An ERP-study of German ‘irregular’ morphology

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Abstract

The plural morphology of German is characterised by five different plural allomorphs (\textendash{}(e)n, \textendash{}e, \textendash{}er, \textendash{}s, zero), partly combined with changes in the vowel (umlaut). While in former studies the \textendash{}s plural allomorph is identified as the regular plural, the remaining forms are categorised as irregular. These observations have been discussed within the framework of the dual mechanism model. One component contains a rule for regular inflection; it provides the default. The second component is designed as a network and hosts irregular plural forms. However, as noted by several linguists, the so-called irregular component of German plural morphology is more structured and contains more predictable plural forms than the dual mechanism model predicts to be the case. Therefore, some plural forms should be less dependent on a network system. Using the technique of event-related potentials, cognitive processing of different irregular German plural allomorphs is investigated in this study. Comparisons include irregular allomorphs with low and high predictability, i.e. true irregulars were compared to subregularities. Indeed, the plural forms identified as subregulars showed a difference in processing by inducing a reduced N400 over right posterior medial electrodes. Up to date, the dual mechanism model treats different so-called irregular forms alike. But in light of these new findings, the network component of the dual mechanism model needs to be refined.

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1. Morphological theory, psycholinguistic models, and recent empirical evidence

The description of morphological processes, the principles by which complex words are formed, has always been a challenge to theoretical linguistics as well as to psycholinguistics. One of the very traditional descriptions, taken over into theoretical linguistics, uses the format of rules. Rules state how a form A is changed into a form B in the context of a specific (e.g. phonological) environment (Chomsky & Halle, 1968). A completely different kind of theory and modelling arose within the framework of connectionism by developing computer models which mimic human language processing in analogy to human neural networks (parallel distributed processing, PDP; Rumelhart & McClelland, 1986). The guiding principle is a frequency-based pattern-matching association. Since the original PDP model of Rumelhart and McClelland, few network systems also were tested on German word lists, among those Goebel and Indefrey (2000), Nakisa, Plunkett, and Hahn, (2000), Hahn and Nakisa (2000), Westermann (2000a,b), and Westermann and Goebel (1995). Although many of the modern networks were able to compensate the disadvantages of the original model by Rumelhart and McClelland, they still have certain short comings (for a detailed discussion compare Sonnenstuhl-Henning, 2003).

A third proposal which is known as the framework of the dual mechanism model (Pinker & Prince 1988, 1994) combines the above mentioned concepts. In this model, two distinct systems generate two distinct linguistic phenomena. The first one hosts rules for generating predictable forms (default forms). For unpredictable, i.e. the irregular, forms the second system is at work. It is designed as a storage mechanism, a network from which each single inflected form can be retrieved. Note that instead of frequencies, phonological similarities between word forms (rhymes) provide the glue building up the connections between single entries. However, as will become obvious in the next section, the dual mechanism model needs further refinement with respect to the storage component, because several subregularities within the group of irregulars are not adequately treated by this latter part of this model.

In the following, in Section 2 we will first outline some peculiarities of German plural formation and some previous relevant studies on the cognitive representation of these. We will then report on an EEG study that is designed to test a certain aspect of the dual mechanism model: the network component hosting irregular inflected forms. In particular, we concentrate on the distinction between words that underlie inflectional processes, which we call subregularities and words which are truly irregular items. Subsequently, we will discuss if and in what way this part of the dual mechanism model can match the facts of the German plural system.

2. The models and German plural morphology

The plural forms of English nouns are formed by either adding an -s to the singular form (desk–desks) or by a number of unpredictable internal changes, applying to a very small number of high-frequency words: foot–feet, sheep–sheep, child–children. In contrast to English, German plural morphology offers a range of relatively frequent ways of forming
the plural of nouns: five different plural affixes, (-∅, -e, -er, -(e)n, -s) and an umlaut process: see Adler/Adler-∅ ‘eagle + Pl’, Garten/Gärten-∅ ‘garden + Pl’ Stein/Stein-e ‘stone + Pl’, Hand/Händ-e ‘hand + Pl’, Muschel/Muschel-n ‘shell + Pl’, Schal/Schal-s-‘scarf + Pl’). Since the umlaut process as well as the alternation between -(e)n and -n may be described as independent phonological processes, these two phenomena will not be discussed any further here (for details see, e.g. Wiese, 1987, 2000).

The complexity of German inflectional morphology offers an ideal case for testing a morphological system with respect to the psychological status of regularities and irregularities. Applying each of the theoretical frameworks mentioned above to German plural morphology, we will conclude that each of them has particular shortcomings.

A unitary rule account for German plural forms as developed by Mugdan (1977) includes 10 rules, but also has to face a collection of 17 (partially long) lists of exceptions (cf. also among others Köpcke, 1988). A unitary network model based on frequencies, on the other hand, cannot explain why language learners overgeneralise the -s affix, and also, why in judgment tasks plural forms with -s are preferred when applied to a nonce word, although the -s plural is the one with the lowest frequency in the lexicon (cf. Table 1; for details compare, among others, Bartke, 1998; Clahsen, Marcus, Bartke, & Wiese, 1996; Marcus, Brinkmann, Clahsen, Wiese, & Pinker, 1995; Niedeggen-Bartke, 1999; Sonnenstuhl-Henning, 2003). To date, the nature of German plural morphology seems to be captured best by the dual mechanism model (Pinker & Prince 1988, 1991). A substantial body of psycholinguistic research provides evidence for the view that even children by the age of 3 years draw a qualitative distinction between regular plurals (in the German plural system this is represented by the -s affix) and irregular plurals. Evidence comes from analyses investigating the the language of normally developing children as well as of language-impaired children, of adults and of people with different kinds of diseases such as Alzheimer’s, Huntington’s, or Parkinson’s disease, aphasia, and Williams’ syndrome (Bartke, 1998; Clahsen, 1999; Clahsen & Almazan-Hamilton, 1998; Clahsen et al., 1997; Penke, 1998, Rice & Oetting 1993, Rothweiler & Clahsen 1993, Sonnenstuhl-Henning, 2003; Ullman et al., 1997; Weyerts, 1997 among others). Methods applied range from analyses of spontaneous speech samples, verbal elicitation tasks, and reaction time experiments to the technique of event related potentials (cf. among others Bartke, 1998, Clahsen et al., 1997, Penke et al., 1997, Sonnenstuhl, Eisenbeiss, & Clahsen, 1999; Weyerts, 1997 among others). Methods applied range from analyses of spontaneous speech samples, verbal elicitation tasks, and reaction time experiments to the technique of event related potentials (cf. among others Bartke, 1998, Clahsen et al., 1997, Penke et al., 1997, Sonnenstuhl, Eisenbeiss, & Clahsen, 1999; Weyerts, 1997 among others)

