewing the reliability of the findings) showed that it takes participants longer to name actions in the past tense than in the present tense. This could well be because the present tense is much more frequent in discourse and spoken language. These findings, as well as the conclusion, are in need of empirical support and precise evidence. Experiments 1 and 2 tested independent samples of subjects and should be replicated in Experiment 3 with dependent samples. Therefore, Experiments 1 and 2 were combined into Experiment 3, in which participants were presented with both tenses, making tense a fourth factor. The interaction of regularity by tense (probably by SOA as well) is of most interest.

7.3 Experiment 3 – Present and past tense

The regularity effect in the past tense (cf. Experiment 2), compared to the missing regularity effect in the present tense (cf. Experiment 1), suggests that tense is an influencing factor for verb production. Indeed, the possibility of regularity effects modulated by tense seems probable. While the present tense does not necessarily have to activate regularity, the past tense should do so. To the extent that regularity is a property of individual forms, and to the extent that both picture and distractor activate their feature during word production, increased (morphological) interference in the past tense for items that are paired with incongruent distractors is hypothesised compared to those with congruent distractors and compared to all present tense conditions. More pronounced interference effects in the former than in the latter condition indicate competition during lexical selection and may be attributed to the differing regularity status of the interfering stimuli.

7.3.1 Method

Participants

Thirty-two students of the University of Leipzig were recruited to participate in the experiment. None of them had taken part in Experiments 1 or 2.

Materials and Procedure

The same set of 32 black and white line drawings from Experiment 1 was used in Experiment 3. Experiments 1 and 2 in their original form, i.e. completely, were combined to create Experiment 3. The sequence of tense was counterbalanced across participants. 50 percent were asked to name pictures first in the present tense (Experiment 1) and afterwards the past tense (Experiment 2), the remaining participants were asked to name them the other way around (Experiment 1 after Experiment 2). The second and third training phase, as described in Experiment 1, were included once more before the change of tense to ensure that participants correctly named the pictures in the appropriate (new) tense.

Stimuli presentation followed the procedures of Experiments 1 and 2.

7.3.2 Results

Again, naming and measurement errors were excluded, as well as reaction times shorter than 200 ms or longer than 1500 ms and latencies deviating more than two standard deviations from subjects mean. 4.7 % of all data were excluded as outliers using the same criteria as described in Experiments 1 and 2. Errors identified as voicekey errors and wrong namings made up 4.5 % of all data, in sum 9.2% of all data were identified as errors leading to missing data. The percentages of errors separated for each tense are given in Table 9.

Table 9. Percentage of missing values (Experiment 3).

	Percentage of missing values		
Type	present	past	total
Naming and measurement	3.1	5.9	4.5
Cut off	3.4	6.0	4.7
Total of missing values	6.5	11.9	9.2

Table 10. Mean Response Latencies (RT, in Milliseconds), Accuracy Proportions (PA, in %) and Absolute Errors (Err), Varied by Regularity, SOA and Distractor (Experiment 3)**.**

	Regularity		SOA				Distractor				Tense	
	reg	**nreg**	**-200**	**-100**	**0**	**100**	**ident**	**neut**	**incon**	**con**	**pres**	**past**
RT	650	676	661	670	665	654	626	655	680	689	653	673
PA	6.9	11.5	8.9	9.7	9.2	8.9	7.7	8.3	10.7	10.0	6.5	11.8
Err	281	472	183	199	189	182	158	170	220	205	268	485

Table 11 summarises the results of Experiment 3.

Table 11. Mean Response Latencies (RT, in Milliseconds, standard deviations in parentheses), Varied by Regularity, SOA, Distractor and Tense (Experiment 3).

	Stimulus onset asynchrony									
PAST TENSE	**-200**		**-100**		**0**		**100**		**M**	
Distractor	**reg**	**nreg**	**reg**	**nreg**	**reg**	**nreg**	**reg**	**nreg**	**reg**	**nreg**
identical	609	638	604	645	628	667	629	661	617	653
	(91)	(82)	(93)	(94)	(90)	(91)	(79)	(84)	(89)	(88)
neutral	656	679	654	706	649	699	637	674	701	730
	(99)	(96)	(92)	(102)	(102)	(93)	(90)	(91)	(140)	(135)
incongruent	658	714	681	715	669	723	665	707	649	689
	(94)	(99)	(97)	(90)	(103)	(125)	(108)	(114)	(96)	(96)
congruent	692	730	703	727	679	698	667	690	685	712
	(116)	(116)	(104)	(103)	(106)	(105)	(113)	(116)	(111)	(110)
M	653	689	659	698	656	696	649	682	654	692
	(104)	(105)	(103)	(102)	(102)	(105)	(99)	(102)	(102)	(104)
PRESENT										
identical	598	617	607	629	617	630	607	631	607	627
	(93)	(95)	(92)	(97)	(95)	(97)	(77)	(94)	(89)	(95)
neutral	640	644	646	644	627	652	636	651	637	648
	(102)	(89)	(94)	(95)	(89)	(96)	(89)	(102)	(94)	(95)
incongruent	651	694	670	693	662	685	650	654	658	682
	(94)	(100)	(101)	(99)	(106)	(104)	(108)	(98)	(103)	(101)
congruent	676	688	691	706	670	692	664	657	675	686
	(105)	(118)	(103)	(110)	(104)	(110)	(120)	(101)	(108)	(111)
M	641	661	653	668	644	665	639	648	644	660
	(102)	(106)	(102)	(105)	(101)	(105)	(102)	(99)	(102)	(104)

An ANOVA was performed using a within-subjects design with four independent variables: DISTRACTOR TYPE (four levels: identical, neutral, congruent and incongruent), REGULARITY of the verbs (two levels: regular or non-regular), TENSE (two levels: present or past) and SOA (-200, -100, 0, +100 ms). Dependent variables consisted of naming latencies and percent accuracy.

The ANOVA yielded significance for all four factors: DISTRACTOR TYPE [F1(3,93) = 92.73, MSE = 4481.68, $p < .001$; F2(3,45) = 144.46, MSE = 1473.72, $p < .001$], REGULARITY [F1(1,31) = 97.04, MSE = 3589.48, $p < .001$; F2(1,15) = 6.61, MSE = 26770.56, $p < .05$], TENSE [F1(1,31) = 22.20, MSE = 10138.86, $p < .001$; F2(1,15) = 80.71, MSE = 1463.58, $p < .001$] and SOA [F1 (3,93) = 3.82, MSE = 4599.40, $p < .05$; F2(3,45) = 8.04, MSE = 1256.32, $p < .001$].

There were interactions between the following factors: TENSE x REGULARITY [F1(1,31) = 20.21, MSE = 2673.41, $p < .001$; F2(1,15) = 12.48, MSE = 2133.93 $p < .01$], SOA x DISTRACTOR TYPE [F1(9,279) = 4.45, MSE = 2746.66, $p<.001$; F2(9,135) = 2.81, MSE = 2320.08, $p < .01$] and SOA x DISTRACTOR TYPE x TENSE [F1(9,279) = 2.16, MSE = 1444.31, $p<.05$; F2(9,135) = 2.02, MSE = 934.77, $p < .05$].

Post hoc analyses of the main effects showed a significant difference between control (identical and neutral) and experimental (congruent and incongruent) distractors, but not between congruent and incongruent distractors (Scheffé test $diff_{crit;\ p<.05}$. = 12.0).

Table 12. Mean Response Latencies (RT, in Milliseconds), Varied by Distractor and Response Latency difference between control and experimental stimuli (Experiment 3).

	Distractor type			
	control		experimental	
	identical	neutral	incongruent	congruent
RT	626	655	680	689
M	641		685	
Effect	**+44**			

While the SOAs -100 ms and +100 ms showed a marked difference, the same could not be said for the -200 ms and 0 ms SOAs (Scheffé test $diff_{crit;\ p<.05}$. = 8.6). See Table 10 above.

The Scheffé-test for the TENSE x REGULARITY interaction ($diff_{crit;\ p<.05}$. = 26.4) revealed a regularity effect in the past tense: non-regular verbs were produced more slowly than regular ones in the past tense. In the present tense they were produced with equal speed (see Table 13).

Table 13. Mean Response Latencies (RT, in Milliseconds), Varied by Regularity and Tense (Experiment 3).

	Regularity	
Tense	**reg**	**nreg**
past	654	692
present	644	660

The interaction DISTRACTOR TYPE by SOA (Table 14) manifests in identical distractors being faster than all other distractors for SOA -200 and -100. Unfortunately, the interaction does not originate from the reaction times of the critical congruent and incongruent distractors. A post hoc Scheffé test for the triple-interaction SOA x DISTRACTOR TYPE x TENSE (Table 15) specifies this finding for the past tense SOA -100 and -200 only: $diff_{crit;\,p<.05}$. = 39.7.

Table 14. Mean Response Latencies (RT, in Milliseconds), Varied by Distractor and SOA (Experiment 3).

	SOA			
Distractor	**-200**	**-100**	**0**	**+100**
identical	615	621	635	631
neutral	654	662	655	649
incongruent	679	689	683	668
congruent	696	706	684	669

Table 15. Mean Response Latencies (RT, in Milliseconds), Varied by Distractor, Tense and SOA (Experiment 3).

	SOA			
PAST				
Distractor	**-200**	**-100**	**0**	**+100**
identical	623	624	647	644
neutral	667	679	673	654
incongruent	685	698	694	684
congruent	711	715	688	678
PRESENT				
Distractor	**-200**	**-100**	**0**	**+100**
identical	608	618	624	619
neutral	642	645	639	643
incongruent	673	681	673	652
congruent	682	698	681	661

Error analysis

Inspection of the Accuracy proportions allows for the presumption of a tense effect (cf. Table 16). An Anova was computed with the factors TENSE, DISTRACTOR TYPE and REGULARITY.

Table 16. Accuracy Proportions (in %, absolute numbers in parentheses), Varied by Regularity, Tense and Distractor (Experiment 3).