Table 1
Type-frequencies of plural formsa dominant patterns emphasized

<table>
<thead>
<tr>
<th>Affix</th>
<th>Feminine (%) (n = 11 060)</th>
<th>Non-feminine (n = 14 502)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>-(e)n</td>
<td>95.74 (10 589)</td>
<td>9.56 (1 387)</td>
<td>46.85 (11 976)</td>
</tr>
<tr>
<td>-e (± umlaut)</td>
<td>2.98 (330)</td>
<td>44.28 (6 422)</td>
<td>26.41 (6 752)</td>
</tr>
<tr>
<td>-er (± umlaut)</td>
<td>–</td>
<td>6.78 (983)</td>
<td>3.84 (983)</td>
</tr>
<tr>
<td>-s</td>
<td>0.87 (97)</td>
<td>5.83 (845)</td>
<td>3.68 (942)</td>
</tr>
<tr>
<td>-∅ (± umlaut)</td>
<td>0.39 (44)</td>
<td>33.55 (4 865)</td>
<td>19.20 (4 909)</td>
</tr>
</tbody>
</table>

a When coding errors in CELEX (Baayen et al 1993) were observed, we corrected the coding for our countings. Countings are based on the 1 Mio corpus. Different from Bartke (1998), Clahsen et al. (1996), and Marcus et al. (1995), compounds are also included in these countings. This leads to slightly different results, but the general tendency is preserved.
1997; Weyerts, Penke, Dohrn, Clahsen, & Münte, 1997). An overview of these studies is provided by Clahsen (1999).

The previously mentioned studies related to German plural morphology confirm the view that the -s affix constitutes the default plural. To serve as a default, several specific criteria have to be fulfilled as discussed in detail by Marcus et al. (1995), and, for acquisition data, by Bartke (1998). The list of criteria runs as follows:

1. Novel words lacking an entry in the mental lexicon (example: klots)
2. Unusual-sounding words (example: fneiks)
3. Onomatopoeia (example: Wauwaus ‘bow wows’)
4. Quotations (example: Es sind drei ‘Manns’ in dem Satz. ‘There are three ‘Manns’ in the sentence’)
5. Surnames (example: die Manns ‘the Manns’)
6. Unassimilated borrowings (example: Kiosks ‘kiosks’)
7. Truncations (example: Sozis, short for ‘socialists’)
8. Acronyms (GmbHs ‘plcs’)
9. Nominalisations (example: die Wenns und Abers ‘the ifs and buts’)
10. Eponyms (example: Fausts)
11. Product names (example: Opel Kadetts (car brand); in contrast to Kadetten ‘cadets’)
12. Nominalisation of VPs (example: Rührmchnichtsans ‘touch me nots’)

Finally, overregularisations from language learners as well as from patients can be added:


Note that this variety of contexts for the application of the -s affix is not reported for any other plural affix of the German plural system; it is unique to the -s affix. It should be added that the plurals affixed with -s are not simply transferred from English or from French, since the first -s plurals are reported to be much older than the first English or French borrowings (Öhmann, 1961), and because the -s affix is used under many circumstances unrelated to borrowing from these languages (see the list presented above). If one would adopt the idea of a borrowed -s plural, one would have to leave quite a few questions unanswered: (i) why do names always get inflected with the -s affix, (ii) why do children overgeneralise massively the -s affix, but not the remaining plural allomorphs, and why do new coinages receive the -s affix but not a different plural allomorph (for further discussion cf. Wiese, 2000: 137f). Therefore, the -s affix can be regarded (i) as a truly part of the German plural system and (ii) as the only default form.

Recent ERP studies also support the view that regular morphology is processed differently from irregular forms. When investigating German participles, Penke et al. (1997) found a left fronto–temporal negativity in response to incorrect irregular participles (e.g. *gelad-et—correct: geladen ‘loaded’; examples from Penke et al., 1997). Surprisingly, no differences were found when the authors compared the brain responses to correct regulars (e.g. *getanz-en ‘danced’) with responses to incorrect regulars (e.g. *getanz-t ‘danced’). In a similar study, plural forms inflected with the -(e)n affix were investigated. When comparing
brain responses to correctly inflected irregulars with responses to incorrectly inflected irregulars (e.g. *Muskel-n ‘muscels’ resp. *Kajüte-s ‘cabins’), a left anterior negativity was observed (cf. Weyerts et al., 1997). Additionally, the incorrect forms were linked to a negativity at fronto-temporal sites. In contrast, correctly and incorrectly inflected -s plurals (e.g. Karussell-s ‘merry-go-round’ resp. e.g. *Oskar-n ‘Oskars’) did not evoke such an effect. Instead, the incorrect forms lead to a phasic negativity at about 380 ms with a maximum at central sites (Cz).

Unfortunately, these studies compared correct forms to incorrect ones. Usually, this kind of comparison will lead to an early left anterior negativity (LAN) which is well-documented by many studies (Friederici, Pfeifer, & Hahne, 1993; Friederici, Hahne, & Mecklinger, 1996; King & Kutas 1995; Kluender & Kutas 1993, Kutas & Hillyard 1983; Münte, Heinze, & Mangun, 1993; Neville et al., 1991; Rösler, Friederici, Puetz, & Hahne, 1993, Segalowitz & Chevalier 1998). In line with, for example, King and Kutas (1995) and Kluender and Kutas (1993), Weyerts et al. argue that the LAN observed in their study can be interpreted as an indicator for a memory load which increases when semantic, syntactic or other grammatical anomalies are presented. Other studies emphasised the LAN as an expression of syntactic incongruity (among others Rösler et al., 1993; Friederici et al., 1993, 1996). Potentially, there are different negativities with different functional correlates subsumed under the cover name of LAN. In a similar study, Niedeggen-Bartke et al., 2002 analysed the group of correctly inflected items and the group of incorrectly inflected items separately. By doing this, the authors made sure to analyse morphological effects without interfering correctness effects. In sum, this study found (i) different brain responses to default forms, and (ii) most importantly, different brain responses to differently inflected so-called irregular forms (zero versus -(e)n plurals). This last observation comes at surprise since the dual mechanism model predicts equal treatment of different irregular plural forms. This, in turn, raises the question whether different irregular plurals are all equally irregular. Probably, some features create a certain impact of predictability, which, in turn, leaves one or the other affix less unpredictable and therefore, less irregular.

As suggested by Wiese (1999) and others, some rather clear-cut tendencies of regularity in the domain of so-called irregulars should be taken into consideration. These tendencies have always been discussed by scholars of German morphology (see, e.g. Mugdan, 1977; Köpcke, 1988; Eisenberg, 1998 chapter 5.2.1). We will call these regularities “subregularities” in the remainder of this paper, to emphasize that we do not dispute the role of the -s plural as the default, and, in this sense, regular case.