		Distractor			
Tense	Regularity	**inc**	**con**	**id**	**neu**
past	**reg**	9.8 (50)	11.7 (60)	6.8 (35)	6.1 (31)
	nreg	18.4 (94)	14.6 (75)	13.3 (68)	14.1 (72)
present	**reg**	5.5 (28)	6.1 (31)	3.9 (20)	5.1 (26)
	nreg	9.4 (48)	7.6 (39)	6.8 (35)	8.0 (41)

The error analysis of all missing values confirmed significant main effects for the three factors: DISTRACTOR TYPE [$F1(3,93) = 7.09$, $p < .001$; $F2(3,15) = 5.06$, $p < .01$], REGULARITY [$F1(1,31) = 47.7$, $p < .001$; $F2(1,15) = 5.6$, $p < .05$], TENSE [$F1(1,31) = 28.9$, $p < .001$;

$F2(1,15) = 24.7$, $p < .001$]. A paired-samples t-test comparing only the congruent and incongruent conditions revealed that the type of critical distractor does not have an effect: $t1(254) = 0.65$, $p = 0.515$, $t2(126) = 0.43$, $p = 0.667$. The analyses of errors revealed that the number of errors was statistically the same in the congruent and incongruent conditions.

7.3.3 Discussion

Experiment 3 strongly resembled the previously described Experiments 1 and 2 in question and method. However, Experiment 3 addressed the influences of tense on the hypothesised abstract regularity node of verbs more closely. Tense was established as within-subjects factor (besides Regularity, SOA and Distractor type).

Although the data of the PWI experiment revealed four significant main effects, naming latencies did not differ regarding the type of critical distractor as in the previous experiments. In fact, participants did process the distractors, as shown by their delayed responses in the experimental conditions compared to the control conditions as before. But the distractors did not induce interference of two simultaneously activated abstract feature nodes in the incongruent condition. There was neither an interaction of Distractor type with Tense nor Regularity as had originally been hypothesised. It seems unlikely, then, that Distractor type is affecting verb production (especially morphological processing). This finding is in sharp contrast to the Bordag & Pechmann (2009) study, demonstrating the psychological reality of conjugation and declension classes and their encoding in Czech. The congruency effect observed in that study was interpreted as a result of the activation of generic grammatical features.

In this experiment we thus replicated the Tense effect, now in a within subjects design. The Tense main effect shows that the production of past tense forms results in longer articulation latencies than present tense forms. One possible explanation is the less frequent occurrence of past tense forms in the language (see section 5). The Tense main effect thus could be interpreted as a pure frequency effect. Frequently accessed words have lower activation thresholds and memory traces and therefore are retrieved faster for production. This is in accordance with the Dual Route Mechanism. Considering the Tense by Regularity interaction, the factor Tense only plays a role for the production of non-regular verbs as proposed because they are assumed to be stored. Non-regular verbs are produced more slowly than regular verbs in the past tense. Regular verbs are not affected by Tense because their word forms can be built online and are not necessarily stored in memory. Generating regularly built word forms does not depend on memory processes (except retrieving the stem) and activation thresholds. This is supported by the observation that present tense naming yielded fewer errors than naming in the past tense and non-regular verbs caused more errors in the past tense than in the present tense, but both failed to reach significance. To sum up, in German, careful disentangling of the frequency and regularity factors is necessary when addressing this issue further.

The Tense x Regularity x SOA interaction demonstrates the time course as found in previous experiments in the same time window, i.e. the interaction is a replication and, hence, methodological changes in the design of the experiment (the addition of the fourth factor Tense) are not the reason for the observed null effect.

Combining the missing Distractor type effect with the Regularity effect in the past tense, it is indeed plausible that no Distractor type effect arises in the *present* tense. Regular and non-regular processing are equal because it is not necessary to distinguish for regularity[40]. But the regularity effect in the past tense gives reason to believe that regularity is cognitively distinctive in the past tense. It remains an unanswered question, then why the expected interaction Regularity x Tense x Distractor type rests insignificant. It seems to be an amazing, paradoxical situation that in spite of the pronounced Regularity effect, naming

40 The majority of verbs follow a completely regular conjugation in present tense.

under different distractor conditions does not lead to interference: the Regularity main effect and the interaction Regularity x Tense point to different processing of regular and non-regular verbs, which consequentially should cause modulation of interference. If that is not the case, it is necessary to modify the hypothesis or, respectively, accept the alternative hypothesis (H0).

So far, we do not have any empirical evidence for an abstract representation of regularity. This is not easy to accept because Bordag & Pechmann got very reliable congruency effects with the same paradigm for conjugational class in Czech which is like regularity in German arbitrary grammatical information with morphological implications. However, the results must be interpreted cautiously, since they may reflect errors by accident. On the other hand, consistent evidence was virtually impossible because of the inconsistency among items with respect to the visibility of their regularity status in the third person present tense: some of the non-regular verbs involved umlaut (e.g. er *gräbt* [he is digging]) whereas others employed alleged regular stems (e.g. er *trinkt* [he drinking]). This difference could have been a determining factor increasing the variances in the data and therefore also contributing to the pattern of results.

Taken together, it seems appropriate to conduct one more experiment, this time further controlling the material for some additional factors. The major change was to redefine and divide non-regular verbs and to include a third type of German verbs, namely hybrid verbs, as explained in the introduction.

7.4 Non-regular verbs revisited

Because of the theoretical importance of the regularity congruency effect, Experiment 4 again tested for the Distractor type and Regularity effect on target naming latencies, using different materials. Linguistically, the classification of verbs in regular and non-regular verbs rests on verbs’ past and/or participle formation. If a particular verb employs a non-regular stem in either one or both forms, the verb is said to be non-regular. The question is whether the cognitive representation corresponds to the linguistic criteria.

It should be pointed out again that some non-regular verbs in Experiments 1-3 were object to umlaut processes, i.e. non-regularities, even in the third person singular present tense (e.g. *graben* - er *gräbt* [to dig – he is digging]). In the material, present tense stimuli therefore show great variability and it cannot be excluded that this is mirrored by great uncertainty in the data. However, present tense performance is quite interesting to examine the representation of verbs in the mental lexicon. To clarify the question clearly, more fine-grained distinctions of verbs in the experimental stimuli are necessary, such as a 'semi-regular' category.

Coming back to the definitions given in the introduction, the German verb system is set up by three basic paradigms. The non-regular paradigm is comprised of hybrid and irregular verbs. This is a stroke of luck because it enables us to explore whether either verb forms are separately, individually stored and marked as regular or non-regular or whether verbs belong to inflectional paradigms which are as a whole regular or non-regular. Hybrid verbs turned out to account for this dissociation. If they were produced in present tense by applying a rule like assumed for regular verbs both should behave alike. In other words, the question in Experiment 4 is whether hybrid verbs and irregular verbs are processed similarly or if morphological processes dissociate within hybrid verbs, i.e. their present (regular) and past tense (non-regular) production. For paradigmatic representation of verbs a tense specific pattern to our results is expected.

7.5 Experiment 4

Experiment 4 aims to clear up the Distractor type null effect and resolve the question of whether regularity is a property of whole verb paradigms, not of individual verb forms.

If it was the regularity of particular word forms instead of paradigms that caused the pattern of the obtained regularity effect for non-regular verbs in past tense only, the same pattern will be found in the replication. For the irregular verb type it is expected that both past and present tense forms are irregular and therefore do not dissociate in reaction times. It is a priori not obvious how hybrid verbs' naming latencies will depend on the involved factors. If past and present tense articulation latencies are separable one can conclude that verb forms are not stored paradigmatically but individually. If present and past of hybrid verbs do not differ, the whole paradigm is marked as hybrid (or irregular, that relation has to be checked on the basis of the data).

It is important to note another aspect of the new hypothesis: regular verbs' present and past tenses and hybrid verbs' present tenses need not necessarily fall into the same group, although all word forms seem to be regular. The reason is that regular verbs use the same stem for both tempora and therefore are more frequent than hybrid verbs' present tense stems. The latter are expected to elicit longer reaction times than the former.

For this purpose the stimulus material was revised and adapted. An experiment was designed that contained all three types of verbs in three accurately matched groups.

7.5.1 Methods

Participants

Eighteen students of the University of Leipzig were recruited for Experiment 4. They were paid for their participation.

Materials and Procedure

To reduce variance in the data, a new and proper set of verbs was built up. In Experiment 4, irregular and hybrid verbs were considered as different verb types for the first time. Until now, they were paid no attention in the current study, as well as in former studies. The three groups were equated in terms of frequency, length, initial phoneme (Pechmann, Reetz & Zerbst, 1989), ablaut patterns and transitivity. Verbs containing allomorphy (ə-epenthesis *bluten, ich blute, ich blutete* versus none in *lachen, ich lache, ich lachte*) were strictly excluded to avoid ə-epenthesis to affect reaction times as it is probably an additional process. Materials were counterbalanced so that each item appeared in each condition. Nine intransitive German verbs were chosen for each group. Actions were depicted in black and white line drawings. Some were taken from Masterson & Druks (1998), but several were designed for this purpose in the same style and comparable complexity.

Word-distractor pairs were neither semantically nor phonologically related and they were incongruent in respect to ablaut patterns (Wiese, in prep.) to keep that factor constant. Distractors belonged to the response set, as before.

In addition to the new set of verbs, a second step to keep the new data clean was a reduction of item repetitions. Morphological processes are sensitive to repetition (Zwitserlood et al., 2002)[41]. Frequently and recently used word forms are assumed to be stored in short term memory and thus easier to name on subsequent trials. If this were the case, there would be no morphological processes to study anymore after repeated occurrence of the stimuli. Further, with multiple iterations, the effect of the distractors might change across blocks. Hence, SOA +100 was skipped, as it did not show any effects in Experiments 1-3[42] and decided to leave out the neutral (xxxxx) control condition. The identical condition was not removed, because participants seem to recognise that distractors are sometimes helpful and therefore read them (Pechmann & Schriefers, unpublished). Additionally, the experiment was split in two identical halves (but with different randomisations). Thus, the design at least permitted to examine whether participants'

41 The authors reported that first occurrence of the stimuli were responded to slower than second or third occurrences which did not differ from each other.

42 Another possible explanation for the insignificance is suggested by the results of a study by La Heij and van den Hof (1995). They discovered that the semantic interference effect size drops with (a) small target sets and (b) repeated presentations of targets.

behaviour changed with repeated occurrences of word distractor pairs.

The presentation of trials proceeded exactly as in Experiments 1-3. Dependent variables were naming latencies and error rates. The primary comparison was between the congruent and incongruent condition like in the previous experiments.

7.5.2 Results

Voice key errors, wrong responses, hesitations and time outs were removed from the data. The data were corrected also for outliers which were reaction times shorter than 200 ms or longer than 1500 ms and values that exceeded two standard deviations from the subjects mean. All in all 9.4% of all data were excluded. The cut off was effective for 5.4 % of all data.

Table 17. Percentage of missing values (Experiment 4).

	Percentage of missing values		
Type	present	past	total
Naming and measurement	4.3	3.7	4.1
Cut off	5.4	5.3	5.4
Total of missing values	9.7	9.1	9.4

Table 18 gives a summary of the mean reaction times for the four factors in Experiment 4.

Table 18. Mean Response Latencies (RT, in Milliseconds), Accuracy Proportions (PA, in %) and Absolute Errors (Err), Varied by Regularity, SOA and Distractor (Experiment 4).

	Regularity			SOA			Distractor			Tense	
	Reg	**hyb**	**irr**	**-200**	**-100**	**0**	**ident**	**incon**	**con**	**pres**	**past**
RT	635	697	707	672	686	677	644	696	694	673	684
PA	3.2	11.6	13.4	8.0	9.3	11.0	9.1	9.1	10.0	9.7	9.1
Err	63	225	260	155	180	213	177	176	195	282	266

The participants can be seen to be faster in the present tense (M=673, SD=106) than in the past tense (M=684, SD=104) and to be faster in the identical control condition (M=644, SD=103) than in both experimental conditions (incongruent M=696, SD=106 and congruent M=694, SD=100, see Table 18). Reaction times for regular verbs (635 ms) are faster than for irregular (707 ms) and hybrid verbs (697 ms). This visual inspection is confirmed by the statistical analyses, which included the four factors DISTRACTOR TYPE (three levels: identical, congruent and incongruent), REGULARITY of the utterance (three levels: regular, irregular, hybrid), TENSE (two levels: present or past) and SOA (three levels: -200, -100, 0 ms).

Table 19 states the results precisely.

Table 19. Mean Response Latencies (RT, in Milliseconds, standard deviations in parentheses), Varied by Regularity, SOA, Distractor and Tense (Experiment 4).

	Stimulus onset asynchrony											
PAST	**-200**			**-100**			**0**			**M**		
Distractor	**reg**	**irr**	**hyb**	**reg**	**irr**	**hyb**	**reg**	**irr**	**hyb**	**reg**	**irr**	**hyb**
identical	597	650	640	620	677	663	612	706	672	610	676	658
	(90)	(114)	(100)	(95)	(107)	(112)	(85)	(107)	(99)	(91)	(111)	(104)
incongruent	649	727	725	666	754	728	654	723	729	656	735	727
	(82)	(106)	(104)	(82)	(106)	(102)	(110)	(109)	(115)	(92)	(107)	(107)
congruent	642	723	722	662	744	723	651	723	722	652	730	722
	(72)	(92)	(108)	(81)	(104)	(96)	(97)	(122)	(110)	(84)	(106)	(104)
M	629	700	696	649	725	704	639	717	708	639	714	703
	(85)	(110)	(111)	(88)	(110)	(107)	(99)	(113)	(111)	(91)	(111)	(109)
PRESENT												
identical	603	647	653	605	665	662	601	681	665	603	665	660
	(84)	(112)	(121)	(100)	(114)	(109)	(90)	(103)	(106)	(91)	(110)	(112)
incongruent	639	722	694	660	717	722	631	717	694	643	709	703
	(91)	(120)	(123)	(87)	(100)	(109)	(103)	(107)	(111)	(94)	(119)	(115)
congruent	655	715	705	652	730	720	626	699	707	644	714	710
	(92)	(111)	(91)	(82)	(103)	(107)	(86)	(120)	(117)	(87)	(112)	(105)
M	632	695	684	639	703	700	619	699	688	630	699	691
	(91)	(119)	(115)	(93)	(109)	(112)	(94)	(111)	(112)	(93)	(113)	(113)

A subject and items ANOVA were performed on naming latencies with DISTRACTOR TYPE, REGULARITY, TENSE and SOA as between subjects factors. The ANOVA yielded significance for all four factors: DISTRACTOR TYPE [F1(2,34) = 67.62, MSE = 4085.17, p < .001; F2(2,16) = 110.20, MSE = 1275.68, p < .001], REGULARITY [F1(2,34) = 162.39, MSE = 3037.14, p < .001; F2(2,16) = 13.87, MSE = 18869.99, p < .001], TENSE [F1(1,17) = 5.03, MSE = 5603.75, p < .05; F2 (1,8) = 18.37, MSE = 991.41, p <.01] and SOA [F1(2,34) = 6.90, MSE = 2107.60. p < .01; F2(2,16) = 9.46,MSE = 902.94, p <.01].

The post hoc Scheffé test shows for SOA ($diff_{crit;\ p<.05.}$ = 9.3) that the reaction times for distractors appearing at SOA -100 ms differ from those appearing at -200 and 0 ms. For DISTRACTOR TYPE ($diff_{crit;\ p<.05.}$ = 12.9), it revealed a dissociation between the identical control condition and the experimental conditions (congruent and incongruent, see Table 20).

Table 20. Mean Response Latencies (RT, in Milliseconds), Varied by Distractor and Response Latency difference between control and experimental stimuli (Experiment 4).

	Distractor type		
	control	experimental	
	identical	incongruent	congruent
RT	644	696	694
M	644	695	
Effect		**+51**	

The REGULARITY main effect stems from a significant difference between regular verbs on the one and hybrid and irregular verbs on the other side ($diff_{crit;\ p<.05.}$ = 11.2, Table 18).

According to the ANOVA there was an interaction between the factors SOA and TENSE [$F1(2,34) = 3.55$, $MSE = 1700.79$, $p < .05$; $F2(2,16) = 4.72$, $MSE = 457.91$, $p < .05$]. The post hoc Scheffé test was significant in neither F1 nor F2 ($diff_{crit;\ p<.05.}$ = 35.4). Resolving the interaction SOA x DISTRACTOR TYPE [$F1(4,68) = 6.68$, $MSE = 1352.09$, $p < .001$; $F2(4,32) = 3.81$, $MSE = 1205.61$, $p < .05$] with a post hoc Scheffé test ($diff_{crit;\ p<.05.}$ = 39.0) reveals that the control condition differs from the experimental conditions at SOA -100 and -200 but not at SOA 0, when picture and distractor emerge simultaneously. This finding contains information about the time course of processing of the distractors and is a replication of the previous experiments. Triple interactions were not significant either. There was also no interaction between the four factors Regularity, SOA, Tense and Distractor type.

Analyzing the first and second half separately to detect a potential repetition effect gave the same results as the omnibus analysis.

A curious finding is the observation that the naming latencies of hybrid and irregular verbs did not differ from each other in both tenses. Not only is the interaction insignificant, but even numerical latency difference is extremely small (Table 21).

Table 21. Mean Response Latencies (RT, in Milliseconds, standard deviations in parentheses), Varied by Regularity and Tense (Experiment 4).

	Regularity			
Tense	**reg**	**irr**	**hyb**	**M**
past	639	714	703	685
	(91)	(111)	(109)	(104)
present	630	699	691	673
	(93)	(113)	(113)	(106)
M	635	707	697	679
	(92)	(112)	(111)	(105)

Hybrid verbs' past and present tense production, as well as their mean reaction times, are much closer to the latencies of irregular verbs than they are to regular ones. As this point aroused interest, it will be followed up on in Experiment 5, as it was not the focus of the picture-word-interference experiment.

7.5.3 Discussion

Experiment 4 was designed to test for the mental representation of regularity with a PWI paradigm. The objection raised against Experiment 3 was met in Experiment 4. Hybrid verbs were introduced as a third verb type to reduce variances in the data through more carefully controlled material.

The results of Experiment 4 point to an influence of the Distractor type, but they do not substantiate the predictions of node-like representation of regularity. The crucial manipulation of the regularity relation between the target and the distractor again leads to no result. Naming in the control condition is significantly faster than in the experimental conditions. Verbs seem to confuse participants, but not by their regularity. The amount of this unspecific interference effect is exactly the same for both experimental conditions. Hence, concerning regularity, there is not enough evidence to decide whether verbs are stored with a generic regularity feature. The null effects in the previous experiments were not due to the material. Carefully checked stimuli in Experiment 4 yielded the same results.

The results obtained in Experiment 4 are important for several reasons. First, they demonstrate that the congruency effect from the first experiments is robustly obscure. Second, the Regularity effect emerged again as highly significant as well as the Tense effect. Only the interaction between both factors revealed in Experiment 3 could not be replicated, which is surprising. Studying Table 18, probably the most striking aspect is that the reaction time differences between the present and past tense flattened. If, as presumed in the discussion of Experiment 3, Tense is crucial for the activation and encoding of regularity in language production, the base for the interaction is missing here.

The Experiments 1-4 show that Regularity is involved in the production of verbs but its representation as supposed as a generic feature node cannot be demonstrated. It must be represented differently as the expected congruency effect like for encoding of gender or declension and conjugation classes was not found. Actually, when dealing with null effects, it could be objected that if the hypotheses are correct, the feature does indeed exist, but the employed experimental paradigm was not sensitive enough to reveal it. The method will therefore be evaluated in the next section.

7.6 Discussion of Experiments 1-4

The Experiments 1-4 did not reveal the expected regularity congruency effect. If the hypothesis about the psychological reality of regularity is correct, the absence of the congruency effect has two main consequences: On the one hand, it casts doubts on the adequacy of the picture-word interference paradigm for the study of the linguistic processes involved in verb production although the paradigm had successfully been employed by Roelofs (1993) and Vigliocco and colleagues (Vigliocco, Vinson, Damian & Levelt, 2002; Vigliocco, Vinson, Lewis & Garrett, 2004; Vigliocco, Vinson & Siri, 2005) studying verb retrieval. In the studies mentioned, semantic interference effects similar to effects obtained by studies concerning nouns were observed in verb naming. On the other hand, the absence of the congruency effect highlights the fact that the encoding of grammatical features is probably so tightly intertwined with morphological processing that studying one (the representation of the regularity feature) ignoring the other may in fact prove to be impossible. The following reasoning proceeds along these two lines.