First, constraints regarding the phonological shape of a pluralised form have to be satisfied, i.e. all noun plurals have to end in a schwa syllable—except for the -s plural (cf. Wiese, 2000). Next, one of the affixes has to be chosen. For affix selection, the most salient subregularities, confirmed by the patterns of loan-word integration, are the following.

(i) Feminine nouns predominantly take -(e)n as the plural affix. In comparison, the plural form of non-feminine nouns cannot be clearly predicted by gender alone.1

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1 Recall that German has three grammatical genders for nouns: feminine, masculine, neuter. For the plural morphology, masculine and neuter gender operate largely in the same way.
If a non-feminine noun comes with a final stressed syllable, plural forms predominantly take the -e suffix (e.g. *Hund-e* masc ‘dogs’).

Non-feminine nouns ending in a so-called reduced syllable, as in *Filter*, *Segel*, *Garten* (‘filter’, ‘sail’, ‘garden’) take a zero plural. No noun consisting of just a single syllable or of two full syllables (see *Hund* ‘dog’ or *Arbeit* ‘work’) ever has a zero plural.

Only a clear minority of plural nouns is marked with -er (e.g. *Gläs-er* neut ‘glasses’). This view is confirmed by the countings based on the CELEX lexical database (Baayen, Piepenbrock, & van Rijn, 1993) as illustrated in Table 2. This table also illustrates that nouns are only rarely affixed by -s, and that there is evidence for strong probabilistic tendencies within the group of irregulars.

To summarize, we identify three rather strong subregularities in the German noun system: (i) the tendency of feminine nouns to take -(e)n, (ii) the tendency of non-feminine nouns to take -e, and (iii) the tendency of non-feminine nouns ending in a reduced syllable to take the zero plural. Beside these tendencies, there are truly unpredictable forms such as e.g. *Pantoffel-n* masc ‘slipper’ or *Mütter-Ø* fem ‘mothers’, and the medium-sized number of nouns taking -er, such as *Geist-er* masc ‘ghosts’.

Even if other researchers do not share the basic idea of the default component in conjunction with an irregular network, many of them join the assumption that predictions within the area of irregularities are possible. Szagun (2001) noted that the German plural system consists of some strong regularities, some of which depend on word endings, while others are probabilistic. Although her list of subregularities is larger, she interprets her acquisition data by stating that the error pattern is ‘influenced by the regularities of the German plural marking system’ (Szagun, 2001: 133).

Evidence for the subregularities noted above arises not just from quantitative patterns as found in lexical databases (e.g. CELEX, Baayen et al., 1993), but also from the integration of loan words. As exemplified in Table 2 by a few words drawn from a large pool of such loan words.

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2 These and the following countings are based on the standardised corpus of 1 Mio. words.
words, many loan words adopt the subregular plural forms just identified. That is, as unassimilated loans they take the -s suffix (as predicted by the dual mechanism model), but once they are morphologically integrated into the German language, they follow the subregularities sketched above.

To be sure, small sets of counter-examples to the pattern of data presented in Table 2 exist, and the distinction between assimilated and non-assimilated loan words is not always clear-cut. They may differ between individual speakers. Nevertheless, Table 2 represents the dominant pattern for loan word assimilation in Modern Standard German. In contrast, recent loans never take -er as a plural suffix, in spite of the fact that existing high-frequency nouns do take this suffix.

The goal of our analyses is to compare brain responses to irregulars with brain responses to subregulars in the sense just defined. According to the predictions made by the dual mechanism model, the subregularities discussed here should not be reflected by different behavioural and/or brain responses. Since anything that does not work like a real default is categorized as irregular in the model, it is therefore, assumed to be stored in its fully inflected form, no matter what kind of plural affix is spelled out for the individual item.

To summarize our considerations: we assume that the -s-plural for German nouns acts as a rule-based default plural, applying across the board and under ‘emergency’ conditions, that is, if no other plural form is possible. The three subregular plurals are those, which follow clear-cut, but specific morphological and/or phonological conditions, as identified above. These rules have lexical exceptions, resulting in the plural forms identified as irregular. They are not productive, as demonstrated by the behaviour of loan words entering the language. The over-all question of the present paper is whether this linguistically motivated three-level system is matched by different patterns of brain activity.

3. EEG-study of “irregular” plural forms

The stimuli were selected for evaluating (i) the effect of different genders while keeping the proper noun plural marker constant, and (ii) the effect of different kinds of linguistically based subregularities of plural endings while keeping the factor gender constant. Specifically, plurals formed by the -e affix versus the -(e)n affix are compared (-e as the preferred plural form for nouns with masculine or neuter gender versus -(e)n as the preferred plural form for nouns with feminine gender). Note that all comparisons will include only plural forms, which are categorized as irregular in the work discussed above. Neither the dual mechanism model (Pinker & Prince 1988, 1994; Pinker 1999) nor previous findings (Weyerts et al., 1997) predict any differences in brain responses within this set of plural forms.

4. Methods

4.1. Participants

22 students of the University of Marburg were recruited. They received either course credit or a monetary compensation. Mean age was 24.4 years (range 19–39). All subjects
were right-handers, native speakers of German, and naive with respect to the objective of the experiment. Data from four subjects had to be discarded because of too many errors or EEG recording artefacts. Thus, the final sample of the ERP study comprised data of 18 participants (four males, 14 females).

4.2. Material and Stimuli

The critical items were selected by the following formal criteria: (i) the number of letters of plural forms varied between five and nine; (ii) number of syllables varied from 2 to 3; (iii) token frequency of singular as well of plural forms was classified as low-frequent, i.e. frequency is \( \leq 20 \) (per 1 million words in the CELEX corpus (Baayen et al., 1993); (iv) singular forms were classified as monomorphemic in the CELEX database. Item groups were matched for these features.

The list of critical items contained 160 irregular plural forms. Out of these, 80 items were those with the \(-n\) plural affix, half of which were feminine (e.g. Burg-en\(_{fem}\) ‘castles’), and half of which were of non-feminine gender (e.g. Bär-en\(_{masc}\) ‘bears’). Another 80 items carried the \(-e\) affix, equally distributed over non-feminine and feminine nouns (e.g. Bräut-e\(_{fem}\) ‘brides’; Deich-e\(_{masc}\) ‘dikes’). Since the item group of feminine nouns marked with the \(-e\) affix could not be completed when obeying the formal criteria just mentioned, we had to repeat several items by adding compounds such as Altstädt-e\(_{fem}\) ‘old towns’ or Walnüss-e\(_{fem}\) ‘walnuts’. To avoid interfering repetition effects, this single list was neglected in all analyses.