7.6.1 Critical evaluation of the picture-word interference paradigm

The first and most salient interference measurement was the Stroop task (Stroop, 1935). Over the years, the picture-word interference paradigm was developed as an instance of the Stroop task. In the Stroop task, the participant has to name the colour a word is printed in, while the word itself denotes an incongruent colour (e.g. reading the word *blue* written in *green* letters, one has to say "green"). This results in interference and inhibitory effects reflected by increased reaction times and higher error rates. While one is trying to say the word's colour ("green"), *blue* automatically becomes activated through reading *blue*. Recognizing known written words is a very fast and unconscious process. Automatic actions are very hard to suppress, something that can only be done with cognitive effort. Reading is such an action. Therefore, in the example above, "green" and *blue* compete for spelling out, i.e., the attentional reading process is disrupted by the automatic reading.

The picture-word interference (PWI) paradigm follows the same principles as the Stroop task. In PWI tasks, participants are presented with a picture (target) and a written word (distractor). They are instructed to name the picture, ignoring the word. However, perceiving picture and distractor demands simultaneous processing of both items. Therefore, naming latencies vary as a function of the relation between the target and the distractor (cf. Schriefers et al., 1990; Roelofs, 1992).

Concerning lexical access in language production, a twofold picture regarding interference can be drawn: semantically, it is known that a high number of lexical neighbours causes interference (Schriefers et al., 1990; Levelt et al., 1991). Semantic competitors inhibit each other, i.e. semantic closeness renders lexical retrieval difficult, reflecting the need for deeper processing (gathering information to select the target item). This interference effect is supposed to be lexical, because it disappeared when participants had to categorise the pictures instead of naming them (Schriefers et al., 1990). The phenomenon can be assumed to reflect competition among features of lexical items (Schriefers et al., 1990; Roelofs, 1992; Starreveld & La Heij, 1995, 1996).

On the contrary, the presence of phonological neighbours has been shown to facilitate processing. This phonological facilitation effect, however, occurs because of specifying similar motoric patterns and activity; hence, the target reaches the activation threshold faster (Schriefers et al., 1990; Levelt et al., 1991).

> *"Interference paradigms study how perceptual events interfere with each other [emphasis by the author] by virtue of similarity. The basic idea here is that some form of interference must result when perception and action make use of the same codes at the same time. Action should then be impaired by concurrent perception (sic!), and perception should be impaired by concurrent action. This prediction is not compatible with separate coding and should therefore provide a strong test of feasibility of the common coding approach".* (Prinz, 1997)

Although the above quote concerns action control and planning, Prinz (1997) admits that similar views have emerged for language perception and production [p.133]. Concerning the latter, *common coding* refers to shared representations of grammatical features in different modalities, like gender values that are the same in production and comprehension or – of crucial importance here – the regularity of verbs. Reliable results were obtained for gender (Schriefers, 1993), word class (Pechmann & Zerbst, 2002) and DC/CC (Bordag & Pechmann, 2009).

For the current study, there are manifold reasons that could lead one to believe that the experimental paradigm was not sensitive enough. To claim that the paradigm was not sensitive enough means that distractors were not processed deeply enough to activate the grammatical feature at test. For the proper processing of distractors it is important that

(1) the target and the distractor meet at exactly the right moment (SOA)
(2) sufficient attention is paid to the distractors
(3) linguistically, the level of the picture and the distractor processing are the same (lemma vs. word form)
(4) distractors activate their regularity feature

Judging from personal experience conducting picture-word interference experiments, the SOA time windows used in the present study were narrow enough to at least discover a trend of a congruency effect if it really laid *between* two SOAs (Pechmann & Zerbst, 2002; Pechmann et al., 2004). Additional support comes from the fact that Bordag and Pechmann (2009) presented the target and the distractor simultaneously, i.e. at SOA 0 exploring inflectional processes, and got significant results for a comparable phenomenon[43].

In fact, participants processed the distractors properly as naming latencies were affected by the type of distractor. Comparing experimental and control conditions, naming was fastest with neutral distractors, slower for identical distractors and slowest when congruent or incongruent distractor verbs appeared.

43 By experience, the time window from SOA -200 to SOA +100 was broad enough to ensure simultaneous processing of the picture and the distractor because reading might be faster than production.

Thus, the clear distinction between control and critical conditions proves the perception and processing of distractors.

In picture-word interference tasks, irrelevant input has to be suppressed. In discrete two stage models like the Levelt model (Levelt, 1989; Levelt et al., 1999), only one lemma (the target lemma) will be selected and processed on lower levels. Therefore, it is a legitimate question whether or not distractors are processed on the word form level. An answer is given by WEAVER++ (Roelofs, 1997): Word form perception activates lemmas and word forms in parallel. WEAVER++ has an implemented *input control* and can handle stroop-like tasks. Hence, for the current study, it can be assumed that distractors affect the lemma as well as the word form level. Consequently, all lemma-associated grammatical features should be activated and interfere in case of incongruity.

It is not only necessary that target and distractor are theoretically processed on the same level but the distractors' grammatical features need to be activated properly. Although no definite claims can be made, it is likely that distractors in a picture-word naming task undergo the same operations like the target (also assumed in Bordag & Pechmann, 2009). Putatively, distractors are processed in the same way as the target. That means for the current experiments, that distractors are automatically, unconsciously inflected for third person singular like the target. In consequence of the inflectional processes, it follows that the distractors should have activated their abstract regularity feature. Crucially, both target and distractor are processed on the same levels and have activated their regularity features which were either congruent or incongruent with different implication for the expected interference effect. So far, there is no argument against the sensitivity of the chosen paradigm.

7.6.2 A caveat

The encoding of the regularity feature is probably so tightly intertwined with morphological processing that it encounters difficulties in dissociating lemma level and word form level processes. Morphological processing, e.g. the concatenation of stem and affixes of regular verbs, is assumed to proceed at the word form level but the information about a verbs' regularity status is part of the lemma. In the current study, it is possible that one process overrode the other. The following paragraph will argue that previous studies like Bordag and Pechmann (2009) clearly showed lemma level effects with the PWI paradigm which is not manageable with regard to German regularity.

The PWI paradigm has successfully been used to elicit congruency effects in Czech through the activation of declensional class of nouns and conjugational class of verbs, respectively. Incongruent distractors delayed the articulation. Moreover, Bordag and Pechmann (2009) set up a PWI experiment to elucidate the process behind the DC congruency effect (see section 4.4) to explore whether the observed congruency effect originated on the lemma or word form level. The data favour an interpretation of the congruency effect occurring not on the form level. Instead, the congruency arose on the lemma level because the same influence of declensional class was observed regardless of whether target and distractor were overlapping in form or not. Therefore, it is concluded that abstract features competed for selection. DC is a grammatical property stored in the lexical entry which has morphological implications like regularity. The properties of Czech conjugation, however, did not allow constructing an equivalent experiment with verbs.

For German regularity, an experimental dissociation of lemma and word form processes remains unresolved. From the experimental design employed in Experiments 1-4, it is not clear whether lemma and word form level processes interfered with each other and if they probably cancelled each other out. The German conjugational system does not allow a clear dissection of morphological processing and encoding of grammatical features, nor does the declensional system. As a last resort one could try to elicit regularity congruency effects with a non-verbal variant of the PWI paradigm. As the task is non-verbal, no word forms were involved and the effects could be attributed to the lemma level.

On a more practical note, experimental possibilities in speech production are limited by methodological constraints. Artefacts produced by vocalizations present a great challenge. In particular, the PWI paradigm taps comprehension and production processes in contrary ways. Further research is needed to investigate the influence of comprehension and production on behaviour in PWI experiments.

7.6.3 Intermediate conclusion

The purpose of the experiments reported above was the investigation of the representation of a regularity feature and its time course of activation.

Unfortunately, the critical manipulation failed, since one cannot conclude anything from null effects. However, it is reasonable to further follow up on the assumption that regularity is a lexically specified grammatical feature. Two reasons are:

Regularity is an arbitrary feature that has to be learnt and stored (like gender)

According to the WR both regular and irregular forms are stored in the same mental lexicon and have to be retrieved. The language production system needs information on when the regular route has to be blocked and when it has to be open. Morphological processes have to be triggered.

So far, the data allow only speculations on how regularity as a property of verbs is represented: as the regularity status did not induce morphological interference, it could be represented as a privative feature. Privative features are known from phonology like for example [labial] to describe the place of articulation of phonemes. Privative features are either existent (e.g. [labial]) or absent. It becomes evident that privative features do not have counterparts (e.g. [-labial] and [+labial]) which could cause competition. Regarding regularity, let us assume that only regular verbs are provided with a feature specifying it for *regular*. As there is only one value for the feature, no competition could arise in the experiments and therefore no congruency effect was observable. It could be that there is no *node* representing the verbs regularity status but that regular word forms are marked by a *slot* for the tense suffix which irregulars are lacking. However, this answer is highly speculative.

There is no denying of the robust regularity effect observed in the experiments reported. Regular verbs are produced significantly faster in past and present tense than non-regular verbs. Neither previous studies nor Experiments 1-4 considered whether regularity is represented as a property of individual forms (implicit assumption of DRM) or of whole inflectional paradigms. Hybrid verbs are suitable to test these two hypotheses. This issue is addressed in Experiment 5 once more. To explore the relation between verb type and tense and to figure out processing mechanisms, the experimental paradigm can be simplified.

7.7 Experiment 5

The previous experiments tested whether an interference effect for regularity can be discovered and located on the lemma level. They served to approach an answer about storage and retrieval of verb lemmas. Even though there is a feature, it is still an open question why non-regular verbs are produced more slowly than regular verbs (see section 2.1 and Seidenberg & Bruck, 1990 as cited in Seidenberg, 1992) and whether regularity is represented as a property of individual forms or of whole inflectional paradigms. Therefore, the purpose of Experiment 5 is to address morphological processing issues. Attention is shifted from the lemma level to the word form level and more precisely to the morphological layer.

The widespread view to explain the distinction in articulation latencies of regular and non-regular verbs is the blocking mechanism (see section 2.3.1). The Dual Route account is now challenged by the threefold distinction of verbs in German in regular, hybrid and irregular classes. Hybrid verbs are the object of investigation in the following experiment. It was a simple picture naming paradigm studying inflectional processes from articulation latencies in present and past tense. If articulation latencies reflect different mechanisms the Tense by Regularity interaction and a comparison of processing hybrid verbs to regular verbs are of crucial interest.

For hybrid verbs, the Dual Route Model predicts a qualitative distinction between a rule-governed process in present tense and lexical retrieval of ready-made entries in past tense and no distinction between the present forms of hybrid verbs and regular verbs.

Alternatively, in a lexical entry complexity account, comparable to Lukatela (1980) for language comprehension, it is reasonable to expect the same reaction times for irregular and hybrid verbs in both the past and present tense because both have to select the correct word form out of several possible word forms. Since regular verbs do not have competing word forms, they are produced faster than the former. Furthermore, the expectations include a Tense effect for irregular and hybrid verbs (past slower than present) but not for regular verbs. The reason is that for regular verbs, the same stem is employed in present and past tense.

In fact, Experiment 5 is a follow up of Experiments 1 to 4. Articulation latencies measured in Experiment 4 showed no Tense by Regularity interaction, but instead a main effect of hybrid and irregular verbs opposed to regular verbs. This finding is contradictory to the assumptions of the DRM. For elucidation and replication, a simple picture naming experiment is sufficient. If it succeeds to replicate the previous findings and to find an interaction between the factors Regularity and Tense, the blocking mechanism has to be reconsidered.

7.7.1 Method

Participants

Thirty-six native German speaking students of the University of Leipzig were recruited. They were paid as compensation for their participation.

Materials and Procedure

The same set of 27 black and white line drawings from Experiment 4 was used as experimental stimuli. Pictures depicted the actions of intransitive German verbs. Each of the verbs was classified as regular, hybrid or irregular verbs. The groups were matched for frequency and onset.

Participants were first administered two familiarisation phases. In the first level they saw the stimuli with the correct name of the picture written below in the infinitive. For practice they were asked to produce the infinitive for each target picture. The infinitive was chosen to minimise word form repetitions and to avoid pre-processing before the experimental measurement itself. A second familiarisation level checked whether participants memorised all picture names correctly from memory without picture names written on the screen.

At test, each trial started with a fixation-star appearing in the centre of the screen that indicated that the initial sentence fragment *„jemand"* [*someone*] had to be produced. After the disappearance of the fixation star the picture emerged in the middle of the screen. The depicted action was named in the 3rd person singular present or past tense. Articulation latencies were measured by a voice key. Tense was counterbalanced across subjects and blocked. Participants were instructed which tense was required before each of the two blocks. Each picture was named only once per tense to avoid effects of repetition priming.

Apparatus

The setting was the same as used and described for the picture-word interference experiments.

7.7.2 Results

Incorrect responses were excluded from all analyses. Reasons for exclusion were wrong namings, hesitations during articulation, technical problems with measurements and voice key triggering (exclusion of 13.3 % of the data for these reasons). A cutoff discarded articulation latencies shorter than 200 ms and longer than 1500 ms as well as values plus or minus two standard deviations from the subject's mean. They were handled as missing values. The total of missing values was 13.5 %.

Table 22. Percentage of missing values (Experiment 5).

	Percentage of missing values		
Type	present	past	total
Naming and measurement	12.8	13.8	13.3
Cut off	0.2	0.1	0.2
Total of missing values	13.0	13.9	13.5

Reaction times measured in Experiment 5 can be seen in Table 23.

Table 23. Mean Response Latencies (RT, in Milliseconds, standard deviations in parentheses), Varied by Regularity and Tense (Experiment 5).

	Regularity			
Tense	**irr**	**hyb**	**reg**	**M**
past	638 (185)	619 (171)	480 (106)	577 (171)
present	577 (170)	547 (158)	447 (93)	520 (153)
M	606 (180)	583 (169)	462 (101)	549 (165)

A two-way repeated measures analyses of variance (ANOVA) yielded significant main effects of REGULARITY (three levels), [F1(2,70) = 116.61, MSE = 3579.28, $p < .001$; F2(2,16) = 21.61, MSE = 5312.15, $p < .001$] and TENSE (two levels) [F1(1,35) = 41.41, MSE = 4058.29, $p < .001$; F2(1,8) = 168.14, MSE = 254.98, $p < .001$]. The interaction between REGULARITY and TENSE reached significance by subjects and very scantily by items [F1(2,70) = 6.92, MSE = 1153.38, p < .01; F2(2,16) = 3.64, MSE = 485.99, p = .05]. A post hoc Scheffé-Test ($diff_{crit;\ p<.05}$ = 20.2) revealed that reaction times do not differ between irregular and hybrid verbs and that their articulation latencies depended on the factor tense (production is faster in present tense) whereas that particular tense effect is not significant for regular verbs.

Analyzing error rates as independent variable for the interaction between the two factors Regularity and Tense all missing values, including wrong namings, hesitations, time-outs and cut offs, were taken into consideration (13.5 % Table 21 above).

Table 24. Percentage of missing values, varied by Tense and Regularity (Experiment 5).

	Present	Past	total
regular	3	8	5,5
hybrid	17	13	15
irregular	19	21	20
total	13	14	13,5

The analyses of error rates mirrored those of reaction times with respect to the main effect for Regularity [F1(2,70) = 33,88, MSE = 0.01, p < .001; F2(2,16) =10.06, MSE = 0.01, p < .01] and the interaction between Tense and Regularity for subjects only [F1(2,70) = 5.11, MSE = 0.01, p < .01; F2(2,16) = 2.04, MSE = 0.01, p = .162]. A post hoc Scheffé test ($diff_{crit;\ p<.05}$. = 0.09) resolving the Regularity main effect revealed that non-regular verbs were associated with more errors.

7.7.3 Discussion

Experiment 5 measured articulation latencies for picture naming of actions. Three groups of German verbs – regular, hybrid and irregular – were explored in the past and present tense. Postulating two different mechanisms for the processing of regular and irregular inflection, the DRM cannot account for all data in Experiment 5, in particular not for the fact that even regular forms of hybrid verbs (present tense) are produced more slowly than regular forms of the regular verbs (past and present tense). As the data did not show an interaction with tense for hybrid verbs, it is necessary to revisit the DRM.

Crucially, the present forms of both hybrid and irregular verbs were produced more slowly than (and did not differ statistically from) the regular present forms of the regular verbs. Irregular and hybrid verbs were produced more slowly in the past than in the present tense. Present tense and past tense reaction times did not differ for regular verbs. Since the material has been checked carefully for word form and lemma frequency as well as for other confounding factors, the interaction can only be attributed to a deeply rooted linguistic phenomenon.

The naming latencies of hybrid and irregular verbs did not differ from each other in both tenses. Strikingly, verbs according to their articulation latencies can be split up and subdivided into regular verbs and verbs having at least one irregular form (hybrid verbs and irregular verbs). This consideration goes hand in hand with the two groups as revealed by the Scheffé test. The crucial explanatory factor seems to be the complexity of the lexical entry: if a verb has multiple stems (irregular and hybrid verbs), the retrieval of the appropriate one takes longer than the retrieval of a single stem entry (regular verbs). Regular verbs do not have competing word forms. If for irregular and hybrid verbs two or more word forms are encoded, then one may be selected during morphological encoding. The selection of the current word form is time consuming. Error rates confirm the higher processing cost for irregular and hybrid verbs since more errors occurred for naming of hybrid and irregular verbs independently of tense.

The regularity effect observed in Experiment 5, showing a dissociation between regular and non-regular verb forms, is supposed to occur even without sentential context, as it is caused by the lexical entry complexity that should not change by syntactic context. In general, the results of Experiment 5 are in line with the previous experiments (1-4): The Regularity effect was observed with both the PWI paradigm and the naming task. Comparing the data of the picture-word interference task and the simple naming, the Tense by Regularity interaction might not have been significant in Experiment 4 because the Tense effect was not as pronounced as in Experiment 5. It is possible that the tense effect was evened out in Experiment 4 because of too many item repetitions.

Hybrid verbs' present tense articulation latencies show that regularity cannot be bound to individual word forms as they are superficially regular but dissociated from regular verbs in reaction times. Hence, regularity generalizes on all forms within a paradigm. From a learner's point of view, it is really pragmatic to store and mark verbs paradigmatically either as regular or non-regular. If there is at least one non-regular form in the paradigm, verbs are learnt and treated as non-regular. That makes sense from a learner's perspective.

The following chapter concludes this thesis along these lines and discusses an adaptation of WEAVER++ (Roelofs, 1997). So far, the model is neutral about the question of whether one or two word forms are encoded for non-regular verbs. Possibilities for further research are discussed in the General Discussion (section 8).

8 General Discussion

This dissertation investigated the representation of regularity and the inflectional processes involved in the production of regular and non-regular German verbs. Particularly, the generation of past and present tense stems was explored. So far, the role of regularity has only been explored with respect to past tense or past participle forms, where it is overtly marked in most investigated languages (Pinker, 1991, 1999; Clahsen, 1999; Clahsen et al., 2001). The data presented dispute the Words and Rules Theory (Pinker, 1999) and the underspecified lexical entries assumption by Clahsen (1999). The data are consistent with a model that takes lexical entry complexity into account where competing word forms of a verb determine its processing difficulty.

The present thesis explored three groups of German verbs in the past and present tense: regular, irregular and hybrid verbs. Hybrid verbs in German have completely regular conjugation in the present tense and irregular conjugation in the past tense. The first four experiments aimed at tapping into the activation and encoding of abstractly represented regularity information in speech production. The experiments used the traditional picture-word-interference paradigm to test for a regularity congruency effect. Based on the conjugation class congruency effect in Czech (Bordag & Pechmann, 2009), it was hypothesised that regular and non-regular verbs should interfere more strongly across category than two verbs of the same verb type. Slower RTs in the incongruent condition than in the congruent condition were expected, reflecting competition between abstract grammatical features for regularity. Contrary to this assumption, the critical conditions did not exhibit the expected congruency effect. Nevertheless, all four main effects in Experiments 3 and 4 (for distractor type, regularity, tense and SOA) were significant. Most importantly, the data showed an effect of distractor type. Although this effect was obtained only between experimental and control - not within experimental – conditions, it allowed the conclusion that the paradigm employed was sensitive to the experimental manipulation. The null results in Experiments 1-4 tentatively speak against an abstract representation of regularity as generic nodes.

Neither previous studies nor Experiments 1-4 considered the possibility that regularity may be a property of individual forms (implicit assumption of DRM) or of whole inflectional paradigms. Hybrid verbs are suitable to test these two hypotheses because their regularity status dissociates in past and present tense. Thus, a picture naming task was used in Experiment 5. This task revealed that regular verbs were produced significantly faster than hybrid and irregular verbs. The significant interaction of regularity and tense showed that the past tense naming latencies of non-regular verbs exceeded their present tense naming latencies. However, for regular verbs, past and present tense naming latencies were similar.