Additionally, 160 incorrectly inflected items were presented: 80 items originally carrying an \(-e\) affix were presented with an \(-en\) affix equally distributed over gender (e.g. *Axt-en\(_{fem}\) ‘axes’; *Fasan-en\(_{masc}\) ‘pheasants’), whereas 80 originally \(-n\) inflected items were marked with an \(-e\) affix (e.g. *Farm-e\(_{fem}\) ‘farms’; *Bandit-e\(_{masc}\) ‘bandits’; cf. Table A1 for the item list). Because of our strict criteria in balancing the conditions, the list of feminine nouns originally carrying an \(-e\) affix (e.g. *Axt-en\(_{fem}\) ‘axes’) again had to be filled up by a number of compounds. Therefore, we had to ignore this single list in further analyses.

All critical items were inflected for plural either correctly or incorrectly within a test session, whereas no item was repeated, i.e. no participant saw the same stem (target) more than once. To ensure this and for reasons of design balance, two versions of the item list were constructed. The 160 target items inflected correctly in version one were presented inflected incorrectly in version two, and vice versa. By doing this, the analyses include each item in each correctness condition. Interferences induced by a specific stem can, therefore, be excluded.

The list of items was completed with 160 filler items. To avoid strategic behaviour by the subjects in looking just at the end of words, these items displayed a manipulation of letters at the beginning of the word (e.g. Bassen transformed from Tassen ‘cups’; Palinen transformed from Pralinen ‘chocolate’). No other existing word resulted from these changes.

Target words were presented in sentences containing five words. In all sentences, the target word was presented in the second position of the sentence, as illustrated by the following example: Verschneite Alpen sind sehr gefährlich ‘Snowy Alps are very dangerous’.
The items were presented in whole sentences because we wanted to minimize confounding effects based on other inflectional process, e.g. case inflection. First, the position of the critical word emphasizes its function as subject. In German, nouns in subject position receive nominative case, i.e. no overt case marking interferes with plural marking. Thus, it is clear that the inflection marks plural and nothing else. Second, when presenting items with an incorrect plural affix, sometimes a word form might be generated that does exist as a case-marked form (e.g. Vokalen ‘vowel dative, plural’). Similarly, one could misread a plural incorrectly inflected with the -(e)n affix as a denominal verb, because German verbs in the infinitive or the first or third person plural are marked with the -(e)n affix. However, subject position and the preceding adjective minimize the possibility to interpret this inflected form as a verb or as a dative-marked noun that lacks agreement with its adjective. Instead, the syntactic context strongly supports the interpretation of a noun with an incorrect plural affix, occurring in the nominative case.

Still, because we are aware of possible confounding effects within the group of incorrectly inflected nouns, we will base our discussion on comparisons including the correctly inflected forms while presenting and discussing the results of the incorrect forms briefly and separately.

4.3. Procedure

Participants sat in an electrically shielded, dimly lit, and sound attenuating room facing a computer screen (ATARI SM 124, refresh rate 70 Hz), positioned at eye level 70 cm in front of the subject. A trial started with a frame presented in light grey in the centre of the screen. The frame served as fixation aid and extended 5 cm horizontally and 2 cm vertically. The sentence was presented word by word centred within the frame. Letters of the words were presented in black with a vertical size of 0.5 cm (visual angle 0.4°). The end of each sentence was indicated by a period after the last word. The first word was always presented 1 s after frame onset. Words of each sentence appeared as a rapid serial visual display with a presentation time of 250 ms and an ISI of 250 ms.

Subjects were instructed to decide if the critical word was incorrect, either with regard to orthographic rules or to the plural ending. They were told to respond after the presentation of the sentence. The index fingers of the left and right hand rested in two cavities equipped with light gates. An upper movement of a finger opened the gate and reaction time was recorded. The finger used for each response was counterbalanced across subjects. Subjects had to decide within 2 s. Late and incorrect responses were fed back.

Across subjects, sentences were randomly ordered with the restriction that not more than three consecutive sentences belonged to the same experimental condition. They were presented in blocks of 24 sentences each, and short (>20 s) breaks were given between them.

4.4. EEG-recording, artefact handling, and signal extraction

The EEG was recorded from 61 electrodes using a cap in which AgAgCl inserts are fixated by individual electrode supports (System FMS, Falk Minow Services, Munich).
Electrodes were positioned according to a modified version of the 10–20-system of electrode placement. The cap was positioned on the head with reference to the nasion, inion and the preauricular notches so that the vertex electrode was positioned correctly. The horizontal and vertical EOG was monitored with appropriate bipolar electrode pairs.

All scalp electrodes were referenced to the nosetip. Impedances of all electrodes were kept below 8 kOhm by preparation of the scalp site and application of an electrolyte gel. Two sets of 32-channels amplifiers (SYNAMPS, NeuroScan) were used for EOG and EEG recording. Band pass was set from DC to 40 Hz and the sampling rate was 250 Hz. Prior to each experimental block, a DC-reset was initiated automatically.

All trials were inspected by one of the experimenters. Trials with artefacts, i.e. amplitudes larger than 125 μV, were rejected. Epochs with eye-blinks were detected by a wavelet analysis and corrected using a linear interpolation algorithm. Drift artefacts were corrected according to a method suggested by Hennighausen, Heil, and Rösler (1993). ERPs were extracted from the edited set of raw data by averaging single trials separately for subjects, electrodes, and experimental conditions. Only trials with correct answers were used for the ERP average.

4.5. Dependent variables and statistical analysis

Error rate, mean reaction time and brain responses were measured for the six experimental item groups. For the statistical analysis (ANOVA), each electrode position was specified by factors caudality (anterior vs. posterior), laterality (left vs. right), and verticality (inferior vs. mid-vertical vs. superior). For defining these factors we followed Niedeggen, Rösler, and Jost (1999) (cf. Fig. 1).

Average voltage amplitudes were computed for consecutive intervals of 30 ms length (seven sampling points) beginning with the onset of the critical word and ending 900 ms after it. To isolate the influence of target words, measurements were referenced to a baseline of 100 ms length which preceded word onset.

The ERP was segmented by calculating the global field power. By means of this, four time windows of 60 ms length each were set (230–290; 290–350; 350–410; 410–470 ms) Later, a fifth time window was added (470–530 ms). No further time windows were included, since semantical and syntactical processing might interfere with morphology processing at such later points in time.

For each epoch and each condition, the average amplitude was computed. Afterwards, for each epoch a multivariate ANOVA (MANOVA) was used considering experimental condition × caudality × laterality. To avoid an increase of the likelihood of type-I errors, effects were considered for interpretation only if they fulfilled the hierarchical constraints described by Rösler et al. (1993). Probabilities of observed F-ratios were adjusted according to the formulas of Greenhouse & Geisser; reported p-values are epsilon-corrected. If effects reached significance, post hoc tests regarding the electrodes of interest were administered.
5. Results

5.1. Behavioural data

Naturally, analysis of reaction times showed no effect, since reaction to the critical word had to be postponed until the sentence was finished, i.e. three words after the critical word had been on display. Therefore, we will not discuss reaction times any further. Instead, error rates are potentially relevant, and are shown in Fig. 2.