Considering the absence of the regularity congruency effect in Experiments 1-4, it seems to suggest that regularity is not – or at least not alone – a generic feature like e.g. conjugation class, although very similar experiments on conjugation class in Czech (Bordag & Pechmann, 2009) supported the idea of a generic feature. A clear congruency effect – longer articulation latencies with differing conjugational classes – in a PWI task was in accordance with generic nodes for verb classes. Bordag and Pechmann (2009) therefore suggested the existence of psychologically real representations of conjugational classes in Czech. The corresponding node for conjugational class is selected for each verb appropriately during grammatical encoding. Abstract class nodes *mediate* the selection of the appropriate ending on the phonological level. In addition, Bordag and Pechmann ensured that the congruency effect does not reflect competition for the phonological form of the appropriate ending. In discrepancy to Bordag & Pechmann (2009), the results presented here did not differ for items paired with distractors sharing the regularity status than for items paired with distractors deviating in regularity.

Comparing naming latencies of both studies at the same level of SOA (0 ms), participants were naming action pictures in Czech at an average of about 100 ms slower in all conditions than German participants. This could be an effect of different subject groups. Alternatively, it may also be that the phonological properties of Czech words require more processing time. Czech permits more complex consonant clusters and has alveolar trills which do not exist in German words. Most syllables in Czech start with consonants (up to four). Czech has also relatively infrequently open syllables of the structure (CV). Preparation and realisation of phonetic plans of consonant clusters take time and cause longer latencies which in turn set up time and ample opportunity for interference to occur. However, the present study used the same method; the results and the evaluation of the paradigm (section 7.6) argue against an isolated methodological cause.

Theoretically, there are parallels between CC in Czech and verb regularity in German. Both are features determining the inflection of verbs. However, the data presented above argue against such an assumption. German verbs seem not to be organised in classes or, more likely, the classes are not mentally represented in the form of generic nodes as was predicted. Hence, the German conjugation system deviates from the Czech conjugation system on some major points. Although German verbs' regularity status classifies and clusters verbs into some kind of classes, these classes are different from Czech CCs. This raises the question of which properties of Czech verbs may account for this difference? Most probably, the experiments explored different levels of representation. CCs in Czech are a subordinate ordering principle and exceptions (i.e. non-regular forms) can be found *within* CCs. In German the reverse is true: German verbs are primarily regular or non-regular and non-regulars form smaller sub-classes (Wiese, in prep.).

Referring to Bordag and Pechmann (2009), regularity is an internal feature like gender or CC in Czech. All three are lemma-specific, context independent, have morphological implications and are indispensable features. Regularity cannot be bypassed or neglected in production as could be done for gender (e.g. La Heij et al., 1998 reporting absent gender congruency effects on Dutch bare noun naming). Like CCs, regularity is not dispensable, because in order to inflect a verb it is first necessary to know which processes to start. These attributes have implications on whether and how regularity is represented. The lack of evidence for explicitly represented regularity information in the mental lexicon constitutes a puzzle: which mechanism triggers the decision to handle a stem as either regular or non-regular? Since regularity is an arbitrary feature[44], it can only be lexically organised. As the regularity status did not induce morphological interference in the experiments reported above, it seems to be inherently represented with the structure of the lexical entry of each verb.

For combining these conclusions with the research cited in chapter 1.3 about typologically different inflectional systems, it is helpful to reconsider the typological dimension. One frequently applied criticism challenging generativist explanations for linguistic phenomena is that it may not be possible to find universal mechanisms of lexical organisations across languages (cf. Lukatela et al., 1980). Lukatela et al. (1980) investigated the lexical representation of Serbo-Croatian nouns in a lexical decision task and found considerable differences between Serbo-Croatian and English. Both are Indo-European languages and therefore related to German. English and German belong to the Germanic language family and Serbo-Croatian is a member of the South-Slavic branch. As Czech also belongs to the Slavic branch, German and Czech participants do not need to behave in the same way in similar tasks.

Even though the experimental paradigm did not reveal the expected congruency effect, it yielded reliable regularity main effects in Experiments 2-5. The analyses revealed that regular verbs in the present and past tense were produced significantly faster than all other verbs. Crucially, the naming latencies of hybrid and irregular verbs did not differ in both tenses. Indeed, the results reported here

44 While most German verbs are regular, many of the most frequent verbs are non-regular. Contrariwise, almost all low-frequent German verbs are regular and all new verbs are conjugated regularly. Though it is a really interesting question whether frequency or pragmatic factors impose pressure on the vocabulary or the language processor, this work cannot contribute to this issue (the reader is referred to Schmidt, Langner Helmut & Wolf, 1996: 191–203, 241–253, 309–323).

for irregular verbs converge with those obtained in previous experiments. Prasada et al. (1990) and Seidenberg & Bruck (1990) tested whether regularity affects articulation latencies and suggested Dual Route processing and connectionist networks, respectively. As mentioned in the introduction, this thesis is not foremost a contribution to the past tense debate (e.g. Prasada et al., 1990; Seidenberg & Bruck, 1990). Nevertheless, the reaction times to German hybrid verbs in the present tense are a challenge for single route models. As in the present tense, hybrid verbs are supposed to share features with regular verbs, both should be produced equally fast. In fact, since hybrid verbs are produced as slow as irregular verbs, the obtained results are in conflict with single route models as well. Similarly, the past tense results reported converge with those obtained in previous experiments designed to test Dual Route Models (Clahsen, 1999; Clahsen et al., 2004; Marcus et al., 1992) in that they demonstrate the dissociation of regular and non-regular verbs. Concerning the Words and Rules Theory, a crucial flaw is that many aspects cannot be easily applied to the processing of German and especially German present tense verbs.

According to the Words and Rules Theory (Pinker, 1997, Pinker, 1999; Clahsen, 1999), regular forms are composed of a stem and suffixes whereas irregular forms are stored as ready-made entries. Regularity is represented as a property of individual forms (implicit assumption of DRM). To produce non-regular verbs, the regular route is pre-empted by the non-regular route. This is called *blocking* and delays the production of non-regular verbs. The important conclusion to be drawn from criticisms against the blocking mechanism (section 2.3.1) is that German provides a test case for the blocking mechanism if one is to consider not only past tense, but also present tense. In German present tense, (er) *beiß-t* [he bite-s] and (er) *lach-t* [he laugh-s] are both built regularly. However, *beißen* [to bite] is non-regular and *lachen* [to laugh] is regular in the past tense. The crucial finding of longer reaction times for hybrid verbs than for regular verbs in the present tense in the current study is challenging for both Pinker (1999) and Clahsen (1999): Both claim fully regular processing for regular words and do not differentiate between present and past tense. However, it was found in the present thesis that the superficially regular inflection of hybrid verbs affects production latencies equally strong as the irregularity of verbs. In short, neither blocking nor Dual Route accounts can fully explain the data presented here.

Clahsen (1999) did not consider present tense processing and therefore no claims about present tense are made in his work. It will be shown in the following that non-regular verbs' lexical entries are not only underspecified for past tense word forms but also for present tense. Janssen (1999) found initial evidence for irregularity in present tense in Dutch; the current study underlines the validity of his claim.

Still, the following perspective provides a more promising line for the interpretation of the current results: irregular and hybrid verbs have more than one potential stem. According to this criterion, verbs can be split up and subdivided into regular verbs on the one hand and *non-regular* verbs having at least one irregular form (hybrid verbs and irregular verbs) on the other hand. The classification of German verbs in two instead of three classes of verbs goes hand in hand with the current psycholinguistic results. Even though a rule could be used to generate present tense forms, hybrid verbs follow processing principles of non-regular verbs (assuming articulation latencies reflect processing mechanisms; Donders, 1868, 1969). Hence, no individual forms of hybrid verbs are classified as regular or non-regular, but rather the whole paradigm of a particular verb. As this distinction has not been made before, this had to be shown first. The crux of the matter: their typical and common characteristics are stem vowels like /ei/ in *beißen* and /ie/ in *biegen* that do not have fronted counterparts and therefore cannot mutate to umlaut. Their nature is irregularity and so they are listed together with irregular verbs in German dictionaries (Kunkel-Razum, 2006).

Non-regular verbs are intrinsically marked as non-regular. They are psychologically distinct from regular verbs in that their lexical entries are more complex. More precisely, regular and non-regular verbs' lexical entries differ concerning their complexity at the level of the word form. Processing proceeds in similar ways at the lemma level, it is likely that the origin of the latency differences can be located on the word form level where for non-regular verbs multiple stems are available. These stems are not yet inflected for person and number.

Consequently, the aspects emphasized allow the conclusion that if a verb has multiple stems (irregular and hybrid verbs), the retrieval of the appropriate one takes longer than the retrieval of a single stem entry (regular verbs). Although hybrid verbs are superficially regular in the present tense, the present experiments demonstrated that they form a single group with irregular verbs. It can be seen in Figure 7 that non-regular verbs have several word forms available to choose from.

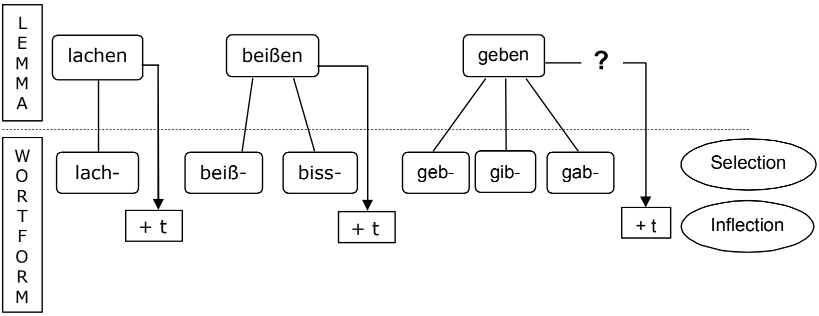

Figure 7. Complexity of lexical entry. Simple and complex German verbs.

It is conceivable that it is not *blocking* that prolongs the reaction times for non-regular verbs, but an additional stem selection process. The following assumptions cannot be directly drawn from the data, but are in the scope of interpretation. The regularity effect is indicative of a *selection* effort in the non-regular inflection. The generation of the correct word form is more costly for non-regular verbs because more stems are related to one lemma. Ranging from two to five potential word forms (including subjunctive), non-regular verbs can posses a veritable pool of stems, e.g. *brechen* [to break]: *brech*-e, *brich*-st, *brach*-∅, ge-*broch*-en, *bräch*-e. Hence, compared to regular verbs, there is *selection* in the access of non-regular verbs as opposed to the mere lexical *retrieval* of a single stem from a single lemma. Most importantly, this argument against blocking is neither a descriptive-linguistic nor a deductive, but a cognitive one. Having more than one potential stem in the lexical entry, processing costs for non-regular verbs are higher because of the selection of the appropriate stem. The selection mechanism dispenses with the blocking mechanism and gets around the impediment of the general principle of mental grammar to creatively compute complex utterances - an extremely powerful device for communicating.

The lexical entry complexity model proposed here has substantial similarities with the Satellite model of Lukatela (Lukatela et al., 1980), although the Satellite model was initially conceived for the representation of nouns. For these, the model locates the nominative as the base form in the centre, inflected word forms (satellites) are arranged as nuclei around it. A parallel architecture can be envisaged for the representation of German verbs. Potential verb stems (e.g. *brech-*, *brich-*, *brach-*, *-broch-*, *bräch-*) are ordered around a base form, e.g. the infinitive (e.g. *brechen* [to break]) or the first person present tense (e.g. (ich) *brech-e* [(I) break])[45]. As regular verbs only have one stem, they are atomic. Crucially, the more satellites a verb has, the more difficult it is to retrieve its correct word form. However, the Satellite model is a very uneconomic variant of lexical representation. Verb paradigms in German have more individual forms than nouns do (six per tense and mood vs. four cases per singular and plural), so a full representation of inflectional paradigms produces a lot of redundant information[46]. Furthermore, as a consequence of full listing, one would expect numerous suppletive forms in any language lacking German verbal inflection apart from *sein* [to be] and *haben* [to have]. The model proposed here will account for economy principles and subregularities within non-regular inflection.

The representation of non-regular verbs is best explained and modelled in terms of underspecification of lexical entries. In theoretical linguistics, underspecification is a phenomenon where certain features are not represented in the underlying structure, but

45 Lukatela's argument for exposing the nominative in the centre were significantly shorter reaction times to that particular form. I am not aware whether the infinitive of any other inflected form is faster than others. To elaborate the Satellite model for verbs, all inflected forms would have to be tested to find the base form.

46 Except for suppletive paradigms like sein [to be].

are unequivocally derived in an incremental process. This proposal is consistent with Clahsen (1999), but will be extended to present tense. Underspecification theories (e.g. Minimalist Morphology, cf. Wunderlich, 1996; Clahsen, 1999; Distributed Morphology, cf. Halle & Marantz, 1993) hold that features should only be underspecified if their values are predictable. For example, English front vowels (/i, ɪ, e, ɛ, æ/) are unrounded; hence, it is not necessary for these phonemes to include the distinctive feature [−round], because all [−back] vowels are [−round] vowels. This principle inspired the basic architecture of lexical entries for non-regular verbs in Clahsen's (1999) approach: it assumes internally structured lexical entries in form of feature pairs of phonological and morphological information. However, the new conception of structured underspecified lexical entries is characterised by omission of features in the mother node (cf. Clahsen, 1999, underspecified subnodes). Subnodes are incrementally specified instances of the mother node. Mother node and subnodes are complementary templates. The mother node provides one or more slots which have to be filled by one of the related subnodes. Slots are filled while generating the intended word form. Information is not inherited but mother node and subnodes complement another. Compare the lexical entry for the irregular verb *singen* [to sing], as shown below:

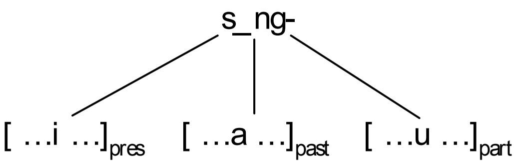

Figure 8. Lexical entry of the hybrid German verb singen [to sing].

The tense-feature is conceptually specified. A subnode is selected according to the specific tense value. With the selection of the appropriate subnode, the missing vowel can be inserted in the mother node. Non-regular verbs mainly exhibit vowel changes. Selecting the subnode takes time and explains the regularity reaction time effect as this cost does not apply to regular verbs. Subnodes are instantiations of the mothernode, which are inserted at the level of word form.

Nevertheless, the distinction between regular and non-regular verbs still requires the corresponding distinction of two qualitatively different morphological processes (cf. Pinker, 1999, and others). The data presented here showed that regular and non-regular verbs were differently affected by the tense of an utterance. The interaction effect observed in Experiment 5 demonstrated a slowing down in past tense naming of irregular and hybrid verbs but not of regular verbs. Regular verbs take only one stem in both tenses and add the appropriate suffixes. As regular verbs employ the same stem in either tense, no RT difference is expected. Non-regular verbs, however, employ special past tense stems. These are used infrequently because of the generally low discourse frequency of past tense in German (see chapter 5: 15 percent past tense utterances). Highly frequent subnodes (e.g. present tense) are activated much easier than low frequent ones (e.g. past tense). The observed tense effect traces back to this fact. Thus, the tense effect of non-regular verbs may be a hidden frequency effect and also confirms two different morphological processes for regular and non-regular verbs. Still, in a modified version, the Dual Route Mechanism can capture German verb production. To produce a regular verb, the tense suffix is activated together with the stem, i.e. the null morpheme in present tense and –te for past tense. Stem and suffix need to be concatenated subsequently. Hence, regular word forms are computed using two morphemes (word form and tense suffix) and the operation merge. This mechanism resembles the one proposed by Pinker (1999).

The assumption of separate lexical entries for each non-regular form has to give way to the idea of underspecified lexical entries of non-regular verbs (see Discussion of Experiment 5; Clahsen, 1999). Lexical entries of non-regular words do not contain full word forms because this would multiply shared information (e.g. s, n, g, in the example above), which would be quite redundant. German features much regularity among non-regular inflection. Some researchers even assume subclasses like *sinken-sank-gesunken* and *trinken-trank-getrunken* (Wiese, in press). The subnodes of underspecified lexical entries introduced above may visualise the relatedness of subclasses of verbs: *sinken-sank-gesunken* and *trinken-trank-getrunken* share the same subnodes. Subnodes are finally inserted in different mother nodes. The structure clearly prohibits full listing.

It is important that previous psycholinguistic data can be explained with the lexical entry complexity account. Relevant questions here are: (1) How, for example, is it possible to explain the anti-frequency effect of regular verbs (Clahsen, 1996) without blocking?; (2) Why do children over-generalise the formation of regular verbs by applying the rule to non-regular verb stems?; (3) Why do most speakers of German not produce *beißte* as preterite of *beißen* [to bite]?; (4) Why are new words in a language inflected regularly?

The answer to the first question is that high frequent regular verbs' lexical entries are also complex. They embody both one decomposed and one full form for the purpose of immediate retrieval of very frequent forms. The appropriate form has to be selected from several forms which takes time. The phenomenon of over-generalisation of children traditionally has been explained as a phase in language acquisition of becoming aware of rules and mastering their application. In the selection account, rules exist further on. They have to be learnt and applied to regular verbs. At the age in which children overgeneralise the rule to non-regular verbs, they have not yet learned the particular non-regular verb form; however, they know the concept of the verbs and its infinitive. As there is no stored word form to retrieve, they apply the rule to the infinitive which is available.

The past tense stem of *beißen* is *biss*. The lexical entry of *beißen* contains a mother node [b_] and a subnode [… iss …]$_{past}$, which is unique in its past tense feature and can be inserted in the mother node template. Processing is triggered by the structure of the lexical entry. Mother node and subnode map onto each other. There is still a Dual Route architecture but the new model stipulates rules on both routes. New words in a language are inflected regularly by *add – suffix* rules because new words do not have a lexical entry from which non-regular forms can be generated. Then, for example, the past tense of a new verb is computed because the rule add *–te* can apply to the new root.

Before closing this discussion, the implications of the current results for language production models will be considered. The theoretical considerations together with the empirical data allow for the formulation of a comprehensive hypothesis concerning the production of regular and non-regular verbal inflection. In particular, the focus is on the Levelt model (Levelt, 1989; Levelt et al., 1999), because the hypotheses were mainly derived from its architecture. The emphasis is on the preparation of past and present tense regular and non-regular verb stems for articulation. Both types of verbs are supposed to inflect tense marked stems for person and number alike though this is in need of further investigation. The crucial adaptation is to integrate the selection mechanism and to dispense with the blocking mechanism (Pinker, 1999).

Foremost, the adaptation of the Levelt model has to account for the fact that structural complexity of lexical entries renders the selection of correct word forms more difficult. In addition, the adaptation has to locate the application of rules within the model. All in all, this proposal is also a modification of the Words and Rules Theory (Pinker, 1999) and its implementation inside the complex production process as represented in the Levelt Model under consideration of underspecified lexical entries.

Figure 9 shows the full model of lexical entry complexity based on the Levelt model, but adapted to deal with both the previous and the current data.

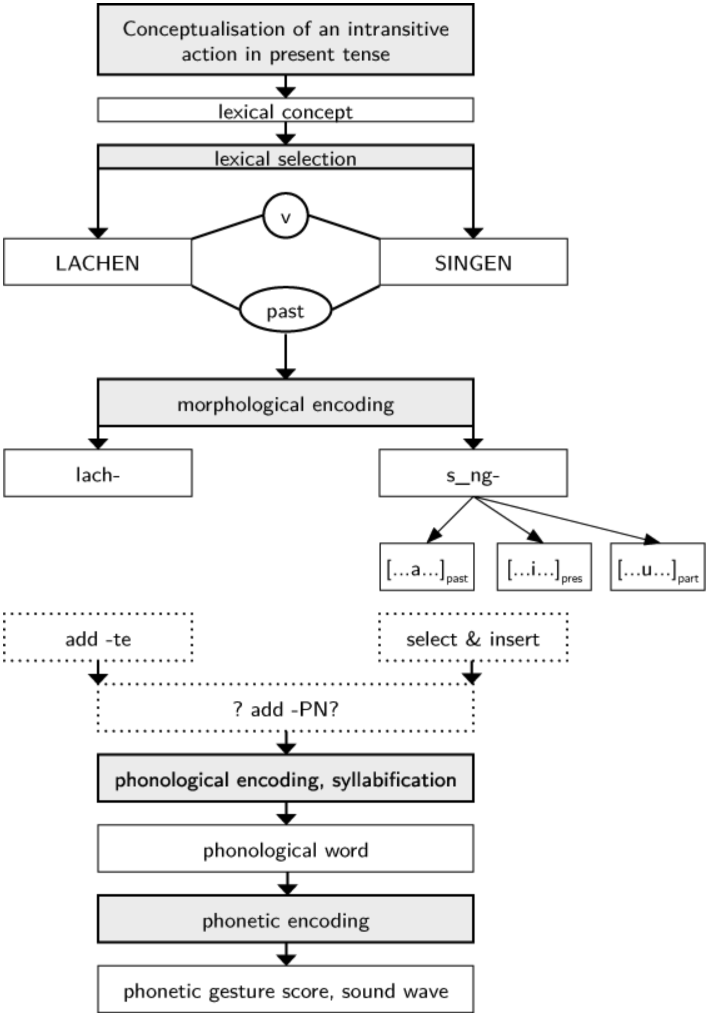

Figure 9. Generating the past tense of *lachen* (reg) [to laugh] and *singen* (nreg) [to sing].