An overall analysis of variance reveals a significant main effect of ‘plural form’ \( (F(5,85) = 42.95, p = .0001, \varepsilon = .574) \). A detailed post-hoc analysis of the four pairs of item groups in question reveals results, which will be supported by the ERP data reported below.

When looking at the correctly inflected plural forms, a comparison of feminine nouns with -(e)n plurals versus non-feminine nouns with -(e)n plurals reveals no significant difference \( (F(1, 17) = 0.19, p = .6650) \). In contrast, comparing non-feminine -(e)n plurals with non-feminine -e plurals, significantly more errors are observed for the non-feminine -(e)n plurals \( (F(1, 17) = 18.14, p = .0005) \). This can be interpreted as a facilitated acceptance of plurals displaying a subregularity (non-feminine -e plurals). These are identified as correct sooner as their counterparts with an affix working against the subregularity.

A comparison between non-feminine nouns incorrectly displayed with the -(e)n plural and non-feminina incorrectly presented with the -e plural shows a significantly higher error...
rate for the incorrect -e plurals. These incorrect -e plural forms are more often accepted as correct \((F(1, 17) = 75.98, p = .0001)\). A similar result is observed when analysing feminine nouns incorrectly presented with the -e plural versus non-feminine nouns incorrectly marked with the -e affix: again the non-feminines carrying an incorrect -e affix are linked with a significantly higher error rate \((F(1, 17) = 83.02, p = .0001)\). At first glance, this seems to contradict the results concerning the group of correctly inflected nouns, because now the subregularity is the target of more errors. Anyway, the results obtained by the analyses of incorrect plural forms allow the conclusion that plural forms in the form of a subregularity are—by mistake—more often accepted as the correct plural form. Exactly this kind of behaviour would be predicted by assuming the -e plural affix as the preferred form for non-feminine nouns, i.e. displaying a subregularity. In the following we will show by analysing EEG recordings that subregularities are parsed differently from truly irregular plural forms.

5.2. **ERP data**

5.2.1. **ERPs: comparing correct versus incorrect**

A comparison between correctly inflected and incorrectly inflected forms reveals a main effect for correctness which starts at about 410 ms and remains until 590 ms after onset. It becomes apparent again at the latest time window provided by our analysis, i.e. from 770 to 830 ms. Full details of statistical analysis are provided in Table 3.

This observation strongly suggests that the factor correctness can interfere easily with other factors. As can be noted from Fig. 3, the maximum of the negativity appears at left fronto–temporal sites.

The interactions of caudality × correctness as well as lateralization × correctness are just barely observable and appear preferably rather late. Because of this late appearance, their function is difficult to interpret.

In comparison, the interaction of caudality × lateralization × correctness occurs in nearly every epoch from 350 up to 650 ms, and again from 770 to 830 ms. This result
strongly suggests an important influence of the factor ‘correctness’. Thus, the factor ‘correctness’ could lead to confounding results when not kept apart from the variables under study.

As for the main effect for correctness, this effect of a left fronto-temporal negativity (cf. Fig. 3) resembles the effect observed by Weyerts et al. (1997). But since Weyerts et al. conducted comparisons only between regular and irregular plural forms (without paying attention to the factor correctness), the findings presented here suggest several causes underlying the effects observed by Weyerts et al.

As observed by, for example, Kutas and Hillyard (1984) and Münte et al. (1993), morphosyntactic deviations lead to an early negativity at left anterior sites. This LAN effect could be an expression of working memory load (cf. Kluender & Kutas 1983) or a correlate of detecting a syntactic incongruity (Rössler et al., 1998). Accordingly, one might conclude that ‘light’ errors are corrected on-line in working memory.

In order to investigate in detail the influence of different types of inflectional morphology, we will report a series of statistical comparisons that include various plural markers and two gender features. In each single analysis, brain responses to a subregularity in the sense defined above will be compared to a set of real irregular plural forms. Main attention will be given to the comparison of correctly inflected forms. Thus, in the following sections we report results with respect to different linguistically motivated comparisons. Within each comparison, the results based on correctly inflected nouns are presented first. Subsequently, we will briefly report the results based on incorrectly inflected nouns.

5.3. ERPs, non-fem. -(e)n versus non-fem. -e

When looking at the brain responses triggered by nouns with non-feminine gender which are correctly inflected with either an -(e)n plural (e.g. Bären ‘bears’) or an -e affix (e.g. Vokale ‘vowels’), another effect becomes apparent (cf. Fig. 4).
As documented in detail in Table 4 and in Fig. 4, at around 400 ms after presentation of the critical word, a negativity is observed over right posterior sites, which is significantly reduced by non-feminine nouns with an -e plural. This negativity can be observed over several time epochs and is disclosed by the following interactions.

Beginning at about 350 ms up to 470 ms, an interaction of lateralization × plural affix reaches significance. Additionally, an interaction of caudality × plural affix is found which has its onset somewhat later, at about 470 ms. Furthermore, an interaction for

Fig. 3. Top: Grand average ERPs evoked by correct and incorrect plurals. ERPs are referenced to a 100 ms long baseline preceding word onset and negative in this and all other figures is up. Bottom: Standardized difference topography ‘incorrect–correct’. Maps are computed from the average amplitude of epoch 350–630 ms after word-onset using a spline interpolation. Darker shading indicates that the negative amplitude was larger for incorrect plurals than for correct forms.

As documented in detail in Table 4 and in Fig. 4, at around 400 ms after presentation of the critical word, a negativity is observed over right posterior sites, which is significantly reduced by non-feminine nouns with an -e plural. This negativity can be observed over several time epochs and is disclosed by the following interactions.

Beginning at about 350 ms up to 470 ms, an interaction of lateralization × plural affix reaches significance. Additionally, an interaction of caudality × plural affix is found which has its onset somewhat later, at about 470 ms. Furthermore, an interaction for
caudality × lateralization × plural affix is noticeable within the time epoch of 350–410 ms (cf. Table 4).

Note that the -e plural is the plural allomorph which was identified as a subregularity for the group of masculine nouns. A similar observation can be made when comparing incorrectly inflected nouns of non-feminine gender such as e.g. *Fasan-en ‘pheasants’ vs. e.g. *Bandit-e ‘bandits’. The brain responses induced by plurals marked with -e show a negative wave
beginning at around 470 ms after onset lasting until around 590 ms at right medial electrodes.\(^3\)

In sum, these analyses suggest a difference between -e-marked plurals and -(e)n-marked plurals. Most significantly, the affix representing the subregularity evokes a brain response different from that of the affix representing a member of the irregulars.

5.4. ERPs, -(e)n plurals and *-e plurals with feminine resp. non-feminine gender

When comparing the correctly inflected -(e)n plurals separated for gender, no difference in brain responses is revealed. A less negative wave was predicted for the feminine nouns, because they show the subregularity, but no such effect was observed. The EEG data mirror the results obtained by analysing the error rates. There, too, no differences could be observed.

In contrast, when looking at plural forms incorrectly inflected with the -e affix (e.g. *Farm-e ‘farms\(_{\text{fem}}\)’ vs. *Bandit-e ‘bandits\(_{\text{masc}}\)’), the subregularity is instantiated by nouns with non-feminine gender. It is predicted that this group of items then should evoke smaller negativity. In fact, a reduced negativity was observed within the time windows between 470 and 590 ms at right medial electrodes.\(^4\) Different from the analysis for correct forms, this result suggests that a subregularity (non-feminine nouns (incorrectly) inflected with the -e affix) is able to trigger a brain response which differs from that to irregular nouns (feminine nouns (incorrectly) inflected with the -e affix).

5.4.1. ERPs: Difference potentials

To further investigate the influence of the assumed subregularity for non-feminine nouns, we compared difference potentials. First, the difference of brain responses to non-feminine nouns incorrectly inflected with the -e affix (e.g. *Bandite ‘bandits’) versus brain responses to non-feminine nouns correctly inflected with the -(e)n marker (e.g. Bären ‘bears’) was compared to the difference of reactions to non-feminine nouns

\(^3\) (a) time window 530–590 ms: main effect for plural affix \((F(1, 17)=4.60, p = .047)\); (b) time window 470–530 ms: interaction of lateralization (plural affix \((F(4, 68) = 2.97, p = .025, (. = .566)\); interaction of caudality (lateralization (plural affix \((F(8, 136) = 2.28, p = .025, (. = .550)\). (c) time window 530–590 ms: interaction of caudality (lateralization (plural affix \((F(8,136) = 2.41, p = .018, (. = .571)\).

\(^4\) (a) main effect for plural affix between 530–590 ms \((F(1, 17)=5.36, p = .033)\); (b) interaction for lateralization (plural affix between window of 470–530 ms \((F(4, 68) = 3.68, p = .009, (. = .572)\).
incorrectly inflected with the -(e)n allomorph (*Fasanen ‘pheasants’) versus the ones to non-feminine nouns correctly inflected with the -e marker (e.g. Zwerge ‘dwarfs’). The aim of this analysis is to eliminate possible interferences from the correct forms which are assumed of being part of the participants’ mental lexicons. The prediction is that the net effect of the inflections by the -e affix will be expressed by a reduced negativity.

As displayed in Fig. 5 and Table 5, a main effect for the difference can be observed in the time window of 530–590 ms. In the same time window, an interaction

![Grand average ERPs evoked by comparing the difference (no. 1) of non-feminine nouns carrying an incorrect -e affix resp. a correct -(e)n affix and the difference (no. 2) of non-feminine nouns inflected with an incorrect -en plural resp. a correct -e plural. ERPs are referenced as indicated in Fig. 3. Bottom: Standardized difference topography ‘difference 2–difference 1’. Maps are computed from the average amplitude of epoch 290–590 ms after word-onset using a spline interpolation. Darker shading indicates that the negative amplitude was larger for the net effect evoked by difference no. 2, namely by incorrectly marked -en forms.](image)
for caudality \times \text{difference} reaches significance. Moreover, from about 290 ms onwards, an interaction lateralization \times \text{difference} is present. These results demonstrate clearly the difference in parsing (incorrect) plural forms marked -e versus -(e)n.5

In sum, these results indicate that a subregularity, if compared to an irregular form, influences brain responses by evoking a smaller degree of negativity.

To pursue this point, a second set of difference potentials was calculated. In this setting, the difference of non-feminine nouns correctly versus incorrectly marked with the -e affix (e.g. Zwerge ‘dwarfs’ vs. *Bandite ‘bandits’) was compared to the difference of non-feminine nouns correctly versus incorrectly inflected with the -(e)n affix (e.g. Bären ‘bears’ vs. *Fasanen ‘pheasants’). Again, this procedure allows for the circumvention of the interfering factor of incorrectness, and thus leads to a comparison between the pure effect of the -e affix versus the -(e)n affix, with the former affix representing the subregularity. The subregularity, represented here by the non-feminines with an -e affix, is expected to lead to a reduced negativity.

This, in fact, is what we found. As shown in Fig. 6, a reduced negativity initiated by -e inflected forms can be observed, while no main effect for the difference is present, but an interaction caudality \times \text{difference} can be observed. Additionally, an interaction caudality \times \text{lateralization} \times \text{difference} is obtained (details of statistical analyses are listed in Table 6).6

To conclude the presentation of results, this final comparison reveals further evidence that the assumed subregularity is mirrored in different brain responses, namely by a reduced negativity.

Table 5

<table>
<thead>
<tr>
<th>Effect</th>
<th>Time window (ms)</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main effect</td>
<td>530–590</td>
<td>(F(1, 17) = 6.085, p = .024)</td>
</tr>
<tr>
<td>Interaction lateralization \times difference</td>
<td>290–350</td>
<td>(F(4, 68) = 2.738, p = .003)</td>
</tr>
<tr>
<td></td>
<td>350–410</td>
<td>(F(4, 68) = 4.378, p = .003)</td>
</tr>
<tr>
<td></td>
<td>410–470</td>
<td>(F(4, 68) = 6.202, p = .000)</td>
</tr>
<tr>
<td></td>
<td>470–530</td>
<td>(F(4, 68) = 3.392, p = .013)</td>
</tr>
<tr>
<td></td>
<td>770–830</td>
<td>(F(4, 68) = 2.590, p = .044)</td>
</tr>
<tr>
<td>Interaction caudality \times difference</td>
<td>530–590</td>
<td>(F(2, 34) = 4.601, p = .017)</td>
</tr>
</tbody>
</table>

5 At first glance, the large deflections in the HEOG electrodes might have influenced the activity recorded by the scalp electrodes. However, this is unlikely, because the HEOG electrodes recorded activity that originated close to the frontal scalp electrodes (row F7–F8) which do not show different response activity. The more posterior electrodes show the effects discussed above, namely on central and parietal scalp electrodes. If the eye movements as recorded by the HEOG would be of importance, a gradient influence affecting especially the close-by electrodes would have been expected.