For present tense generation, the past feature is deactivated but the present tense node is activated instead. Further, -∅ instead of –te and $[\ldots i \ldots]_{pres}$ become available. They do not start by default and in parallel, unlike established in the Words and Rules Theory. No blocking is assumed, but time-consuming selection and control processes.

Tense is conceptual information and is activated during the conceptualisation of the message. After conceptualizing the message, corresponding verb lemmas are activated. The tense information is represented as a diacritic feature at the lemma level (Levelt et al., 1999). If a past tense sentence is intended, the PAST diacritic will be activated together with, for example, the verb SINGEN. Lemmas and diacritic values are linked to corresponding morphemes. At the word form level, two nodes are involved in the production of regular verbs: the root and the tense suffix. Both are concatenated by a rule merging the constituents. Non-regular verbs activate their complex lexical entry. The Levelt model can handle selection at the word-form level. Its implementation in WEAVER++ is neutral about the question of whether one or two word forms are encoded for non-regular verbs. If two forms are encoded, one of these may be selected during phonological encoding. Non-regular verbs activate the template and insert the vowel specified for the intended tense: a *select & insert* rule applies and rule-driven concatenation takes place at the word form level.

In the next step of the process, according to the revised model, person and number suffixation brings together the processing mechanisms of regular and non-regular verbs, the hypothesis being that inflection for person and number proceeds similarly for both verb types. Suffixes for person and number are attached to the stem in any case, according to the feature specified conceptually. A specific rule applies to add the inflectional ending for person and number to the tense marked stem. Phonological encoding follows.

The discussion demonstrates the interplay of *representation* vs. *processing*. Regularity must be mentally represented information that triggers rules. In fact, both regular and non-regular verbs are generated by rules. Rules are *lexical procedural knowledge* (Levelt, 1989:185) combining roots and morphemes to tense marked stems and, finally, fully inflected word forms.

It is not competition, but complexity that renders correct selection of inflected word forms more difficult. The lexical entry complexity account predicts long RTs for inflected forms throughout non-regular paradigms not only for superficially visible non-regular word forms. Hence, it predicts the processing advantage of regular verbs also for subjunctive ("Tom sagt, jemand *lache*." [Tom says somebody laughes]) and the German present tense participle (*lachend* [laughing]). Subjunctive and present tense participle are conjugated completely regularly. However, non-regular verbs' lexical entries are more complex. Although all forms of subjunctive and present tense participle are superficially regular, according to the theory of lexical entry complexity, non-regular forms should yield slower responses. Moreover, the selection may be more difficult with high similarity. Further exploration of the selection mechanism is conceivable with suppletives in comparison to irregular verbs, the former being less similar to each other than irregulars. Therefore, reaction times should be shorter. Whether the inflection for person and number proceeds similarly across regular and non-regular paradigms is in need of further inspection.

The research reported here may also establish important new assumptions concerning noun phrase production. The linguistic aspects and the proposed cognitive mechanisms might be similar for the type of memory representation which I proposed for regular and non-regular verbs. Nouns in plural either have null morphemes [Segel - Segel], umlaut [Vater - Väter], Suffix [Auto - Autos] or Suffix plus umlaut [Baum - Bäume]. Hence they differ in their number of possible stems. A successful replication of the observed effects with nouns may account for a general cognitive mechanism and could tease apart the influence of person and number encoding. If the effect shows up in singular where no umlauting occurs, it can be concluded that it is not a phonological process (cf. Penke, 2006) that delays naming. Then, the processing disadvantage of non-regular nouns can only be attributed to the selection of one stem out of multiple stems.

One consequence of a class-wise representation of verbs with respect to agrammatic aphasic patients is that if they have a disorder in the generation of verb forms, either because of an inflectional or a lexical retrieval deficit, the production of inflected verbs should be impaired in either tense, not only in a particular one.

The experiments presented in this thesis investigated the representation of regularity and the inflectional processes involved in the production of regular and non-regular German verbs. Three groups of German verbs were explored in past and present tense to address these questions. Existing models did not explicitly address the question how regularity is represented and whether regularity is represented as a property of individual forms (implicit assumption of DRM) or of whole inflectional paradigms. The experiments investigated hybrid German verbs to test these two hypotheses. The results of the current experiments do have important consequences for the Word and Rules Theory mentioned in the theoretical part of this thesis (Pinker, 1999). In sum, the present thesis provides data supporting that regularity is paradigmatically, inherently coded in lexical entries. Rather than through abstract node representation, the paradigmatic effects can be explained as a resulting from complexity of lexical entries. For defining complexity, it has to be differentiated whether a verb has one or multiple stems. If a verb has multiple stems (irregular and hybrid verbs), the retrieval of the appropriate one takes longer than the retrieval of a single stem entry (regular verbs). In other words: the complexity account outruns the blocking mechanism of the Words and Rules Theory (Pinker, 1999). Importantly, shedding light on the past and present tense of German verbal inflection, this thesis gains a more complete picture of mental lexicon and grammar. Still, at this point, it is only possible to complement the speech production model of Levelt (Levelt, 1989, 1999) along the temporal axis. It will be promising to see whether there exists a mechanism of language control for the selection of one particular stem or the suppression of remaining stems, respectively. Last but not least, future research will have to investigate neuroanatomical correlates of selection processes and whether distinct brain regions are activated during production of regular and non-regular verbs.

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Appendix

Stimuli for Experiment 1, 2 and 3

regular verbs – 3rd present, 3rd past

angeln [to fish] – er angelt, er angelte
beten [to pray] – er betet, er betete
betteln [to beg] – er bettelt, er bettelte
bluten [to bleed] – er blutet, er blutete
bohren [to drill] – er bohrt, er bohrte
klopfen [to knock] – er klopft, er klopfte
knien [to kneel] – er kniet, er kniete
kochen [to cook] – er kocht, er kochte
lachen [to laugh] - er lacht, er lachte
läuten [to ring] – er läutet, er läutete
niesen [to sneeze] – er niest, er nieste
schaukeln [to swing] – er schaukelt, er schaukelte
tanzen [to dance] – er tanzt, er tanzte
weben [to weave] – er webt, er webte
weinen [to cry] – er weint, er weinte
winken [to wave] – er winkt, er winkte

non-regular verbs – 3rd present, 3rd past

beißen [to bite] – er beißt, er biss
essen [to eat] – er isst, er aß
fahren [to drive] – er fährt, er fuhr
fangen [to snatch] – er fängt, er fing
fliegen [to fly] – er fliegt, er flog
gießen [to water] – er gießt, er goss
graben [to dig] – er gräbt, er grub
lesen [to read] – er liest, er las
rennen [to run] – er rennt, er rannte
schieben [to push] – er schiebt, er schob
schlafen [to sleep] – er schläft, er schlief
schwimmen [to swim] – er schwimmt, er schwamm

singen [to sing] - er singt, er sang
springen [to jump] – er springt, er sprang
tragen [to carry] – er trägt, er trug
trinken [to drink] – er trinkt, er trank

Stimuli for Experiment 4 and 5

regular verbs – 3rd present, 3rd past

bauen [to build] – er baut, er baute
betteln [to beg] – er bettelt, er bettelte
bohren [to drill] – er bohrt, er bohrte
gähnen [to yawn] – er gähnt, er gähnte
klopfen [to knock] – er klopft, er klopfte
küssen [to kiss] – er küsst, er küsste
lachen [to laugh] - er lacht, er lachte
tanzen [to dance] – er tanzt, er tanzte
tauchen [to dive] – er taucht, er tauchte

hybrid verbs – 3rd present, 3rd past

beißen [to bite] – er beißt, er biss
biegen [to bend] – er biegt, er bog
gießen [to water] – er gießt, er goss
greifen [to grasp] – er greift, er griff
kneifen [to pinch] – er kneift, er kniff
kriechen [to crawl] – er kreicht, er kroch
pfeifen [to whistle] – er pfeift, er pfiff
trinken[to drink] – er trinkt, er trank
ziehen [to pull] – er zieht, er zog

irregular verbs – 3rd present, 3rd past

blasen [to blow] – er bäst, er bließ
braten [to fry] – er brät, er briet
brechen [to vomit] – er bricht, er brach
dreschen [to thresh] – er drischt, er drosch
essen [to eat] – er isst, er aß
graben [to dig] – er gräbt, er grub
lesen [to read] – er liest, er las
tragen [to carry] – er trägt, er trug
treten [to kick] – er tritt, er trat

The incredible productivity and creativity of language depends on two fundamental resources: a mental lexicon and a mental grammar. Rules of grammar enable us to produce and understand complex phrases we have not encountered before and at the same time constrain the computation of complex expressions. The concepts of the mental lexicon and mental grammar have been thoroughly tested by comparing the use of regular versus non-regular word forms. Regular verbs (e.g. walk-walked) are computed using a suffixation rule in a neural system for grammatical processing; non-regular verbs (run-ran) are retrieved from associative memory. The role of regularity has only been explored for the past tense, where regularity is overtly visible.
To explore the representation and encoding of regularity as well as the inflectional processes involved in the production of regular and non-regular verbs, this dissertation investigated three groups of German verbs: regular, irregular and hybrid verbs. Hybrid verbs in German have completely regular conjugation in the present tense and irregular conjugation in the past tense. Articulation latencies were measured while participants named pictures of actions, producing the 3^{rd} person singular of regular, hybrid, and irregular verbs in present and past tense. Studying the production of German verbs in past and present tense, this dissertation explored the complexity of lexical entries as a decisive factor in the production of verbs.

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