6 Here, too, the large deflections in the HEOG and VEOG electrodes might have been the cause of the activity measured by the scalp electrodes. Again, this is not likely for the reasons given in footnote 5.
Fig. 6. Top: Grand average ERPs evoked by comparing the difference (no. 1) of non-feminine nouns carrying an incorrect and correct -e affix and the difference (no. 2) of non-feminine nouns inflected with an incorrect and correct -en plural. ERPs are referenced as indicated in Fig. 3. Bottom: Standardized difference topography ‘difference 2–difference 1’. Maps are computed from the average amplitude of epoch 290–410 ms as well as 590–650 ms after word-onset using a spline interpolation. Darker shading indicates that the negative amplitude was larger for the net effect evoked by difference no. 2, i.e. -en inflected forms.

Table 6
Difference potentials, comparison of non-fem. -e/*-e (e.g. Zwerge ‘dwarfs’ vs. *Bandite ‘bandits’) versus non-fem. -en/*-en (e.g. Bären ‘bears’ vs. *Fasanen ‘pheasants’)

<table>
<thead>
<tr>
<th>Effect</th>
<th>Time window</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interaction caudality × difference</td>
<td>290–350, 350–410</td>
<td>$F(2, 34) = 4.303, p = .021$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$F(2, 34) = 4.967, p = .012$</td>
</tr>
<tr>
<td>Interaction caud × lat × difference</td>
<td>290–350</td>
<td>$F(8, 136) = 2.705, p = .008$</td>
</tr>
</tbody>
</table>
6. Discussion

To sum up our results of the ERP study, the following observations were made. A reduced negativity over central, medial, and posterior sites was induced by:

- nouns of non-feminine gender correctly inflected with the -e affix (cf. Fig. 4),
- nouns of non-feminine gender incorrectly inflected with the -e affix,
- the net effect of plural formation with the -e allomorph (cf. Figs. 5 and 6).

Note that in all these cases it is the subregularity as part of a linguistic system which triggers the reduced negativity. These results suggest that there does exist a difference between different kinds of plural forms that are uniformly categorized as irregular in the literature so far.

Scalp distribution and occurrence over time suggest that the observed negativities may be interpreted as instances of an N400 effect. The N400 is regarded mainly as an expression of semantic violation (cf. Kutas & Hillyard, 1983; Münte, Heinze & Mangun, 1993; Rösler & Hahne, 1992; Rösler et al., 1993; Rösler et al., 1998; Segalowitz & Chevalier 1998; van Petten & Kutas 1991 among others). Semantic violations are evoked by contextually unexpected words, and the amplitude of the N400 is influenced by the degree of non-expectancy: the lower the degree of expectancy, the higher the amplitude (for an overview see Segalowitz & Chevalier 1998).

Analogously, our results concerning morphological anomalies might mirror the degree in the violation of expectancy. If a word displays the morphology of a linguistic subregularity, the subjects’ expectancy is more easily fulfilled than if the critical word displays an irregular form (which, by definition, is a non-predictable form). In turn, the N400 will be reduced in cases of presentations of subregularities. A similar observation was made by Münte et al. (1999), who also elicited an N400 by presenting regular verbs within a priming paradigm. In this task, too, morphology influenced the amplitude of an N400 effect in the way described above.

In sum, these results suggest that some morphologically complex words are represented in a decomposed fashion, in particular, words belonging to regular and subregular morphology. Additionally, other words fall into the class, which is processed by an associative network component. That is, the truly irregular words are assumed to be stored fully inflected.

Linking these findings to a study by Ullman et al. (1997), the lateral distribution of the effects obtained here further allows for a careful interpretation of the local distribution of different morphological phenomena. Default processes seem to obtain effects over left fronto-temporal sites, while entries governed by subregularities as part of the mental lexicon or the declarative memory seem to be located over presumably right central/medio-posterior sites.

A similar dissociation was observed in the study by Ullman et al. (1997). They investigated patients with word finding problems and impairment of declarative memory (posterior aphasia resp. Alzheimer’s disease) as well as patients with deficits concerning grammar (anterior aphasia and Parkinson’s disease). While the former group displayed a specific impairment for irregular verbs, the latter patient group had deficits in processing regular verbs. Ullman et al. (1997) observed this dissociation in patients with lesions in
the left hemisphere, while the effects for subregular and irregular morphology carried out here are observed over electrodes at the right hemisphere. However, this presumed dissociation vanishes if one considers that “right hemisphere distribution does not imply right hemisphere generation” (Kutas & van Petten 1994:105). There is agreement that the N400 can be generated at least in part within the left hemisphere, although the maximum of scalp effects is often observed over the right hemisphere. “Thus, the typical right-greater-than-left-asymmetry of the N400 should be taken as reflective of the dipole orientation of a left hemisphere generator” (Kutas & van Petten 1994:114). In sum, the observations made by Ullman et al. (1997) on different kinds of patient groups match the results carried out here. Computation of irregular and subregular plural forms seems to be placed at posterior sites. This observation emphasizes the difference between true regular plural forms (defaults) and rule-like subregulars.

Two questions remain: first, which (linguistic) features govern the likelihood for the plural forms of subregular status, and, second, why is no such effect observed for feminine nouns taking the -(e)n plural?

In fact, two relevant factors are investigated in the present study. The first is the factor of gender and its close interaction with the particular preponderance of a certain plural allomorph. As shown in Table 1, nouns of feminine gender prefer the plural formation with the -(e)n affix. For non-feminine nouns the case is less obvious: both -e and -Ø occur, with -e forms occurring more frequently.

The second factor is the interaction between phonological form and the kind of plural affix. As countings from the CELEX database suggest, this tendency is even stronger when the nouns’ endings provide a specific phonological environment, a schwa (cf. Table 7) or a syllable containing a schwa-like -el or -er (cf. Table 8). Table 7 shows that, irrespective of gender, nouns with final schwa strongly prefer the affixation of -(e)n.

A noun ending in a syllable like -el or -er, too, allows for some predictions: feminines strongly prefer to take the -(e)n affix (e.g. die Kugel-Kugel-n ‘bowl \textsubscript{fem.pl}’), whereas non-feminines prefer to take the zero plural (e.g. der Igel-Igel-Ø ‘hedgehog \textsubscript{masc.pl}’ cf. Table 8).

Table 7
Nouns with final schwa: type-frequencies of plural forms

<table>
<thead>
<tr>
<th>Gender</th>
<th>-(e)n</th>
<th>Affix</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>-(e) (±umlaut)</td>
</tr>
<tr>
<td>+ fem (n=903)</td>
<td>99.9% (902)</td>
<td>–</td>
</tr>
<tr>
<td>-fem (n=97)</td>
<td>86.5% (84)</td>
<td>–</td>
</tr>
</tbody>
</table>

Table 8
Nouns with final Schwa syllable (final -el or -er): type-frequencies of plural forms

<table>
<thead>
<tr>
<th>Gender</th>
<th>-(e)n</th>
<th>Affix</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>-(e) (±umlaut)</td>
</tr>
<tr>
<td>+ fem (n=120)</td>
<td>98.3% (118)</td>
<td>–</td>
</tr>
<tr>
<td>-fem (n=387)</td>
<td>1.3% (5)</td>
<td>–</td>
</tr>
</tbody>
</table>
The critical items, in particular the non-feminine nouns, used in our investigation provide a conflict between morphology (gender) and phonology (final schwa syllable). There are non-feminine nouns taking very predictably the zero affix for plural marking—though in special circumstances only. Therefore, differences between these two subgroups might not show up in ERPs.

7. General discussion

The results of our investigation partly confirm the dual mechanism model, but they also demand some extensions. As known from previous studies, a clear distinction has to be drawn between default forms and non-default forms. Results from behavioural studies as well as from ERP-studies clearly support this distinction (see Clahsen et al., 1997; Niedeggen-Bartke et al., 2002; Penke et al., 1997; Sonnenstuhl et al., 1999; Sonnenstuhl-Henning, 2003; Weyerts et al., 1997 among others). Particularly, in our previous ERP-study comparing -s plurals and irregular plurals (Niedeggen-Bartke et al., 2002), we noticed that plural forms, marked correctly as well as incorrectly with the -s affix, evoke a LAN. This allows us to conclude that brain responses to regular versus irregular morphological processes are different. Processes of regular morphology will evoke an early left-anterior negativity. This result replicates findings by Weyerts et al. (1997) investigating German plurals, and Penke et al. (1997) studying German verb inflection.

More important, when analysing the error rates for irregular plurals, we also observed a higher acceptance for any incorrect irregular plural form over an incorrect default form. Therefore, the separation of the mental lexicon into two components (rule versus network) as stated by the dual mechanism model is supported empirically.

However, our present study was designed to investigate linguistically motivated differences within the storage component of the so-called irregulars. The main results can be summed up as follows:

i. Truly irregular nouns are more often accepted as correct if erroneously carrying the plural affix that mirrors a subregularity; cf. error rates in Fig. 2.

ii. Plural forms representing a subregularity because of their plural affix and gender evoke a reduced N400 in comparison to truly irregular plural forms. In this case, the specific subregularity is represented by the -e affix in combination with masculine gender. It is irrelevant whether the -e affix leads to a correctly resp. incorrectly marked plural form. In either case, negativity is reduced.

These results lead to the conclusions that subrules within the component of irregular morphology, too, initiate brain responses different to irregularities not governed by these subrules: the former elicit a reduced N400 effect.

Therefore, the network component of the dual mechanism model has to be expanded in a way that subregularities may be represented by rules, while the remaining irregular forms are listed as full forms. Our results also suggest that a default rule is processed differently from rules expressing the regularities called subregular in this paper. These observations
lead to a reformulation of the dual mechanism model. Next to the default component and the phonologically structured network system, a third processing component must be considered. This third component, too, is rule-guided, but as suggested by different brain responses to default forms versus subregular forms, it is clearly of a different cognitive nature.

Making use of the basic ideas of the theory of minimalist morphology (Wunderlich & Fabri 1995; Wunderlich, 1999; Kilbury, 2001), Niedeggen-Bartke (2001) suggests a restructuring of the storage component, such that a lexical entry as such contains more than phonological information. Information about, e.g. gender also has to be taken into consideration. In extending the amount of lexical information and adopting the representation of monotone inheritance trees, the network component is able to build up paradigm-like groups of words with similar inflectional behaviour. The building of those paradigm-like groups is based on probabilistic tendencies given by the language. It remains to future research whether the rules for subregularities form a separate processing component or whether they constitute a well-organized and somehow integrated part within the network system.

A similar suggestion was made by Ling & Marinov (1993), who mimicked the production of English past tense verbs in a symbolic pattern associator (SPA) and observed cluster formations within the so-called irregular verbs. Moreover, they created a computer model which was able to recognise certain regularities among the group of irregular verbs that, in turn, were used as input for a rule-guided system. Since they do not exclude the possibility that a rule might affect just one single word, they interpret their working model as being closely related to traditional rule-based accounts (Ling & Marinov 1993:277). But this kind of rule dependency begs the question for many single-word rules when investigating the German plural system (cf. detailed discussion in introduction). Exactly this difficulty was circumvented in the dual mechanism model by assuming a phonology-guided association network hosting irregular forms.

However, a division into just two components seems to be too coarse. Recently, the suggestion was made that regular and irregular inflection depicts the poles of a continuum (Penke et al., 1999: 232; Westermann, 2000). This might imply that a word could be typically regular, somewhat regular, or typically irregular—with multiple shadings in either direction.

In our view, this weakens the dual mechanism model too much. Instead, we can clearly observe a threefold division into default forms, subregularities and true irregulars. Since rules governing subregularities seem to be processed differently from default rules as well as true irregulars, future research has to investigate whether subregularities are stored in the fashion of default rules or whether they are stored in a template-like fashion as suggested by Ling & Marinov (1993). A first attempt has been made by Sonnenstuhl-Henning (2003) in her modification of the dual mechanism model, the extended dual mechanism model. Her data, based on a large battery of different priming experiments, also provide strong evidence for a tripartite model of the mental lexicon. However, details of the hierarchical structure and the information provided by the lexical entry must be clarified in future research.
Acknowledgements

Thanks for helpful comments and advice go to Harald Clahsen, Kerstin Jost, Michael Niedeggen, Matthias Schlesewsky, Ingrid Sonnenstuhl-Henning, and Eva Smolka.

Appendix A. List of critical items

<table>
<thead>
<tr>
<th>Feminines  -en plural</th>
<th>Non-feminines -e plural</th>
<th>Non-feminines -en plural</th>
</tr>
</thead>
<tbody>
<tr>
<td>Achten</td>
<td>Doktrinen</td>
<td>Bisse</td>
</tr>
<tr>
<td>Almen</td>
<td>Dressuren</td>
<td>Busse</td>
</tr>
<tr>
<td>Alpen</td>
<td>Ethiken</td>
<td>Dachse</td>
</tr>
<tr>
<td>Boxen</td>
<td>Frisuren</td>
<td>Deiche</td>
</tr>
<tr>
<td>Buchten</td>
<td>Gebühren</td>
<td>Dochte</td>
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<td>Grafiken</td>
<td>Elche</td>
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<td>Heiraten</td>
<td>Farne</td>
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<td>Hoheiten</td>
<td>Fasane</td>
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<td>Kliniken</td>
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<td>Koliken</td>
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<td>Notizen</td>
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<td>Kelche</td>
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<td>Marschen</td>
<td>Kniffe</td>
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<tr>
<td>Kuren</td>
<td>Mixturen</td>
<td>Lachse</td>
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